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Title image: Detail of Drone Documentation Processing of Ayutthaya in Reality Capture by CyArk.

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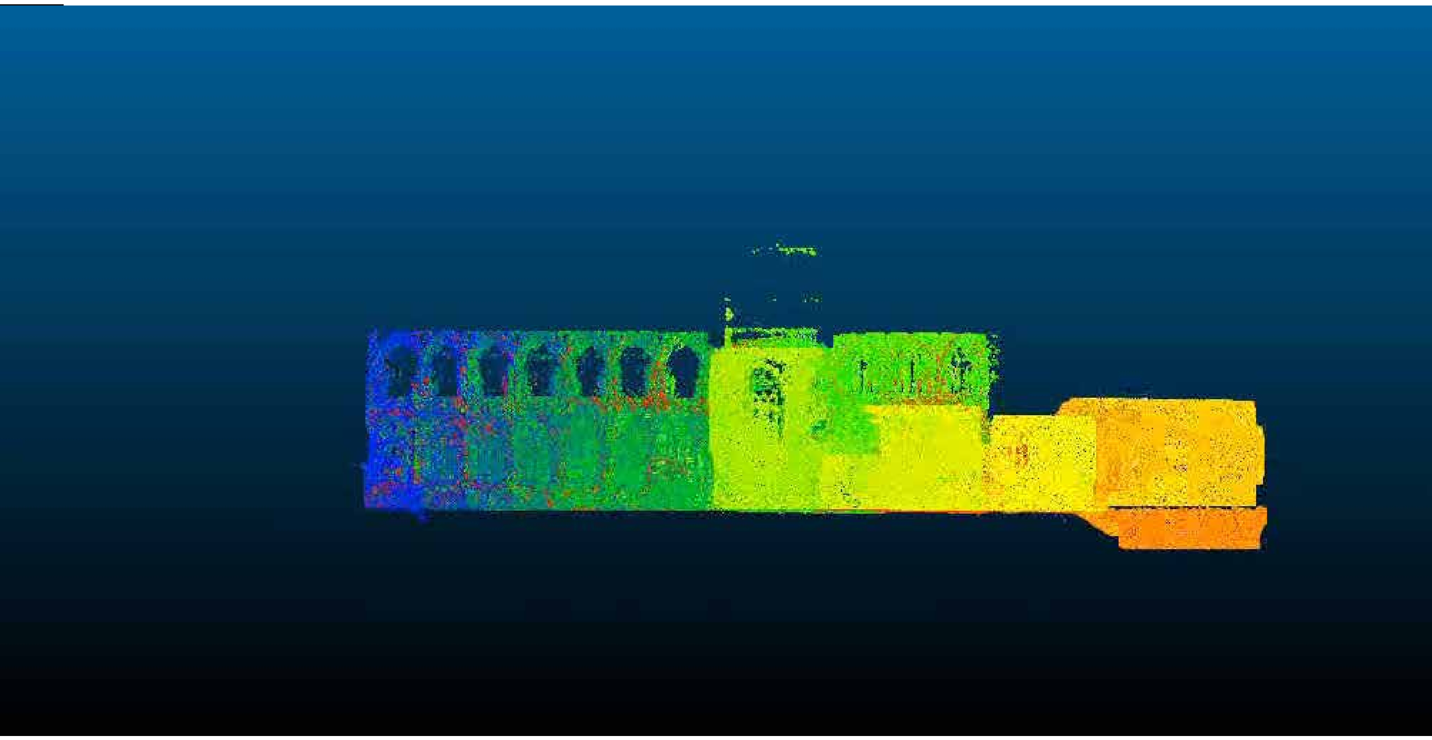
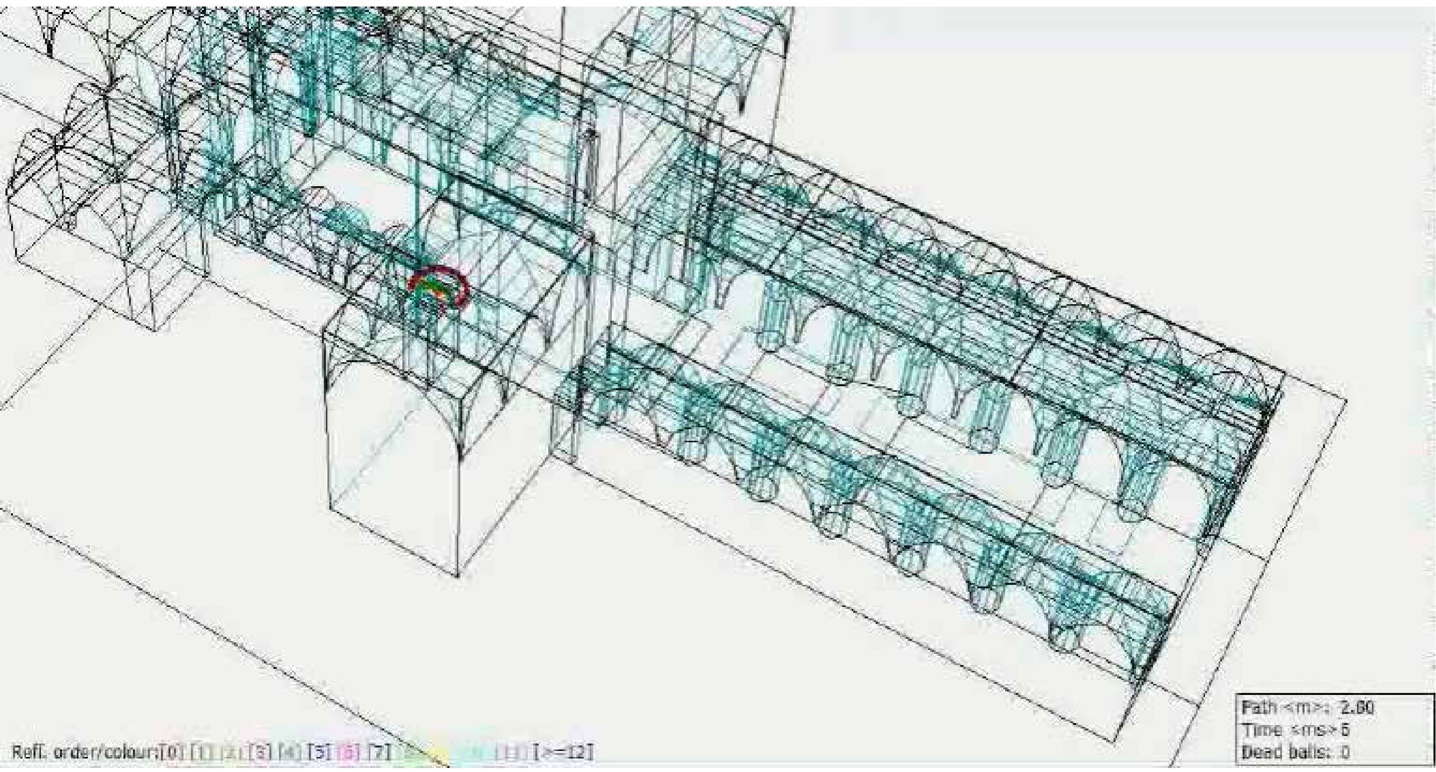


Video 1. Point Cloud of Hereford Cathedral, colour scaled to highlight architectural components (nave in blue, Lady Chapel in yellow). (Tower missing from scan; modelled from plans and elevations). Rendering: Justin Underhill.



Video 2.: Odeon Sound Visualization, Hereford Cathedral, (of human singers situated in the choir). Rendering: Justin Underhill.

Editorial

Creating New Spaces in Art History

Harald Klinke, Liska Surkemper, Justin Underhill

Art History as a discipline of images

The journal's previous issue, "Visualizing Big Image Data" focused on Art History as a discipline of images and how visualization tools in Digital Art History present new research possibilities. A discipline's methods and insights are only as accessible as their evidence, and for Art History this has always structurally necessitated the transformation of artworks – scattered as they are around the world in different places and contexts– into reproductions in various media formats; each with their own media specificity and historical temporality. Thus, the history of our discipline is also a media history, a trajectory of different visual representations and their respective impact on art historical research and teaching.

And of course, the digital revolution is by no means the first time that a technological change has inaugurated new ways of presenting and narrating images and their histories; Heinrich Wölfflin's use of double projections of diapositives changed the former text-based lecture style into a form of "aesthetic pedagogy",[1] and Aby Warburg and André Malraux used photographs and prints to create larger and movable image templates as research instruments of visual comparison, classification and orientation (fig. 1 and 2).

Today, the computer allows us to go beyond analyzing a few pictures at a time by processing thousands and millions of images at once and bringing it into new visual structures (fig. 3). Whole art collections are now not only represented by long spreadsheets of textual metadata (including the name of the artists, title of artwork, and date), but also by image clusters showing a 2D body of work. Visualizations like these allow us to discover and document long-term diachronic and stylistic changes which are overlooked or oversimplified when we restrict ourselves to smaller sample sets.

This creates a new type of imagery, visualizations of Big Image Data (BID). Such visualizations of image clusters and collections may be categorized as what W.J.T Mitchell called metapictures in his famous publication on "Picture Theory": "The metapicture is a piece of movable cultural apparatus, one which may serve a marginal role as illustrative device or a central role as a kind of summary image, what I have called a

Figure 1: Aby Warburg, Mnemosyne Atlas, panel 37, historic photography: Warburg Institute, London.

'hypericon' that encapsulates an entire episteme, a theory of knowledge. [...] In their strongest forms, they don't merely serve as illustrations to theory; they picture theory".[2] With his fundamental conviction *ut pictura theoria* Mitchell called for a mixed media approach (meaning the use and production of images alongside texts) to help theorists more fully understand visual culture—a practice he continues to investigate in his current work.[3]

As a discipline, Art History now has the opportunity to expand its traditional communicative framework by creating its own meta-images as a form of theory. To supplement (or perhaps challenge) their theoretical interests in the juncture of visual structure and semantic content, art historians can experiment with picture making themselves and explore how these BID visualizations produce new art historical insights. In addition to Mitchell's theoretical interest in the digital image atlas and its historical connections to patterns of madness,[4] one must also take into account the effort of contemporary research projects, DAH hackathons and summer schools that work on establishing systematic approaches.[5] To create valuable outcomes such Digital Art History

Figure 2: Maurice Jarnoux, André Malraux in front of photo reproductions for his book "Le Musée imaginaire", 1947. Photo: MACBA Barcelona (Museu d'Art Contemporani de Barcelona).

projects are in need of interdisciplinary teams that entail more than art historians and technologists. Therefore, Tracy Berg-Fulton et al. propose in this issue "A Role-Based Model for Successful Collaboration in Digital Art History" to establish standards for assembling a team for a contemporary art historical research project.

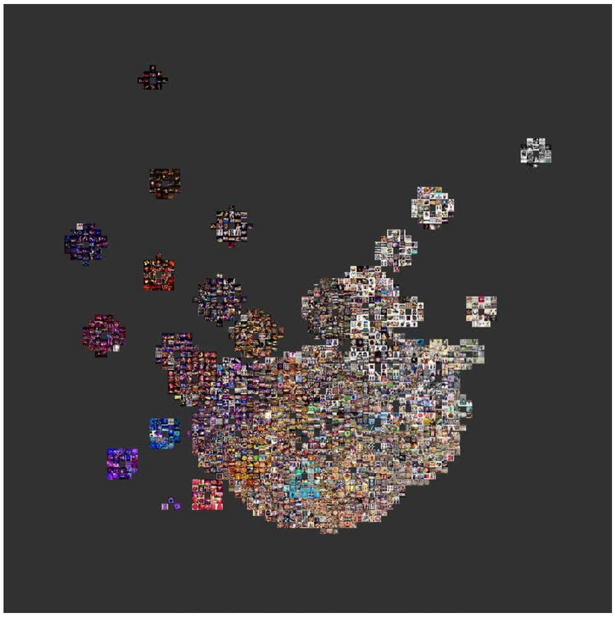


Figure 3: Damon Crockett, direct visualization technique Growing Entourage plot of Instagram photos, 2016.

Of course, Art History is much more than a discipline of flat, 2D images. Even digital image atlases and metapictures often surpass the limitations of arranging the large image sets on x- and y-coordinates by adding the z-axis—thus, creating a three-dimensional space in which a more complex relational network can be visualized and navigated (fig. 4).[6] Art History is centrally concerned with vast array of three-dimensional objects, such as sculptures, and spaces, such as architecture. Digital technologies allow the creation of virtual spaces, which in turn allow us to simulate and compare aspects of a visual culture's three-dimensional timespace that cannot be communicated as a single, still image. With the third issue, then, it is fitting to focus on the third dimension in Art History, and the digital realm that continues to mediate and transform it.

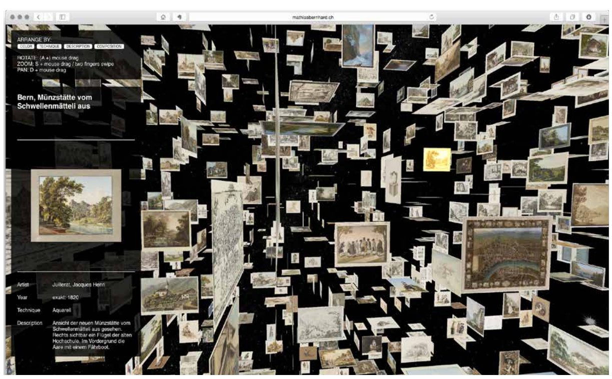


Figure 4: Matthias Bernhard, Screenshot of browser application "Guggelman Galaxy" in which the relational network of the art collection can be experienced, 2016.

Art History as a discipline of objects and space

Mario Carpo's featured article "Big Data and the End of History" functions as a hinge between journal issue #2 and #3, discussing how the introduction of Big Data has changed our culture of science, design thinking and the narration of architecture. He shows how the need for data compression technologies allowed for certain aesthetics in architecture, and how nowadays design processes change by integrating the "messy directness" of nature, which is only possible due to unlimited data storage and retrieval. Carpo foresees not only a dismissal of ancestral story-building but also of story-telling—arguing that we may be losing the need for a continuous narration and theory due to the introduction of search engines.

The next three articles converge upon the problem that architectural reconstruction poses to both the disciplinary configuration of traditional Art History, and its use as an evidentiary tool. Although visualization is a common component of contemporary architectural design workflows, and has been widely used by art historians and museum professionals for over twenty years, as a research practice it nonetheless remains constrained by traditional Art History's vision of the researcher as a solitary, self-sufficient humanist. Sander Münster, Kristina Friedrichs, and Wolfgang Hegel's article, 3D Reconstruction Techniques as a Cultural Shift in Art History?" addresses this problem, documenting the standard workflows specific to Digital Art History and architectural heritage, and in the process advocates for interdisciplinary collaboration between art historians and the computer graphics specialists that use these visualization tools. In the same vein, Stefan Boeykens, Sanne Maekelberg, and Krista De Jonge reflect collectively upon a decade of teaching and producing architectural reconstruction at the University of Leuven in "(Re-)Creating the past: 10 years of digital historical reconstructions using BIM". The authors highlight the underdiscussed and undertheorized problem of uncertainty in reconstruction, and the ways that Historical Building Information Modelling (HBIM) allows teams to document, accommodate, and even visualize such uncertainty. Finally, Una Ulrike Schäfer fastidiously catalogues the vocabularies of uncertainty that currently circulate in archaeological and architectural reconstructions as visual outputs of viewing platforms and user interfaces, showing how far we are from exhausting the design lexicon that is theoretically possible for digitally sharing the past with others.

Engaging Critique

We believe that it is vital for the relevance of this journal (and the subfield it represents) that it is not a self-partitioned pool of enthusiasts; we must listen

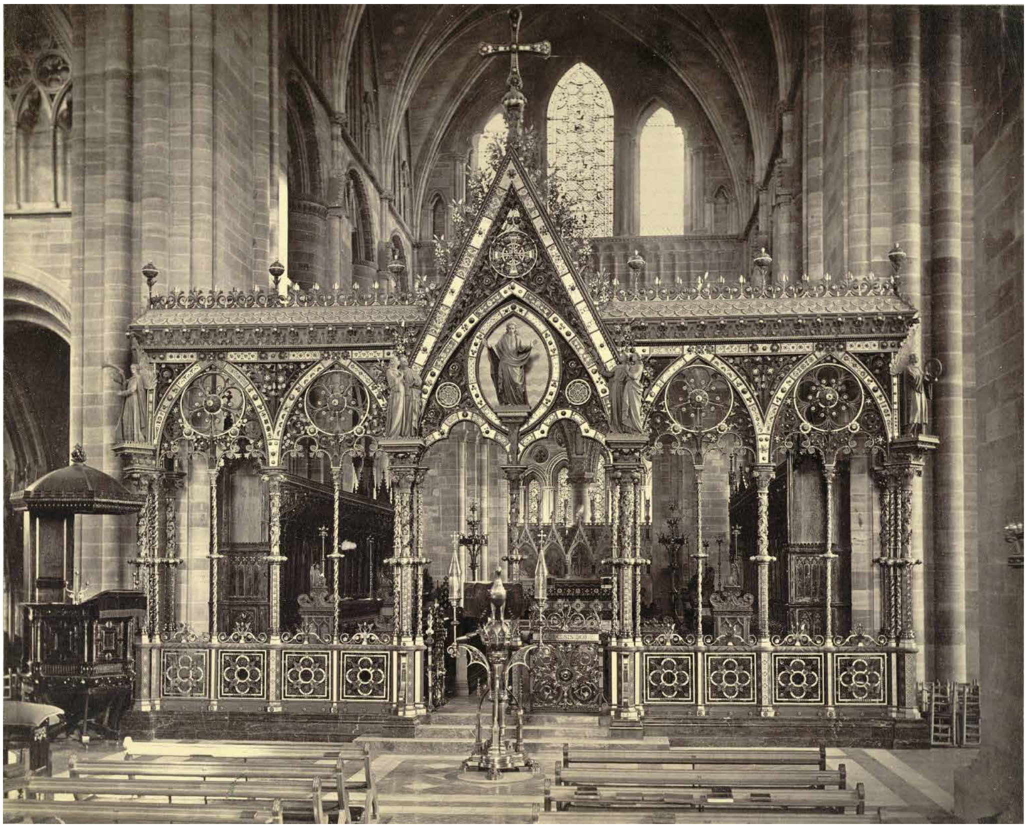
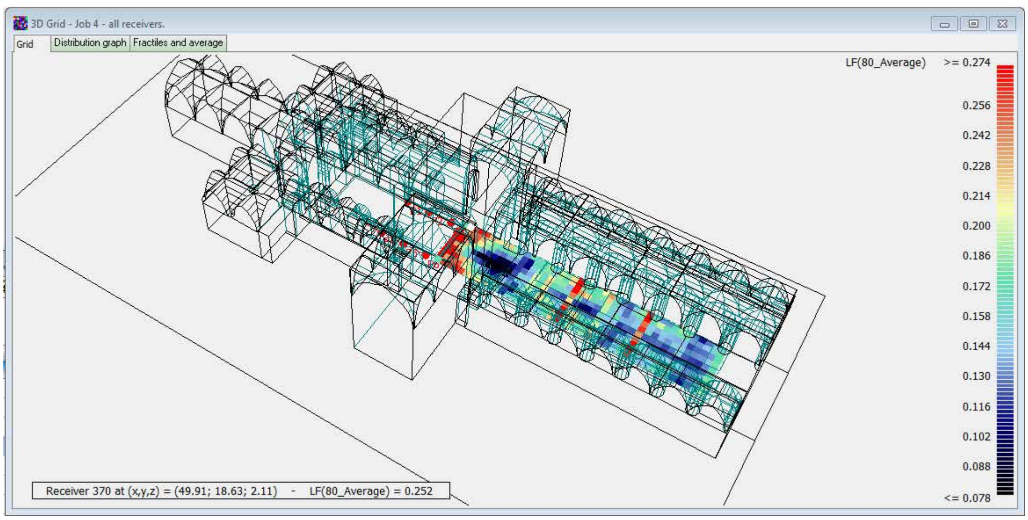


Figure 5: The Hereford Screen at Hereford Cathedral prior to its installation at the Victoria and Albert Museum, London.

Figure 6: Odeon grid map showing distribution of C80 in nave and crossing of Hereford Cathedral, (for human singers situated in the choir). Digital image: Justin Underhill.



to well-argued criticism in order to stay aware of what direction(s) we want to go. Thus, we have set up a critical section with three articles which interrogate the sense and purpose of Digital Art History.

Ulrich Pfisterer's article on "Big Bang Art History" poses general questions as to whether Digital Art History is really the "next big thing" on the scientific horizon. Claire Bishop argues "Against Digital Art History", by first discussing problems with digital Art History in relation to neoliberal metrics, and ending with a suggestion how the 'distant reading' method might nevertheless be deployed critically in the analysis of art. Giacomo Mercuriali's contribution on "Computational Imagination and Digital Art History" explores the parallel rise of computer vision technology and Digital Art History. He frames the conflicts that inevitably arise between computer scientists and art historians in this new discipline and describes concomitant epistemological problems. He closes with an outlook on how interdisciplinarity can be achieved.

Welcoming a New Editor

This third issue sees an addition to our editorial board. Justin Underhill is currently a Mellon Postdoctoral Fellow at the University of California, where he specializes in digital documentation (laser scanning and photogrammetry) as well as 3D reconstruction in a variety

Editors: Liska Surkemper, Harald Klinke. Photo: Janusch Tschech. Artwork "Nachschub": Li-Wen Kuo.

Welcome to the IJDAH-team: editor Justin Underhill.

of formats, including VR. He is particularly interested in the potential for computer graphics and digital reconstruction to propose new phenomenologies of visual experience, in particular those that challenge or undermine narratives that equate the objects of art history with the still, immutable surfaces so often suggested by photographic reproduction. In a recent study the Hereford Screen, a monumental cast iron choir screen now installed at the Victoria and Albert Museum in London, he used laser scanning and photogrammetry to digitally capture both the screen and the space in which it was intended to be permanently displayed, Hereford Cathedral (fig. 5; laser scan in Video 1). Using advanced acoustic simulations, he was able to show how sounds from the choir would have been transmitted throughout the cathedral (Video 2), and that when the screen was originally installed, the sculptures of musicians placed atop the screen would have visualized an important spatial effect known as source broadening for observers in the nave (fig. 6).[7]

Justin works broadly on visual cultures of Western Europe and the Americas from 1200 AD to the present, and believes that Digital Art History can supplement and facilitate research into the corpora of art-historical subfields that often go overlooked for lack of textual documentation; as a comparativist, he also utilizes research from cognitive neuroscience and perceptual psychology to make connections between the virtual spaces documented by historical reconstruction. He believes passionately in advocating and promoting forms of research that are not merely textual, and looks forward to developing the International Journal for Digital Art History as a venue for experimental digital research visualizations.

Further, we are in the process of developing a new workflow for *International Journal for Digital Art History*. We have always conceived of the journal as an experiment in digital publishing, and in order to expedite the publishing process, each article will be released as soon as it is available; readers will not have to wait for the entire issue to be published. This will ensure a quicker publication that keeps in touch with the rapid developments in this field. Once we have all articles together, it will eventually be bound to one issue in a print version.

Call for papers #4

Digital Art History is often described as a methodological addition to Art History. However, in the next issue we want to explore the digital transformation of art institutions: The departments of Art History, its libraries, archives and the museums are changing profoundly. Now is the time to think about: What will be the future of such institutions that are "doing art history"? How will Art History look in 10 years from now? Please look on the last page for the full call for papers.

Notes

[1] Christopher P. Heuer, “Bruno Mayer. Glasphotogramme für den kunstwissenschaftlichen Unterricht”, in *Kunstgeschichten 1915. 100 Jahre Heinrich Wölfflin: Kunstgeschichtliche Grundbgriffe* (Passau: Klinger, 2015): 229.
[2] W. J. T. Mitchell, *Picture Theory: Essays on verbal and visual representation* (Chicago: The University of Chicago Press, 1994): 49.
[3] W. J. T. Mitchell, *Seeing Madness: Insanity, Media, and Visual Culture,* 100 Notes, 100 Thoughts: Documenta Series no. 83 (Berlin: Hatje Cantz, 2012).
[4] W. J. T. Mitchell, *Method, Madness and Montage*, youtube-Link: https://www.youtube.com/watch?v=1eQzaENZoHo. Date accessed: 13 july 2018.
[5] See for example the summaries of workshops from Nuria Rodrigez and Sonja Gasser in this issue: 188-199.
[6] See article Mathias Bernhard, “Gugelmann Galaxy: An Unexpected Journey through a collection of Schweizer Kleinmeister”, *International Journal for Digital Art History*, no. 2, oct. (Munich: Graphentis, 2016). Available at: http://journals.ub.uni-heidelberg.de/index.php/dah/article/view/23250. Date accessed: 13 july 2018. doi:https://doi.org/10.11588/dah.2016.2.23250.
You can read more here: Justin Underhill, “Sound and Vision in the Hereford Screen”, *British Art Studies*, no. 5, https://doi.org/10.17658/issn.2058-5462/issue-05/junderhill. Date accessed: 13 july 2018.

Survey

Do you like the content and format of the journal? What would you like to see in the future? What would you like to tell us?

Please take part in a one-minute-survey until September 15: https://goo.gl/Xqzg3z

We can’t wait to hear your thoughts!

Harald Klinke has a Ph.D. in art history and a Master of Science in Information Systems. Currently he is Assistant Professor at the Ludwig Maximilian University, Munich, and member of the Program Committee of the DFG-funded project "The Digital Image". He conducts research on visual communication, digital media, and Big Image Data in art-historical contexts.
From 2008 to 2009, he worked as a Lecturer of Visual Studies (Bildwissenschaft) at the Art History Department of the University of Göttingen. From 2009 to 2010, he conducted research, supported by a grant from the German Research Foundation (DFG), as a Visiting Scholar at Columbia University, New York. He has published books on art theory, digital images and digital transformation.

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Liska Surkemper is a Ph.D. candidate for architectural and cultural theory at the Technical University Munich. She conducts research on visual epistemology and the interrelationship of pictures, architecture and economy.
From 2010 to 2014, she was a researcher and lecturer at the Department of Art Research and Media Philosophy at the University of Arts and Design Karlsruhe. She was also coordinator for the DH project "Memory of Scientific Knowledge and Artistic Approaches", which was supported by the German Federal Ministry of Education and Research (BMBF). Together with computer scientists, designers and arts scholars she helped develop the web application "Presenter": a tool for visualizing, sharing and archiving scientific and artistic knowledge.

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Justin Underhill is a Mellon Postdoctoral Fellow in the Digital Humanities at UC Berkeley. He earned his PhD in Art History from Berkeley, completing a dissertation, "World Art and the Illumination of Virtual Space," that uses advanced software to reconstruct the architectural contexts in which works of art were displayed. Such research explores the relation between pictures and the lighting of the space in which they were originally viewed. Underhill continued this work in his prior appointment as a Mellon Postdoctoral Fellow in the Digital Humanities at the University of Southern California. Presently, among other projects, he is developing art.rip, a site dedicated to digital capture, forensic visualization, and the history of art.

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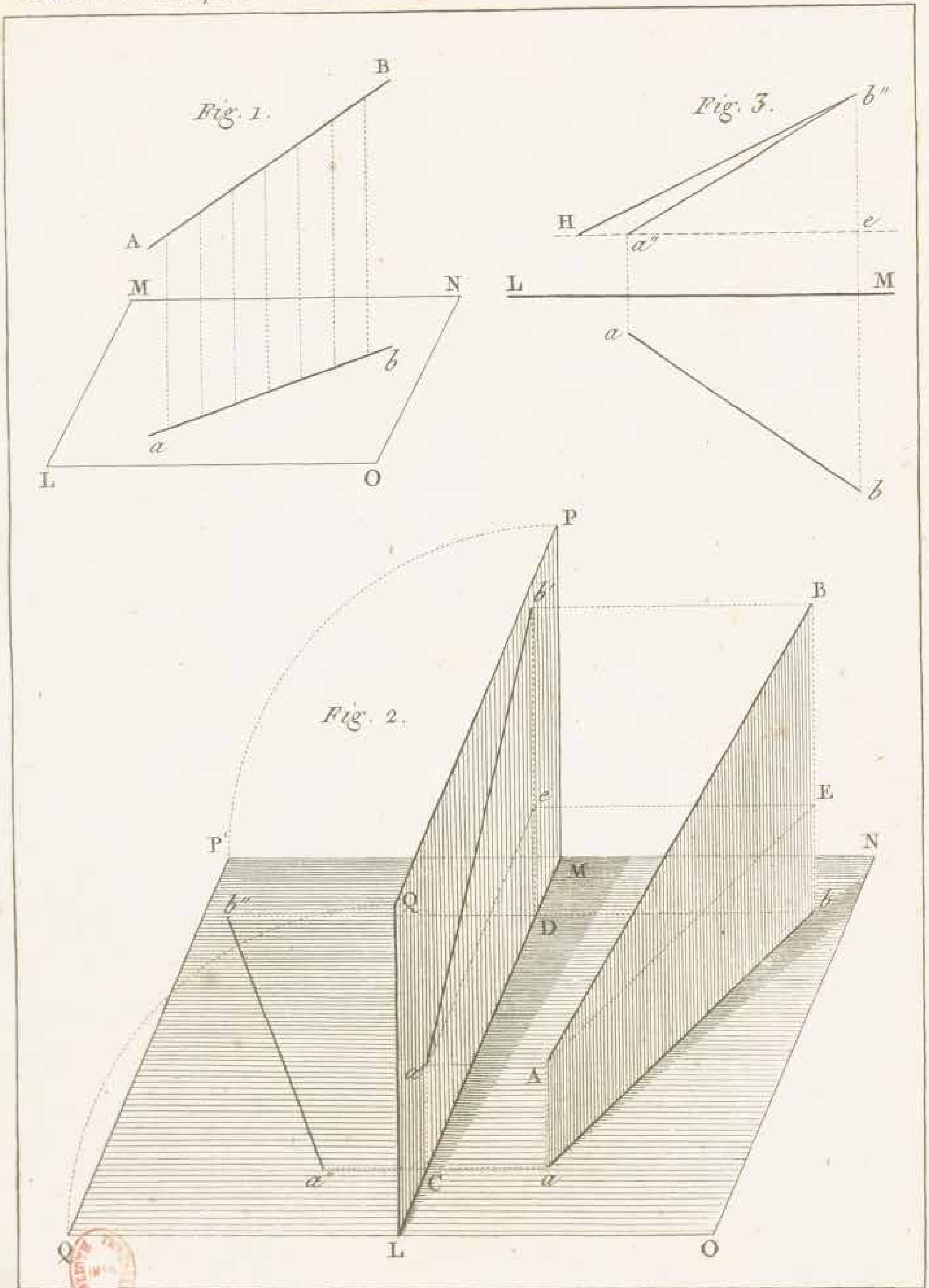
Featured Article



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Featured Article

Big Data and the End of History

Mario Carpo

Abstract: As data storage, computational processing power, and retrieval costs diminish, many traditional technologies of data-compression are becoming obsolete. This unprecedented state of data opulence, where more and more data are expected to be always more easily available at ever decreasing costs, is bringing about significant changes in contemporary computation, and fostering a revival of Artificial Intelligence technologies that were seen until recently as of limited practical use. A similar techno-cultural disruption is already conspicuously affecting architectural design. Informational models in three dimensions are replacing the basic tools of the designer's trade since the Renaissance – scaled drawings in plans, elevations, and sections. Furthermore, Big Data and computation allow digital designers to compose and engage with the messiness of some natural processes without going through the traditional mediation of abstract and general mathematical theories and patterns. Just like computation is replacing the causal laws of modern science with the brute force of data-driven simulation and optimization, blunt information retrieval is increasingly, albeit often subliminally, replacing causality-driven, teleological historiography, and demoting all modern and traditional tools of story-building and story-telling. This major anthropological upheaval challenges our ancestral dependance on shared master-narratives of our cultures and histories.

Keywords: Data compression technology, 3D modeling, digitally intelligent design, post-spline digital style

Introduction[1]

At the time of writing, in the summer of 2014, *Big Data* is a cultural trope more than a technical term.[2] Yet the expression originally referred simply to our technical capacity to collect, store, and process increasing amounts of data at decreasing costs, and this original meaning still stands, regardless of hype, media improprieties, or semasiological confusion. Historians of information technology would be hard pressed to see this as a novelty: Moore's law, which describes a similar trend, has been known since 1965, and it holds true to this day. Yet, even more than the adoption of the term by specialists and in some professions, the "Big Data" phenomenon indicates that some crucial qualitative threshold may indeed have been crossed of recent—or at least, suggests a general belief that it may soon be. And there may be more to that than media hype. Today, for the first time in the history of humankind, data is abundant and cheap, and getting more so every day. If this trend continues, one may logically infer that at some point in the future

Figure 1: Gaspard Monge, Géométrie descriptive. Augmentée d'une Théorie des ombres et de la perspective: extraite des papiers de l'auteur (Paris : Courcier, 1820), 189.

an almost infinite amount of data could be recorded, transmitted, and retrieved at almost no cost. Evidently, a state of zero-cost recording and retrieval will always be impossible; yet this is where today's technology seems to be heading to, asymptotically. But if that is so, then we must also come to the inevitable conclusion that many technologies of data-compression currently in use will at some point become unnecessary, as the cost of compressing and decompressing the data (sometimes losing some in the process) will be greater than the cost of keeping the raw data in its pristine state for a very long time, or even forever. When we say data-compression technologies, we immediately think of JPEGs or MP3s. But let's think outside of the box for a second.

Data-Compression Technologies We Don't Need Anymore

Big Data, which many today see as a solution, was more often a problem throughout the history of humankind. For example, hand-processing big numbers with traditional arithmetic tools takes time and effort—and the bigger the numbers, the higher the risk of errors. Hence that glorious invention of baroque mathematics, logarithms, which use tables of conversion in print to turn big numbers into small numbers, and the other way around; and, crucially, convert the multiplication of two big numbers into the addition of two smaller ones. Laplace, Napoleon's favorite mathematician, famously said that logarithms, by "reducing to a few days the labor of many months, doubled the life of the astronomer."[3] As well as, we may add, of many twentieth-century engineers: logarithms are at the basis of that other magical tool, the slide rule, whereby engineers of the twentieth-century could calculate almost everything in almost no time. But, even though I myself still studied logarithms in school for many months, I never learned to use my father's slide rule, because by the time I was fifteen I could buy a Texas Instruments pocket calculator for next to nothing. That worked much faster and more precisely than all the logarithmical tables and slide rules combined. Today, logarithms are a relic of an age gone by: a fascinating chapter in the history of early modern mathematics, which no astronomer or engineer would waste time on. Logarithms are a technology of data compression we don't need any more.

To take another example closer to the daily life of today's design professionals: scaled drawings in plans, elevations, and sections have been the basic tool of the designer's trade since the Renaissance, and the geometrical rules of parallel projections were famously published in 1799 by Gaspard Monge under the name of descriptive geometry (fig. 1). But seen from a historical perspective, and from today's vantage point, descriptive geometry is another cultural technology typical of a Small Data environment, as descriptive geometry uses parallel projections to compress big 3D objects into a set of small flat drawings, which can be easily recorded, stored, and transmitted on simple sheets of paper. In this instance, the compression of data is also a visible and physical one. No one could store the Seagram Building in reality—it is quite a big building—but many offices could store (and some did, in fact) the batch of drawings necessary to make it, and, if needed, to remake it. Today, however, using digital technologies, we can store not only a huge number of planar drawings, but also full 3D avatars of buildings, on a single memory chip—including all the data we need to simulate that building in virtual reality, or to build it in full. And technologies already exist that allow designers to operate directly in 3D, hence avoiding the mediation of planar drawings and of the geometrical projections underpinning them. In short, if buildings can be entirely notated as informational models in three dimensions from the start, the ways to represent them may change at all times based on need, and in many cases without falling back on plans, elevations, and sections. Descriptive geometry is another cultural technology for data compression already on the way out (and in fact, few schools of architecture still teach it).

The list of cultural technologies that have been with us from time immemorial, but which are being made obsolete by today's Big Data, is already a long one. To take an unusual suspect, the alphabet is a very old and effective technology for data compression: a voice recorder, in fact, that converts an infinite number of sounds into a limited number of signs, which can be easily notated, recorded, and transmitted across space and time. This strategy worked well for centuries, and it still allows us to read transcripts from the voices of famous people we never listened to and who never wrote a line, such as Homer, Socrates, or Jesus Christ. Yet today's technologies allow us to record, transmit, retrieve, and process speech as sound, without converting it into alphabetical signs (for the time being, the machine still does it, unbeknownst to us; but this may change, too). Thus today we can already speak to some machines without using keyboards, and receive answers from machines that vocalize words we no longer need to read. Keyboards used to be our interface of choice to convert the infinite variations of our voice (Big Data) into a short list of standardized signs (Small Data), but this informational bottleneck, typical of Small Data environments, is already being bypassed by today's speech-recognition technologies.

If the prospect of building without drawing frightens many architects, a civilization without writing may appear more than apocalyptic—almost a contradiction in terms. Yet, in purely informational terms, most technologies of notation (from numerals to Euclidean geometry; from musical scores to the Laban scripts for dancers) are tools we created in order to convert complex, data-rich phenomena into stripped-down and simplified transcriptions that are easier to keep, edit, and forward to others. These transcriptions are less and less necessary today as, thanks to Big Data, we can record, transmit, and manipulate digital avatars that are almost as rich in data as the originals they replace (and far richer in metadata). Of course, no digital replica will ever replace a natural phenomenon in full, as every copy implies some degree of abstraction, hence some data will always be left out or lost in the process. But in practice, once again, it is the tendency that matters, and this tendency has already started to affect today's science, technology, and culture.

Let's take another example—and one well-known one among architects, as it has been at the core of digitally intelligent design for the last twenty years: the calculus-based, digital spline. Calculus, another great invention of baroque mathematics, is the ultimate Small Data technology, as it compresses an infinite number of points into a single short notation, in the format $y = f(x)$. In practice, the script of a function contains all the points we may ever need to draw or produce that line (curve, or, adding one letter, surface) at all possible scales. But let's put ourselves, again, into a Big Data state of mind, and let's assume we can have access to unlimited, zero-cost data storage and processing power. In that case, we could easily do away with any mathematical notation, and simply record instead a very long, dumb log: the list of the positions in space (X,Y,Z coordinates) of many points of that line—as many as necessary, perhaps a huge number of them (fig. 2). That file will record the individual positions in space of a cluster or cloud of points that may not appear to follow any rule or pattern—any rule or pattern would in fact be of no use, so long as the position of each point is known, measured, and recorded, in two or three dimensions. This is exactly the kind of stuff humans don't like, but computers do well. A long time ago we invented dimensionless Euclidean points and continuous mathematical lines to simplify nature and translate its unruliness into short, simple, elegantly compressed notations: Small Data notations, made to measure for the human mind; notations we could write down, and work with. But today computers do not need any of that any more. Today's digital avantgarde has taken due notice: some digital designers have already discarded the Small Data, calculus-based spline (Bézier's spline), which was so important for the digital style of the 1990s, and have started to use Big Data and computation to engage the messy discreteness of nature as it is, in its pristine, raw state—without the mediation of elegant, streamlined mathematical notations.[4]

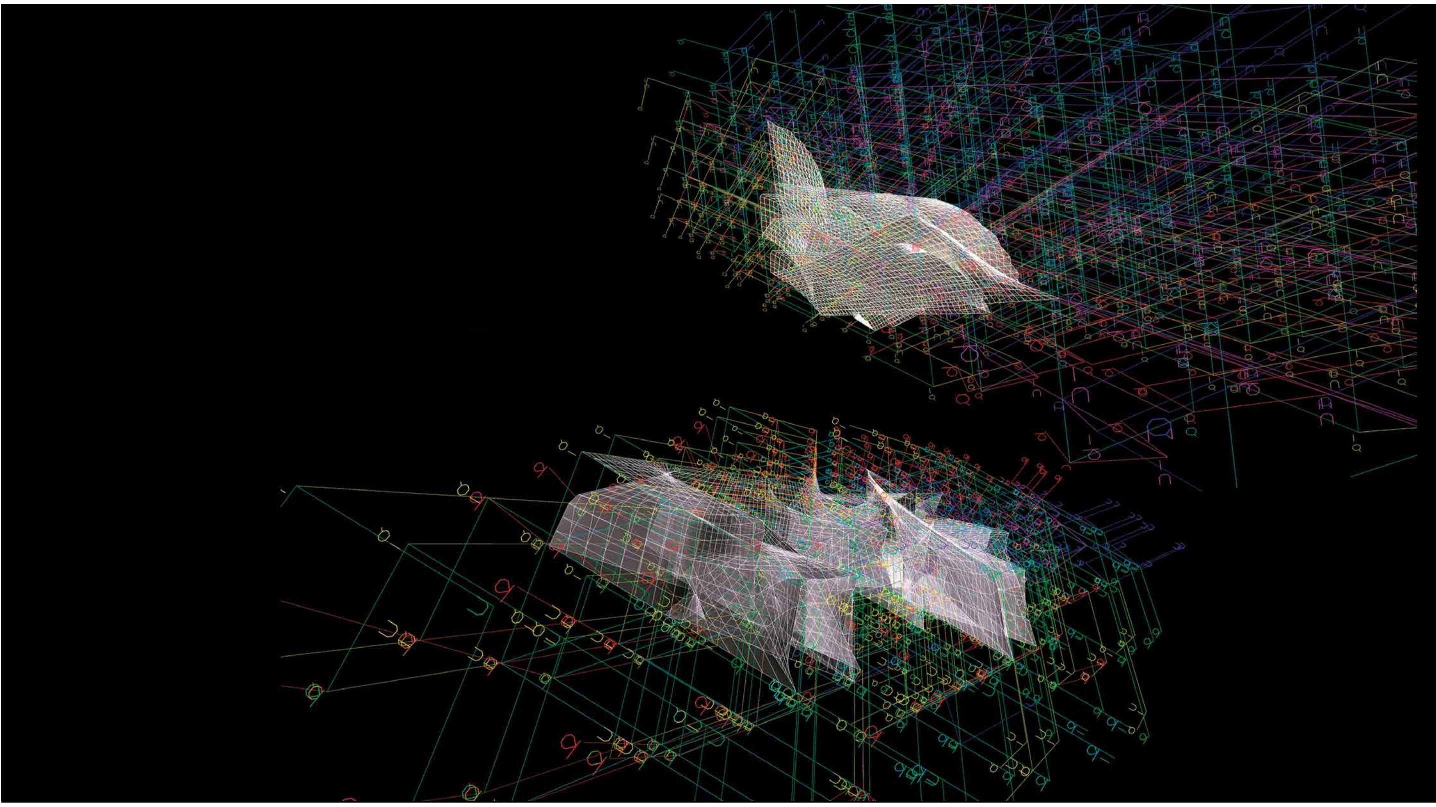


Figure 2: Karl Chu, X Kavya, The Turing Dimension, 2010. Credits: Karl Chu X Phylum project records. Canadian Centre for Architecture. Gift of Karl Chu © Karl Chu.

Search, Don't Sort: The End of Classical and Modern Science

This new trend in today's post-spline digital style may be discounted as a fad, a quirk, or an accident. It shouldn't be. All major, pervasive changes in our visual environment are signs of a concomitant change in our technical, economic, and scientific paradigms. Indeed, if we look back at our data-starved past from the perspective of our data-opulent present, all the instances just mentioned (and more could be added) suggest that Western science as a whole, from its Greek inception, could be seen today as a data-compression technology developed over time to cope with a chronic shortage of data storage and processing power. Since the data we could record and retrieve in the past was limited, we learned to extrapolate and generalize patterns from what data we had, and we began to record and transmit condensed and simplified formal notations instead of the data itself. Theories tend to be shorter than the description of most events they apply to, and indeed syllogisms, then equations, then mathematical functions, were, and still are, very effective technologies for data compression. They compress a long list of events that happened in the past into very short scripts, generally in the format of a causal relationship, which we can utilize to describe all other events of the same kind, including future ones. In his last book, *Discorsi e Dimostrazioni Matematiche*, which had to be smuggled out of Tuscany and printed in a Protestant country to escape the Inquisition's censorship, Galileo reported and illustrated a number of experiments he had made to study how some beams break under load.[5] But we need not repeat any of his experiments, nor any other, to determine how standard beams will break under most standard loads, because, generalizing from Galileo's experiments and many more that followed, we have obtained a handful of very general laws, which all engineers study in school: a few, clean lines of mathematical script, easy to commit to memory, which derive from all the beams that broke in the past, and describe how most beams will break in the future under similar conditions. This is how modern science worked—until now.

For let's imagine, again, that we can collect an almost infinite amount of data, keep it forever, and search it at will at no cost. We could then assume that every one of those experiments—or more generally the experiential breaking of every beam that ever broke—could be notated, measured, and recorded. In that case, for every future event we are trying to predict, we could expect to find and retrieve a precedent, and the account of that past event would allow us to describe the forthcoming one without any mathematical formula, function, or calculation. The spirit of Big Data, if there is one, is probably quite a simple one, and it reads like this: whatever happened before, if it has been recorded, and if it can be retrieved, will simply happen again, whenever the same conditions reoccur. This is not very different from what Galileo and Newton thought. But Galileo and Newton did not have Big Data; in fact, they often had very little data indeed. Today, instead of calculating predictions based on mathematical laws and formulas, using Big Data we can simply search for a precedent for the case we are trying to predict, and retrieve it from the almost infinite, universal archive of all relevant precedents that ever took place. When that happens, Search will replace the method of modern science in its entirety.

This apparently weird idea is not science fiction. This is already happening, in some muted, embryonic way, in several branches of the natural sciences, and more openly, for example, in weather forecasting. Once again, this may not be either a rational or a palatable fact, but it is a tendency—it is in the air, whether we like to admit it or not. And sure enough, some historians of science have already started to investigate the matter—with perplexity and reservations, as we could expect.[6]

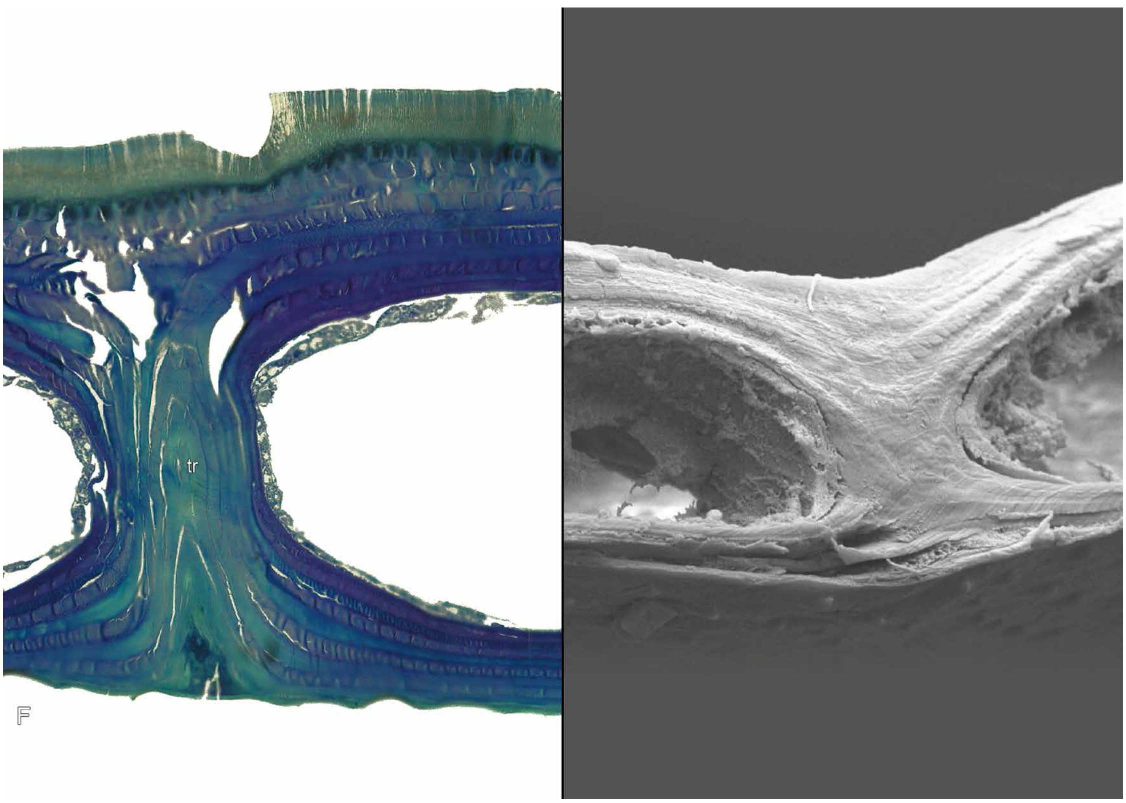
Indeed, from an even more general, philosophical point of view, mathematical abstractions such as the laws of mechanics or of gravitation, for example, or any other grand theory of causation, are not only practical tools of prediction but also, perhaps first and foremost, ways for the human mind to make sense of the world—and some could argue, as many did in the past, that the laws thus discovered are Laws of Nature, that disclose and unveil inner workings. Conversely, if abstraction and formalization (i.e., most of classical and modern science, in the Aristotelian and Galilean tradition) are seen as merely contingent data-compression technologies, one could argue that in the absence of the technical need to compress data in that particular way, the human mind can find many other ways to relate to, or interpret, nature. Epics, myth, religion, and magic, for example, offer vivid historical examples of alternative, non-scientific methods; and nobody can prove that the human mind is or ever was hardwired for modern experimental science. Many postmodern philosophers, for example, would strongly object to that notion.

This is probably not a coincidence, since the postmodern science of Big Data marks a major shift in the history of the scientific method. Using the Big Data approach to science (i.e., prediction by search and retrieval of precedent, instead of prediction by the transmission of general laws), modern determinism is not abandoned, but employed at a new, granular scale. Western science used to apply causality to bigger and bigger groups, or sets, or classes of events—and the bigger the group, the more powerful, the more elegant, the more universal the law that applied to it. Science, as we knew it, tended toward universal laws, which bear on as many different cases as possible. Today's new science of Big Data is just the opposite: using information retrieval and the search for precedent, Big Data causality can be applied to smaller and smaller sets, and it works best when the sets it refers to are the smallest. Indeed, the new science of Big Data only works in full when it does not apply to a class or group of events, but only to one, specific, individual case—the one we are looking for. In that too Big Data represents a complete reversal of the classical (Aristotelian, scholastic, and modern) scientific tradition, which always held that individual events cannot be the object of science: most Western science only dealt with what Aristotle called forms (which today we more often call classes, universals, sets, or groups).

In social science and in economics, this novel Big Data granularity means that instead of referring to generic groups, social and economic metrics can and will increasingly relate to specific, individual cases. This points to a brave new world where fixed prices, for example, which were introduced during the industrial revolution, will cease to exist (and famously, this is already happening). Likewise, the cost of medical insurance, calculated as it is today on the basis of actuarial and statistical averages, could become irrelevant, because it will be possible to predict, at the granular level, that some individuals will never have medical expenses, hence they will never need any medical insurance, and some will have too many medical expenses, hence no one will ever sell medical insurance to them. This is a frightening world, because the object of this new science of granular prediction will no longer

Figure 3: **ICD/TKE Research Pavilion2013-2014**, Institute for Computational Design (ICD, Prof. Achim Menges) and Institute of Building Structures and Structural Design (ITKE, Prof. Dr.-Ing. Jan Knippers) at the University Stuttgart. Based on the differentiated trabeculae morphology and the individual fiber arrangements, a double-layered modular system was generated for implementation in an architectural prototype. ©ICD/ITKE Universität Stuttgart.

Figure 4: Correlation of fiber layout and structural morphology in trabeculae. © Dr. Thomas van de Kamp, Prof. Dr. Hartmut Greven | Prof. Oliver Betz, Anne Buhl, University of Tübingen.



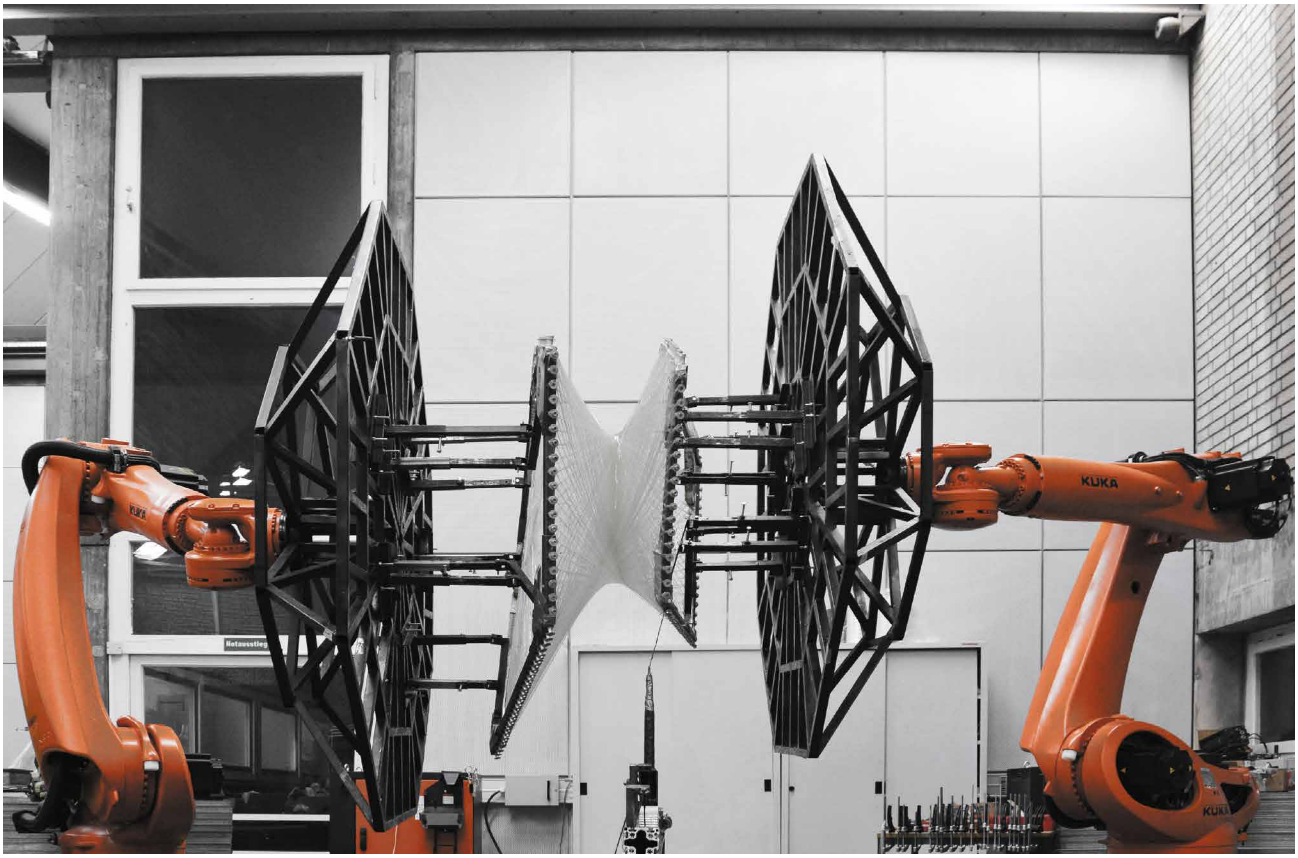
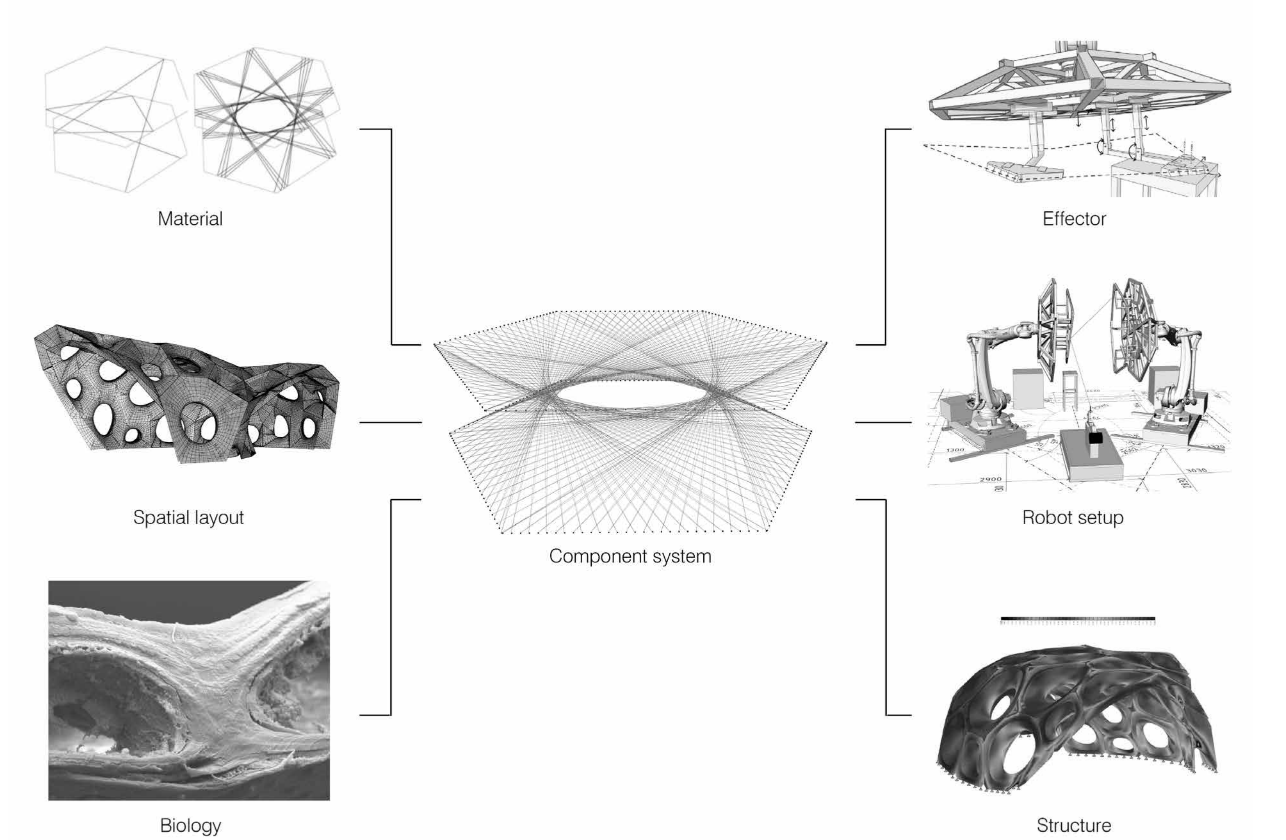


Figure 5: Dual robot fabrication setup: Coreless filament winding. © ICD/ITKE University of Stuttgart.

Figure 6: Integration of multiple process parameters into a component based construction system. © ICD/ITKE University of Stuttgart.



be a statistical abstraction—it will be each of us, individually. This may be problematic from a philosophical and religious point of view, as it challenges traditional ideas of determinism and free will; but in more practical terms, it is also simply incompatible with most principles of a liberal society and of a market economy in the traditional, modern sense of both terms.

In the field of natural sciences, however, the picture is quite different, and apparently less frightening. Following the old (i.e., the "modern") scientific method, natural sciences too used to proceed by generalization and abstraction, applying more and more general formulas to larger and larger swaths of the natural world. To the contrary, using the new method of granular retrieval of precedent, we are no longer limited to predicting vast and general patterns—we can try and predict smaller and smaller events, up the most singular ones. As recent works by Neri Oxman, Achim Menges, and others have proven, we can now design structural materials at minuscule, almost molecular scales, or quantify and take into account the infinite, minute, and accidental variations embedded in all natural materials (fig. 3-6).[7]

This runs counter to the method of modern science, which traditionally assimilated all materials, natural and artificial alike, to homogeneous chunks of continuous matter: for the last two centuries the main mathematical tool at our disposal to describe structural and material deformations was differential calculus, which is a mathematics of continuity, and abhors singularities; to allow for mathematical modeling (i.e., a quantitative prediction of their behavior), new industrial materials were designed to be isotropic and continuous, and natural materials were doctored, processed, and tinkered with to achieve some degree of homogeneity.

To the contrary, using the granularity of Big Data, we may now model the structural behavior of each individual part in a hypercomplex, irregular, and discontinuous 3D mesh, including the behavior of the one part we are interested in— that which will fail, one day. Used this way, the new science of granular prediction does not constrain but liberates, and almost animates, inorganic matter.

Search, Don't Tell: The End of Classical and Modern History

Since data scarcity has been a universal human condition across all ages, cultures, and civilizations, we can expect to find similar strategies of data compression embedded in most, if not all, cultural technologies we have been familiar with to this day. Historiography, or the writing of history, codified as an academic discipline and cultural practice in the course of the nineteenth century, is no exception.

Like the modern scientist, the modern historiographer must infer a theory (in the case of history, more often an argument or a story) from a vast archive of findings. This data is not reported as such (even though today facts and sources are often listed or referred to in footnotes), but it is subsumed and transfigured, as it were, in a larger narrative—namely, a history—that derives from the original findings, but encompasses and describes them in more general terms. In this sense the historiographer, like a bard or ancestral storyteller, must condense and distill an accumulation of accidental experiences into one streamlined sequence or story, following a linear plot that is easier to remember and to recount, while most of the factual events that inspired it are destined to remain anecdotal—i.e., literally, unsaid. Halfway between the storyteller's plot and the scientist's theory, the historiographer's narration, or history, weaves endless anecdotes into one meaningful narrative.[8] This narrative, once again, functions as a lossy data-compression technology: only the story thus construed will be recorded and transmitted and will bear and convey memories, wisdom, or meaning, whereas most of the individual events, experiences, or (in the Aristotelian sense of the term) accidents that inspired it will be discarded and forgotten.

Yet, as Walter Benjamin had already intuited, today's increasingly abundant dissemination of raw information goes against this ancestral strategy of story-building and story-telling.[9] Let's imagine, once again pushing the argument to its limits, that a universal archive of historical data may be collected, recorded, transmitted, and searched at will, by all and forever. The term "historical" would become ipso facto obsolete, as all facts must have occurred at some point in time in order to have been recorded, hence all data in storage would be "historical," and none more so than any other. And since Google has already proven that no two searches are the same, every search in this universal archive would likely yield new results—based on user preference, context, endless more-or-less secret parameters, and the sheer complexity and whim of search algorithms. Consequently, at that point no "narrative," theory, story, or sequence would be stronger than any other; in fact no narrative, theory, sequence, or story would even be needed or warranted any more. Only the data would speak—forever, and whenever asked, never mind by whom, and every time anew.

Again, it is easy to dismiss this Big Data scenario (which, it will be noted, is structurally similar to the postscientific, prediction-by-retrieval paradigm I outlined earlier) as a sci-fi nightmare. Yet, once again, signs of this impending change can already be seen in today's technology and culture, and they are seeping through contemporary social practices. Take this example, which will sound familiar to many scholars of my generation: for all undergraduates studying architectural history in Italy (and elsewhere, for that matter) in the late 1970s or early

’80s, the architectural history survey was basically a book, sometimes two, outlining a much simplified, teleological and ideological narrative of the rise of the modern movement in architecture (in Pevsner’s and Giedion’s historiographical tradition, that was the Hegelian and Marxian story of a linear rise to culmination, with no fall ever to ensue). Our textbooks (no names mentioned) contained a limited selection of small, and often very poor black-and-white pictures of the buildings under discussion, and these pictures, in most cases, were the only available evidence of buildings that few students, and indeed not many of our teachers, had ever seen. This is why we went to class, when we could: not so much to hear but to see. Giovanni Klaus Koenig’s lectures were popular across the whole university of Florence (and beyond) not only because of Koenig’s unparalleled talent as a jocular storyteller, but also because of the color slides he showed, which he had taken while traveling by car to Germany, Austria, and Switzerland (therefore no images of French or American buildings, for example, were ever shown). Most of the learning we could glean in such a technocultural environment was, and could not have been anything other than, a narrative: a story, or a theory, which we got to know much better than any of those famous buildings upon which those stories were supposedly predicated.

As for the buildings themselves, some we could visit when traveling, and some we would get a glimpse of, somehow, through a handful of color photographs in the relatively few books we could peruse at university libraries or buy in bookshops. A quarter of a century after Malraux’s *Musée Imaginaire*, even the most famous buildings of the twentieth century were still known exclusively through a very limited repertoire of authorial pictures, often due to some well-known photographers working in collaboration with the architects. Before I first traveled to Berlin as a student, I knew Ezra Stoller’s photographs more than Mies van der Rohe’s buildings.

Compare that situation—which was the norm throughout the age of printing and of modern mechanical technologies—to today’s wealth of visual and verbal documentation, available at the click of a mouse, by tapping on a touch-screen, or—as I just did—by saying “Mies van der Rohe” to my smartphone. One generation ago, the same scant data was imparted to all. Today, information is so abundant and easily searchable that each user can find her or his own. But due to the largely unauthorial, raw or crowdsourced nature of most of this wealth of information, each person doing the same search will likely come up with slightly different results, and sometimes with conflicting or incompatible information. That is indeed the way Big Data works, for scientists no less than for students or for the general public: Big Data is useful and usable only on average, and in the aggregate.

Failing that, each enduser will construct her or his own argument based on a random or arbitrary selection from an extraordinary array of data, and each selection will likely be different from all others. Each narrative or argument thus put together will therefore tend to idiosyncrasy and ephemerality. Anyone who has tried to teach a research seminar in the traditional way (i.e. expounding a sequential argument) in front of a group of doctoral students busily ferreting out odd happenstances, Photoshopped images, and wrong information from their tablets in real time will be familiar with this predicament. This does not mean that a thousand anonymous pictures on Instagram and a promenade through Google Earth are worth less than a single shot by Iwan Baan—in fact, in statistical terms, the opposite is true. But this does mean that many cultural habits we used to take for granted were in fact the accidental fallout of data-skimping, and are already incompatible with the data-rich environment we live in. Whether we like it or not, when an infinite amount of facts are equally available for anyone's perusal, search, and retrieval, we may no longer need theories, stories, histories, or narratives to condense or distill data, and to present them in a linear, clean, and memorable array. Again, one may argue that we will always need theories and stories for a number of other reasons, but—as mentioned earlier—that is difficult to prove.

So it would appear that many anti-modern and postmodern ideological invocations or vaticinations, from Nietzsche's "eternal recurrence" and Lyotard's "fragmentation of master narratives" to Baudrillard's or Fukuyama's "end of history," to name a few, all came, in retrospect, a bit too early—but all may soon be singularly vindicated by technological change.[10] What ideology could not accomplish in the twentieth century, technology is making inevitable in the twenty-first. If Search is the new science, *Big Data* is the new history. But not the history we once knew.

Notes

[1] This article was originally commissioned by the editors of *Perspecta 48: Amnesia* (2015: 48-60), a publication of the Yale School of Architecture, and I am grateful in particular to Aaron Dresben and Andrea Leung for their insight, the editorial assistance they offered, and for researching and choosing the illustrations that accompanied the article when it was first published. It is republished here by the permission of the editors and of the Yale School of Architecture. Some of the topics I anticipated here are developed in my book, *The Second Digital Turn: Design Beyond Intelligence* (MIT Press, September 2017), to which the reader is also referred for a more recent bibliography.

[2] On the origin and different meanings of the expression "Big Data", see Victor-Mayer Schönberger and Kenneth Cukier, *Big Data: A Revolution that Will Transform How We Live, Work, and Think* (Boston and New York: Houghton Mifflin Harcourt, 2013), 6 and footnotes.

[3] Pierre-Simon de Laplace, *Exposition du système du monde* (Paris: Imprimerie du Cercle-Social, IV–VI [1796-98]), vol. II, 5, IV, p. 266. ("[Kepler...] eut dans ses dernières années, l'avantage de voir naître et de profiter de la découverte des logarythmes, artifice admirable, dû à Neper, baron écossais; et qui, réduisant à quelques heures, le travail de plusieurs mois, double, si l'on peut ansi dire, la vie des astronomes, et leur épargne les erreurs et les dégoûts inséparables des longs calculs ; invention d'autant plus satisfaisante

pour l'esprit humain, qu'il l'a tirée en entier, de son propre fonds. Dans les arts, l'homme emploie les matériaux et les forces de la nature, pour accroître sa puissance; mais ici, tout est son ouvrage.")

[4] I discussed this in "Breaking the Curve: Big Data and Digital Design," *Artforum* 52, no. 6 (2014): 168–73.

[5] Galileo Galilei, *Discorsi e Dimostrazioni Matematiche intorno* à *due nuove scienze, attinenti alla mecanica e i movimenti locali* (Leiden: Elzevir, 1638), 116–33. In July 2008, a groundbreaking article by Chris Anderson first argued for a scientific revolution brought about by Big Data ("The End of Theory," *Wired* 7 [2008], 108–9). Although that issue of *Wired* was titled "The End of Science," the other essays in the "Feature" section of the magazine did little to corroborate Anderson's vivid arguments. The main point in Anderson's article was that ubiquitous data collection and randomized data mining would enable researchers to discover unsuspected correlations between series of events, and to predict future events without any understanding of their causes (hence without any need for scientific theories). A debate followed, and Anderson retracted some of his conclusions (Schönberger and Cukier, 2013, 70–72 and footnotes). From an epistemological point of view, however, what was meant by "correlation" in that debate did not differ from the modern notion of causality, other than in the practicalities of the collection of much bigger sets of data, and in today's much faster technologies for data processing. Both classical causation and today's computational "correlation" posit quantitative, cause-to-effect relationships between phenomena; and at the beginning of the scientific enquiry, both the old (manual) way and today's computational way need some hypotheses to select sets of data among which even unexpected correlations may emerge. Evidently, today's computational processes make the testing of any such hypotheses much faster and more effective, but the methodological and qualitative changes that would follow from such faster feedback loops between hypotheses and verification were not part of that discussion. A somewhat similar but more promising debate is now taking place in some branches of applied technologies, such as structural engineering. See Mario Carpo, "The New Science of Form Searching," forthcoming in "Material Synthesis: Fusing the Physical and the Computational," ed. Achim Menges, special issue, *AD: Architectural Design* 85 (2015): 5.

[6] See D. Napoletani, M. Panza, and D. C. Struppa, "Agnostic Science: Towards a Philosophy of Data Analysis," *Foundations of Science* 16 (2011): 1, 1–20. As a search always starts with, and aims at, one individual event, the science of search is essentially a science of singularities; but the result of each search is always a cloud of many events, which must be compounded, averaged, and aggregated, using statistical tools. Thus, there are no limits to the level of "precision" of a search (a lower level of precision, or less intension, will generate more hits, or a larger extension in the definition of the set). On this aspect of Aristotelian science, see Carlo Diano, *Forma e evento. Principi per una interpretazione del mondo greco (*Venice: Neri Pozza, 1952). The rejection of modern science as a science of universals is central to the postmodern philosophy of Gilles Deleuze and Félix Guattari. In *Milles Plateaux*, in particular, Deleuze and Guattari opposed the "royal science" of modern science, based on discretization ("striated space") to the "smooth space" of "nomad sciences," based on "nonmetric, acentered, rhizomatic multiplicities that occupy space without counting it and can be explored only by legwork," which "seize and determine singularities in the matter, instead of constituting a general form… they effect individuations through events or haecceities, not through the object as a compound of matter and form." Deleuze and Guattari saw the model of nomad sciences in the artisan lore of medieval master builders, i.e. in the past, before the rise of modern science; and they had no foreboding of the then nascent technologies that would inspire digital makers one generation later. See Gilles Deleuze and Félix Guattari, *A Thousand Plateaus: Capitalism and Schizophrenia*, trans. B. Massumi (London and New York: Continuum, 2004), 406–9 and 450–51. (First published in French as *Milles Plateaux* [Paris: Les Editions du Minuit, 1980]).

[7] See Mario Carpo, "Micromanaging Messiness: Pricing, and the Costs of a Digital Nonstandard Society," in "Money," *Perspecta* 47 (2014): 219–26. See Neri Oxman, "Programming Matter," in "Material Computation: Higher Integration in Morphogenetic Design," ed. Achim Menges, special issue, *AD: Architectural Design* 82 (2012): 2, 88–95, on variable property materials; Achim Menges, "Material Resourcefulness: Activating Material Information in Computational Design," ibid., 2, 34–43, on non-standard structural components in natural wood. This vindicates the premonitions of Ilya Prigogine, another postmodern thinker whose ideas were a powerful source of inspiration for the first generation

of digital innovators in the 1990s. See in particular Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* (New York: Bantham Books, 1984). (First published in French as *La Nouvelle Alliance*: *métamorphose de la science* [Paris: Gallimard, 1979]).

[8] Walter Benjamin, "The Storyteller: Reflections on the Works of Nikolai Leskov," in *Illuminations: Essays and Reflections*, trans. Harry Zohn, ed. Hannah Arendt (New York: Schocken Books, 1968), 83–109. (First published as "Der Erzähler: Betrachtungen zum Werk Nikolai Lesskows," in *Orient und Okzident* [City: Publisher, 1936]). However, Benjamin considers the ancestral storyteller and the oral chronicler as the conveyors of raw data, and sees only the modern novel and historiography as abstract, simplified linear narratives that are construed independently from the events on which they are based and from which they derive. After the works of Marshall McLuhan and particularly of Walter Ong on the cultures of orality, it is easier today to see the bard's/storyteller's recitals as tools of abstraction and memory devices.

[9] See note 7.

[10] Nietzsche's first mention of "eternal recurrence" is in aphorism 341 of *The Gay Science* (*Die fröhliche Wissenschaft*, 1882–87). Lyotard spoke of the "décomposition des grand Récits," or "métarécits": Jean-François Lyotard, *La condition postmoderne* (Paris: Les Éditions de Minuit, 1979), 31. The "end of history" may have been first proclaimed by Jean Baudrillard, *Simulacres et Simulations* (Paris: Galilée, 1981), 62–76 (see in particular p. 70: "l'histoire est notre référentiel perdu, c'est-à-dire notre mythe"). Francis Fukuyama, *The End of History and the Last Man* (New York: Free Press, 1992). See also Fukuyama, "The End of History?" *The National Interest* 16 (Summer 1989): 3–18.

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Digital Space and Architecture

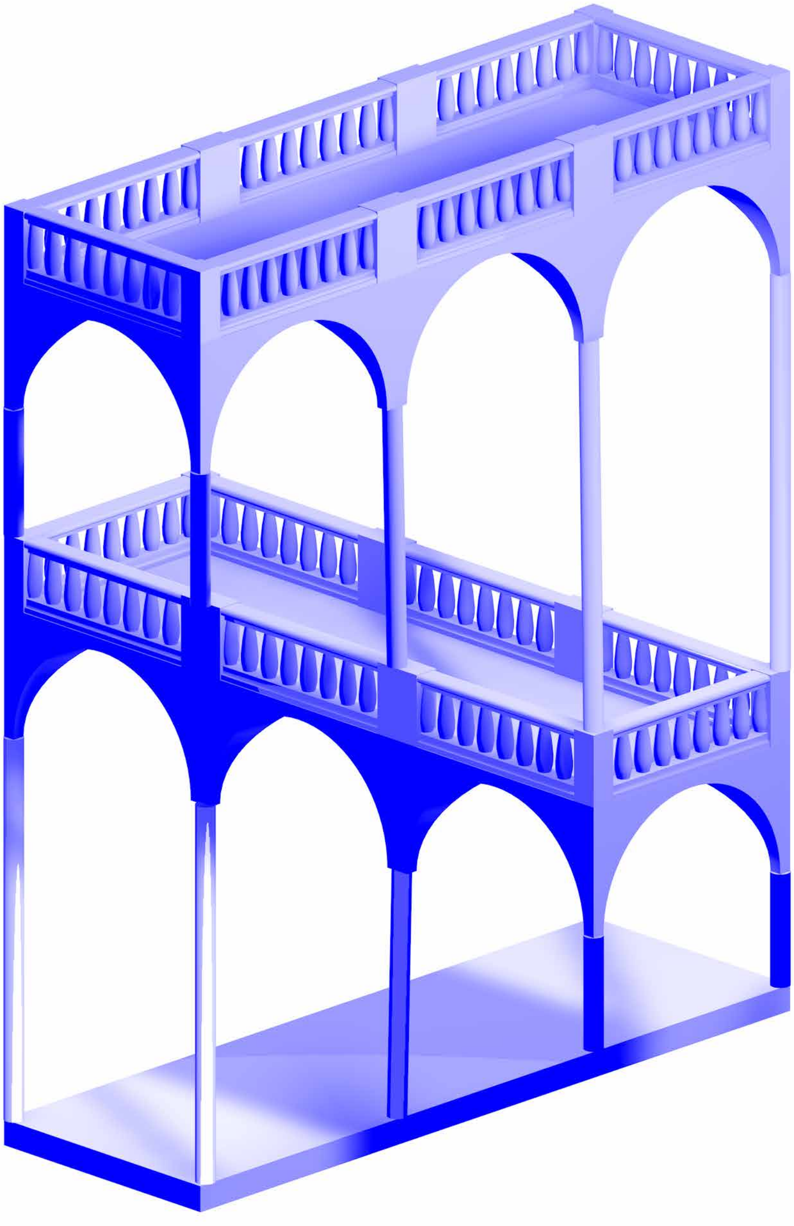

Figure 1: “Impossible Construction”. 3D Visualization by Sander Münster.

Peer-Reviewed

3D Reconstruction Techniques as a Cultural Shift in Art History?

Sander Münster, Kristina Friedrichs, Wolfgang Hegel

Abstract: Digital 3D reconstruction methods have been widely applied to support research and the presentation of historical objects since the 1980s. Whereas 3D reconstruction has been incorporated into a multitude of research applications, essential methodological foundations for more widespread utilisation of digital reconstructions have yet to be developed. Against this background, the aim of this article is to consider how the methodology of 3D reconstruction alters research cultures in architectural and art history by exemplifying three problem areas, (1) research functions of 3D reconstructions and their drawback to a current research culture in art history, (2) consequences of cross-disciplinary project-based teamwork within 3D reconstruction projects, and (3) problems and difficulties caused by imagery as primary media for research and communication.

Keywords: architectural history, methodology, digital 3D reconstruction.

1. Introduction

During the past 30 years, technical as well as methodological issues relating to the use of digital technologies in the humanities have been widely researched and discussed, both with regard to prototypic applications and in terms of organisational prospects and infrastructures. Despite the immense efforts expended on the establishment of Information and Communcations Technology (ICT) and, in particular, digital 3D reconstruction technologies—focusing on "the creation of virtual model[s] of historic entities with a need for object-related human interpretation" (Münster, Hegel, and Kröber 2016)—as day-to-day tools for researchers in the humanities, the current situation is still ambiguous. Whereas 3D reconstruction has been incorporated into a multitude of research applications, essential methodological foundations for more widespread utilisation of digital reconstructions have yet to be developed. In this regard, it can be observed that the methodology and utilisation contexts of digital 3D reconstructions of historical entities have been the subject of numerous research studies.[1] While the majority of this research has focused on individual projects, many general methodological issues, such as scientific value added and the discursive potential of the results, have also been discussed, particularly from the perspective of archaeology and with a view to recording and conserving cultural heritage.[2] So far, however, there is a lack of comparable studies regarding a humanities approach and potentials for the history of art and architecture. This is surprising, since the digital shift, at least according to representatives of digital art history, requires "critical reflection on the methods and practices" of the entire academic discipline of art and architectural history.[3] But what are the reasons for this need for a re-evaluation of the methodology used in art historical research?

The aim of this article is to examine a methodology of digital 3D reconstruction in the context of art and architectural history and to present its significance for research cultures in the history of art and architecture. This will comprise, first of all, a definition of digital 3D reconstruction, followed by a brief review of its development. Considering the question as to how the methodology of 3D reconstruction alters research cultures in architectural and art history, three problem areas will be considered:

- Research context shift: 3D reconstruction not only broadens the spectrum of current research practices and applications in art and architectural history but endorses specific research paradigms, as well as being limited to specific application contexts. What are the research functions of 3D reconstructions? And what are the challenges in relation to current research culture in art history?

- Interdisciplinarity: While art and architectural history are traditionally practiced as individualized research, 3D reconstruction requires cross-disciplinary teamwork as well as organisation in projects. What are the consequences of this paradigm shift for academic culture?

- 3D reconstruction and the visual turn: At present, 3D reconstructions closely relate to an image-based discourse in art and architectural history. This evokes various legitimate concerns about the limitations and biases of images and leads to the question: What problems and difficulties are caused by imagery in these contexts?

2. Definition of digital 3D reconstruction

The central purpose of digital reconstruction is to create a spatial, temporal and semantic virtual model. Essential distinctions are to be drawn between the types of entities under investigation, as to whether they are tangible or intangible entities (such as customs). Furthermore, where working procedures are concerned it is essential to distinguish between a reconstruction of entities that are no longer extant or were never realised (such as designs which were never implemented) and the digitisation of entities that do exist. Whereas digitisation refers to the technological conversion of an object into a digital representation (for example through semiautomatic modelling using laser scans), a digital reconstruction process requires the human interpretation of data (De Francesco and D'Andrea 2008, p. 231, Münster, Hegel, and Kröber 2016). The creation of a model is then mostly done on the computer using manually controlled modelling software.

It should be borne in mind, of course, that reconstruction is a long-established method that was initially utilized in art history long before the advent of computer-aided visualization techniques. As early as the Renaissance, scholars studied the appearance of the architecture of the past, analyzing it by means of images, among other things, and using it in their creative processes as a model for constructing their own contemporary buildings (Carpo 2001, p. 6). As art history became established as an academic discipline, reconstruction gained new importance, especially with regard to architecture that had been lost; for example, studies were made of the appearance of the Late Antique Basilica of St Peter in Rome, which had been demolished in 1514 (Krautheimer 1937-1977, Arbeiter 1988, Andaloro 2006, pp. 312-468), the early construction phases of the Cathedral of Santiago de Compostela (Hinterkeuser 2003, Horst 2012) or, as a prominent present-day example, the Berlin City Palace (Stadtschloss) (Rettig 2011, Conant 1926). Such traditional reconstructions are prompted by questions as to their original appearance, often posed as issues in the field of archaeology, which cannot be verified through in-situ observation. They may also serve—as in the case of the Berlin City Palace—as the basis for an actual architectural reconstruction.

3. The process of digital 3D reconstruction

The process of digital 3D reconstruction encompasses not only the creation of a virtual model[4] by means of software tools, which is mostly done by specialised modellers, but also the subsequent visualisation, through which the model is rendered into a final presentation format. This process is usually closely accompanied by historical research, through which a sound understanding of the object to be modelled is developed on the basis of sources which provide information from the past (Münster 2013, Münster, Jahn, and Wacker 2017). In view of the resulting division of labour, it is essential to consider the cooperation between those involved as well as the associated aspects of communication and quality management. The entire working process of virtual 3D reconstruction can roughly be divided into the fields of sources, modelling and visualisation (cf. table 1), which may be made up of numerous different steps and tasks and take on different forms.

		
Sources	**Modelling**	**Visualisation**
Historical sources such as images: vedute, panoramas etc.; plans; textual sources: construction news, invoices for building work etc.	Semiautomatic model generation Procedural generators Manual modelling using digital tools	Static images or renderings Animations Interactive visualisation (e.g. VR applications or interactive tours)
Contemporary sources such as images: esp. photographs; plans; data: sensory analysis and surveys, topographic reliefs, street maps etc.; texts: scientific papers, esp. studies and architectural history		Data output (e.g. for production or data-based analyses)
Logical sources such as: architectural systems; analogies/ typologies; model logics		

Table 1: Classification of the digital 3D reconstruction process as regards sources, modelling, cooperation and visualisation.

4. A brief genealogy of digital 3D reconstruction[5]

To a greater extent than almost any other aspect of the digital humanities, digital reconstruction is an interdisciplinary field at the interface between research and practical application. Therefore, in addition to questions relating to research and science, there are also numerous applications beyond the academic sphere—for example in the context of teaching, museum displays, virtual tourism, cultural management and entertainment media. Project practice therefore usually addresses issues of both research and communication.

Digital 3D reconstructions have been used in cultural and humanities scholarship for more than 30 years. Furthermore, in the context of architectural history they facilitate research and presentation, and have a growing significance for the long-term preservation, investigation and provision of public access to tangible, intangible and digital cultural heritage and are the subject of broad discourse, particularly from the point of view of archaeology and the recording and preservation of cultural heritage.

A brief outline of the various stages in its development so far will be presented in the following section.

Up to the end of the 1990s, digital models primarily served as substitutes for physical models and graphic representations (Sanders 2012p. 43, Novitski 1998). The first attempts in the sphere of the digital modelling of historical architecture were made in the late 1980s and were at that time an exceptional phenomenon, as in the case of the WINSOM model of the Old Minster in Winchester[6] or the reconstruction of the Abbey of Cluny by Horst Cramer and Manfred Koob (c.f. Cramer and Koob 1993, p. 58-103). In addition to reconstructions of historic, sometimes no longer extant, architecture such as the pioneering reconstruction of the Cathedral of Cluny III (Cramer and Koob 1993), there were also projects in the 1990s which already worked on the visualisation and reconstruction of architecture that had never been constructed—for example, designs associated with the Bauhaus.[7] The reconstruction of destroyed synagogues carried out by Marc Grellert, for example, demonstrated the potential for virtual memorial culture using digital technology (c.f. Grellert 2004). To sum up, it can be stated that in this early phase the spectrum of new opportunities was explored and the applicability of the technology was tested.

As the models were disseminated further and came to be used in research on historic architecture, attention began to be paid, after the turn of the millennium, to the inclusion of digital models in university teaching. For example, as part of the Altenberg Cathedral project, experiments were conducted as to how this new technology could be utilised in the lecture theatre.[8] Difficulties arose from the fact that utilisation of the new methods presupposed that architectural historians possess detailed knowledge in the field of computer technology, although this was not included in the curriculum. This then led to the realisation that in order to continue using this technology, changes would be required in the training of art historians (c.f. Günther 2001, pp. 111). In an essay concerning the Altenberg Cathedral project, Stephan Hoppe had already pointed out the need for special academic debate concerning the "interpretative character of these artefacts [here referring to digital reconstructions]" (Hoppe 2001bp. 99). In particular as regards source evaluation, the creation of digital models requires considerable preliminary work and scientific analysis, which also involves other genres such as photography and drawings, as well as written sources.

Starting points for methodological criticism are provided by the field of Visual Studies, where crucial observations have been made (c.f. Schmidt-Funke 2010, Roeck 2004, Burke 2003, Haskell 1995) but in which the digital 3D reconstruction of historic architecture and its representation have been dealt with only peripherally or not at all, this task having been left almost entirely to the field of architectural research.[9] At the start of the new millennium, the widespread application of digital reconstruction in the academic sphere necessitated the development of exemplary standards as well as the establishment of a scientific community devoted specifically to this field (c.f. Frings 2001, Münster and Ioannides 2015). An overview of the possible means of communicating the scientific content of the models was presented in a talk by Ute Verstegen in 2007, in which various projects and communication systems were presented and analysed (Verstegen 2007).

An elaborate and comprehensive analysis of the current state of research in the *Digital Humanities*, which also includes the use of 3D technologies for reconstructing historic entities, was conducted by the EPOCH network project completed in 2008, which drew on numerous leading European institutions and protagonists to demonstrate not only the status quo but also the development potentials and research desiderata.[10] The results of this analysis were reflected not least in the subsequent funding priorities concerning 3D applications in the field of *Digital Humanities*, which focus primarily on aspects such as the minimisation of costs and the ease of use of software tools for creating digital 3D reconstructions (c.f. European Commission 2011). As the possibilities offered by this technology have grown, the fields of application for digital models have also continued to expand. Rather than serving merely as a substitute for established media, their role as a presentation medium (c.f. Greengrass and Hughes 2008) and in the field of academic research and education, has continued to develop (c.f. Favro 2006). However, the visualisation of historical entities continues to be its principal function.

Since about 2010 a new phase in the development of digital reconstruction has been underway. This is characterised not only by efforts towards methodological validation but also its broad incorporation into relevant disciplines and, not least, its integration into academic teaching. With regard to achieving wide impact, the Framework Programme for the Humanities, Cultural and Social Sciences established by the German Federal Ministry for Education and Research (BMBF) in 2013, for example, aims to "create the prerequisites for networking between disciplines in virtual research environments and to significantly expand the research area, access to digital sources and their availability." (Bundesministerium für Bildung und Forschung 2014).

4. Digital techniques as a cultural shift in humanities scholarship?

Against this background, a major task is to enrich the currently highly application-oriented process of using digital reconstruction tools for visual humanities research purposes by providing it with a critically reflected methodological basis and by anchoring it in academic culture.

What is the purpose of digital research methods in the context of architectural and art history? According to Heusinger, computers support art history scholarship in the following ways:

- Data collection, e.g. through digitisation;
- Data retrieval from database records with the transfer of knowledge;
- Examining visual humanities questions, e.g. a composition of complex figurative paintings;
- Reconstructing, simulating, and producing objects; and
- Administering and organizing people and objects.[11]

A general question asked concerning the use of digital methods in these contexts is whether computing methods lead to novel, ground-breaking research questions, approaches, or insights. Studies on this topic have been—from the perspective of architectural and art history—primarily conducted with regard to research contexts (i.e. Günther 2001), research objects (i.e. Bentkowska-Kafel, Cashen, and Gardiner 2006), or by distinguishing phases of the research process (i.e. Kohle 2013). On a more general level, scientific activity and the "production" of insights have been widely discussed in sociology and philosophy (i.e. Fleck 1980, Peirce 1931, Latour and Woolgar 1986, Knorr-Cetina 2002). While the use of information and communication technologies in most cases simply extends non-digital possibilities, and general research applications in terms of approaches used and research questions asked are mostly similar to those of the pre-digital age, the qualities and quantities as well as workflows have changed dramatically against the background of digital development (e.g. Moretti 2007). Taking several well-grounded systematisation approaches (Pfarr-Harfst 2013, Günther 2001, Drucker 2013, 9) into consideration, added value for research methodology in the visual humanities that can be provided by digital methods may include:

- Scaling: The use of computing may ease the collection, management, and analysis of large-scale data and information sets.

- Editability: Digital work can be edited, transferred and duplicated, and later modifications to a research paper, for example, are possible.

- Information combination: The combination of information from different fields of knowledge may generate new insights.

- Pattern recognition and application: Patterns or systematics can be used to generate hypotheses or to reduce the complexity of large-scale data (c.f. Spence 2001).

Against the background of the discrepancy between the new technical opportunities that exist and the methodology and issues, which largely remain the same as in the past, there is a need for debate in three areas in particular: of special significance are the fields of the research environment, interdisciplinary collaboration and the critical evaluation of sources and of the models being created; in short, the content-related, methodological and procedural consequences that arise from 3D reconstruction.

5. Research contexts for 3D reconstruction in art history?

The research that underpins digital reconstruction must be recorded and systematized (Pfarr-Harfst 2013). Current approaches are mostly based on historical exemplification—as in the case of the historical method proposed in Section 2—aiming to distinguish several research contexts (e.g. Günther 2001). On a more general level, the process of research and the insights to be gained are widely discussed in sociology and philosophy (e.g. Fleck 1980, Peirce 1931, Latour and Woolgar 1986, Knorr-Cetina 2002). The question of the purpose and function of individual research approaches, such as the process of digital 3D reconstruction, also requires investigation. Although there are various other research approaches—such as numerical techniques like the finite element method (FEM) or computational fluid dynamics (CFD)—visualisation is the most common way to present digital 3D reconstruction. According to Ware, visualisation can support research and understanding in five ways (Ware 2004, cited according to Frischer and Dakouri-Hild 2008, pp. V):

- It may facilitate the cognition of large amounts of data.

- It can promote the perception of unanticipated emergent properties.

- It sometimes highlights problems in data quality.

- It clarifies the relationships between large- and small-scale features.

- It helps in the formulation of hypotheses.

Taking this generic scheme and several approaches to grounded systematisation (Pfarr-Harfst 2013, Günther 2001) into consideration, the authors would like to propose a preliminary typology of research approaches, as shown in table 2, which distinguishes between research objects and objectives of relevant research.

Research approaches	**Source**	**Object**	**System**
Documentation (e.g. compilation and recording of knowledge)	X		
Data quality assessment (e.g. consistency or contingency of sources)	X		
Visualisation (e.g. investigation of shape or appearance)		X	
Creative process (e.g. planning or construction)		X	
Conceptualisation and contextualisation (e.g. typologies, functional segments, archetypical elements, provenance)	X	X	X
Numerical analysis (e.g. structural analysis, lighting)		X	
Hypothetic simulation (e.g. of hypothetic objects deriving from an architectural system)			X

Table 2: Research approaches in digital reconstruction.

Use of 3D digital reconstruction to research a certain historic entity or its parts is common. Three-dimensional reconstruction is also employed to investigate and evaluate sources. Sometimes the focus of research is not on a specific object but rather schemes and systems, for example, an investigation concerning the Vitruvian system of architectural orders. Against this background, 3D reconstruction methods are often employed to derive archetypes or specific features (Ling, Ruoming, and Keqin 2007).

The question concerning the "original" being reconstructed is closely related. The "original" can be a certain intention (e.g. of a builder), a specific source, or a historic object. Research objectives are:

- Documentation: In the case of digital 3D reconstruction, the objectives of a virtual model are primarily to assort, store, and compile spatial-related knowledge (c.f. Sachse 2002). For example, the 3D model of the Domus Severiana provided a spatial map and therefore the possibility to geo-reference sources (Wulf and Riedel 2006).

- Data quality assessment: Contextualisation and assessment of the consistency of sources is a focus of research. For example, digital reconstruction of content depicted in drawings or paintings can be used to test perspective features or consistency (c.f. Carrozzino et al. 2014). Discrepancies between ground plans and elevations or vedute are revealed through this.

- Visualisation: The most common way to visualise is to formulate a hypothesis regarding the shape, properties and appearance of a certain historic object. Concerning this aspect, digital reconstruction allows the non-invasive application and testing of alterations or restoration.[12]

- Process investigation: Another type is research into historical preparation processes (e.g. planning or construction processes employed by craftsmen, sequence of planning phases, modifications, interruptions).

- Conceptualisation: A major question for underlying concepts and intentions, such as structuring concepts (c.f. Saft and Kaliske 2012), refers to functions of certain parts of an object (e.g. rooms, figuration or proportions).[13]

- Contextualisation: Other objectives concern the contextualisation of objects (e.g. geo-location, relationship to other objects, visual axes) and the identification of archetypal characteristics. This may refer, for example, to the craftsman's specifications and typologies, as well as comparison of iconographical concepts. Contextualisation may lead to a research interest in sources and specific objects, as well as systems (Kohle 2013).

- Numerical analysis and simulation: For gaining dynamic data from models there is the possibility of simulating different kinds of forces and processes. Structural analysis is one area of application (c.f. Mele, De Luca, and Giordano 2003), but there is also the possibility of examining the function of certain parts of a building or of path networks in combination with the surroundings.[14]

- Hypothetical simulations[15]: Different usages are possible without making a reference to specific historic entities, for example, the exploration of hypothetically possible objects which derive from a certain architectural order and the related (hypothetical) limits and boundaries of this system (Wagener, Seitz, and Havemann 2016, Ling, Ruoming, and Keqin 2007).

Unlike research findings presented in the form of texts, 3D models require extremely complex information about the appearance of a historical entity in order to produce a concise reproduction. As Fish points out, "CAD systems [...] 'make it hard to be vague'" (Fish 1994, p. 502, cited after Sachse 2002, p. 63)—a statement that undoubtedly applies to all current 3D modelling techniques. 3D reconstruction also forces its creators to answer questions which existing sources leave open, a requirement that contrasts with current scientific procedural models in the humanities and cultural studies, where the attempt to "show how it actually was" (von Ranke 1824, p. 1) has usually given way to centring on a problem (Wengenroth 1998, p. 5). Correspondingly, historical research in the context of 3D reconstructions consists not only of the interpretation and evaluation of existing sources; rather, in order to produce a coherent model, hypotheses have to be developed that go beyond a "dialogue with the sources themselves" (Wengenroth 1998, p. 4). Possible gaps in the sources must be documented, identified and made traceable as such. Any supplementary conclusions made by analogy also have to be accompanied by a valid explanation. Only through such supplementary information can an architectural model, which at first glance seems to be self-explanatory, be open to scientific scrutiny and thus be comparable. This subsequently gives rise to the question of whether 3D reconstructions represent a step backwards in the evolution of historical scholarship.

6. Interdisciplinarity of 3D reconstruction?

In digital reconstructions, information technologies serve to produce virtual historical models. In addition to computer science as the "tool provider", content-related perspectives acquired from archaeology and the history of culture, art and architecture, architectural research and museum studies, are also involved. Owing to the highly specialised nature of the tools, a model is usually created not by the persons responsible for the content themselves, but rather—in the context of an interdisciplinary project—by modellers who come from the disciplines of computer science, architecture, geosciences and engineering as well as design.

The reasons for this lie not least with the process of modelling, which is mostly based closely on the procedural models used in these disciplines. Whereas VR, animation and CAD tools are used to reproduce the form of an object and its surface in varying degrees of quality, BIM and GIS tools serve to systematise and process object volumes and object relationships. What is more, numerical simulation tools such as CFD, FEM or lighting analyses in turn require the use of specialised procedures during model construction and analysis.

On this basis, the work of the art historian is fundamentally different from that of the architect, who is able to undertake his or her construction activities without an additional modeller. Further contrasts derive from their respective approaches; the architect is primarily concerned with their own design process, whereas the art historian seeks to reproduce historical reality as faithfully as possible. Consequently, art historians are required to work strictly on the basis of proven sources, whereas the architect can more freely assimilate various influences. This brief comparison alone makes it clear that the modelling focus in these different disciplines is highly divergent.

Many challenges for 3D reconstruction projects are connected to a lack of interdisciplinary understanding. Intensive support by images during a reconstruction process could foster interdisciplinary communication, in particular, and could be used as a "creoles" (Styhre 2010) for the exchange and sharing of mental models. For that, it is necessary to synchronise terminologies or to employ "common grounds" like symbols, colours or tags. Such decisions and tasks should be started at an early project stage and should be controlled and adapted throughout the entire project process. Ideally, such visual coding schemes would be a mental model shared by all members of the project team and would be documented and based on either extant coding schemes, e.g. from engineering, or would use "natural" codings like physical analogies or concrete depictions (Tversky 2002) to make these issues recognisable at later times or even accessible for later works. But in all cases images would only support communication and, especially for complex tasks and interdisciplinary exchange, personal contact would be more useful than communicating information over long distances.

Resulting challenges include questions regarding the access to and evaluation of models and images, as well as references between reconstruction and (explainable) fundamental knowledge such as sources.

A specific challenge is presented by the division of labour that we see in a typical project. It is evident from published project reports that interpretative 3D reconstruction projects are almost always interdisciplinary in nature, with the working teams mostly only coming together temporarily, unlike the situation in companies (Nausner 2006: 57 f.). The tasks are usually divided between historical research and the creation of the model. Where working procedures are concerned, the division of labour between the historical researchers or historians on the one hand, and the creators of the digital model on the other, are so strong that it is possible to speak of "human-human-machine communication". In this context, the organisation of work, the distribution of tasks, and effective communication are therefore correspondingly important.

7. Images and 3D reconstruction

In art history, in particular, visual media are an important foundation for working, even beyond the predominant genre of painting. Every object, whether it is a painting, sculpture or building, can be investigated anywhere thanks to various visual representations. Regardless of whether a building still exists, images and plans are essential basic sources. In connection with this, a number of basic working techniques can be derived. In addition to the critical evaluation of relevant sources and critical thought, which are required in particular for reconstruction where comparison with the original is not possible, this includes visual comparisons and reference to comparable existing entities.

Generally, research about the use of images is nothing new and has taken place in relation to their utilisation in various contexts like engineering, design or architecture, or in a scientific and research context (Gooding 2004). Regarding the quality of images as visual signs, there are many possible dimensions, such as similarities to a depicted object, visual styles or creation processes (Bresciani 2013).

The use of images in a research-related context would not only include functions such as memorisation, documentation or communication within projects or of results. Such images would also be important for problem solving and related activities, such as information sorting and solution negotiation (Sachse 2002). Particularly the humanities, and especially archaeology, art history, and history of architecture, deal with historic images as sources of reconstruction. Types of sources and their relevance for 3D reconstruction are a prominent topic in academic literature (Hermon 2008, Remondino et al. 2009). However, these are not new phenomena: especially with regard to the reconstruction of architecture—the most prominent type of entity reconstructed in such projects (Münster 2016)—communication via images has had a long tradition since early modern times (Carpo 2001).

Results of 3D reconstruction are mostly static images, animations, or even interactive visualisations like computer games. An approach to their classification is delivered in the engagement taxonomy developed by Grissom et al., which differentiates six degrees of interactivity for such visual output (Grissom, McNally, and M. F. & Naps 2003). Closely related are questions concerning information communicated by such visualisations. Such aspects are theorised in several approaches such as visual decision making (Nutt and Wilson 2010) or visual learning theories (Gagné, Briggs, and Wagner 1988, Pahl and Ahlborn 1998, Schwan and Buder 2006).

Unlike in text-based disciplines, knowledge is mainly gained by the creation of a virtual model and its digital, in most cases, visual demonstration in the case of digital reconstruction. Moreover, contributions of different authors and a multiplicity of intuitive decisions are included in such media which are based on know-how (Münster and Prechtel 2014). So far, neither an academic culture nor mechanisms have not been established for making digital models and related images scientifically linkable and discussable. This also includes the capacity to quote parts or areas in models and images, and the modification of such media by others. In addition to a number of technical requirements, the development of approaches for the documentation of processes and their results, and the capacity of making a model logically transparent, are derived (Hoppe 2001a, Günther 2001).

8. Conclusion

Are digital 3D reconstruction techniques causing a cultural shift in art history? Whereas 3D reconstructions have now become established and recognised at least as a method of illustration beyond representation-related discourse (Sanders 2012: 43), its full recognition as a method of investigating historical facts and circumstances has still not been achieved. This implies questions of its added value for research and the discursive potential of such projects. It is urgent that these questions should be clarified, not least in view of the fact that methods of 3D reconstruction are not only being increasingly used in various ways in art history, but also because the sheer quantity and public use of tools and the liberalised distribution options available via the Internet (c.f. Münster 2011) are increasingly beyond the control of traditional professional discourse.

Our article demonstrates, on the one hand, that the use of methods of 3D reconstruction is bringing about a number of fundamental changes as compared with previous practice in the field of art history. This includes not only the quantitative and qualitative expansion of opportunities for researching architectural objects and sources but also, particularly against the background of numerical simulation and pattern recognition, the development of a large number of approaches to research that were previously not feasible. On the other hand, there are problems associated with the primarily visual investigation of (virtual) reproduced objects and—from the point of view of art and architectural history—the non-transparent design processes, the need for interdisciplinary cooperation and as a holistic representation of the past, what might be considered a "retrograde step" in the disciplinary evolution in art history.

In light of the fact that art and architectural history have developed an elaborate approach to such problems as part of an intensive, centuries-long discourse, it would indeed appear that the need for art historians to learn about computer graphics and 3D modelling is urgently necessary. Looking to the future, two particular challenges are evident. On the one hand, 3D reconstruction for the purpose of research in the history of art and architecture needs to be validated and developed in respect to methodology. What are also of essential importance are impulses from the history of art and visual studies, as well as validation by them as regards research culture and technology, in order to overcome the current methodological deficiencies in digital reconstruction for the purpose of investigating historical architecture.

Notes

[1] Among the historical disciplines utilizing these techniques, archaeology in particular, as well as—to a lesser extent—art and architectural history, play a leading role, both methodologically and conceptually. That it is now firmly academically established is evidenced, not least in archaeology, by a considerable number of established and regular conferences and workshops as well as periodicals. An analysis relating to this is to be found in (Münster, Köhler, and Hoppe 2015).

[2] Examples of such status reports include the final reports of the EPOCH projects and the European Commission's ICT Status Report, which provide a general description of a research landscape and current discourses: (Arnold and Geser 2008, European Commission 2011). An example of an extensive compendium dealing with aspects of scientific digitization and the 3D reconstruction of historical buildings is (Frischer 2008)

[3] International workshop "Digitale Kunstgeschichte: Herausforderungen und Perspektiven", 2014 (http://sik-isea.ch/Portals/0/docs/Z%C3%BCrcher%20Erkl%C3%A4rung%20zur%20digitalen%20Kunstgeschichte%202014.pdf; accessed 15.09.2015).

[4] Aspects of the exemplary character of the model have been discussed at length on various occasions. For an overview of approaches taken by various disciplines and in the history of ideas, see: (Sachse 2002, FN 16), specifically in relation to 3D reconstruction: (Pfarr-Harfst 2016).

[5] The doctoral thesis by Heike Messemer, which is currently nearing completion, aims to develop a genealogy of digital 3D reconstruction. Research findings from this project are presented in (Messemer 2016).

[6] Project period: 1984-1986 - Lit.: (Burridge et al. 1989).

[7] An overview of reconstruction projects from the point of view of art history in German-speaking Europe: List of digital models of historic architecture (http://www.digitale-kunstgeschichte.de/wiki/Liste_digitaler_Modelle_historischer_Architektur; accessed on 15.09.2015). As a compendium of international projects, particularly from the perspective of archaeology up to the mid-1990s: (Forte and Siliotti 1997)

[8] Project period: 1997-1999; persons responsible: Doberkat, Ernst-Erich and Nußbaum, Norbert. Literature: (Hoppe and Scheer 1999)

[9] On this see also (Ackerman 2002) and (Recht 1995). In keeping with the title, (Linfert 1931, S. 133-246) are still also used.

[10] (Arnold and Geser 2008). One specific focus of

this investigation was the positioning of *Digital Heritage*—however, the results represent a state of research which, for the majority of the aspects dealt with, can be generalized as applying to all fields of 3D reconstruction in the historical disciplines.

[11] Based on: (Heusinger 1989). Particularly cited after: (Bentkowska-Kafel 2013, p. 6). Moreover, a range of media and applications in digital humanities scholarship, particularly digital art history, is presented in: (Bentkowska-Kafel, Cashen, and Gardiner 2006).

[12] For example, removing alterations of statues introduced in the course of an earlier conservation treatment. Discussed in (Fontana et al.); For the restoration of fragmented objects, see (Arbace et al. 2013).

[13] The approaches followed until now concentrated mainly on analyzing architectural plans. Discussed in (Wiemer 2005, Masini et al. 2004).

[14] For example creating simulations of ancient ventilation systems. See (Balocco and Grazzini 2009).

[15] A definition of "simulation": (Hinterwaldner 2010, pp. 31-41 & 68-69).

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Figure 1: Reconstruction of the Palais Stoclet in Brussels.

Peer-Reviewed

(Re-)Creating the past: 10 years of digital historical reconstructions using BIM

Stefan Boeykens, Sanne Maekelberg, Krista De Jonge

Abstract: Starting in 2003 the Department of Architecture of the University of Leuven (KU Leuven) has utilized digital reconstructions in several Masters Dissertations. Over the years different topics have been the subject of study, ranging from Burgundian residences to lost religious heritage sites, and addressing a range of methodological difficulties specific to the integration of historic architecture with modern technologies have emerged.

As Historic Building Information Modeling (HBIM) has found its way to a broader audience over the last few years, attention must be paid to the methods and means by which these reconstructions are presented to a wider audience. New technologies inevitably change the perspective of the viewer, shifting from a distant observer to a close inspector (sometimes providing visual access and virtual proximity to reconstructed elements that were never even supposed to be seen up close). New means of communication and visualization need to be realized that fully address the possibilities and limitations of the reconstructions.

Keywords: HBIM, Digital Historical Reconstruction, CAD, BIM, visualization.

Digital Historical Reconstruction today

Computer-Aided-Design (CAD) has changed the way that historians and architects interact with the built environment. In addition to the remarkable increase in detail, accuracy and efficiency, the use of CAD in heritage and conservation has also increased access to cultural heritage. The application of CAD implies using real measurements and scale, allowing for a deeper insight in the building and its construction. When recreating lost building states or constructions it is possible to get a better understanding of their perception by contemporary witnesses, especially of space.

Even though photorealistic visualizations are possible, Alkhoven[1] stated early on that the actual visualization (realistic, idealistically, fictitious) is not the main concern; rather, the underlying narrative and interpretation by the researcher, alongside the reconstruction methodology are of much higher importance. The question of *how* sites looked must always be coupled with the question of *why* they are being reconstructed. This narrative can be communicated by using a combination of techniques demonstrating different aspects of the building. Boeykens et al.[2] describe how architectural analysis may be aided by the use of a variety of 3D modeling and visualization techniques, for the most part applicable to historical reconstruction cases, including improved application of meta-data for model documentation.

In the reconstruction of Josef Hoffmann's Palais Stoclet in Brussels (fig. 1), a combination of direct 3D modeling, laser-scanning (for particular statues) and the extraction of textures from photographs was used on the reconstruction.[3] The final model also allowed the creation of photo-realistic renditions.[4] At the same time, and mostly derived from the same model, a real-time application was created to allow an interactive virtual visit to the building, even though the building itself is not publicly accessible (fig. 2). In this case, the Unity3D game engine provided a good combination of reasonably

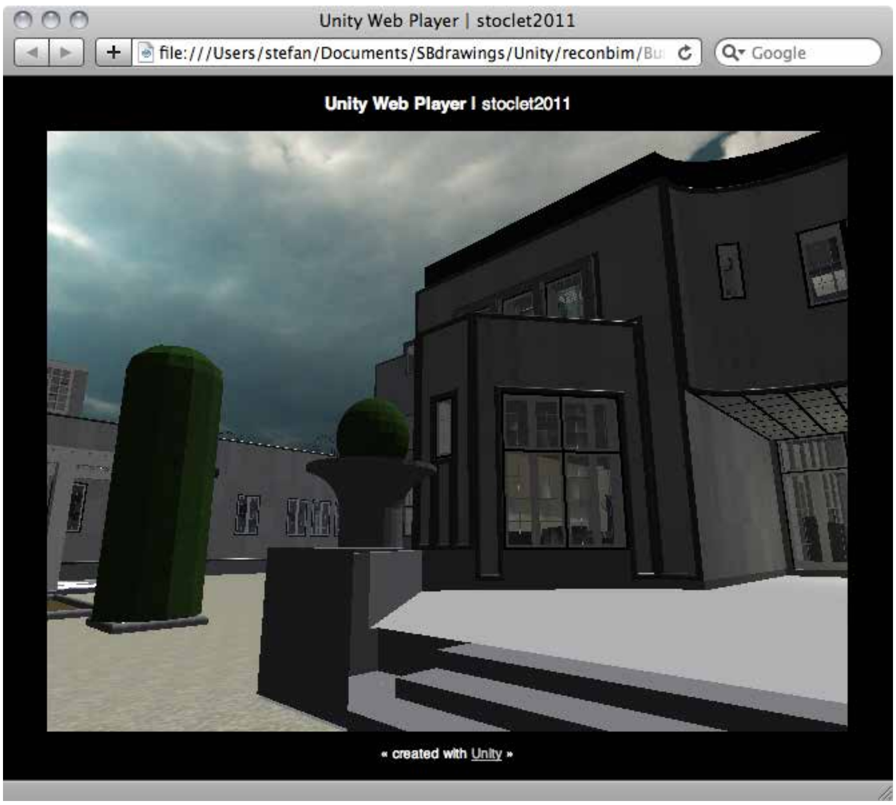


Figure 2: Reconstruction of the Palais Stoclet in Brussels in the Unity Web Player.

straightforward import of geometry from the 3D model while quickly adding the necessary interactivity, such as walking, gravity and collision detection. Early reconstructions involving such a game engine focused solely on real-time interactivity: material, color, light and movement. However, as later applications illustrate, more aspects of the information and embedded metadata could be leveraged.

In other cases the focus is different and various software combinations are being used. Galiana et al.[5] look at the methodology of topographical reconstruction from archeological sites for Ambassador Vich's Palace in Valencia, to reconstruct a morphological plot, main volumetry and layouts of façades, alongside the functional layout. The work of Anetta Kepczynska-walczak[6] looks at performance issues and aims at representing space, time, behavior and light in digital reconstruction models. The main challenge lies not in virtual reconstruction per se, but rather in the stimulation of new methods and fields that become accessible using these techniques. Other examples include the use of Virtual Reality to develop immersive environments for a historical context or Augmented Reality techniques to visualize artefacts as overlays of the current physical world. The use of surveying techniques and their integration in a BIM modeling environment is also widely studied and documented, e.g. with the work of Garagnani[7] discussing Terrestrial Laser Scanning (TLS) and how these results can be properly incorporated into BIM collaborative design processes.

These examples serve to illustrate that no unique, ideal solution exists; rather, the choice of method and software tools has always depended on the aims of the model.

The BIM revolution

The real methodological turning point in the context of digital heritage has come with the implementation of Building Information Modeling (BIM) in the field. BIM is first and foremost a methodology to organize construction projects, through the creation, evaluation and exchange of digital, virtual models. This process is being adopted worldwide and is already compulsory in some countries for public projects. There are many international efforts to organize the BIM process and to further develop the BIM methodology. This aspect falls, however, outside of the scope of this article. Here we focus more specifically on the use and added value of using BIM technology in historical reconstruction: the so-called BIM software tools to create and manage these models.

There are several commercial BIM Software applications available on the market today. They are all grounded in the same philosophy, but implement it in a rather varied way. The oldest and most mature software system still in use today is Graphisoft ARCHICAD: a BIM software for PC and Mac, with a clear focus on architectural design and parametric geometric description of objects. Autodesk Revit, a PC-only BIM platform, has become probably the most-used BIM system worldwide in recent years, partially due to the strong marketing powers of Autodesk. Other systems, such as Bentley AECOSIM or Nemetschek Vectorworks and Allplan are valid alternatives.

Currently, these BIM software systems present a wide range of functionality, with a combination of advanced 3D modeling, extensive documentation capabilities for drafting, and photo-realistic visualization. In addition, they allow for information management and extraction using embedded properties, extraction of quantities into schedules, and integrated evaluation tools for energy calculation. Most systems also support point-clouds from laser scanning and are compatible with the Industry Foundation Classes (IFC), an open standard (ISO 16739:2013) for interoperability and data sharing in the construction industry.

The difference when using BIM software—rather than CAD software—lies in the overall configuration of the model. Rather than separately making 3D models and 2D plans for different floors, sections and facades, BIM represents a holistic approach: the model and all of its related documents are inherently connected. From a single model all related plans, sections, elevations, perspective drawings, as well as the 3D model and schedules, can be derived. Moreover, BIM splits up the built environment into reusable parametric objects, allowing for a more thorough analysis and in-depth information concerning a project and the elements it comprises. These elements are the building blocks of the model and they can be enhanced with information concerning a wide variety of aspects, such as cost or the origin of the component.

The integration of 2D and 3D is also worth noting. In a traditional CAD approach, plans are completely disconnected from the model. They usually evolve independently and there are huge risks of inconsistency. The reconstruction of the garden pavilion of the Rubens House,[8] for instance, reveals several discrepancies between the different 2D survey drawings, which have been manually drafted during the reconstruction and restoration works. Embedding the scans of plans and sections into the BIM environment makes it possible to align the drawings properly, but also revealed their inconsistencies (fig. 3). A reconstructed BIM model has plans, sections, elevations and perspective drawings which are all aligned and consistent. The Rubens pavilion reconstruction also used a BIM technique to embed multiple alternatives into the same model, in particular to allow the comparison of the actual built state and an idealized perfectly symmetrical version thought to represent the architectural vision of Rubens more closely. Similarly, reconstruction has to deal with different levels of accuracy in surveying, depended upon the surveying tools used and the care with which the survey is carried out. In this respect CAD is analogous to drawing on paper as decisions have to be made while drawing. BIM makes it possible to combine different options, thereby taking in all the available information.

In the reconstruction of the Vinohrady Synagogue, which was demolished in Prague in 1951, specific attention was given to the concurrent availability of multiple representations.[9] Based on drawings from the archives and on older city maps, the main layout of the site was first recreated as a 2D CAD drawing, to be used as an underlayer for the BIM modeling. The actual model was used for photo-realistic rendering, which enabled a comparison between remaining black-and-white archive photographs and a realistic colorized rendition of the interior from the same perspective (fig. 4). At the same time, the exact same model was also used for the elevation drawing (fig. 5), ensuring full consistency.

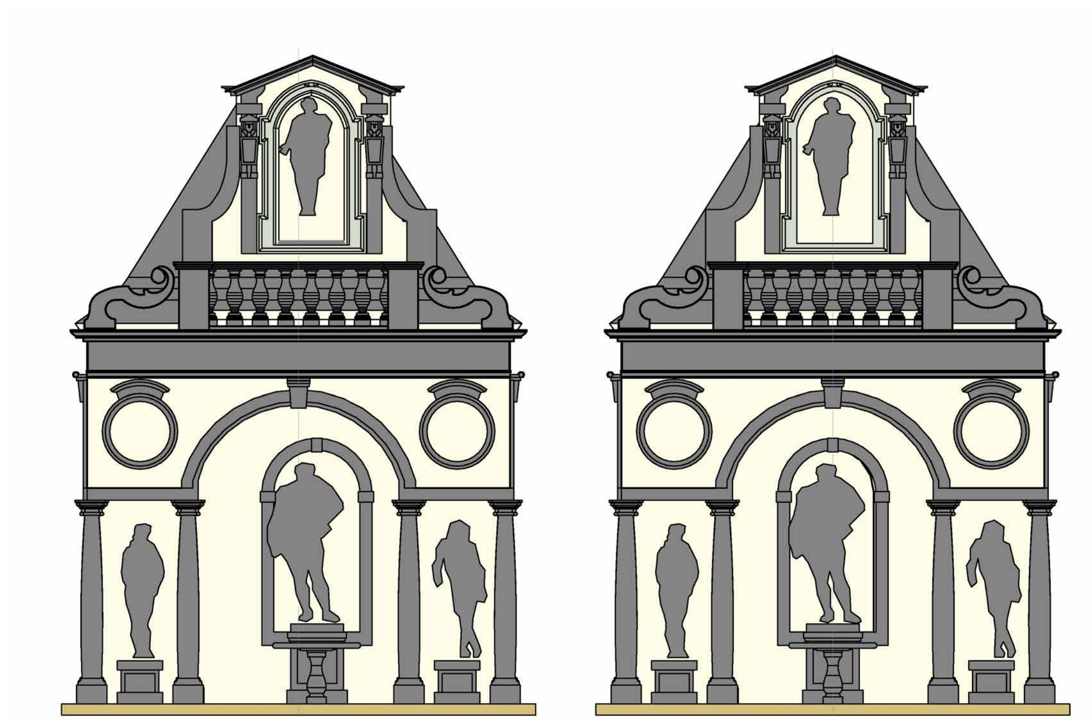


Figure 3: Schematic rendering of two survey drawings of the garden pavilion of the Rubens' House, showing slight differences in the placing of the statues.

Figure 4: Comparison old black-and-white photograph with a realistic rendition of the interior from the same perspective.

Figure 5: Elevation drawing, black-and-white photograph and render of the exterior of the Prague Synagogue.

In the context of digital reconstruction, BIM opens up an even wider range of possibilities. Models in the context of BIM are indeed not simply 3D geometric models. They also embed large amounts of attributes and properties: about materials, dimensions, composition, function, performance, among other characteristics. It is even possible to embed custom data, for any chosen purpose. As such, BIM enables a more data-driven approach: models can be used to query information, but the data can also be used to control geometry, detail and representation. The combination of geometry (dimensions, sizes, quantities) and embedded information offers a major advantage for reconstruction. The model thus becomes a rich knowledge base for a project, a 'thick description'[10] capturing and assembling data from different sources into a single and interoperable whole.

It is possible to formulate what-if scenarios: a single model may contain multiple variants of a reconstruction while staying coherent. This encourages the researcher to investigate possible interpretations more thoroughly, and also to communicate them more adequately and with less effort. In the past, as shown by many reconstruction projects applying regular CAD or 3D visualization systems, this often required the creation of several, disconnected models. While feasible for final, fixed models, the reality is that models are continuously refined over the course of a reconstruction, thus rendering the synchronization of changes over several models hard to manage.

Moreover, the very nature of embedded data in a BIM approach allows for a more flexible series of possible representations. Rather than having a single model with fixed geometry and materials, alternative representations and thematic views are possible. Martens and Peter,[11] for instance, have developed a large series of digital reconstructions based on ArchiCAD BIM as a virtual archive of lost Jewish synagogues. They have mostly focused on the structured methodology and best practices of the software environment, alongside the 3D modeling and visualization results that are offered that way. While this and other cases cover a wide range of possibilities, a KU Leuven student work from the past decade continues to demonstrate its research potential.

HBIM best practice: historical validation

As BIM is still maturing, it requires more methodological research to develop best practices for HBIM also. An important issue concerns the 're-traceability' of every element in the model, in other words its critical underpinnings. Whatever method is chosen for data acquisition, the decisions made during the digitalization process must be documented precisely. The challenge here lies in the historic validation of the decision process and its communication towards any third parties, particularly the viewers of the digital model. At KU Leuven the first part of properly organizing and documenting the reconstruction process has been achieved by establishing a so-called “metafile”: an accompanying report recording the information used for the model and the decisions made in the process.[12] The following table (table 1) shows a small fragment of the meta-file for the reconstruction of the Saint Walburgis Church in Antwerp.[13]

The meta-file is implemented as an Excel table, with a custom setup, which varies between reconstructions. Each row represents a known fact and its sources, whether archaeological, archival or iconographic, alongside the source reference, analysis and interpretation, linked to a part of the building complex. Recreating a lost building or building phase invariably means making hypotheses and suppositions. Each part is graded according to the quality and reliability of the source. The elements in the model can thus be evaluated relative to the information in the meta-file. The resulting “level of (un)certainty” can also be represented by a color code, ranging from green to red. As a separate document, the metafile is less attractive to the viewer of the digital model. Therefore, the model needs a second layer showing the level of certainty achieved for each part. This can be considered the ‘conclusion’ of the metafile.

Building Part	Part / element	Source/Rating	Comments Source	Interpretation / Arguments / Consequences for model	Hypoth. degree
Ground floor		Obj ID 16 (1735?) Obj ID 32 (1798-1803) Obj ID 12 (<1816?): +	Unknown creator & data. Iconography mentions accurate and quite detailed. Assumed drawing created before demolition of the church (before 1816)	Most usable ground plan from catalog, to be used as basis for model. Photograph from document, straightened in Photoshop. Plan was scaled according to Obj ID 16 and OBJ ID 32	2
	Position columns on plan	Obj ID 16 (1735?): ++ Obj ID 18 (1741?): +++ Obj ID 12 (<1816?): +	Detailed discussion Obj ID 16 and 18 iconographic study. Obj ID 18 assumed more reliable. Obj ID 16 mentions dimens. in feet.	To position columns in the longitudinal direction of the plan, the average of the distance between all columns on plan Obj ID 12/	1

Table 1: fragment of the metafile for the reconstruction of the Saint Walburgis Church in Antwerp.

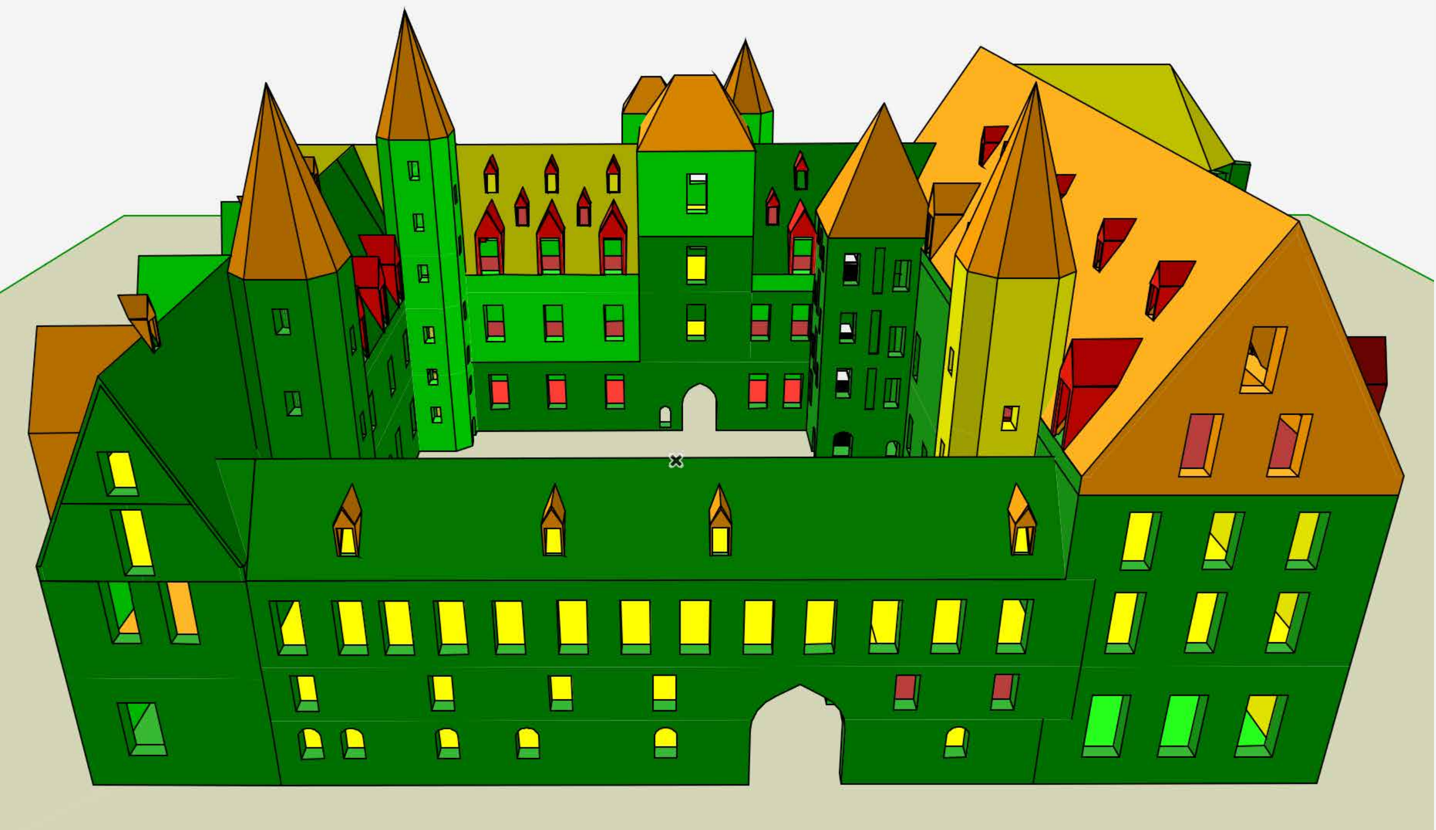
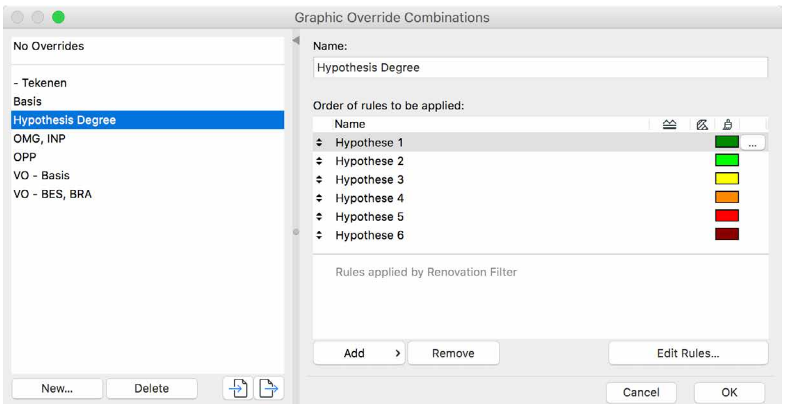
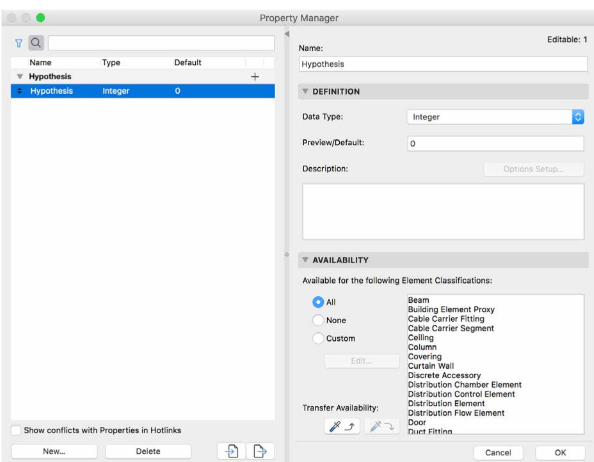


Figure 6: Hypothetical model of the Palais Rihour at Lille, made using Graphic Overrides.





In earlier KU Leuven reconstructions, several techniques were attempted, including creating separate variants of the model manually, using fake materials or using image-editing in Photoshop. While the results were visually satisfying, none were data-driven, nor could the color-coded representations be derived automatically from the reconstruction model. It was thus impossible to embed information and sources that led to the reconstruction in the model. With the adoption of BIM techniques, however, it has become possible to actually embed parts of these meta-data into the model and having them steer the representation. This helps to integrate conclusions more deeply with the model, and reduces the workload and chances of errors creeping in.

In BIM software, a custom parameter can be attached to model elements and filled with the hypothesis value from the meta-file. This can be done directly with the element properties, or in a derived schedule, which facilitates entering the information for a large quantity of elements and helps to discover errors or missing fields more easily. For instance, within ARCHICAD 20 two new features were introduced in 2016 which greatly improve the workflow to embed this information in a custom representation: property tables allow easy creation of custom parameters, which can even be exchanged with MS Excel, so the tables can be entered in a more familiar spreadsheet environment. The results can be re-imported into the model. Additionally, Graphic Overrides allow the visual representation to be derived from element properties. By creating a custom Hypothesis property, with possible values ranging from one to five, a data-driven visualization of the degree of hypothesis is possible by assigning a color code to the different values (1- green to 5 – red). This has been applied in the Palais Rihour reconstruction (fig. 6).[14]

These techniques facilitate integration and automation: the same model can still be represented with regular materials, alongside additional thematic views, driven by model data. This color-coded model represents the conclusion of the historic research, showing the amount of available source material and the plausibility of the reconstruction. For now, the decision-making process leading to this conclusion is not inherently part of the BIM reconstruction, although it could be implemented in custom text fields. This way, the meta-file becomes even more valuable in the context of HBIM.

The snags of HBIM

Modeling a building within a BIM environment essentially implies breaking it down into its constituent elements and assembling it up from there. The model becomes a hierarchic aggregate of elements, their components, and the relations between elements. The current generation of BIM software, while fairly mature and increasingly widespread, focuses mostly on contemporary building practice, especially on the documentation of recent residential and commercial buildings. Likewise, the included material libraries only cover contemporary machine-produced brick masonry and industrial wood construction. When transposed to the historical domain, the available BIM libraries naturally do not fully cover the wide gamut of architectural styles and construction techniques needed to 're-compose' historical buildings. Their application in the context of historical reconstruction thus presents severe limitations.

Moreover, BIM tools are inherently constrained: walls are commonly vertical, with a constant thickness; floors are horizontal and windows are rectangular; stairs are straight and obey building code rules. Even though there is some flexibility in the native element tools (e.g. slanted wall, sloped roof), they are meant for an idealized description of a building. For heritage documentation and especially in the restoration context, it is very difficult to properly describe the actual situation with its irregularities and finer detail. Modeling a profiled vault, timber construction or dormer window thus becomes very complex rather quickly.

A solution to this would be a custom library of historic elements, a concept which is not new. Chévrier and Perrin[15] described the use of 3D animation software (Autodesk Maya) to develop a parametric collection of building elements for the research of a particular corpus of elements for Montréal (Canada) and Nancy (France). A first possibility, which most systems provide, is the direct modeling of these elements as static geometry. Murphy et al.[16] focused on Laser Scanning and using these scans as a reference context for reverse engineering, thus obtaining an 'as-built' BIM component. This method is only applicable when actual artefacts are available and accessible. When there are no physical artifacts left of a particular site, comparative reconstructions can be based on descriptions, excavations, and analogies with other still existing buildings of the same period and style.

In this context, it is tempting to use building or construction guides, and the treatises of the early modern age on the column orders. Most of these were conceived as an elaborated catalogue of architectural forms, often supplemented with reality-based measurements and geometric instructions on how to achieve the discussed shape. Following the same rules, it thus seems possible to construct these elements without too much difficulty, transforming them into digital BIM objects, which could then be developed into a library of elements. But this is not feasible everywhere. In the sixteenth-century Low Countries, for instance, practice-based treatises are lacking and many of the built examples have partially or even completely disappeared. By adding the necessary attributes, it is possible to integrate such objects with reasonable results into the model. It is even possible to add a custom but static 2D symbol for plan representation. While by far the easiest way to add custom elements, this approach nevertheless does not profit by the added value of BIM: these objects are not flexible to adapt and do not react to the expected representation settings found in regular BIM objects, such as scale-sensitive display or adapting to changes in dimensions and properties.

In order to use the full potential of the BIM approach in historic reconstruction, a custom library is seen as the better solution. Here the forms and architectural elements that constitute the basis of the reconstruction are defined. It is most efficient to define generic, parametric elements according to a particular "style" or period, so they can be used for different projects, thus creating a re-usable library. If a true HBIM library could be applied, reconstructions would embed more reusable information. It would become possible to extract lists and counts (e.g. the list of all windows, grouped per size and type), or to derive estimated material quantities from the model, provided that reasonable information is available regarding elements' composition and dimensions. More structured models will also facilitate data mining on models: numerical analysis of model aspects can be used to support project comparisons beyond mere visual aspects. A relatively accurate reconstruction can be used as the basis for deeper analysis, with information that has become more accessible. However, care has to be taken with the development of such objects, in order to maintain full control and usability in the reconstruction process.

The following example displays an arched opening, where the dimensions but also the form of the arch can be parametrically controlled (fig. 7). They are derived from mathematical rules, drawn and parameterized directly in the BIM software. This way, the window element not only contains the geometry, but also actual information, such as dimensions or type. As such, the geometric model becomes richer in embedded information. By allowing parametric control, with graphical hot-

Figure 7: Arched opening with parametrically controlled dimensions and arch type.

spot editing directly in the 3D window, the user can position and reshape elements interactively and still retain full controllability at all times.

However, this approach with a custom library of re-usable elements is also potentially flawed. The building archaeologist's point of view would be diametrically opposed to this, stating that each object (column, window, roof truss) is one of a kind and that the reduction to standard elements means losing the individuality of a building. The method would nevertheless still make sense in certain historical contexts, e.g. for reconstructions post-1860 when industrial fabrication made it possible to produce increasingly standardized elements. Generally, the development of real parametric library objects is justified for re-usable elements, whereas the creation of particular, singular elements may be executed using direct modeling.

Exploring new avenues in Historical Building Information Modeling (HBIM)

Part of the model for La Maison du Peuple by Victor Horta, developed ten years ago, used BIM software for reconstruction purposes.[17] In fact, the student chose to split the model into an abstract interior model, using ArchiCAD BIM software, and a more detailed ornamental façade model, using 3D animation software (3ds Max). This way, plans and main schematics to explain the building were based on the HBIM model, but the intricate organic detail of the façade was deemed too complex at the time for this environment. To that purpose, animation software was

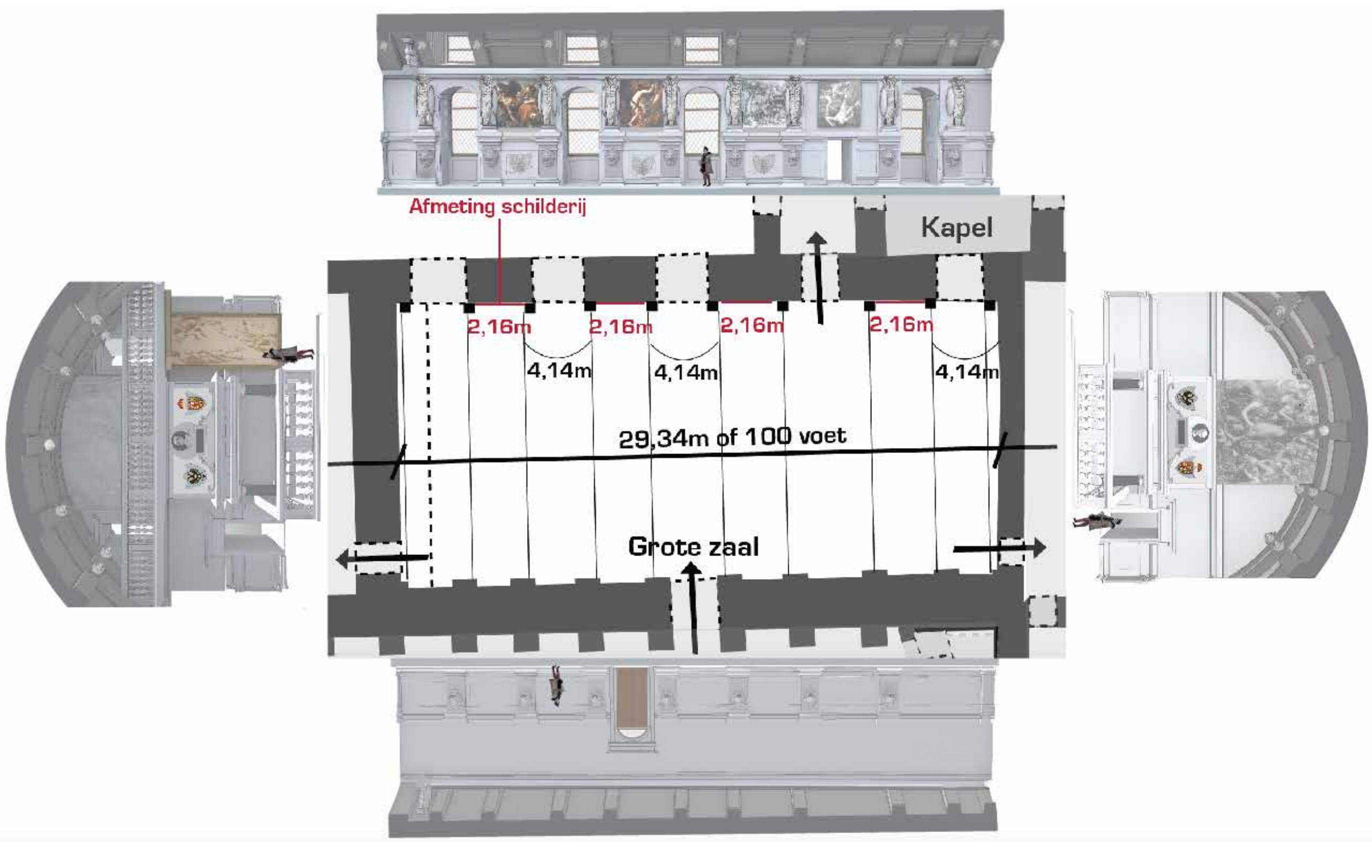
Figure 8: Model for La Maison du Peuple (left: detailed façade model in 3ds Max, right: abstract interior model in ArchiCAD BIM).

Figure 9: Reconstruction of the Rubens House in Antwerp.

Figure 10: Comparison of the reconstruction with a historic photograph of the reconstruction site.

Figure 11: Reconstruction of the great hall of the palace of Mary of Hungary at Binche.

Figure 12: Visual description of the dimensions and wall composition of the great hall at Binche.



used with parametrically driven splines and sweeps. The end result was quite detailed, and pushed the capacity of the lab computers available at that time to the limit (fig. 8). Today, computer power presents fewer limitations, but the complex organic forms of the façade are still not offered by the BIM library, a problem that will be treated in detail later in this paper.

The reconstruction of the Rubens House in Antwerp used a combination of a HBIM Model (fig. 9), an integrated visualization system and an interactive application.[18] As part of the presentation an interactive application was developed, with model geometry extracted directly from the HBIM model. The application used the reconstructed house, which is currently a museum, as a virtual environment with a guided tour of the iconographic source material and explanatory descriptions. The concept could be extended to accompany a physical visit, as the house is open to the public, but the option of a fully controllable walk-through was rejected in favor of focusing on the narrative and educational aspects. The added value thus lies not in the virtual visit, but in the opportunity to present additional information in the context of the project. The visitor is guided and directly embedded in the 3D model, with the possibility to choose between a few key locations. The following image (fig. 10) illustrates how the model compares with a photograph of the 1930s reconstruction, when two possible variants were created on-site to assist decision makers.

An example of a more hybrid use of HBIM can be found in the reconstruction of the palace of Mary of Hungary.[19] The study focused on the circulation route through the palace; because of time limitations only part of the main apartment was recreated in 3D (fig. 11). While HBIM was used for the reconstruction, other tools were explored to evoke the interior of the larger rooms. Where relevant, statues and ornamental elements have been created, but in other places, images have been inserted. A more time-consuming, and indeed more complete way, would have been to model every part: in theory, this is possible thanks to archival material and data from excavations. However, the actual reconstruction into 3D fragments was mostly used to assist the communication of the process and the reasoning behind the reconstruction. It was reshaped and graphically edited with DTP software, to arrive at a more conceptualized visual description (fig. 12). Yet, even then, sizes and volumetric detail of the HBIM model were retained.

In the reconstruction of the lost Aarschot residence of the Croÿ-family,[20] HBIM made it possible to achieve a more realistic result. At any given time, sections could be made through the model, allowing to adapt floor levels, heights and roof slopes, and correct inconsistencies. Certain assumptions and possible reconstruction variants could thus be assessed more easily. The presentation also systematically used color-coding to indicate perceived accuracy of the reconstruction (fig. 13).

In the reconstruction of the Graethem Chapel,[21] two issues were explored: archeological exploration and presentation to the public. The reconstruction thus included different construction phases, to assist a timeline visualization. However, the BIM software had no explicit support for the complex phasing required here. Typically, it can tackle a renovation project, with new/existing and demolished states for model elements, but nothing more extensive. The model was thus split into a large series of more than 60 complementary partial models (hotlinked modules in ArchiCAD terms), with a customized layer structure to assemble the different phases, while at the same time avoiding redundancy. Each element was only modeled once and embedded in the most suitable model component. The assembly models could then recreate the different phases. In addition, a set of customized library objects had to be developed for the elements, such

Figure 13: Schematic section of the Croÿ ducal palace at Aarschot with indication of hypothesis through color-coding.

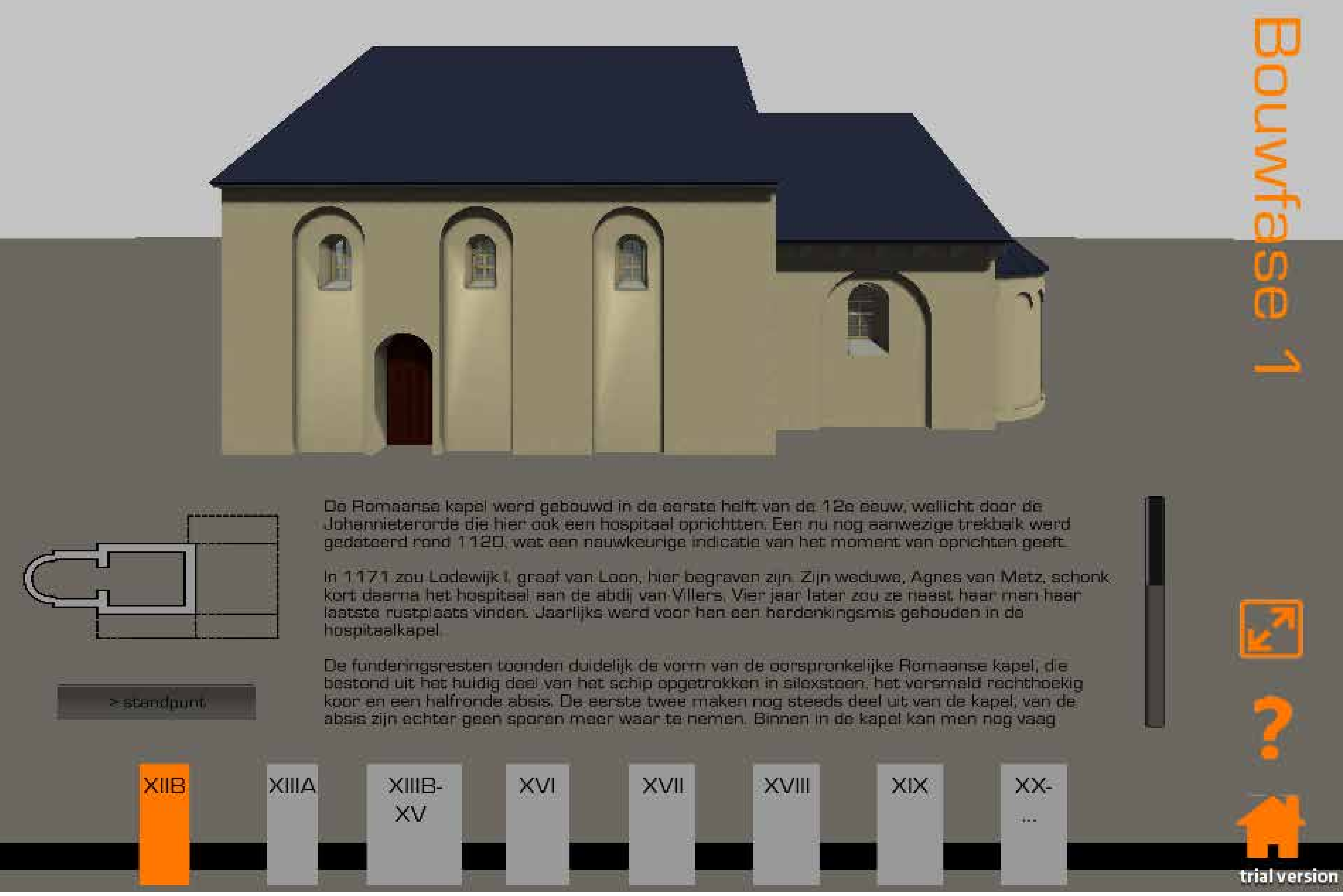
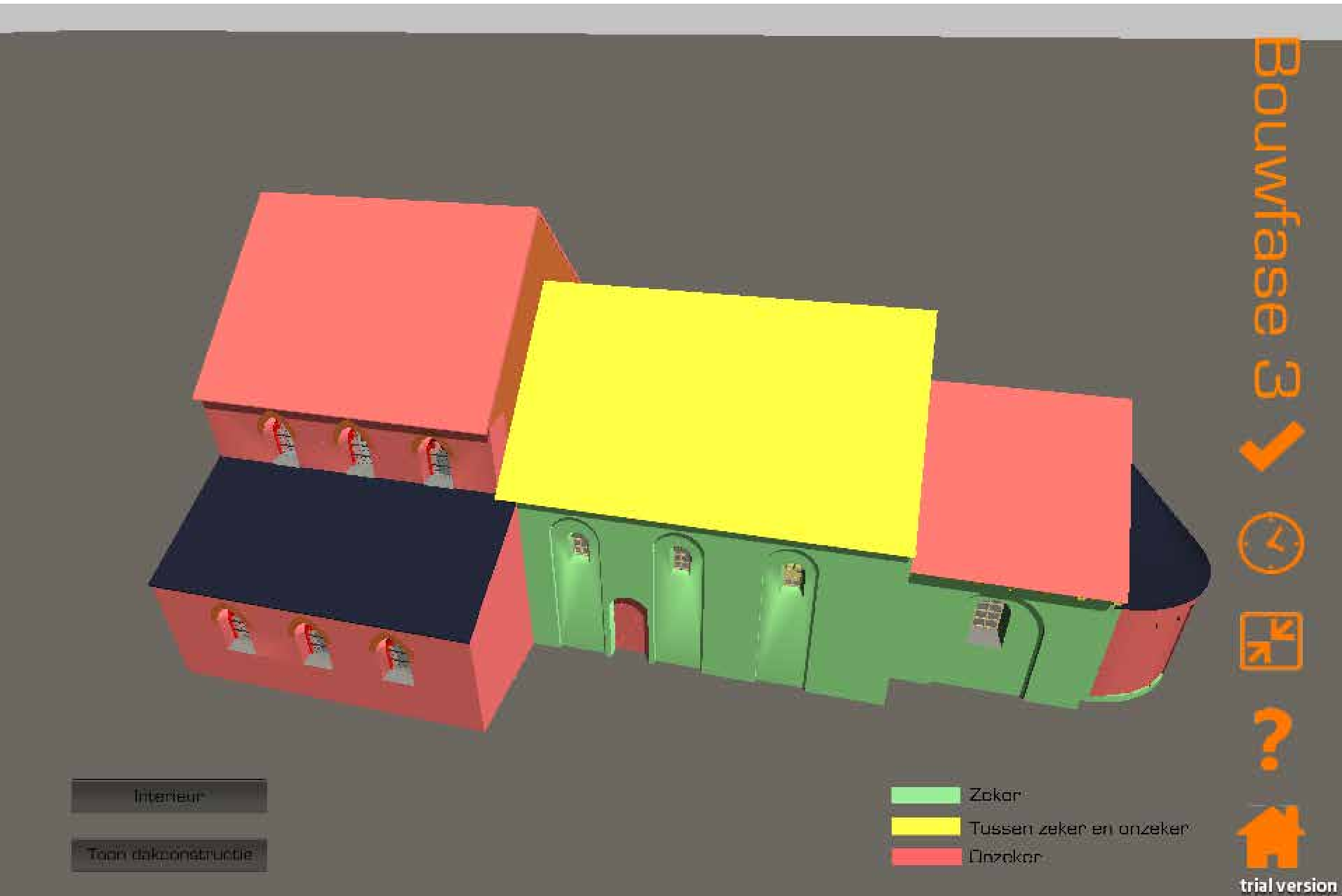


Figure 14: iPad application exploring the building history of the Graethem chapel.

Figure 15: Hypothesis representation of the building history of the Graethem chapel.



as trusses and openings. The end result was also embedded in an interactive iPad application using, again, the Unity game engine, where the re-assembly of partial models could be performed dynamically, using a timeline as graphical user interface for the visitor of the chapel (fig. 14). Each step in the timeline displayed a small explanatory text, the current situation of the model, and allowed the user to toggle different viewpoints.

Additionally, the different parts were also dynamically colored when a hypothetical representation was chosen, without requiring separate models (fig. 15). In this case, the game engine allowed for dynamic colorization, based on model information. Materials are switched dynamically, depending on the dissemination context, to not only represent approximate materialization, but also to represent color-coding to indicate a "Level of Certainty" about the reconstruction of that particular part.

In a series of tests we have also been able to embed information from the model as additional metadata and use the Graphical User Interface (GUI) methods of the game engine to display them in a popup view when the visitor clicks on an element or interface button. That way, we can move beyond merely showing the geometry, but also give access to the underlying information, such as material properties, historical notes or the results from the hypothetical reconstruction embedded in the model. While current examples often rely on splitting the transfer of geometry and information, the use of Industry Foundation Classes (IFC) will present a better integration with a single transfer, allowing "information" to remain connected to the geometric representation. This is a subject to be elaborated in further detail with future reconstructions.

The reconstruction of the fifteenth-century Palais Rihour at Lille[22] also addresses the split-up of the project into separate modules or sub-models. Done properly, it allows the different buildings on a site to be managed more easily, in spite of the increased complexity. As the approach is completely data-driven, all geometry and attached attributes remain fully accessible in the aggregate model. Within general BIM practice, working with multiple sub-models has become a necessity in complex projects, as different disciplines and responsibilities can be separated with greater ease. In addition, as projects demand ever larger BIM model files, performance can still be reasonable when sub-dividing projects in multiple models.

Conclusion

Although CAD has been applied in historical research ever since the early 1990s, the real methodological turning point has come with the implementation of BIM in historical reconstructions. The BIM approach sheds a new light on the methodology of historical reconstruction, enabling deeper insight and opening up new ways of analysis. Best practice for HBIM has become an important issue. With the constant evolution of BIM software packages it becomes increasingly important to go for a holistic approach, where not only plans, sections and 3D visualizations but also the underlying decision-making process leading to the reconstruction is part of the same project file. Thus fully documented, the model not only becomes verifiable but also 'reusable': it can later be adapted by third parties as new information becomes available. With the necessary data management system it would even be possible to customize libraries of parametric elements to reuse over different projects. Apart from economic hindrances, however, all the problems faced by the authors of architectural repertoria must also be faced by the creators of such a library.

In historical reconstruction, modeling *an sich* is not the chief objective. The aim is to achieve a different interaction with the built environment (lost or extant) through a methodology that allows a deeper reading of that environment.

Notes

[1] Alkhoven, 'The Reconstruction of the Past: The Application of New Techniques for Visualization and Research in Architectural History'.
[2] Boeykens, Santana Quintero, and Neuckermans, 'Improving Architectural Design Analysis Using 3D Modeling and Visualization Techniques'.
[3] Lesaffre, 'Digitale Architectuuranalyse: Gevallenstudie Stockletpaleis - Joseph Hoffmann (MSc Thesis)'.
[4] Boeykens, 'Using 3D Design Software, BIM and Game Engines for Architectural Historical Reconstruction'.
[5] Galiana et al., 'Methodology of the Virtual Reconstruction of Arquitectonic Heritage: Ambassador Vich's Palace in Valencia'.
[6] Kepczynska-walczak, 'Performing the Past and the Present for the Knowledge of the Future'.
[7] Garagnani, Mingucci, and Cinti Luciani, 'Collaborative Design for Existing Architecture : The Building Information Modeling as a Frontier for Coordinated Process'.
[8] Boeykens, 'Reflections on the Digital Reconstruction of the Portico and Garden Pavilion of the Rubens House'.
[9] Himpe, 'The Vinohrady Synagogue in Prague - A Virtual Reconstruction (MSc Thesis)'.
[10] Hoppe, 'Northern Gothic, Italian Renaissance and beyond. Toward a 'thick' description of style'. After Clifford Geertz.
[11] Martens and Peter, 'A Long-Term Scope of Actions for Reconstructed Cultural Heritage : Maintaining a Virtual Archive of Non- Existing Synagogues'.
[12] Vandevyvere, Neuckermans, and De Jonge, 'Digital Historical Reconstruction: Case Studies of an Interdisciplinary Task'.
[13] De Voght, 'Reconstructie van de Verdwenen Sint-Walburgiskerk van Antwerpen (MSc Thesis)'.
[14] Bosmans, 'Digitale Reconstructie Palais Rihour (MSc Thesis)'.
[15] Chévrier and Perrin, 'Generation of Architectural Parametric Components'.
[16] Murphy, McGovern, and Pavia, 'Historic Building Information Modelling (HBIM)'; Murphy, McGovern, and Pavia, 'Historic Building Information Modelling—Adding Intelligence to Laser and Image Based Surveys of European Classical Architecture'.creating full 2D and

3D models including detail behind the object's surface concerning its methods of construction and material makeup, this new process is described as HBIM. <B>Originality/value</B> - The future research within this area will concentrate on three main stands. The initial strand is to attempt improve the application of geometric descriptive language to build complex parametric objects. The second stand is the development of a library of parametric based on historic data (from Vitruvius to 18th century architectural pattern books

[17] Vaeck, 'Digitale Architectuuranalyse. Horta's Volkshuis Gereconstrueerd (MSc Thesis)'.

[18] Veelaert, 'Het Rubenshuis. Een Digitaal En Interactief Model van de Reconstructie Door Emiel Van Averbeke (MSc Thesis)'.

[19] Pieters, 'Digitale Reconstructie: Het Paleis van Maria van Hongarije (1545-1554) (MSc Thesis)'.

[20] Ali Salam, 'Digitale Reconstructie van Het Hertogelijk Huis van de Croÿ-Familie Te Aarschot (MSc Thesis)'.

[21] Massart, 'Digitale Reconstructie van de Bouwfase van de Graethemkapel Te Borgloon (MSc Thesis)'.

[22] Bosmans, 'Digitale Reconstructie Palais Rihour (MSc Thesis - in Preparation)'.

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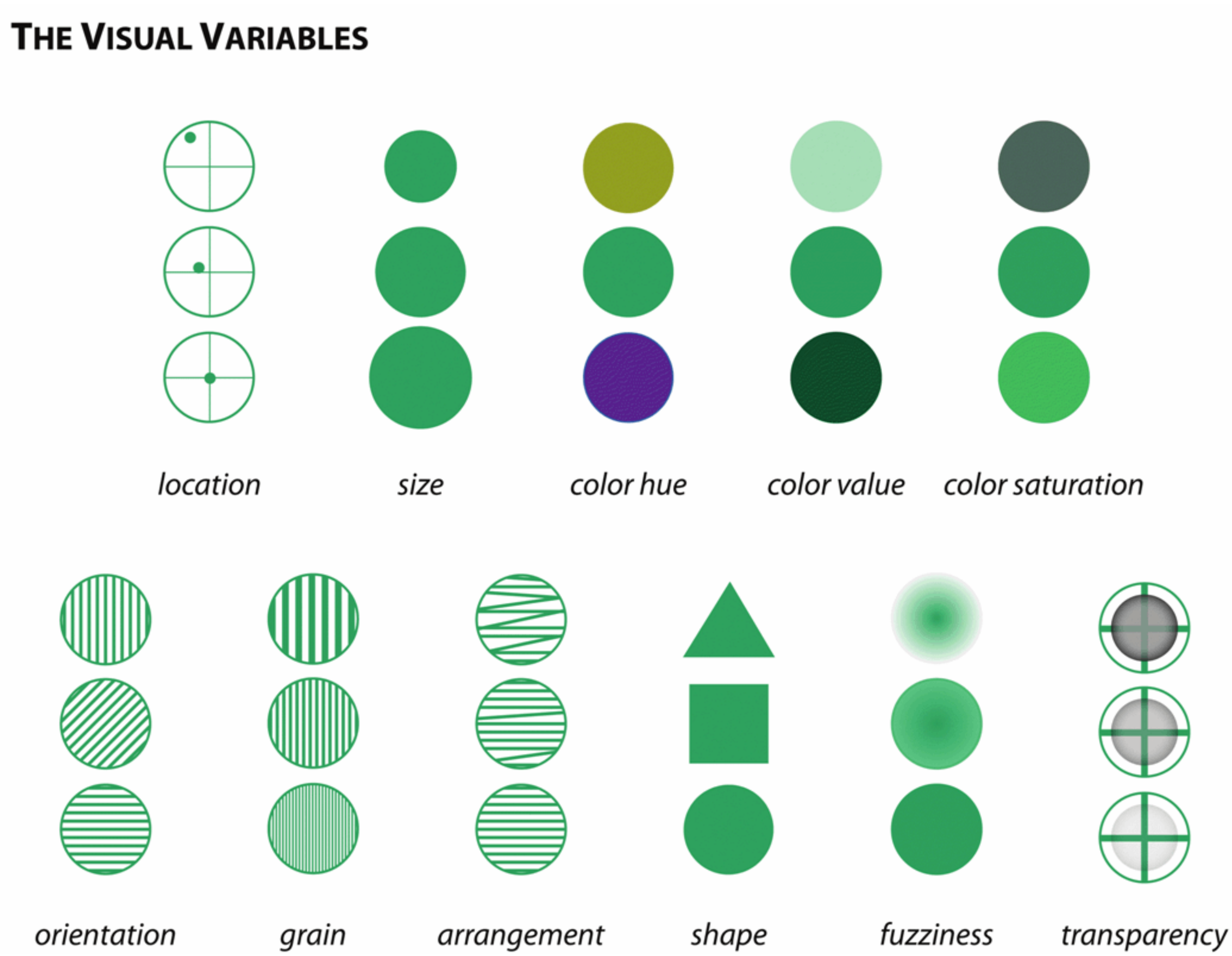

Figure 1: The Visual Variables.

Alan M. MacEachren et al., “Visual Semiotics & Uncertainty Visualization: An Empirical Study,” IEEE Transactions on Visualization and Computer Graphics 18 (12): 2496-2505 (2497). Image used with friendly permission of Prof. Dr. Alan M. MacEachren, Pennsylvania State University and Dr. Robert Roth, University of Wisconsin-Madison.

Peer-Reviewed

Uncertainty Visualization and Digital 3D Modeling in Archaeology. A Brief Introduction.

Una Ulrike Schäfer

Abstract: Uncertainty is ubiquitous in everyday life; domains as diverse as engineering, finance, and insurance are increasingly aware of the far-reaching impact of uncertain data. Well-established research fields like the natural sciences are concerned with the intangible phenomenon of uncertainty, in addition to disciplines like geography, information visualization, and history. In this context, a range of disciplinary approaches were surveyed with regard to the methods and techniques developed and applied to deal with uncertainty. As a result, various efforts were made to consider suitable taxonomies, quantification methods and visualization strategies. Emphasis is particularly laid on archaeology, highlighting research in three-dimensional digital modeling and reconstruction and related archaeological discourse of the last two decades.

Keywords: uncertainty, visualization, archaeology, 3D modeling, digital reconstruction.

Introduction

Understanding uncertainty is one of the great scientific challenges of our time.[1]

Uncertainty is everywhere. Not only in the philosophical sense but also in everyday life. With regard to 'data as the currency of the 21st century' virtually every existing domain of our social life is more or less affected by noise, imperfection or uncertainty. Buzzwords like big data, data mining, predictive modeling or data-driven decision making are prevalent. They indicate pervasive socioeconomic as well as technological transformations which are connected to the rapid growth of accessible information and data sets from a great many heterogeneous and often unevaluated sources (e.g. social media), facilitated by an increasing number of acquisition methods, high performance processing and seemingly infinite storage capacities.

The concept of uncertainty is by no means entirely new. In the natural sciences a wide range of defined, approved and standardized means for complex calculations and the meaningful representation of uncertainties are utilized on a regular basis (e.g. standard deviation, error bars, confidence interval, color coding, or glyphs).

Most likely, every research field is affected by or involved with uncertainty. As a consequence, a considerable amount has been published over the past decades, indicating the effort to somehow get a grip on the intangible phenomenon of uncertainty. The correlated terms thereby differ as widely as the related research fields and it seems impossible to find a generally valid definition (if this would be of any use at all). Despite this variety and diversity, these approaches share at least one general insight: uncertainty is widely understood as a heterogeneous „multi-faceted"[2] phenomenon associated with the terms error, accuracy and imperfection.

A brief historic outline

Archaeology was one of the first domains to utilize the relatively new field of 3D computer-aided solid modeling in the mid-1980s. The three-dimensional digital reconstruction model of the Old Minster in Winchester, created between 1984-86, is said to be „the earliest application in the UK of 3D computer modelling to visualise archaeological data."[3] The digital revival of such long gone historic structures in form of a 3D solid model was only made possible by the collaboration of two specialists sharing competences. Whereas the computer industry (more precisely the IBM Scientific Centre UK) provided up-to-date technology to enable the creation of highly qualitative graphic output, the necessary scientific contents where provided by archaeologists (led by Martin and Birthe Kjølbye-Biddle).

Pioneering work was also done with regard to the production of a two-minute video animation (by Andrew G. N. Walter), showing interior and exterior views as part of a virtual fly-through the reconstructed Old Minster.[4] The rapid progress in computer technology during the 1990s went hand in hand with the substantial reduction of purchasing costs, which in turn facilitated the distribution of suitable technologies and devices for digital 3D modeling. As infrastructure became more widespread and available within academic culture, digital modeling activities increased, so that „[f]or many years, photorealism was the gold standard, and the goal in visualization was to achieve renderings of scientific data that were indistinguishable from a photograph."[5]

The increasing potency of high-end computer technology helped to generate sophisticated photorealistic renderings with a number of seemingly authentic details: familiar perspective, realistic textures and proper shading and lighting conditions. Taken together, these graphic features resulted in images with the potential to convince the average viewer that they were in fact looking at a real object that had merely been photographed. „[S]cholars too will find it harder and harder to maintain any scepticism about the accuracy of the images as those images get better and better. This is all the more true because of the misperception that the images are created by unbiased automata via a mechanical process that requires no human intervention.“[6] In 1996, the Virtual Stonehenge project, sponsored by the English Heritage Company and Intel UK, celebrated the run for high tech, photorealistic and „eye-catching effect[s]“[7]. The project was special because for both institutions, as a public-facing application that implemented „the accurate positioning of stars in the night sky, the use of draping photographs in an attempt at photorealism, as well as the first 'virtual sunrise'"[8] above the digitally re-erected site of Stonehenge.

Eventually, these developments were addressed in the criticism presented by Miller and Richards at the Annual Conference of Computer Applications in Archaeology (CAA) in 1994. Their contribution, "The good, the bad, and the downright misleading: archaeological adoption of computer visualisation" can be seen as a starting point for many of the ongoing debates regarding reconstruction and certainty that continue to the present day. Miller and Richards reason that research all too often focused on attention-getting strategies oriented to the public[9]. Instead, they argued, research should be focused on new insights that only digital tools and methods could yield. The authors additionally emphasize two fundamental problems: for one thing, they underline the lack of quality control, stating that "[w]orryingly, there is little, if any, quality control for computer graphics and they are not subject to the same intense peer review as scientific papers".[10] The other problem relates to the lack of venues for digital three-dimensional reconstructions, even though "[m]ost archaeologists are keen to emphasise that there are many possible views of the past, and that we rarely know anything for certain"[11].

Moreover, there is a tendency to assume that detailed photorealistic computer graphics reflect one given 'historic truth' and that all the things shown must have indeed been there in the way that they were depicted. The same logic assumes that missing elements are not worthy of attention, if their visual absence even registers to the viewer. „The fact that many hours of discussion between computer scientists, historians, and archaeologists went into its design cannot be seen by inspecting the image, let alone can the reasons for the design decisions be [sic!] ascertained nor the uncertainties underlying the decisions."[12]

So, since 1990s, increasing efforts have been made to find and develop appropriate methods to resolve two of these main problems widely discussed in archaeological discourse: the multilayered problem of photorealistic computer graphics and their application in archeological visualizations, as well as the considerable lack of visual empirical clarity that can be established between these visualizations and the material distributions to which they lay claim. At the same time, new practices for evaluating 3D models and workflows (and the material products dreived from them) were developed.

Standardization has also been a recurring issue. Since the beginnings of archaeology as a discipline, a range of methods have been established to deal with uncertainty. These practices and techniques were developed to address specific requirements, e.g. for visualization. Thus, they were not assumed to be standardizable conventions, or even obligatory features of a practice, as in the case of mathematical notation. „Unfortunately the standardisation of the techniques used by illustrators of archaeological material has never been fully discussed and, although there are a number of standard conventions, there are also a number of different methods in use in different parts of the world today."[13] Standardization poses an ongoing, massive challenge to digital documentation, and continues to inspire various workflows, metadata schemes and data formats[14], as well as the setup of an vast number of databases that collect, archive and provide data and information in a systematic way[15]. Moreover, a whole range of international organizations[16] and labs[17] have been founded, which in turn organize major conferences[18], contrive official charters[19] and guidelines, and explore new publication formats[20].

Standards which can document and quantify uncertainty in digital three-dimensional models and reconstructions in archaeology, in a more generalized and applicable way, are still under development. But recent activities show that the discursive landscape of archaeological method evolves fast and renewed attention is being paid to these complex issues, especially in the context of digital cultural heritage.

A brief taxonomy of uncertainty

Other disciplines tackle the problem of uncertainty with a degree of subtlety that warrants further exploration here. These approaches could be of interest for the evolving discourse of uncertainty research in archaeology. Although they widely differ in their frameworks and strategies, these approaches have some aspects in common: after shortly reviewing other relevant texts, I will show how they classify uncertainty. Within such a system we could begin by documenting a number of typological features: 'sources', or 'causes', 'types', 'categories' or 'levels'[22] of uncertainty.

The most commonly mentioned sources (or types, levels etc.) are accuracy (locational, attributal, temporal, logical), error, precision, completeness, consistency, reliability, credibility, validity, subjectiveness and data lineage. These sources (or types etc.) are assumed to generate, introduce, enhance and/or propagate uncertainty during a multi-staged workflow and to directly correspond to the quality, reliability or certainty of information. The exemplary workflow stages listed below are suspected to be focal points for the introduction, transfer or propagation of uncertainty.

- *data acquisition / collection*
  classification and categorizations
- *processing*
  filtering, transformations, sampling, approximation, interpolation, translation, decryption, quantification, simplification, extrapolation
- *visualization*
  mapping, modeling, rendering
- *evaluation & comprehension*
  human bias, incomplete knowledge
- *presentation & dissemination*
  file formats, operating systems, translations, decontextualization

Since the occurrence of uncertainty during these stages of the workflow is ubiquitous and rarely controllable, it is tremendously important to carefully observe, question and document the process in detail, including ambiguities, problems, discussions, and especially underlying decisions made during the processes. One relevant example from archeology is worth noting here. At the Digital Roman Forum Project, where three levels of certainty were assigned to the digital models[23]. A very recent approach comes from Fabrizio I. Apollonio, „Classification schemes and model validation of 3D digital reconstruction process“[24].

After the classification process, quantification inevitably gains in importance as a component of the workflow, especially if appropriate visualization strategies must be chosen. This makes it necessary to quantify the uncertainty observed in the data. For this purpose, a diverse range of methods established in natural and engineering sciences can be applied, including but not limited to Monte Carlo method, probability calculations, possibility theory or heuristic evaluation.

In archaeology, the evaluation of data and information from many different sources of varying quality doubtlessly ranks among the main challenges. The quantification of information and claims derived from human discourse—academic exchanges coordinated by numerous individuals with their own subjective preferences and biases—is an incredibly complex task. The same applies for written sources and all sorts of image material, created, processed and distributed by humans. When we try to visualize uncertainty, we are constrained not only by the repleteness of the information, but also by the instabilities and uncertainties built into the visual apparatus upon which we are relying. These optical uncertainties may of course be exaggerated or attenuated at different levels of processing in the workflow. One solution often encountered involves the creation of a visual vocabulary which can register classes, types, and sources of uncertainty.

A brief outline of visualization approaches

The representation of uncertainty is and always has been something of a dilemma for all archaeologists. Verbally, textually and visually archaeologists have had to develop means of expressing and incorporating uncertainty and ambiguity into the archaeological process and into their representations of archaeology.[31]

In this sense, archaeologists and others who undertake the creation of scientifically reputable and serious visualizations of no longer existent historical contexts are confronted with difficult questions concerning the inclusion or exclusion of information, somehow caught inbetween imaginative additions (missing parts that they assume were once there, traces of usage, or soundscapes, for instance) and a scientifically appropriate but somehow „sanitized view of the past".[32]

Throughout the 19th century, well-known artists like Alan Sorrell or Piet de Jong established a drawing technique of 'artful concealment', by arranging clouds, bushes, branches, columns of smoke and the like on particular spots in the archaeological illustration, to either subtly disguise what should remain invisible, perhaps due to a lack of knowledge or uncertainties[33]. They also lent a sense of liveliness and presence to the scene; as one scholar has argued, „In both their beauty and communicative power, such illustrations cannot be matched in quality yet by methods and tools on computer."[34] Although artists could once skillfully conceal uncertainties, digital 3D modeling technology is based on complex volumetric calculations, which require concrete declarations and values in order to work properly. That is why it is all the more important to note that „[w]hereas it is possible to speak of a tower without knowing or having to be precise about what it looks like, visualization technology forces clear-cut decisions." [35] As a result, a carefully positioned digital cloud would be of no use in a 3D environment, for one thing because the user can easily change the perspective and see everything that is supposed to be camouflaged by the cloud. But the crucial point is that all the parts in the scene have to be modeled either way, even if they are intended to be invisible or covert and even if the required information is incomplete. Thus, the problem remains, because „[i]f we show other structures, we know we are wrong. If we show nothing, we are avoiding certain error but providing a reconstruction that will be equally misleading by showing a void where there were structures." [36]

In any case, while the provision of visual or textual references and explanations to clarify the use of the chosen visualization strategy (e.g. void or reconstruction) is often criticized as insufficient or even missing, the insufficiency of evaluation methods for visualizations (particularly in regards to the visualization of uncertainty) has been identified as a problem across disciplines. „There is much space for improving the way uncertainty information is currently captured, depicted and shared. To make uncertainty visualization successful, there need to be better techniques to capture and model uncertainty data; an agreement on data and implementation; and provision of a socially-agreed system for depiction.”[37] In addition to the questions already mentioned, others are arising: how to find appropriate visual representations (for specific tasks) and identify inappropriate ones (because of their ambivalent meaning, for instance)? Further, there is the problem of designing visualizations that do not distract or mislead viewers. „The sparse nature of uncertainty information, the lack of a consistent format for expressing it and the need to accommodate various display media and user expertise all pose a great challenge to the visualization designer as popular methods in the literature cannot be easily adopted in real-life applications.“ [38]

The development and application of various techniques to enable a more meaningful and comprehensible (re)presentation of information for different visualization types is under constant construction. Many applications are nowadays open source. In the following sections, some of these ‘real-life applications’ shall be briefly outlined. The options listed below are applicable for both 2D images as well as 3D models (or scenes). The first option ‘visual cues’ relates to visual manipulations directly on elements of the model (or image), the second option ‘rendering style’ affects the visualization as a whole, whereas the third option outlines some possibilities to (re)present the visualization results, e.g. renderings, 3D models or whole 3D scenes.

OPTION 1: Visual Cues

Historically the geovisualization community were perhaps the first to realise the importance of uncertainty. This community has long been concerned with issues of data quality so that the limitations of the data are understood when looking at maps.[39]

One of the many influential achievements from the pioneering field of geovisualization (and information visualization as well) is the genesis of methods and means in graphic semiology, established by french cartographer Jacques Bertin. He provides a system „that logically translate[s] information into graphic displays”[40], including his extensive work on ‘graphic (or visual) variables’.[41] Bertin’s initial compilation consists of the following six variables: size, value, texture, color, orientation and shape (plus the two dimensions x and y). They are used „to represent relationships, resemblance, order, and proportion”[42] and also play a vital role for immediate perceptual group selection, natural perceptual ordering (not learned), and quantitative comparisons”[43].

Because of their functionality and potential for specific visualization purposes, Bertin's system of graphic variables was used as starting point for further experimentation in other disciplinary contexts. How such an adaptation could be of use and how it could be done, was considered by Alan MacEachren in his early approach "Visualizing Uncertain Information" in 1992 (see fig. 1).[44]

Many years later, Zuk et al. also tried to adopt the concept into an archaeological framework, as described in their approach „Visualizing Temporal Uncertainty in 3D Virtual Reconstructions"[45]. The authors attempt to integrate and visualize temporal uncertainty from their data within an application called 'TimeWindow' (ArkVis), which basically combines animation, interactive elements ('time slider') and a range of visual cues based on Bertin's variables. „A visual cue can be defined as any visual encoding (color, size, animation, etc.) and used to communicate meta-data. In the current context a visual cue is any visual encoding used to distinguish levels of uncertainty"[46]. Examples of visual cues mentioned by Zuk et al. are 'rising/ sinking', 'wireframe', 'transparency', 'shadow/light', 'blur' and 'depth-of-field' to express previously quantified amounts of uncertainty.

As described above, visual cues were utilized throughout the 19th century, e.g. for 'artful concealment' in archaeological illustrations, history paintings, and graphic reconstructions

Table 1: Further examples of visual cues.[47]

location	color	focus / blurriness	animation
size	color hue	contour crispness	rising/sinking
shape	color value	fill clarity	oscillation
orientation	color saturation	fog	blinking
	transparency[48]	resolution	
textures	opacity	grain	sonification
	pseudo-color	depth-of-field	
pattern	color mapping[49]	(motion) blur	haptics
glyphs			
construction lines[50]	shadow/lighting	level of detail[51]	

of ancient sculptures. In this case, they were applied, if details or parts of the sculpture were missing and commonly assumed to have been on a determined spot at the statue. These graphical additions were distinguishable from the original drawings, showing the actual remains, because a different layout was chosen for the drawing line, as well as differentiating colors.[52]

Color is a common means of representing information, particularly levels of uncertainty. For instance, uncertainty is often symbolized by the color code system of traffic lights, whereby red is used for the highest degree of uncertainty (lack of knowledge etc.) or the most speculative parts of a digital reconstruction. Color as a visual cue has long been thoroughly researched, as a mean to distinguish between material properties or different periods of time and to specifically distinguish the archaeological evidence from the computational reconstructions in an image, as described and experimentally visualized by Eiteljorg and Tressel almost 20 years ago[53]. One recent example is the „escala de evidencia histórica (or scale of historical evidence)[54] presented by Pablo Aparicio, coined as „a color scale that has changed the way archaeologists look at 3D modelling“[55]. The application is demonstrated in the illustration of a roman tower[56] and was used in a rendering of the Portus Theodosiacus showing „the port as color coded according to our current level of knowledge“[57].

OPTION 2: Non-photorealistic Rendering

...visual presentations need not always be realistic. They rather need to convey a message. As long as the user knows (preferably intuitively or inattentively) what to take as real and what not, the visualization could be effective.[58]

One of the problems related to photorealistic renderings in archaeological (or generally historic) contexts is the tendency to convey certainty about the things depicted. One simple but more effective method is to utilize the wide-ranging set of non-photorealistic rendering techniques as a form of „acceptable imperfect presentation"[59]. At least since the 1990s, the development of this visual vocabulary is constantly progressing, especially in and thanks to all fields of the creative industry, like game development or graphic design, resulting in ever improving implementations and effectiveness. „Non-photorealistic rendering (NPR) is any technique that produces images of simulated 3d world in a style other than realism."[60] Efforts were made to imitate well-known art styles, like oil paintings or water color drawings, or for instance the characteristic style of technical drawings. Other known and often used forms are wireframe, pen-and-ink or a vast range of line or pencil styles and shaders.[61]

NPR techniques can be of use for uncertainty visualization because they „add an illustrative quality to the rendering technique...”[62], basically creating abstract visual stylizations which address different perceptive qualities compared to photorealism. They often give the impression of a more incomplete but therefore more flexible, modifiable image, open to changing processes. In this way, distraction from realistic details is considerably reduced, whereas the scope for interpretation and hypothesizing is facilitated by the abstraction.

In 1999, a concrete attempt was made by Strothotte, Masuch and Isenberg, to utilize non- photorealistic rendering techniques for „Visualizing Knowledge about Virtual Reconstruction of Ancient Architecture”[63] with the aid of their newly developed software called ‘SketchRenderer’ and ‘AncientVis’ (fig. 2). „This use of sketchiness or line saturation for various degrees of uncertainty is an attractive and intuitive way of visualizing uncertainty because it is used by artists in hand drawn pictures as well [...]. Users can interpret pictures as they are used to

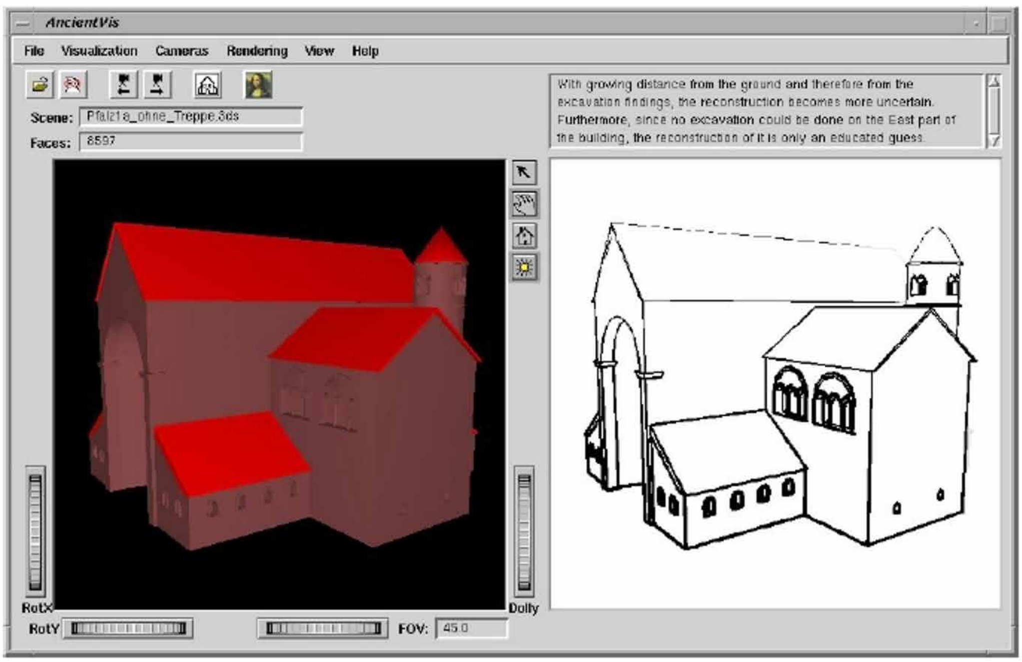

Figure 2: Interface of the AncientVis / SketchRenderer software.

Strothotte, Thomas, Maic Masuch, and Tobias Isenberg. “Visualizing knowledge about virtual reconstructions of ancient architecture.” Proceedings of Computer Graphics International (1999): 36-43 (40). Image used with friendly permission of Prof. Dr.- Ing. Maic Masuch, University of Duisburg-Essen.

doing so in conventional drawings and do not have to learn a new paradigm."[64] The functionality of the software is exemplified by the digital reconstruction of the palace of Otto the Great in Magdeburg (Germany). In this example, increased levels of uncertainty, especially in the upper parts and backside of the building, are visualized by lighter, thinner and more sketch-like lines, in contrast to the bold and straight lines used for the more certain reconstruction of the foundations. The reduction of visual information in some areas draws attention and scales the information available in others, while providing the opportunity for a user to interactively explore the (underlying) complexity of architectural reconstructions.

OPTION 3: Means for (Re-) contextualization

In this option sophisticated three--dimensional visualizations of archaeological contents are suggested to be supplemented by textual information that is embedded within or attached to it, for instance, a project description (e.g. aims, methodology, problems, decisions, debates, assumptions, sources etc.). Ideally, some explanatory notes inform about the way uncertainty was encountered during the research and reconstruction processes.

How this can be done is demonstrated at the "Digital Roman Forum"[65] project. Each 3D model selectable on the website, has its own detailed profile with all kind of information, even about the evaluated 'levels of certainty'. Unfortunately, the underlying evaluation process for these 'levels' is not described in further detail.

The possibilities to add text passages online are technically unlimited. And these web applications are predestined to be linked with data bases like Wikidata or Perseus Digital Library. Thus, further research is enabled, while providing access to additional (or different) data and information, thus generating additional value and ongoing discourse. Metadata for the provided images and 3D models shown could include but it certainly not limited to caption, production date, time and location of the displayed content, key aspects of possible debates or discussions, creator(s) of the 3D model, as well as information about involved parties.

Another frequently expressed demand concerns the expansion of the image repertoire, for instance, by providing alternative reconstructions and hypothesis to the final renderings.[66] This expansion can also be achieved by providing (a) images representing the excavation in progress, from intermediate stages (image overlays) up to the final visual results[67]; (b) images 'from behind the scenes', illustrating the digital reconstruction process as it unfolds, possibly with erroneous renderings and rejected models; (c) images with different perspectives and detail views; (d) alternative rendering styles (e.g. non-photorealism), different lighting (e.g. day/night time) or weather conditions etc. [68] Likewise, a side-by-side view[69], a sequence[70] or an image gallery[71] could be used, as well as videos with cross-fading effects, e.g. between the original record and reconstructed elements[72], image overlay[73] or merging[74], to expand the visual repertoire and make content comparison easier. Either way could help to illustrate the underlying genealogies and distortions related to multilayered project workflows which, although well documented, are often somehow locked-up, but could, if accessible, provide (further) insights.

The popularity of interactive elements is noticeably increasing. Thus, a significant shift is under way from static, inaccessible 'illustrative material' to more dynamic content generation. Therefore, this shift should be carefully observed, evaluated and critically questioned in future research. One example of a popular interactive application is the 'slider'. The main function is to process at least two images by moving a slider to merge, overlay, cross-fade or replace images with each other (for example, to compare an object's original state with a reconstruction).[75]

Another well-known tool is the '3D viewer', the most popular of which is the free plugin Sketchfab.[76] The 3D viewer can be easily implemented on websites, enabling the user to directly observe interactive 3D models by navigating in three-dimensional space, also allowing the user to change the perspective, among other options such as lighting, and rendering style.[77] Moreover, the Sketchfab 3D viewer is capable of showing 3D models directly in Virtual Reality, and also supports sound as an additional feature.

Furthermore, a wide range of interactive applications can be gathered under the term 'interface', allowing the user to manipulate the provided options and parameters. The most basic versions offer the possibility to select/deselect (or enable/disable) specific contents and information, so that the selection will be either directly mapped or removed from a given image or scene.

„Our reconstructions are also too clean and neat. The real world includes people, animals, plants, trash, signs of age and decay on structures, etc. Here again, we can only include some of these items and make mistakes or omit them and present an antiseptic world that is equally misleading."[78] In this sense, a slider could be moved between the two extremes of a range, so that the user can interactively change between images (or even changes a whole virtual scene), that is, between a 'sanitized view' (e.g. mere architectural structures without any further details like textures, etc.) to increasingly speculative scenarios, from in situ conditions to a detailed and highly speculative reconstruction.

A brief contemplation

Life is not perfect. We confront imperfection (and uncertainty) every day. Similarly, data and information as well as their representations will never be perfect. We thus need to get accustomed to and make peace with this fact, not expect decision making based on perfect data, information, and presentation. In that regard, we need to develop principles and methods of ›imperfection (uncertainty) management‹ how to get and understand imperfect information using imperfect representations and reach sound decisions in real-world conditions.[79]

Uncertainty is often perceived and communicated as a problem occurring anytime, anywhere. It requires a lot of careful work and well-prepared considerations to adequately cope with the enormous workload uncertainty entails (including detailed documentation of data, complex evaluation processes, debates, decision making and iterations). With regard to archaeological attempts to visualize uncertainty, one of the main difficulties observed is the ambition to develop images (or 3D models) according to established scientific requirements, that is, to show what is correct, verified and reliable, while at the same time, balancing aesthetic demands for clarity and repleteness. Additionally, the advent of photorealistic computer graphics predisposes us to images that are unambiguous and quickly, uncritically consumed. From this point of view, research fields like archaeology will always be confronted with the dilemma of interpreting, expecting or showing too much and at the same time too little. It is therefor crucial to develop standards and criteria for documenting (and not merely concealing) uncertainty.

Ideally, new forms of interactivity and visual communication yield new scientific insights. To do so they must integrate uncertainty into visualization. „In the end, visualizations are simply communication between people. Thus, when creating uncertainty visualizations, it may be a useful abstraction to think about just two people trying to communicate with each other."[80]

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[16] cf. e.g. ICOMOS, ICROM, INNOVA,

[17] cf. e.g. KVL, DHRLab, CVRLab, VWHL, CultLab3D

[18] cf. e.g. CAA, ACM SIGGRAPH, Europgraphics, EVA, EuroMed, SciVis, VAST, DHd

[19] cf. e.g. The London Charter, ENAME Charta, The Seville Charter

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Interview

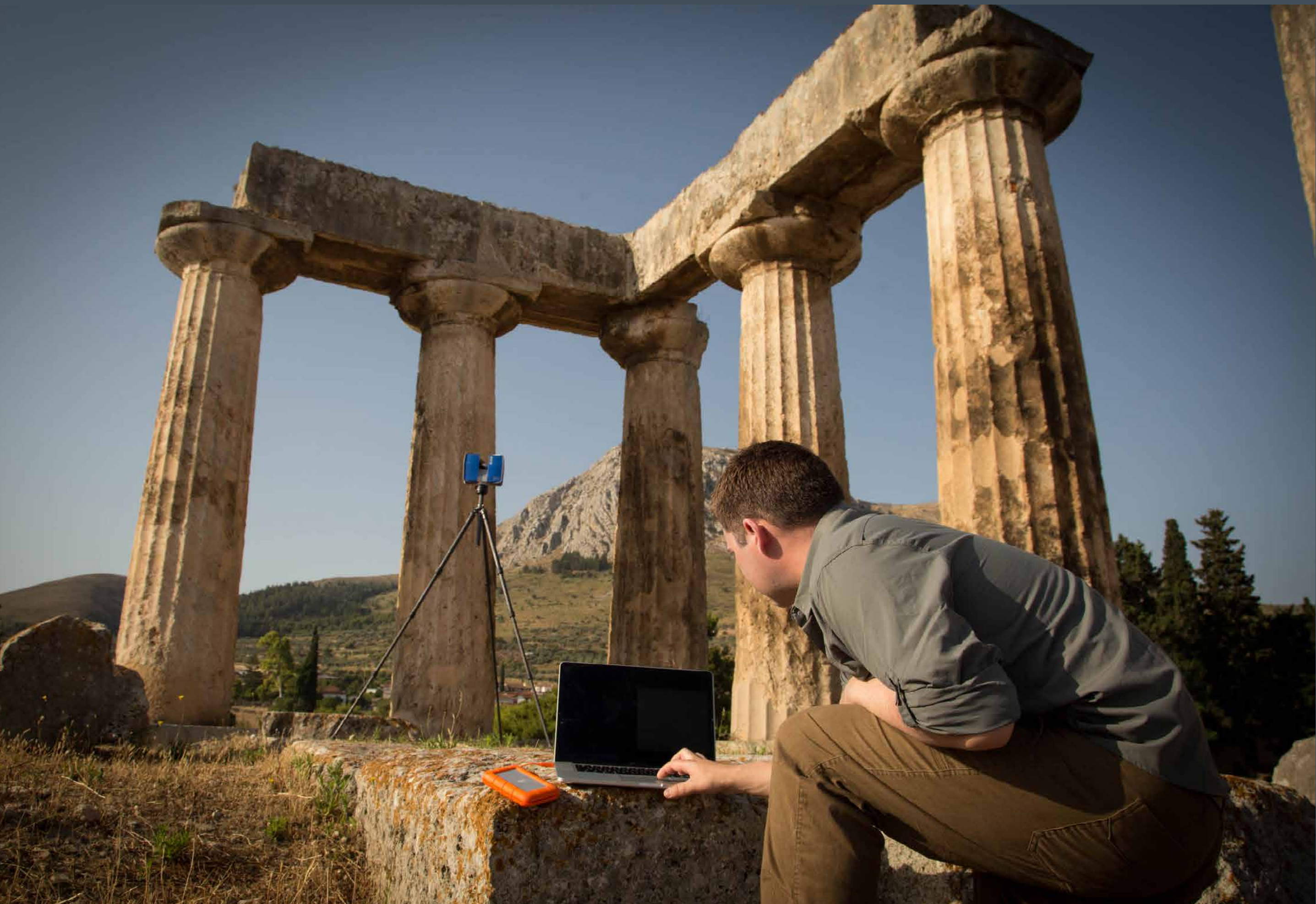

Figure 1: Scanning in the field, Temple of Apollo at Corinth: a laser scanner (blue, on tripod) detects surfaces that face it and registers these surfaces as a series of points in coordinate space. Data can subsequently be reviewed on a laptop in the field, and multiple scans can be pieced together (registered) to form a composite of the site.

In Conversation with CyArk

Digital Heritage in the 21st Century

Justin Underhill

Abstract: CyArk is a California-based nonprofit dedicated to digitally documenting and preserving world heritage. Since 2003, they have used photogrammetry and laser scanning to capture 3D data for over 200 sites; most recently, they have partnered with Google Arts & Culture to create an open-access platform for these sites (https://artsandculture.google.com/partner/cyark). Here, two members of the CyArk team, John Ristevski (Chairman and CEO) and Elizabeth Lee (Vice President of Programs and Development) sit down with Justin Underhill to discuss the past and present of digital cultural heritage.

Justin Underhill (JU): To begin, I thought each of you might talk about how you joined the CyArk team, and more broadly, how you got interested in digital cultural heritage.

John Ristevski

Elizabeth Lee

John Ristevksi (JR): I met Ben Kacyra [the founder of CyArk] in the early 2000s. He had invented the technique for 3D laser scanning, and wanted to apply that technology for good, for cultural heritage. I was doing my PhD at Berkeley, at the time. Looking at digital documentation techniques for architecture and archeology.

Someone said, you should come talk to this guy; he's got an idea. So we met, and he explained his vision for CyArk. It didn't even have a name yet. We decided to work together for a couple of years, and I helped him get the initial concept off the ground. Some of the first projects in the archive were my research projects from Berkeley.

Elizabeth Lee (EL): I had done archaeology, field work, at Berkeley, and with another university, as well. Doing mostly neolithic sites and documenting them with photography. What initially drew me to these new forms of documentation was this idea that you're out at these incredible places, uncovering these amazing secrets, and there's not a really good way to record that.

And more importantly to me personally, was the ability to share that with a broader audience. As I was getting familiar with CyArk, I was also getting more interested in taking documentation data and making it accessible. I remember when our preliminary website was launched—it was really exciting that you could pull up one of the sites in a web browser, and see where certain photos were taken. I think now is a more exciting a time than ever, because the technology for viewing and engaging with these data sets is rapidly evolving, making it much more meaningful for not only researchers, but also just enthusiasts.

Technology for viewing and engaging is rapidly evolving

JU: What do you think is the most exciting platform development?

EL: Well, we are doing a lot right now in virtual reality. As a medium, I think it is really exciting for the type of data that we collect. Because we're collecting photorealistic scaled data of these sites, that you can then recreate virtually, in a one-to-one kind of experience, in a way that was not possible just even a few years ago.

JU: When Kacey [Hadick, CyArk's Heritage and Conservation Program Manager] came to speak to my students, we got to do a virtual reality walkthrough. Do you see your digital content going more and more VR oriented?

EL: Yes. I think right now we have got to push. We're going to have our first public-facing app come out very soon. A free app to transport people to three different World Heritage sites, and let them learn about those places. I think we are optimistic about how that will be received, and hope that that will allow us to do a lot more within the medium.

JU: What are the three heritage sites?

EL: It is going to be Mesa Verde National Park, in Colorado, Ayutthaya in Thailand, and Chavín de Huántar in Peru.

JU: Wow. Nice spread!

JR: Yes; Interesting geographic spread, and interesting spread in terms of the manifestation of climate change of these places. You've got one where

3D laser scanning, terrestrial photogrammetry, and aerial photogrammetry, through drones [...] all those data sets come together

we are seeing the impact of wildfires on the site, in Mesa Verde, while at Ayutthaya it is more about flooding, at this juncture of three different rivers in this delta.

And then at Chavín de Huántar it is the glacial melts. You've got three different kind of manifestations of climate change impacting the sites, in pretty dramatic in catastrophic ways.

JU: I would imagine that at a site like Mesa Verde, some of the sightlines and the actual scale of a site like that could be very overwhelming in VR, relative to other VR experiences. Did you find that to be the case?

JR: In VR, Mesa Verde is actually the most interesting and compelling of the sites (fig. 2). We are just taking one of those little cliff alcoves and we are representing that. When you are inside that actually feels very immersive, and the scale's very human, versus, say Ayutthaya which is a much larger area, and the structures are very monumental. In person, the scale is hard to grasp, and in VR it is hard to grasp. I find that those alcove sites are actually perfect for virtually inhabiting the place, and experiencing it. It has the stronger sense of place, of the three. I think that has to do with the scale-

JU: ... The intimacy of the space?

JR: Yes. The intimacy of the space, and the scale.

JU: Can you take me through the typical process for a site, from start to finish?

EL: It starts, initially, with identifying sites where we can provide real impact. So we do a lot of work with UNESCO, and their regional offices have become good collaborators with us, because they understand the challenges within their region and can help identify needs.

So, we identify a site in need, and then we also have to find funding to support that work. We pair that need on the ground with a funding source that's interested in either that culture or that region.

Figure 2: Digital rendering of Mesa Verde, made available in Sketchfab by CyArk.

We then have to figure out a scope that makes sense, given the funding, and given the challenges on site. Usually we end up on site for about one to two weeks. We mobilize the team. They go out there with a suite of equipment; we use a combination of 3D laser scanning (fig. 1), terrestrial photogrammetry, and aerial photogrammetry, through drones (fig. 3). On site we capture hundreds of scans. Tens of thousands of photos. And then, all that data comes back with the team.

And in the office here, it all gets linked together. All the scans get registered. The photos get registered through common points, and all those data sets come together to form this photorealistic 3D surface model of the site (fig. 4). And then that model can be used to create a virtual reality environment, and it can also be used to create a number of conservation outputs—a base data set that we create, and that goes to those that are working on the site. And then, all the data is archived here, so that it's available for the future (fig. 5).

JU: Ten years ago, photogrammetry was nowhere near where it is today. That's been one of the most dramatic developments I have seen in the past five years. You mentioned drone photography, and you've integrated it in your workflow. Can you say a little more about that?

EL: The biggest advancement in terms of the photogrammetric workflow side has been the software. Camera sensors have also really improved, but the RealityCapture software that we have been able to process images with for the last

Figure 3: Drone at Bagan, Myanmar: aerial photographs captured by a remote-controlled drone provide images of surfaces, such as rooftops, that are inaccessible to the scanner; digital models of these features can be generated from the images and combined with laser scans using photogrammetry software. Photo by Kieran Kesner for CyArk.

Figure 4: Drone documentation of Ayutthaya: Hundreds of drone images are uploaded into RealityCapture photogrammetry software; when they are aligned, a point cloud of the site emerges. In the image above, each orange pyramid represents a different photograph that has been used to generate the model.

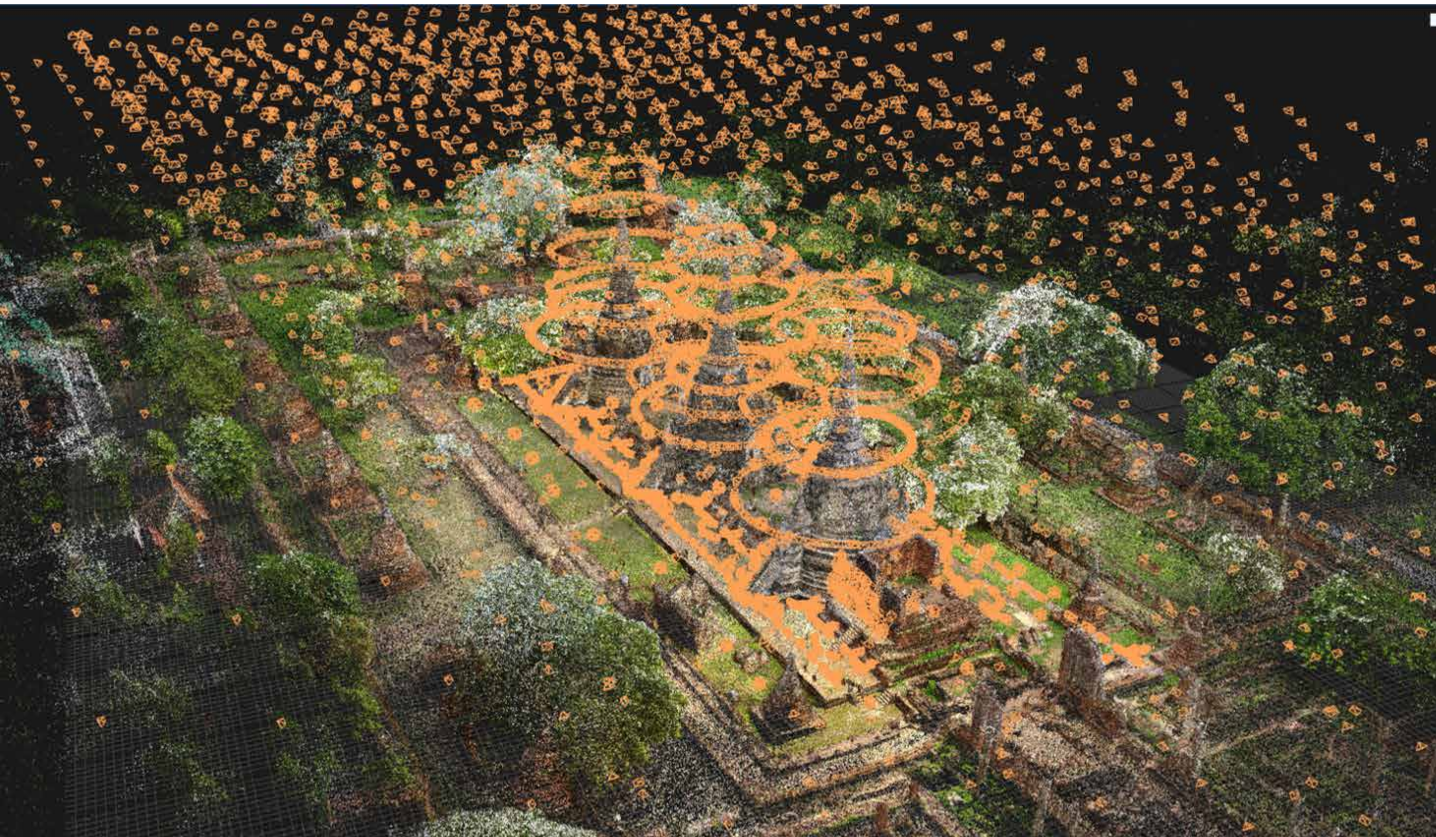

Figure 5: Exterior elevations (top) and clipped interior sections (bottom) of temples at Bagan. Center, (bottom and top): Eim Ya Kyaung temple. Left and Right (bottom and top): Khemingazedi temple.




18 months, allows us to combine the LIDAR with the photogrammetric data. That's been a game changer for us, in terms of the process, because before, we were using both [scanning and photogrammetry], but we didn't have a good way to bring them together.

Now, the software advances have really influenced our process, and we are still figuring out the best way to make sure all of that ties together in a repeatable way. Because the sites that we do end up being so different; some of the sites work quite well, because of the types of features, but at Chavín de Huántar for instance, there is a lot of grass, and it's very open.

It is not just collecting pixels

Parts of the site are a lot less structural than places like Ayutthaya which has very large, very unique lichen growing on the plaster. So you have these patterns that are just inherent, there.

JU: Beautiful reference points that we do not notice until we are back in the lab, and then we are so thankful.

EL: Yes. I think that the software has been a huge boon to our process. And the affordability of things like drones and the types of really high quality cameras that you can get for relatively cheap.

JU: Do you get a lot of requests to donate data?

JR: Occasionally, and one of the things we are trying to ensure is that we have a consistent data quality, across the sites. Especially now, as the methods get more integrated, combining drone imagery with scanning data, we want to ensure that the quality of the data and the archive is applicable to all the types of things we might want to build from it, whether it is a plan, section, or elevation, or VR experience. Texture data is especially tricky; capturing high quality texture data, that is evenly lit, that is a challenge.

JU: In our own backyard, here in the Bay Area, we are lucky to have many LGBT historic sites that remain engaged with their communities. And many of these sites go overlooked as sites for architectural preservation or archaeological investigation. Do you think CyArk will document any of those in the future?

EL: We have talked about a "Modern Social Movements" collection of sites, which I think is interesting.

JR: Especially with a site like Stonewall, which has become a national monument. Doing a site like that would be really interesting. It is complex. It is not just the bar. It is also that landscape, and the neighborhood, and the course of events. There is also a lot of big opportunity to collect narrative information, too. From people that experienced it.

JU: … Oral histories to collect before these people die.

JR: Exactly. I think that is the interesting thing about these modern movements; we are still living in the time where people can actually retell those stories. It is not just collecting pixels and points. It is also collecting the narratives, too, from people who are actually there. I think it is fascinating. I think we would love to do more in that vein, I think it would be an interesting challenge, and also an interesting opportunity would be to retell those stories in VR. It's hard to tell some of these stories and give people a sense of place. I think there is a unique opportunity to do that in VR.

John Ristevski is the Chairman of the Board and CEO of CyArk. John as formerly the Vice President of Reality Capture and Processing at Nokia's mapping company, HERE, where he led the company's initiative to index reality. John joined HERE in 2012 through the acquisition of his company, earthmine, which developed systems to capture and deliver highly accurate street level imagery and 3D data of cities. John is a Fellow of the Royal Institute of Chartered Surveyors and currently serves on the board of the non-profit CyArk. He has lectured at Stanford's Civil and Environmental Engineering Department and has a Master of Science degree from the University of California at Berkeley and degrees from the University of Melbourne in both Geomatic Engineering and Law.

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Elizabeth Lee serves as Vice President for Programs and Development for CyArk. Her expertise includes developing international partnerships in support of technology-driven solutions for cultural heritage protection, education, and appreciation. Originally trained as an archaeologist with excavation experience in Turkey and Hungary, Elizabeth has been applying 3D technologies to the cultural field for over a decade. She has extensive experience in working with foreign governments and local communities including cultural ministries and the United Nations Educational Cultural and Scientific Organization (UNESCO). Elizabeth is a graduate of the University of California, Berkeley and is a member of the US Chapter of the International Council on Monuments and Sites (ICOMOS). She is a past winner in the South by Southwest (SXSW) Eco Place by Design competition.

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Critical Section

Digital Art History has a fraught relationship to history and interpretation.

Against Digital Art History

Claire Bishop

Abstract: This article responds to two issues affecting the field of contemporary art history: digital technology and the so-called computational turn in the humanities. It is divided into two parts: the first connects problems with "digital art history," an offspring of digital humanities, to neoliberal metrics; the second suggests how digital art history's "distant reading" might nevertheless be deployed critically in the analysis of contemporary art.

Keywords: Computational, digital, metrics, reading

Part One[1]

First, let me clarify that I am not talking about *digitized* art history (i.e., the use of online image collections) but rather *digital* art history, that is, the use of computational methodologies and analytical techniques enabled by new technology: visualization, network analysis, topic modeling, simulation, pattern recognition, aggregation of materials from disparate geographical locations, etc. Some of these techniques have been around for several decades and have proven useful, especially for scholars working on periods where there is little surviving visual evidence (e.g., reconstructing ancient sites). Yet the visual theorist Johanna Drucker, writing in 2013, states that so far none of art history's "fundamental approaches, tenets of belief, or methods are altered by digital work"—unlike in the 1980s, when "traditional art history" was upended by the incursion of semiotics, psychoanalysis, Marxism, feminism, post-colonial theory, and post-structuralism (Drucker 2013).[2] Drucker nevertheless imagines that future digital databases will permit new questions to be asked of canonical works; she imagines, for example, a database containing the provenance history of different sources of pigments used in Western manuscript illumination and Renaissance painting, which would situate a work like Van Eyck's *Arnolfini Wedding* (1434) in relation to global systems of trade and economic value. Her vision of digital art history thus stands as a combination of digital technologies, network analysis, and connoisseurship.

Rather than thinking in terms of theoretical changes, however, we should compare the incursion of digital reproduction into art history to previous technological innovations. Prior to the late nineteenth century, art historians employed originals, casts, prints, sketches, and verbal descriptions to support and disseminate their research (Nelson 2000). The introduction of photographic reproduction enabled wholly new methodological approaches in art history—from the formalism of Heinrich Wölfflin, who introduced the slide comparison to the art history lecture in the 1880s, to the iconographical approach of Aby Warburg in the 1920s, who drew upon a vast archive of photographic reproductions from antiquity to advertising to advance his theory of *nachleben*. The change wrought by the digitization of slide collections since 2000 is therefore not only one of size and speed (an increased quantity of images for analysis and faster search returns), but also one of method, opening the door to "distant viewing." Already well known in Comparative Literature as "distant reading," this method proceeds by subjecting vast numbers of cultural artifacts to quantitative computational analysis.

A troubling introduction to this method can be found in the first issue of the *International Journal for Digital Art History*, launched in June 2015. In the first of six articles, new media theorist Lev Manovich introduces five key terms from data science that he believes to be useful to art historians: *object, features, data, feature space*, and *dimension reduction* (Manovich 2015). His text is illustrated with examples of his own research projects that draw upon Big Data, including *Selfiecity* (visualizations of thousands of Instagram selfies in different cities around the globe, assessing the images in terms of age, gender, position, frequency of smiling, etc.) and a principle content analysis (PCA) of over six thousand Impressionist paintings, calculating visual similarities in content and coloration.[3] Another paper, by K. Bender, analyzes 1,840 works of art from the thirteenth to the twentieth centuries showing the figure of Aphrodite or Venus, revealing that on average, artists turned to this theme 2.8 times in their lives (Bender 2015). A third article reports the results of feeding 120,000 portraits from the thirteenth to the twentieth centuries through facial-recognition software in order to establish whether the "canon of beauty" had changed over time (de la Rosa and Suárez 2015). Unsurprisingly, it had—the study concludes that there is a conspicuous decrease of "beauty" in the twentieth century. Only to someone entirely unfamiliar with modernism would this come as a surprise.

I admit that most academic papers, when boiled down to one line, risk sounding simplistic, but in this case the fatuity is extreme. Basic terms like *beauty* (and even *portraiture*) remain uninterrogated; instead, the authors observe that the "more average and symmetrical, the more beautiful a face is usually ranked," noting with approval that this criterion turns "a subjective opinion such as what face is beautiful into something measurable and objective" (ibid.). A complex human evaluation is reduced to statistical calculation. Equally blunt is the claim, found in almost every essay in this journal's inaugural issue, that "this empirical finding has never before been highlighted in art history"—as if novelty were a sufficient measure of interest and substance. Further, the data set affirms the art historical canon ("Impressionist paintings," "figures of Aphrodite or Venus") rather than challenging it or even addressing it critically. Who decides what is understood as the canon? What is left out? On the evidence of these articles, practitioners of digital art history have a limited awareness of critical debates within art history (such as the long-standing, and some would say long-dead, question of "beauty"), but also a limited grasp on how to frame a meaningful research question. Theoretical problems are steamrollered flat by the weight of data.

This silence, however, seems to be to digital art history's advantage. This new approach is already finding its way into museums, and not just conservation departments that have long had a relationship to scientific research. Consider the network map produced by the Museum of Modern Art, New York, for the exhibition "Inventing Abstraction 1910–1925" (2012–13), created by the curators in collaboration with a professor and a doctoral student at Columbia University's business school.[4] The map, an update of Barr's well-known diagram for the catalogue *Cubism and Abstract Art* (1936), covered a wall at the entrance to the exhibition. On the exhibition website, the map allows users to click on various names, mapped geospatially from the West to the East, in order to see which artists were in contact with whom during this period. One positive outcome of this mapping was that several female artists, usually relegated to the sidelines, were repositioned as key players: Sonia Delaunay and Natalia Goncharova were ranked as the "most connected" alongside Jean Arp, Guillaume Apollinaire, Pablo Picasso, Tristan Tzara, and Alfred Stieglitz. But what does it really mean to be "connected"? As art history doctoral students Jonathan Patkowski and Nicole Reiner argue in their critique of the exhibition, this map recodes the early twentieth-century artist as a contemporary networked entrepreneur whose importance is now gauged in terms of number of social connections (i.e., documentable acquaintances) rather than artistic innovations (Patkowski and Reiner 2013). Carefully reasoned historical narrative is replaced by social network (the avant-garde equivalent of LinkedIn) and has no room for non-human agents that elude quantification—such as African artifacts, which were crucial to the development of abstraction, or the imperial powers that mobilized their circulation in Europe.

My point is that subordinating art history—whether the invention of abstraction, Impressionist painting, or the new genre of the selfie—to computational analysis might well reveal "empirical findings never before highlighted in art history," but this method also perpetuates uncritical assumptions about the intrinsic value of statistics. In *Undoing the Demos* (2015), Wendy Brown argues that neoliberalism should be regarded less as a political formation than as a form of reason, a system of governance in which "all spheres of existence are framed and measured by economic terms and metrics, even when those spheres are not directly monetized" (Brown 2015, 10). Her examples include any online activity that measures output by the number of "likes" or "followers," from Facebook and Instagram to online dating. Digital art history is just such a subordination of human activity to metric evaluation. It is inextricably linked to the ascendancy of the digital humanities, which has flourished despite financial cuts to the "analog humanities", and which is seen as a way to make humanities' outputs "useful"—like science, technology, engineering, and mathematics (i.e., industry-preferred STEM subjects).[5] In the words of new media scholar Richard Grusin, "It is no coincidence that the digital humanities has emerged as 'the next big thing' at the same moment that the neoliberalization and corporatization of higher education has intensified in the first decades of the twenty-first century" (Grusin 2013). This is not to say that the digital humanities are doomed to be the unwitting handmaidens of neoliberal imperatives, but it is important to note how its technopositivist rationality is disturbingly synchronous with the marketization of education: the promotion of MOOCs as value-for-money content delivery; the precarious position of adjunct professors; the tyranny of academic rankings; and the remaking of the university away from "quaint concerns with developing the person and citizen" and toward a model of the student as self-investing human capital (Brown 2015, 23).[6] Any study that mobilizes Big Data needs to reflect critically on the mechanisms by which this data is gathered: corporate data mining, state surveillance, and algorithmic governance techniques.[7]

Digital art history, as the belated tail end of the digital humanities, signals a change in the character of knowledge and learning. Ideals like public service, citizenship, knowledge as an end in itself, and questions of what is just, right, and true have decreasing validity because they resist quantitative measurement, and moreover do not easily translate into information that optimizes the performance of society (i.e. generate) profit. Instead, research and knowledge are understood in terms of data and its exteriorization in computational analyses. This raises the question of whether there is a basic incompatibility between the humanities and computational metrics. Is it possible to enhance the theoretical interpretations characteristic of the humanities with positivist, empirical methods—or are they incommensurable?

We have to be careful how we phrase this dilemma. Drucker floats the possibility—although she eventually rejects the idea—that visual art might be fundamentally resistant to computational processing and analysis because it is so emphatically tied up in narratives of singularity, individuality, and exceptionality. These valorizing terms are of course not exclusive to art history and play an important role in canon formation across all of the humanities. We know from Franco Moretti's controversial method of "distant reading"—analyzing literature not by studying particular texts, but by aggregating massive amounts of data—that singular genius is one of the first concepts to fall by the wayside when dealing with literature as an integrated system of global publishing. On the one hand, this is appealing: who among us could really argue that the canon isn't too white, male, and European? And Moretti is right to observe that close readings can become a "theological exercise—very solemn treatment of very few texts taken very seriously" (Moretti 2000).[8] When you glance at Moretti's work—such as *Graphs, Maps, Trees* (2007)—it is conspicuous that paradigmatic examples and block quotes have been replaced with diagrams, models, and schemas, but at least these graphs trigger interpretation: a social history supported by statistics rather than text mining the number of times a given word appears in Proust.[9] Moretti's earlier work, prior to setting up the Stanford Literary Lab in 2010, is especially interesting in trying to analyze all literature from a given period, both canonical and noncanonical; questions of historical causality remain central for him, in part because they are the blind spot of distant reading, the argument that statistics cannot supply.

Yet, increasingly, Moretti—like Lev Manovich—proceeds with the data set in advance of a research question, or what digital humanist Alan Liu calls "tabula rasa interpretation—the initiation of interpretation through the hypothesis-free discovery of phenomena" (Liu 2013).[10] In this model, topics are generated without an initial concept or question from an interpreter looking to confirm a theme or pattern; computers read texts/images algorithmically, with minimal human intervention. In the case of Manovich's Cultural Analytics (a hybrid new interdiscipline), data are aestheticized into patterns, but the task of interpreting these patterns is left up to others.[11] As a result, digital art history has a fraught relationship to history and interpretation. Does the data set exist in history before being sequenced digitally or is it only actualized once it has been laid out via the digital archive? Are the assembled historical "facts" found or produced? What's the relation between what's empirically observable and what's true? Technology is presumed to provide objective access to reality in a way that subjective interpretation cannot. The result is an avoidance of argumentation and interpretation, as exemplified by the articles in the *International Journal of Digital Art History*.[12] Computational metrics can help aggregate data and indicate patterns, but they struggle to explain causality, which in the humanities is always a question of interpretation. In effect, a post-historical position is assumed: the data is out there, gathered and complete; all that remains is for scholars to sequence it at will. Here, computational methods become another manifestation of the drive for mastery over history and the archive. The analog humanities, by contrast, remain outside the logic of tidy deliverable answers; their importance, as media theorist Gary Hall notes, lies in their ability to hold open a space for "much-needed elements of dissensus, dysfunction, ambiguity, conflict, unpredictability, inaccessibility, and inefficiency" (Hall 2013, 798).

Part Two

Contemporary art, perhaps more than any other art form, is entirely embroiled in digital technology: it permeates the production of work, its consumption and circulation. It is noticeable that artists are increasingly turning to cut-and-paste methods to create work across a wide variety of media. Pre-existing cultural artifacts are remixed and reformatted, generating a mise-en-abyme of references to previous historical eras. As part of this historical orientation, obsolete technologies have acquired a new auratic currency (8 and 16mm film, slide projectors, fax machines, even VCR players), as has the trope of the archive. We are currently in a hybrid moment where non- or pre-digital materiality is sustained alongside a digital way of thinking: an approach to information in which sources are decontextualized, remixed, reorganized, and archived. This hybridized interpenetration of digital and non-digital extends to the distribution and consumption of art. Today, most exhibitions reach their audiences as jpgs: artists increasingly mount their shows with the installation shot in mind, and gallery lighting has become brighter so that photographs 'pop' on a back-lit plasma screen. Works of art are bought and sold as jpgs, without collectors ever having seen the original in person.

My current project, "Déjà Vu: Reformatting Modernist Architecture," has engaged in a type of distant reading—one that could only have been realized with the assistance of digital technology, but which is steered by a critical human eye. In the slideshow that accompanies the lecture version of "Déjà Vu," I replace the singular, paradigmatic example with hundreds of case studies—works of art gathered from North and South America and Eastern and Western Europe since 1989. Over three hundred images scroll before viewers, in different combinations; the aim is to move beyond the traditional illustrative slide comparison to a scenario in which the images begin to create an argument in their own right, bolstering (but also at moments contesting) my interpretation. Over the course of an hour, the audience experiences a number of déjà vus: works of art, all of which take as their starting point a pre-existing work of modernist architecture or design (including iconic structures by Le Corbusier, Oscar Niemeyer, and Vladimir Tatlin), also recur in different sequences.[13] The title refers to Paolo Virno's theory of déjà vu as a distanciation from agency: he describes it as a pathological condition of watching ourselves live and feeling that the future has been fatalistically prescribed for us, and connects this

Distant reading serves as a critique of the system in which these works thrive.

condition to the post-political consensus after 1989.[14] Something of this fatalism is conveyed in the relentlessness of my PowerPoint, which generates the feeling of scrolling through a tide of images (as when searching online), and yet each work appears before us, rather than being aggregated into a single graphic visualization. The PowerPoint partly repeats the numbing effect of the online image world, but also becomes a tool to make this available to interpretation.

Given that the rise of this artistic trend is a convergence of ideological narratives about a geopolitical condition ("the end of history") encountering the proliferation of digital media, this flow of images generates an argument about repetition and banality without me having to spell it out verbally. The slideshow has occasionally infuriated audiences, who see it as leveling the specificity of artists' practices in different parts of the world, and ignoring attempts to chart gender or race through the quotation of modernist forebears (even though my text draws out these historical and ideological differences). My reason for presenting images in this "distant," non-hierarchical way is that I believe there *are* no paradigmatic examples of this trend, and that the differences between these works are less significant than their similarities. My target is the mainstream, the mediocre, the déjà vu: the work we feel like we've seen before, the highlights of modernism already witnessed, the projects by artists that are unquotable because they are themselves so reliant upon quotation.

Distant reading serves as a critique of the system in which these works thrive: not just the rapidity of image circulation online, but also the New York art world, with its thousands of commercial galleries and their disproportionate impact upon museum practice, all of which creates an increasingly off-putting haze of hype and high finance around contemporary art. This condition is rarely resisted by artists here, who leave art schools with huge debts and need to get on the career ladder as soon as possible in order to start repaying loans. The MFA-debt/gallery-profit cycle has made it increasingly difficult to write about contemporary art without also wanting to run a mile from it. Distant viewing is my expression of this distance. The disjunctive simultaneity of proximity and distance is also the condition of consuming images in the twenty-first century and thus the subject of my paper as much as its method. As such, I hope that my project functions as a critical intervention both into a contemporary art history that seems always to bolster singular figures for the market, and into a digital art history that privileges computational over ideological analyses.

Notes

[1] This paper was written for a conference on new methods in the humanities at Duke University in November 2016 and first published on their website https://humanitiesfutures.org/papers/digital-art-history/

[2] Drucker draws the useful distinction between digitized and digital art history on page 5.

[3] Selfiecity can be found online at www.selfiecity.net. The main findings include the following: more women take selfies than men and strike more extreme poses; the average age of selfie photographers is 23.7; people in Moscow smile less than people in São Paulo and Bangkok. The project used Amazon's Mechanical Turk workers to classify 640 selfies from each city, taken from a random sample of 120,000 images from Instagram.

[4] Paul Ingram and Mitali Banerjee, www.moma.org/interactives/exhibitions/2012/inventingabstraction/?page=connections

[5] The term analog humanities is taken from Sterne 2015, 18.

[6] The Washington Post recently reported that Purdue University (Indiana) has partnered with businesses as an alternative to student loans: investors front students the money to pay for education in exchange for a share in future earnings (Douglas-Gabriel 2015).

[7] This problem is not confined to digital art history. As English/Comp Lit scholar Brian Lennon notes, ". . .the digital humanities has displayed almost no specifically political interest in the world outside the university and too little explicit interest of any kind in the broader interinstitutional politics of the world within the university in its imbrication with the institutions of security and military intelligence" (Lennon 2014, 140–41).

[8] For a concise response, see Schulz (2011).

[9] Influenced by historian Ferdinand Braudel's theory of the longue durée, Moretti argues that the novel developed as a system of its genres (in other words, we cannot speak of "the novel" but only of a whole set of forty-four genres). Looking at the publication rates for novels over periods of decades, he moves from quantitative facts to speculation and interpretation; for example, he suggests that the rise and fall of the various genres of the novel in the United Kingdom correlate to twenty-five- to thirty-five-year cycles (i.e., to generations of readers) (Moretti 2007). Earlier work, such as "Conjectures in World Literature," provocatively conclude that the modern novel first arises not as an autonomous development but as a compromise between a western formal influence (usually French or English) and local materials"; in other words, the Western European novel is an exception, not the rule (Moretti 2000).

[10] This can be seen, for example, in Moretti's quantification of the plot of Shakespeare's Hamlet (Moretti 2011).

[11] See Gary Hall's incisive critique of Manovich (Hall 2013).

[12] Likewise, the authors of the paper on beauty and portraiture conclude that "any approach to the culturomics of art history and beauty also takes into account cultural evolution and cultural history as forces that shape the results we find in the data"—without feeling any obligation to supply this (Rosa and Suárez 2015, 125).

[13] This type of work is near unsearchable on the Internet because search engines cannot cope with self-reflexivity (contemporary art quoting modern art). My examples were therefore amassed slowly, via exhibition catalogues, artists' websites, press releases, Tumblrs, and blogs.

[14] Post-politics is a term used by political philosophers—including Jacques Rancière, Chantal Mouffe, Slavoj Žižek, and Jodi Dean—to describe the post-ideological consensus that dominated global politics after the Cold War.

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Art History faces a problem of legitimacy today.

Big Bang Art History

Ulrich Pfisterer

The History of Art is in the midst of its own big bang. Amit Sood, the head of the Google Cultural Institute and Art Project, announced such in February 2016 at the Innovation Conference TED in Vancouver. Through its "Arts & Culture" program, Google already offers virtual tours of over one thousand museums and cultural institutions throughout the world, and also provides access to more than six million high-resolution digitized works of art (it should be noted that these figures continue to rise steeply).

Sood's visualization of this data—portrayed diachronically as a rapidly forming cloud (ideally displayed on as large a screen as possible) and anchored by an origin point represented by a single work of art, such as the *Venus of Berekath Ram* (created around 250,000 years ago)—does indeed give the impression of an explosion of artistic and cultural activity. Moreover, the visualization of this art historical big bang also marks a second, methodological big bang: the explosive growth of methods and discourse comprising Digital Art History, which has made such a visualization possible in the first place.

Google's goal is clear: "every piece of art you've ever wanted to see–up close and searchable". In the foreseeable future, all artefacts of world culture should be available virtually and (hopefully) openly accessible, and beyond that they should be arranged and categorized to allow for searching with the utmost ease according to any conceivable criterion. Mind you, this recognition and classification according to different material and figurative qualities no longer takes place solely through human tagging, but is also facilitated by machine learning (and will continue to be). The concluding part of Sood's presentation suggests that the sheer quantity of this art-historical data collection and its media specificity will eventually result in a new kind of Art History and new forms of art historical research–one of several net positives he predicts for humanity in the information age, along with entertainment, social justice and global exchange.

Some takeaways from the digital spectacle of Sood's product showcase: first, the outspoken confession by Sood, an IT expert, that he has no clue about art history. As far as Google is concerned, Digital Art History does not seem to compulsorily require art historians. Second, beyond the great technical possibilities of data collection and processing, there are actually no further (art historical, image-theoretical, museological) questions built into this project. Perhaps such questions are unwanted or unwarranted.

But how should we understand it when Sood concludes by pointing to a particularly eye-catching collection of files to prove the potential possibilities of this virtual marvel, only to show that as a result of immense computing power, all the images concerned can be grouped together as variations of the canonical bust portrait? Even if we appreciate the innovative potential of this particular visualization, critical questions arise: how, for example, would Google's art-minded algorithms categorize Marc Quinn's *Shithead* of 1987–a classic bust format in a transparent cryocooler?

In any case, one cannot completely dismiss the suspicion that Google Cultural Institute, and related projects on Computer Vision, Image Processing and Network Science, are less concerned with a genuine interest in art, but to participate in its nobilitating aura, the social attribution of meaning and the economic potential.

Third, and most importantly: Sood gives the impression that Art History as a discipline has not managed to make a decisive contribution to these developments despite some efforts. Could be worse, one might think, if it was not about the future of the discipline as a whole.

Science of Art

First of all, policy debates about whether we really need Digital Art History have long been settled. For many years, there have been excellent Art History databases, search engines for images, publications, exhibitions and online museum presentations, since 2015 there has even been even a dedicated journal, the *International Journal for Digital Art History*. Big players such as the Google Cultural Institute and, by comparison, small institutions such as the Getty Research Institute are facilitating development with substantial financial commitments. The reality and necessity of these digital infrastructures (and the torrent of images that circulate through them) cannot be stopped, in any case. For Art History as a discipline, this simply means keeping up, while critically developing topics, methods and theories internal to the discipline, or, alternately being phased out.

What is missing, however, is a discussion within the discipline led with self-confidence: this must not only reveal its added value in academic papers (and this text does not do anything else initially), but must also prove its point as widely as possible through concrete examples and research results. The fact that there are not many of these is due to the fact that demand is faster than research. Databases and online publications are only a first step, even if the medium of course is inseparable from its contents. Digital "context analyses"—such as the evaluation of geographical movements of artists or objects in a certain period of time or even a computer-aided identification of potential research gaps—may not be the ultimate goal. But it is not about evaluating approaches and questions in a comparative way. As long as digital analysis fails to deeply engage formal and the aesthetic principles, Digital Art History will always be subject to criticism that it does not advance the "genuine core" of the field.

The question of the specific potential of art history as a field was most rigorously posed in the decades around 1900 in discussions about an "exact" Science of Art, a *Kunstwissenschaft*. At that time, Art History wrestled with its reputation within the circle of established humanities. Art History had to develop an independent profile somewhere between aesthetic philosophy and history, with interdisciplinary links to (perceptual) psychology. Without any historical shortcuts and traditional ideas of the center and the periphery, I want to say that under completely different circumstances, art history again faces a problem of legitimacy today.

There are two precipitants of this crisis: On one hand, the interests of the subject have expanded so rapidly under the auspices of globalization and Image Science (*Bildwissenschaft*, another big-bang phenomenon) that thinking and explaining how everything can come together now seems impossible. This creates the impression that the "competence ceiling" (*Kompetenzdecke*) of Art History is becoming increasingly thin and tearing apart.

On the other hand, so many other disciplines have gravitated to this expanding field of visual analysis, artifactual analysis, and aesthetics, that entire areas of art history seem to be dealt with elsewhere. This does not only apply to photography, film and media studies, but also to ethnology and (art) pedagogy, which have long been semi-independent or entirely independent fields. In the meantime, Literature and Theater Studies, History, History of Science, Psychology, Biology and all forms of Computer Vision, Image Processing, Big Data and Network Science have become increasingly relevant.

Art history, on the other hand, may have to cede certain research areas and questions to other fields as it continues to focus on the traditional frameworks that, allegedly, constitute its disciplinary core. Among the many opportunities missed, this would be the greatest, for the visual and its images will become even more crucial in our digital age, in which we see forms of communication that are no longer so highly constrained, as they have been in our (western) epistemes, by the primacy of text. One could imagine no greater legitimizing force for Art History. Nor a greater challenge.

The Great Divide

Digital Art History requires new skills. Art historians already navigate the interdisciplinary quicksand between Philosophy, Literary Science, Psychology, Sociology, etc. However, the digital technology presents a different kind of divide even for digital natives of the humanities.

In his study, Maximilian Schich has made a data visualization of this distance, showing how often the humanities and natural sciences quote each other. Schich speaks of a "skiing area" crisscrossing the disciplines and explains this configuration to a desirable new ski slope. Others might see the darkness in the chart as a great divide, and this uncertainty points to the multiple forms that an ambiguous figure may acquire. Such ambiguities or oscillations in appearance are unlikely to be resolved in the short term by computer algorithms. In any case, these new demands cannot and must not mean that only the Computer Sciences fill out missing competences within the humanities and build cross-disciplinary bridges. Conversely, it is equally important to emphasize the need for critical self-reflection on forms of representation and the conditions of visual knowledge production in the digital domain—a bridge that art history could and should help build.

The consistency of Sood's big bang Art History as a presentation is dependent upon both the visualization arts of Google and with the audience's understanding of the big bang (which is probably determined less by astrophysics than by the opening credits of *The Big Bang Theory*). Yet even the starting points remain problematic. For one thing, it has yet to be determined whether the *Venus of Berekath Ram* or her contemporary, the *Venus of Tan-Tan*, were intentionally made or were instead the result of geological activity.

Even if we obtained definitive proof that they were the intentional product of *Homo erectus*, the next recorded (and incontrovertibly man-made) data point, produced around 200 000 years later in the Upper Palaeolithic, presents a significant gap. From the outset, it is also unlikely—without counting exactly—that more art was produced in Europe in the sixth century than in the first century after the beginning of Christianity, as the suggestion of a cultural explosion actually demands. Such objections could be continued for pages. The big bang analogy seems to work from a distance and in extreme time lapse, but the closer one gets, and the closer one looks at time periods, the more "anomalies" appear. And here it becomes necessary to ask how the distance generated by Big Data relates to the actual gain of knowledge about works of art and artistic ideas.

Furthermore, the question of what Google determines to be "art" has not even been asked. Sood's main examples, the works of van Gogh and the collections of Guggenheim Museum in New York, are icons of the Western canon. Google is merely digitally spotlighting iconic works of art and institutions. Contrary to the project's pretense of making everything accessible to all, cultures that are not "artful" in this Western sense are at least provisionally marginalized. Such objections also highlight distortions within Western art historical narratives; we might imagine how our understanding of European Renaissance art will change when hundreds of thousands of drawings, tens of thousands of prints, thousands of medals, works by goldsmiths, etc. are all digitized and the canon is no longer dominated by painting and sculpture.

It is the scientific, social and political task of Art History to fastidiously document and describe the cultural conditions of seeing, thinking and doing that comprise computer science, as well as the natural, technical and life sciences. The success of a Digital Art History, as it is understood here, is proved by the fact that its specific competence is in demand by the sciences beyond the great divide. And it is these specific competences that Digital Art History will be challenged to preserve relative to other Digital Humanities methodologies, which are primarily focused on textual analysis.

Digital Serendipity

One might claim that most of these objections will dissolve over time. "Just be patient", one might think, "soon, Google will have digitized every artwork, along with the rest of the world". Questions of choice and canon formation, of center and periphery, and even of the ontology of art, will then be clearly resolved: everything will be available and searchable. Indeed, this dream for an exact Science of Art mirrors the fictional version of the world described by Jorge Luis Borges in his short story *On Exactitude in Science*. The digital is conceived as an exact image of reality, much like Borges's one-to-one map scale. And for digital documentation, this would be an ideal setup.

Of course, more data does not directly result in more knowledge; too much unstructured data may actually limit insight. In spite of this, one might hope for a serendipity effect, whereby new, unexpected results and associations arise in the process of digitization. But even so, the situation is not yet completely outlined: Even today, some computer-generated results seem to be based on such complex operations that the results are no longer exactly comprehensible even for experts. This phenomenon will become increasingly common as AI is integrated into computer programs to make them self-programming. In this foreseeable future, a circle will close for Art History: the methods-driven Science of Art had previously renounced approaches that could only cite the gut feeling of "experts" as arguments, be it on issues of attribution, quality or the aesthetic effect. If total digitization is indeed the end game of Google Art Project, one can imagine a new form of inconcretness: search results, as particular to the layers of filtering and selection that isolated them as the gut feeling is to the connoisseur.

Nor can we ignore the problem that the phenomena of art itself will never be fully articulated as a data structure, as long as the visual and the aesthetic remain at least partially irreducible and incommensurable relative to other systems (be they numerical, textual, or linguistic), and as long as aesthetic observation is guided by the belief that "art" retains a kind of "inexhaustible surplus" of sensation and meaning. These incongruities and the misunderstandings that arise from them require the skills of Art History as a critical counterpart for the Computer Sciences and all other sciences concerned with images and aesthetics.

Conversely, Art History must tackle what is probably the greatest challenge and imposition of the digital in the field of images and art: sometimes quantification and mathematical methods can help us understand formal design and aesthetic phenomena, in spite of all the hype about creativity, uniqueness and novelty. Changes in proportions, color scheme or compositional structure could be analyzed much more reliably, for example on the basis of large amounts of data, than with the previous highly selective comparison. We have yet to see a lengthy, game-changing study in this emerging discipline. Only such a project could definitively demonstrate that humanities and natural sciences or technology sciences can converge in a research program. In this respect, Digital Art History has the chance to productively overcome a divide between the sciences that has seemed categorically unavoidable since at least Dilthey. In any case, Digital Humanities determines not only the disciplinary future of Art History, but also those of all the humanities.

With all the confidence in the near future, we certainly should not completely forget the very latest small art event of the present: such as *Van Gogh Alive - The Experience*. Opened in October 2016 in Rome, it is the new tourist magnet of the Eternal City (which is claimed on the homepage of the exhibition). Not a single true van Gogh is presented, but gigantic digital, multisensorial (mood) images and spaces pay tribute to the man with the cut off ear and the open-pastose brushstroke. The scene would not be complete without the latest cinematic gimmick, a projection system that allows surround experience in high resolution. They're likely the same images that Google uses. One can only hope that such cultural and intellectual implosions will disappear in the wake of Digital Art History's big bang.

Notes

1 First published in German in Merkur 71 (816), 2017, 95-101. Translation by Harald Klinke and Justin Underhill.

2 Amit Sood: Every piece of art you‘ve ever wanted to see — up close and searchable, TED2016, https://www.ted.com/talks/amit_sood_every_piece_of_art_you_ve_ever_wanted_to_see_up_close_and_searchable. At the conference *TED - Technology, Entertainment, Design - "Ideas Worth Spreading"* every speaker has maximum 18 minutes of speaking time, attendees most recently pay $ 6000 conference fees.

3 Maximilian Schich, *Figuring out Art History*. In: International Journal for Digital Art History, no. 2, 2016.

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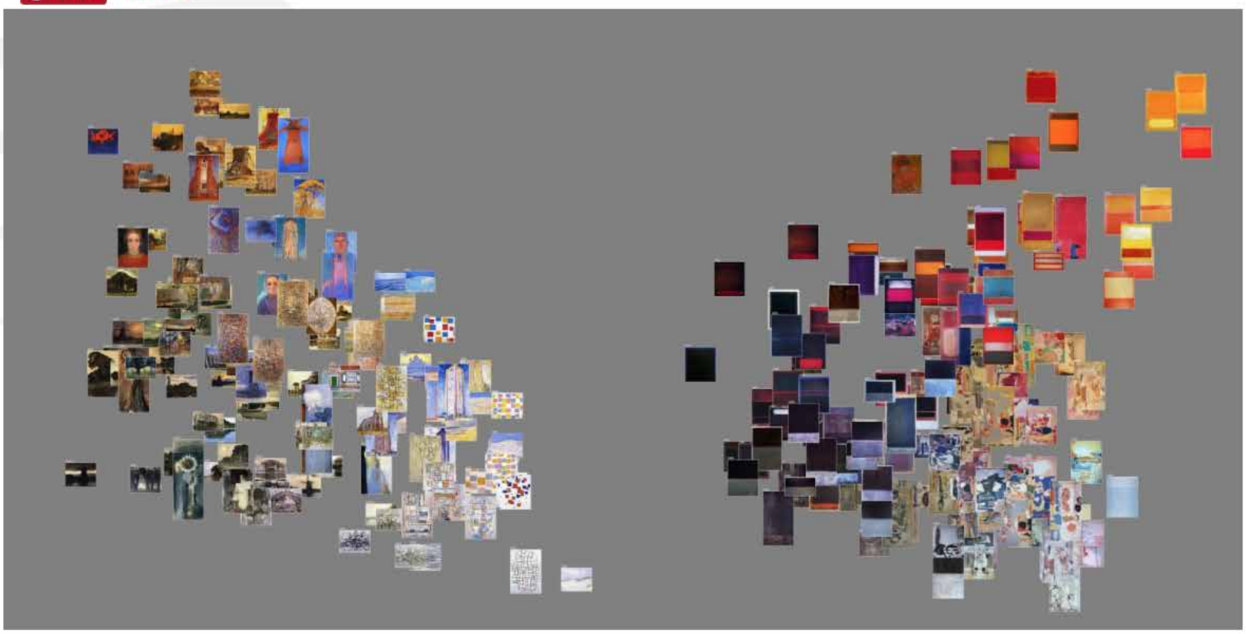
Mondrian vs Rothko: Revealing the Comparative "Footprints" of the Modern Painters

Salva Tweet



Data: 128 paintings by Piet Mondrian (1905 - 1917) and 151 paintings by Mark Rothko (1944 - 1957). Mapping: X-axis: brightness mean, Y-axis: saturation mean. This visualization demonstrates how image plots can be used to compare multiple data sets. In this case, the goal is to compare similar number of paintings by Piet Mondrian and Mark Rothko (produced over comparable time periods of 13 years) along particular visual dimensions. See the full size image on Flickr.

Figure 1: Lev Manovich; a comparison of brightness and saturation of a selection of about 130 paintings by Mondrian and Rothko. Screenshot from: http://lab.culturalanalytics.info/2016/04/mondrian-vs-rothko.html

Digital Art History and the Computational Imagination

Giacomo Mercuriali

Abstract: This essay explores the parallel development of computer vision technology and digital art history, examining some of the current possibilities and limits of computational techniques applied to the cultural and historical studies of images. A fracture emerges: computer scientists seem to lack in the critical approach typical of the humanities, a shortfall which sometimes condemns their attempts to remain technological curiosities. For their part, humanists lack the technical knowledge that is needed to directly investigate large archives of images, with the result that art historians often must limit digital research to databases of text or metadata, a task that does not necessarily facilitate the study of the images themselves. A future dialogue between the two areas is required to foster this new branch of knowledge.

Keywords: Computer vision, digital art history, computational imagination.

Alternative Futures

Let us think for a moment about the futuristic world conceived by Isaac Asimov in some novels and short stories. In this narrative universe, the Multivac, a supercomputer kept by the United States in a secret location, is employed by the public administrators to make the most critical decisions about the state of war, public health and scientific problems. Multivac acquires data thanks to the work of a selected group of engineers, who fill it with information and pose questions in natural language. The machine responds via text strings. In some short novels, which prefigure the Internet, every citizen can employ the Multivac in almost the same way, posing questions through private terminals and receiving personalized answers. In *The Last Question* (1956) the most intriguing story among the series, Multivac's potentialities coincide with all Earth's computing power: it has now acquired a kind of intellectual supremacy over humans, who use it to direct their interstellar expansion towards the limit of the universe.[1]

In our reality, it was mostly the work of individuals has provided the world network with multitudes of data and metadata, available in different states of aggregation, the biggest of which are known as *big data*. We then find ourselves in a specular position compared to that devised by Asimov as the initial episode of the Multivac saga: an immense quantity of data is available through the Internet, and yet any artificial intelligence technology is nowadays able to coherently and autonomously operate on the total mass of information. In the field of information technology, futurologists multiply their cabalistic prophecies, striving in attempts to determine the "point of no return", when the ultimate self-improving artificial intelligence will be born, finally merging with our biological body.[2]

It is interesting to notice that in Asimov's fiction the Multivac acquires and hands out information only in the form of text strings; his epoch didn't know about the graphical interfaces that today mediate the interaction between users and software. By contrast, George Orwell's *1984* (1949) constitutes a milestone of modern science-fiction precisely because it stages the appearance of an icono-technical knowledge based on the continuous and pervasive analysis of large amounts of images which condemns the dim inhabitants of the state of Oceania, transformed in an enormous panopticon, to follow the totalitarian form of life imposed by the government's Party.[3] Orwell's novel can, therefore, be inserted inside a millennial line of thought that, starting with Plato, has suspected the social role of images. As a result, we are accustomed to think that, on the one hand massive computing based on linguistic information seems to naturally facilitate social development; on the other hand, large-scale elaboration of iconic data is primarily thought as a form of danger for humankind.

Imagination and algorithms

This presupposed dystopic scenario is indeed already part of our reality: we use facial-recognition software to classify the images stored in our PCs or social networks when they prompt automatic tags for persons that recur a certain number of times within our digital photo albums. In 2016, a Russian firm developed a system that identifies individual faces (morphology, gender, age, emotions) comparing the images taken by public CCTVs and photo albums uploaded in Vkontakte (a Russian social media platform).[4] If the police force implements this technology in its surveillance system—as it is already the case in China—it will be almost impossible for citizens to anonymously move in urban areas—at least without disguises or anti-recognition camouflages, such as those developed since 2010 by the artist Adam Harvey.[5] Automatic face-detection systems based on the computation of iconic big data will be presumably added fast (if they have not yet been implemented) to the telecommunication systems employed by the USA for combat and forensic objectives, as recently revealed by Edward Snowden.[6]

We are therefore crossing the threshold of an epoch in which the prosthetic delocalization of the imaginative faculty, our capacity for thinking images and operate with them, moves towards the progressive demonstration of what

Charles Baudelaire affirmed in a letter which attracted the attention of Walter Benjamin while he was working on his unfinished essay on the 19th century: "Imagination is the most scientific of the faculties".[7] The economic and intellectual efforts of the IT industry is preparing a future in which the irreducibility of language and image, which had seemed partitioned for a thousand years, will be torn down by algorithms which manipulate pixels: machine vision is leading to self-driving vehicles, identification of tumors, bombing and special effects in the visual arts. As we await the oft-heralded bodily reabsorption of technical prostheses through biotechnologies, our current moment is marked by the exponential growth of automatic imaginative faculties that are stemming from new methods of automated calculus, statistical analysis of enormous databases, and production of novel hardware .

From the perspective of "artistic" production, the frontier of the computational imagination is rapidly expanding: we need only to name a few of the artistic applications, such as the generators of actor-avatars employed in cinema since the end of the '90s or the program designed by Robbie Barrat which "paints" in different styles via neural networks.[8]

What would happen if an ideal Multivac were utilized by a group of historians, rather than police states or marketing firms? What would result if this kind of artificial intelligence would direct its efforts not to the identification of potential terrorists or our tastes about furniture and fashion,[9] but rather to the analysis of the history of visual culture? This possibility is grounded in recent acquisitions in information technology: Google's research of images *through* images has been implemented just in 2011, and there is still a lot of space for the improvement of the relative algorithm.[10]

The development of a new research field

The multidisciplinary field of digital art history tries to integrate the mathematical and statistical expertise of information technology scientists with art history and visual culture studies. For the moment, the rift that still separates the competences of those who were trained in each of those disciplines is quite large and the effects of this situation can be perceived in the distinctive features of the publications and research projects that are currently holding the label of digital art history.

As an emerging subfield of digital humanities, the discipline nowadays is fostered by the recently born *International Journal for Digital Art History*. Among the authors who published their researches in the review, Lev Manovich is one of the most representative. Manovich, professor of theory and history of media at the City University of New York, has been processing iconic big data at the "Cultural Analytics Lab" for the past decade. His image sources come from museums, movies, videogames, social networks, and magazines.[11]

On some epistemological problems in digital art history

In his paper *Data Science and Digital Art History*,[12] Manovich describes his methodology, as part of a "quantitative turn" that the humanities as a whole have experienced in the 20th century: the digital version of an image contains certain kinds of information that can be employed as a yardstick, allowing well-designed algorithms to automatically compare a vast number of documents, a task unachievable by a human mind with its limited memory. Big iconic data sets—an artist's oeuvre, the shots of a movie, the covers of *Time* magazine—are filtered through a computing process that selects only certain features of the source document; then each object gets assigned coordinates that locate each of them in an n-dimensional "feature space". This space of virtually infinite dimensions is subsequently flattened into one or various bi-dimensional graphics where the relative distances of the objects (measures that stem from the criteria chosen by the experimenter at the beginning of the process) become perceivable to our eye.

We can now grasp in a glimpse, for example, the differences in brightness and saturation between the corpus of Piet Mondrian and Mark Rothko, thus evaluating general characteristics that only well-experienced connoisseurs of their work might appreciate.[13] At the same time, we ask ourselves if Manovich's conclusions ("Projecting sets of paintings of these two artists into the same coordinate space reveals their comparative 'footprints'—the parts of the space of visual possibilities they explored. We can see the relative distributions of their works—the denser and the more sparse areas, the presence or absence of clusters, the outliers, etc. The visualizations also show how Mark Rothko—the abstract artist of the generation which followed Mondrian—was exploring the parts of brightness/hue space which Mondrian did not reach») can give fundamental insights to the art historian. Moreover, they contain some epistemological problems.

First of all, the features analyzed are, strictly speaking, the photographic reproductions of the paintings and not to the artworks themselves. The phenomenical attributes of paintings strongly depend on the illumination to which they are exposed (not to say about the position—distance, nearness, parallax, relative movement—of the perceiver) and in many cases—such as Rothko's *Seagram* series—are relevant to the conception of the artwork itself. Secondly, dealing with numbers of reproductions, in the probable case of a lack of a careful normalized process in the shooting procedures that generate the digital photographs of the study set, a certain quantity of error will affect the relative positions of the objects in the feature space of optical values such as brightness and saturation. This error will not presumably be so discriminant as to impede high-level considerations—we could easily think of a fast and efficient visualization of "color-periods" inside the production of an artist (e.g., Picasso's "pink" and "blue" periods)—but, in the case of further employment of this map, we must remember that errors expand exponentially. Lastly, it is questionable whether the inclusion of a reduced number of documents and not all the catalogue of the artists in the calculus leads to a neutral scatter of the images on the table or, rather, to a biased result (the "visual possibility" insight being then compromised).

Manovich's enthusiasm is also shared by other research groups. In 2014, a team led by Babak Saleh at Rutgers University published a paper entitled *Toward Automated Discovery of Artistic Influence.*[14] The scientists, committed, like Google, to the challenge of automatizing the semantic description of images, have developed an "influence" algorithm that works on certain formal similarities between the images of the initial data set. The team reported that the program they wrote was able to spot a never-before-seen connection between two paintings: one from 1870 by Frédéric Bazille and the other from 1950 by Norman Rockwell. This result was harshly criticized by the art historian Griselda Pollock, that accused the computer engineers of utilizing an anachronistic methodology: the reductionist paradigm of connoisseurship.[15] Saleh's supervisor, Ahmed Elgammal, replied some months later explaining that the new research field of "computer vision" is only at its beginning and that its long-term objectives are the realization of a program that could pass what he names a "visual Turing test".[16]

This statement is interesting because it seems to widen the classical proof of computational intelligence that computer engineers have been trying to attain for more than half a century. In the original version, the test consists in a linguistic game in which the computer is required to mimick the communicative abilities of a human being. Elgammal's suggestion indicates that nowadays the research on AI is aware that language is only half of the moon, the bright one. The discovery of the dark side corresponds to the project of providing the machine with an imaginative capacity.[17]

Multivac's paradigm remains the foundation of computer sciences; as a matter of fact, Elgammal continues with a consideration on the digitalization of archives: "Perhaps there will be a day when the technology could evolve to look at the historical, social, and personal context of art—a day when computers could mine these vast stores of heterogeneous data to conduct an analysis of artistic influences that goes beyond the connoisseurial approach".[18] To overcome such approach, with a view on a *Bildwissenshaft* 2.0, it would however be necessary to automatize the critical analysis carried out by human researchers, who comprehend typologies of resemblance (e.g. anthropomorphism, pseudomorphosis, the informal) which can complicate the induction of relationships (of influence) on strictly mimetic similarities.[19]

Blending big iconic data

Different approaches, which aim instead to present large numbers of images inside graphics or navigable 3D virtual spaces in aesthetically pleasing ways, are currently being explored by Google. The big firm, compared to other research teams, can avail itself

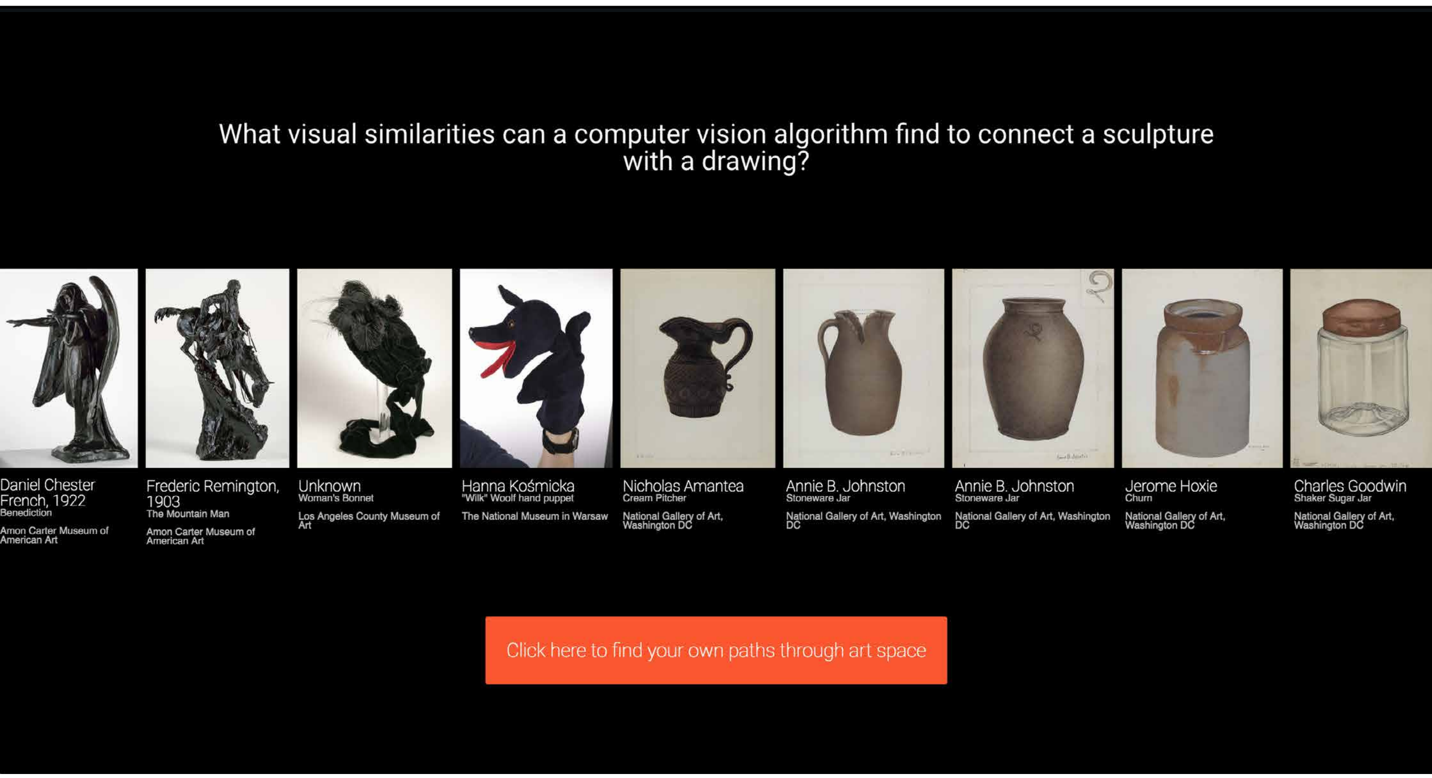


Figure 2: The “degrees of separations” that relate a symbolistic sculpture wich a drawing of a glass jar for X Degrees of Separation. Screenshot from: https://artsexperiments.withgoogle.com/xdegrees/8gHu5Z5RF4BsNg/BgHD_Fxb-V_K3A.

of the quality of the data gathered via its Art Project, which brought the cameras of Street View inside the major museums of the world. The online application *X Degrees of Separation* is presented as such: "Using Machine Learning techniques that analyze the visual features of artworks, X Degrees of Separation finds pathways between any two artifacts, connecting the two through a chain of artworks. This network of connected artworks allows X Degrees of Separation to take us on the scenic route where serendipity is waiting at every step: surprising connections, masterful works by unknown artists or the hidden beauty of mundane objects".[20] It may be superfluous that such paths are limited by the initial set since, for the moment, a universal catalog of (so-called) artistic objects does not yet exist. It is nevertheless certain that Google's projects could be integrated,

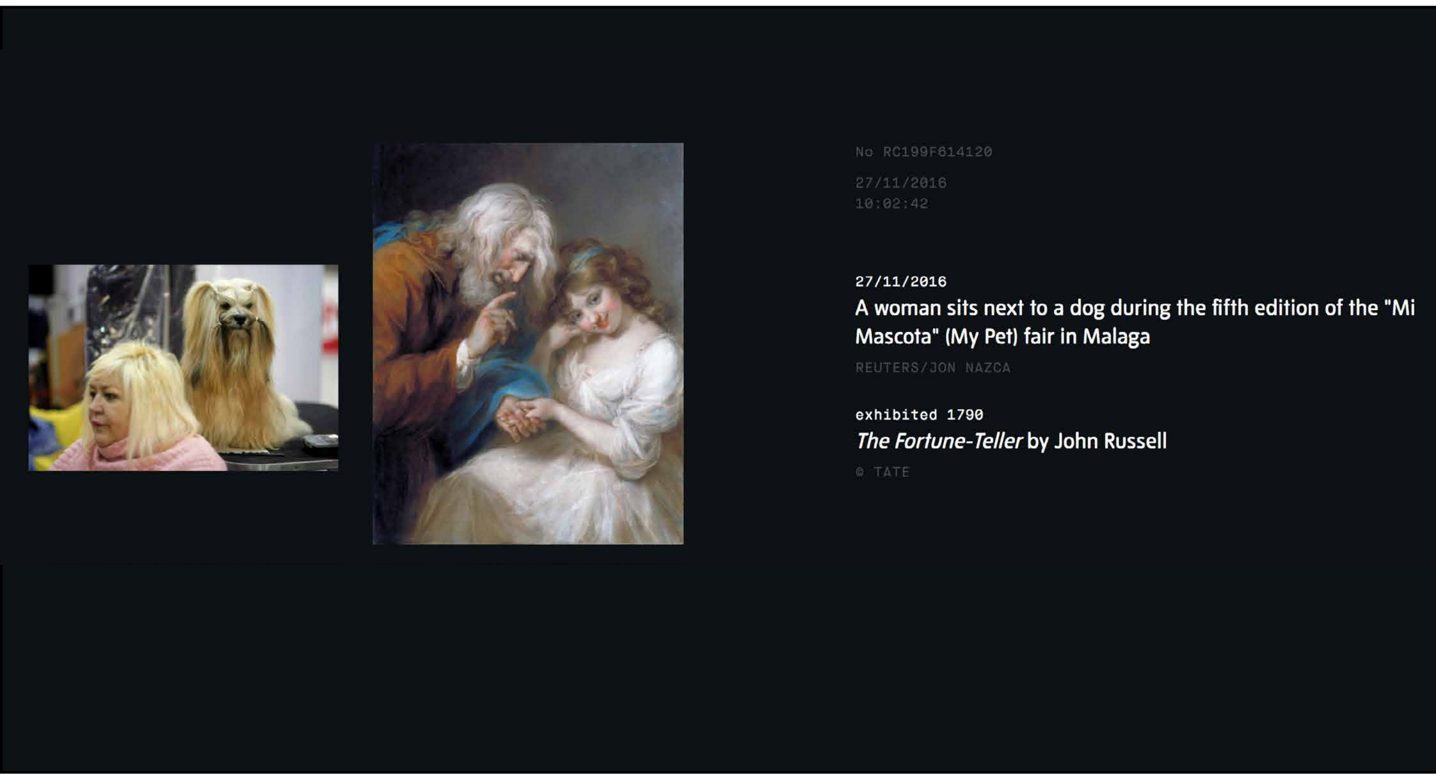


Figure 3: The photography of a pet competition is related by *Recognition* to a XVIII century painting. Screenshot from: http://recognition.tate.org.uk.

in the near future, with systems of iconographic classification such as Iconclass.[21] What research possibilities would be opened performing semantic researches on big sets of images that were not previously carefully cataloged by human archivists—that is to say, the vast majority of the cultural heritage which is currently undergoing a process of digitalization around the world? An essay is given, again, in Google's experiment *Tags*, which nonetheless retains amusing censorship since it does not allow one to search for "nudes", while other search terms such as "rifle", "gun" or "guillotine" are currently allowed.[22]

An essay similar to Google's was that one performed by Recognition, a program developed at the Italian innovation center Fabrica, winner of Tate Gallery's 2016 IK Prize.[23] An algorithm automatically compares photographs coming from international press agencies with the artworks held by the important English collection. The similarities are chosen through criteria of formal and metadata resemblance; unfortunately, it remains unclear whether any specific knowledge could be gained by such operations.

The quest for interdisciplinarity

For the moment, traditional art historians can continue to sleep tight. As long as the strong separation between data sets and algorithms or AIs will be maintained, it is impossible that some computer will steal their job. Nevertheless, some departments of art history and architecture are developing study programs and research centers whose aim is to gather the competences of humanists and computer scientists under one roof. Institutions such as the Getty Research Institute, the Courtauld Institute of Art and the Frick Collection are preparing for the future of digital art history.[24] These initiatives reflect the slow reception of this new discipline whose origins are to be found in the late '80s.[25]

Nowadays, the digital art history projects fostered by humanists can be divided into three areas that, contrary to the projects based on computer vision and AIs, apply the new technological possibilities to information that are external to the images themselves and, interestingly, often present their research in the form of another image.[26] The first class employs digitized text databases to develop statistical approaches; one possible application is the analysis of archival material related to collections: such is the case of the Medici archive recently digitized by the Fondazione Memofonte.[27] These second kind of process facilitated by digital technologies is the architectural rendering of historical sites; such is the case of *Visualizing Venice*, which aims to build a virtual 3D model of the Serenissima that should be navigable at its different time periods.[28] Finally, the third type of research, an expansion of social history of art, is the so-called "network analysis" which, applied to

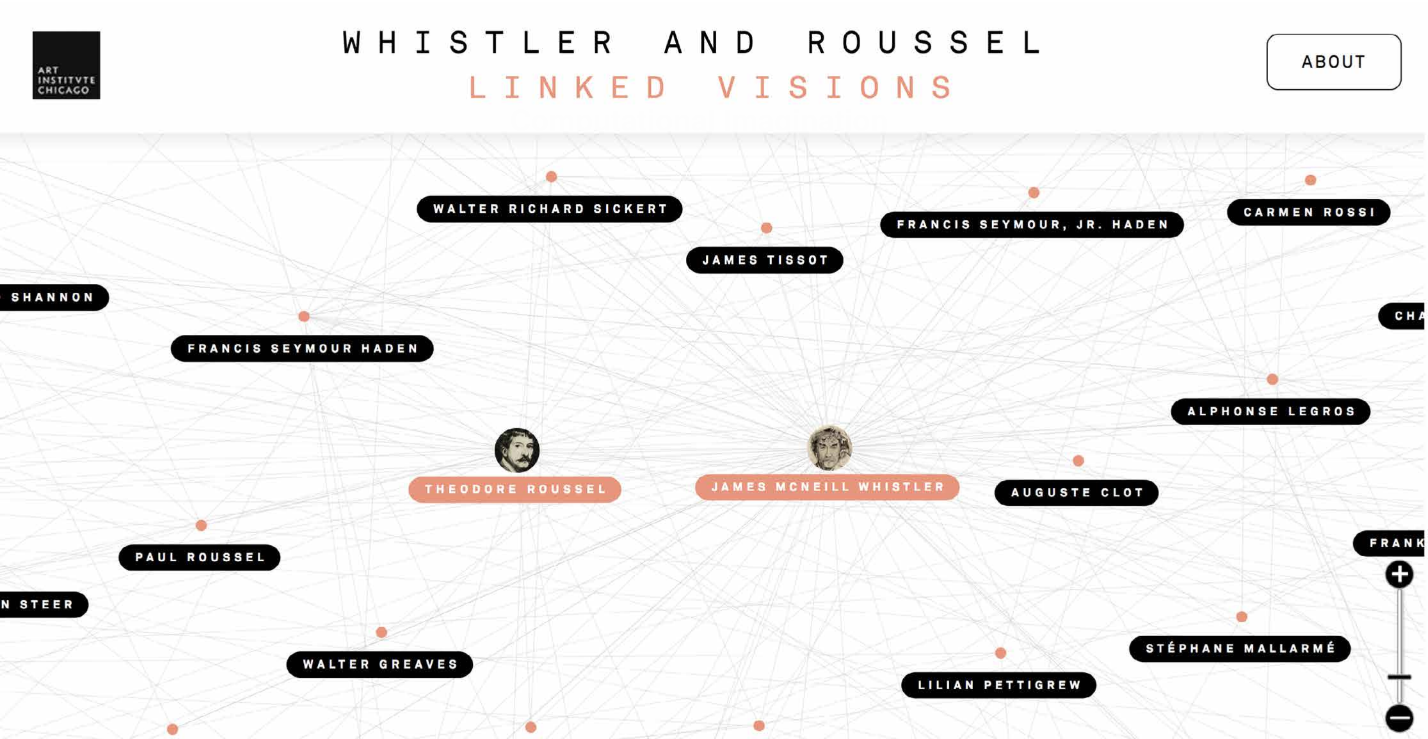


Figure 4: The relational network of Theodore Roussel and James Whistler: models, patrons, artists, pupils and family members. Screenshot from: http://linkedvisions.artic.edu/network.php

art circles, galleries and the art market, visualizes different kinds of social realtions.

In this overview, I tried to trace the borders of two areas of research which still await coherent overlap. For the moment, a fracture emerges: those who study images with methods of computer science seem to omit a certain epistemological problems, with results that, from the perspective of the art historian, are more curiosities than new knowledge. At the same time, their work expands the awareness of the need for imaginative capacities for the future AIs, which should have a high level of image comprehension in order to interact with "intelligence" with the world. On the other hand, the humanists who try to update their practices, tend not to possess the technical programming skills that would be necessary to apply a critical approach to the study of images themselves, and, for the moment, they investigate information of another kind, which reside in the contextual appearance of the data.

If in the future new scholars with a double competence will be trained, maybe we could progress a little towards the goal of an intelligent computational imagination, that will let us not only to drive cars, identify diseases and monitor our neighbor but also to glance with a new perspective towards our past.[29]

Notes

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[22] "Tags"; https://artsexperiments.withgoogle.com/tags.

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[24] See: the Getty's "Digital Art History Initiative" of 2014 (http://getty.edu/research/scholars/digital_art_history/index.html); the Courtauld's "Digital Art History Research Group", active since 2016; (http://courtauld.ac.uk/research/research-forum/research-groups-and-projects/digital-art-history-research-group); the Frick's "Digital Art History Lab" (http://www.frick.org/research/DAHL). In Italy, to my knowledge, there is only one introductory course offered by Elisabetta Molteni, Maria Chiara Piva and Stefano Riccioni at the Università Ca' Foscari of Venezia since the academic year 2015/16, entitled "Digital Art History" (http://www.unive.it/data/insegnamento/224320/programma).

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[27] "Fondazione Memofonte", http://www.memofonte.it/ricerche/collezionismo-mediceo-inventari.html.

[28] "Visualizing Venice", http://www.visualizingvenice.org

[29] Harald Klinke's 2017 "Coding Dürer Workshop" goes in this direction; http://codingdurer.de. Another interesting essay is: Leonardo Impett and Sabine Süsstrunk, "Pose and Pathosformel in Aby Warburg's Bilderatlas", Computer Vision – ECCV 2016 Workshops, ed. G. Hua e H. Jégou (Amsterdam: Springer, 2016), 888–902.

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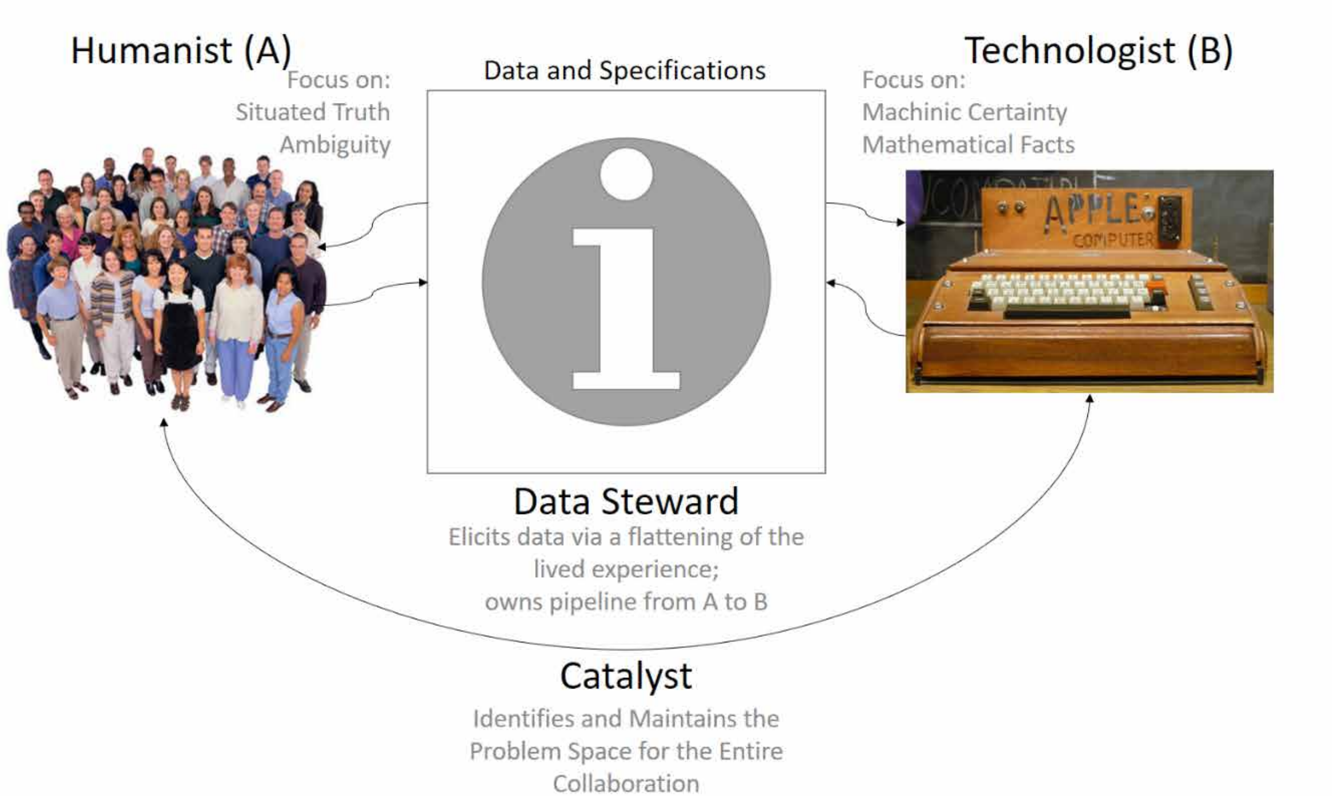

Figure 1: A Model of the Collaborative Universe in the Digital Humanities, based on a figure from Brian Cantwell Smith, “Limits of Correctness” (1985).

Peer-Reviewed

A Role-Based Model for Successful Collaboration in Digital Art History

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Abstract: Sustained dialogue and collaborative work between art historians and technologists have a great deal to offer both fields of inquiry. In this paper, we propose that effective collaborations in Digital Art History require more than just a humanist and a technologist to succeed. Indeed, we find that there are four different roles that need to be filled: Humanist, Technologist, Data Steward, and Catalyst. Our approach is predicated on a few foundational convictions. First, we believe that art historians and technologists occupy distinct problem spaces. As we will outline, although these realms are distinct they are not of necessity in opposition to one another. Second, we bring to the fore essential questions about the status and function of data that must be addressed by the collaborators: what sort of data are being used? What counts as effective and compelling analysis of this data? Third, we recognize that there are certain structural impediments to collaboration, such as different reward structures and motivations. Finally, we assert that each of the participants must have a deep commitment to their particular engagement with the project, which requires sustained effort and the maintenance of disciplinary respect. We firmly believe that the most effective of these projects will not be based on technological solutionism, but rather will be founded in the most humanistic of tools: empathy and respect.

Keywords: Digital Art History; Collaborations; Interdisciplinary Work; Interdisciplinary Respect

Introduction[2]

The advent of the digital age has been heralded for its disruptive power in a number of different domains. For its part, the incorporation of digital humanities (to the extent that such a field can be cogently delimited)[3] is seen as a way to break art history out of the "sluggish" practices that permeate both the museum world and the academy.[4] While digital technologies certainly open new avenues of inquiry, we believe that the rhetoric of disruption is counterproductive, not least because it reflexively engenders a defensive posture in many art historians who might otherwise be sympathetic to the incorporation of digital technology in art historical inquiry. We are committed to the proposition that, far from precipitating a crisis in the discipline, the judicious use of contemporary computing and digital technologies can allow art historians to confront one of the abiding issues in our field, which is ultimately the question of scale: how does the art historian relate the discrete units of analysis on which his or her work is based to larger questions of historical causation and change?

Since its inception as an academic discipline, art history has struggled with the issue of scale. Winckelmann made a point of repeatedly asserting his autoptic authority over the objects he discussed. That is, he claims to have seen, with his own eyes, every object of ancient art: "All that I have cited as evidence—paintings, statues, gems, and coins—I have myself seen and examined repeatedly."[5] The actual veracity of this claim is not as important as its rhetorical force. Winckelmann claims personal command over an entire archive of knowledge.[6] His interpretation of the interrelations between climate, political-economy, and religion (among other factors) in the development of ancient art is predicated on his ability simultaneously to compare data points from different domains of knowledge, all of which are stored within his own brain and personalized note-taking system.

However, the limits of such claims quickly came into focus. The next generation of art historians and archaeologists quickly challenged Winckelmann's sweeping claims about the teleological development of ancient art. Rather than follow Winckelmann's master narratives about the development of the history of art, authors such as Antoine-Chrysostôme Quatremère de Quincy, Ennio Quirino Visconti, and Friedrich Wolf burrowed into the detailed analysis of objects, buildings, and texts pointing to specific instances where the visual evidence contradicted Winckelmann's claims.[7] If Winckelmann created art history from thirty thousand feet, the subsequent generation viewed their units of inquiry under a microscope. Winckelmann expanded the field to the limits of knowledge at the time, however, those limits were quickly revealed as false by the introduction of new material. Through a process of contraction, focus was placed on newly discovered (or re-discovered) exemplars that did not fit within his schematic mapping of the history of art.

This process of expanding and then contracting the field's focus has been repeatedly iterated over two and a half centuries. Riegl overturned the study of late Roman art and proposed a sweeping new paradigm of how cultural and artistic transformation occurred, introducing a new *Kunstwollen*, a term that has beguiled art historians since. Riegl himself defined the term differently at various moments in his career, but for our purposes it suffices to note the *Kunstwollen* was a term he used to identify the artistic spirit of a given age.[8] Yet, Riegl's sweeping notion of *Kunstwollen* emerges from an attentive analysis of only a few objects. As Jas Elsner has observed in a perspicacious article on Riegl:

"Whenever we make an argument on the basis of visual or material evidence we take something extremely specific, of which the discussion is inevitably a precise and detailed contextual or formal description, and we use this as a step to generate a large generalization. Whether our art history is interested in artists, patrons, or viewers, in sociological context and conditions of production, in strict morphological connections or in high semiotic theory, our generalizations inevitably leap beyond what is strictly provable by the precise analysis of something so particular as a specific object or set of objects."[9]

Elsner was not the first to observe how the rapid and dynamic shift in focus from the individual object to the broader cultural context unsettles the foundations of the discipline. Erwin Panofsky had made a similar point in his essay on the "History of Art as a Humanistic Discipline:"

"It is true that the individual monuments and documents can only be examined, interpreted and classified in the light of a general historical concept, while at the same time this general historical concept can only be built up on individual monuments and documents; just as the understanding of natural phenomena and the use of scientific instruments depends on a general physical theory and vice versa. Yet this situation is by no means permanent deadlock. Every discovery of an unknown historical fact, and every new interpretation of a known one, will either 'fit in' with the prevalent general conception, and thereby corroborate and enrich it, or else it will entail a subtle, or even a fundamental change in the prevalent general conception, and thereby throw new light on all that has been known before."[10]

A similar observation animated Donald Preziosi's yet more recent critique of "art history's self-image as a science of singularities or unique artifacts that at the same time are constructed as tokens of a class, exemplars of the multifarious forms of tekhnē."[11]

Panofsky, Preziosi and Elsner are all saying essentially the same thing: the central challenge for art history is to incorporate the individual object into broader narratives without sacrificing the specificity of each unit of analysis. And yet, if the central challenge faced by Winckelmann, Riegl, and other art historians was how to organize the archive of known art historical objects so that meaningful and truthful analysis may occur, we are now faced with a dilemma. The universe of known art historical data has superseded what any single art historian (or group of art historians) can realistically expect to hold in his or her brain at any single moment. Claims to autoptic authority vested in a single human being are no longer persuasive.

We believe that computer technology offers relief from this expectation. Computers are quite good at reducing large amounts of data into discrete units of analysis that can then be intelligently and carefully interpreted by human beings. In this, we find ourselves aligned with Hubertus Kohle and Max Marmor, who recently suggested that digital technologies can aid in "the discovery of art historical correlations that human intelligence cannot easily identify, but which only human intelligence can confirm."[12] We believe that developing an effective framework for interdisciplinary collaboration between art historians and technologists can provide a breakthrough in how art historians confront data in order to extract historical truths that can serve as the building blocks for broader humanistic narratives about changes and developments in culture.[13]

We would like to underline at the outset that this is one way of thinking about computing in the humanities, but this is not the only way. We will outline a model for approaching the history of art that is predicated on data analysis that requires computation; there are numerous other ways to use computers in art history that do not require data analysis.

Our approach also does not attempt to create a new system of art historical inquiry, thus perpetuating the weaknesses that underwrote earlier attempts to create master narratives of artistic development. Instead, we propose to use the power of the digital computer to shift to an ever larger dimensionality. While this will help us regain the thirty-thousand-foot perspective sought by Winckelmann, Riegl, and others, our aim is to create a slightly different foundation for this work than autoptic authority vested in one human being. The goal of this is to analyze in a humanistic way a system of data that is larger than a single human can possibly conceptualize. This process will in most cases require collaboration between people trained in different disciplines.

This article draws attention to the complexities and the novelties of this twenty-first-century type of intellectual work. Making the process (and challenges) of collaboration visible and subject to scrutiny helps ensure that art historians and technologists can equally bring to bear their own disciplinary expertise on the important task of carrying out humanistic inquiry in a digital environment. Our proposal for a role-based design for interdisciplinary partnerships will be outlined using examples drawn from relevant collaborations in which the authors have participated. We have used our own experiences to identify the key roles that are necessary to a successful collaboration and to isolate a number of possible factors that could cause the collaboration to end in failure. We end with a call to situate the empathy necessary for creating effective collaborations within the context of humanistic inquiry.

The Process of Digital Art History

The techniques of art history focus on the creation of new interpretive narratives drawn from the historical evidence of visual and material cultures. The traditional process is to obtain enough information through research and observation that an individual's understanding of a domain can be sufficient to synthesize new understandings by combining and recontextualizing the existing evidence.

But there are also interesting questions that cannot be practically answered by unassisted human intellect, either because the quantity of information available is too great or because that information is in an inaccessible form. Computers can assist in the synthesis of this evidence through the lessening of this complexity, a process called dimension reduction.[14] This is a common computational technique used to clarify and help make sense out of data that may have any number of different features and traits—an almost defining characteristic of humanities data—by distilling it and representing it more simply. This technique does not replace the need for human intellect, but instead uses technology to augment the intellect by reducing the information into something that can "fit inside" the human brain, once again allowing the process of synthesis and interpretation to occur.

The obvious risk of using a computer to do this is that the process necessarily involves simplification, and without a deep understanding of what information is essential and what information is not, it is entirely possible to generate information that is either trivial or misleading.[15] Additionally, without a strong understanding of what the computer is doing, it can be easy to generate information that does not reflect the needs of the interpreters. While digital technology excels at manipulating and correlating information, the reduction of data to a simple number is rarely interesting. The intention of this collaboration is not for the computer to "solve" art history, but to augment the historian's intellect by reducing data into a summary that is comprehensible to the historian. Sometimes this flattens the result down to a single "obvious" statement, but more often it takes thousands of discrete facts and consolidates them down to a dozen or more new facts.

The process of executing these implicit transformations on information makes up the majority of the work needed to successfully collaborate on a project. These projects can be conceptualized as a work pipeline—a "pipeline" being a critically important workflow technique in the technology sector—with five steps:

1. A question is identified as being potentially answerable through computation.
2. The required information from the collective art historical field is identified and gathered.
3. This information is transformed and regularized into structured digital information, or data.
4. This data is analyzed through a computational process, producing a set of results.
5. These results are synthesized into new art historical knowledge.

That is, this process is inevitably begun when a content expert recognizes that the potential for an interesting historical analysis exists within an available pool of information, but also sees that evaluating this potential requires the synthesis of such a large amount of information that the work can be enhanced through computational dimension reduction. To do so, a computational technique must be identified that is capable of reducing the pool of data in a way that creates a meaningful summary of the information, and this technique must then be executed. To do this, however, the extant information needs to be transformed into a form that a computer can process. Given the limitations of computers, this transformation process is often much more complex and extensive than is assumed, and without oversight it is easy for essential intellectual context to be lost. It is also possible for enormous effort to be exerted capturing information that will not be needed. Finally, once the trustworthy, computable data has been produced, the process of dimension reduction can proceed and will produce a set of results.

These results are not the end. They will need to be interpreted by a content expert both for new meaning and also for validity—the technologist cannot always tell nonsense from a surprising result. One animating conviction of this project is to remember always that the answer "given" by a program is not self-sufficient. It is the answer to a question that a human asked, but the question has to be meaningful for the answer to be meaningful. The challenge of this sort of collaboration resides in identifying the kinds of meaningful questions that we can ask computers to answer based on the data that we can provide. We tend to think of these as the "impossible questions;" questions that humanists know how to ask, but where the answers would require a lifetime of work to answer. The collaboration, or the work of the collaboration, is for the team to work together to define the question meaningfully enough that the historian's question can be answered, but rigorously enough that the technologist can turn it into code.

The Four Collaborative Roles

We have identified four roles that are essential to this process. Up until now we have discussed the "Humanist" or the "Art Historian," and the "Technologist," but we have identified two further roles, those of the "Data Steward" and the "Catalyst." Steps 1, 4, and 5 above are readily identified as falling under the purview of the Technologist and Humanist. However, steps 2 and 3 are typically where the bulk of the labor takes place and are also the areas where implicit assumptions from the various domains can problematize the process. Because disciplinary expectations make invisible the decisions that are continually being made throughout the process of steps 2 and 3, it is frequently looked upon as "grunt work" or "data entry."[16] This inevitably leads to decisions being made without sufficient disciplinary context, which has significant effects on the validity of the results and thus the new knowledge that is being produced. We identify this area as the domain expertise of the "Data Steward." The final role, the "Catalyst," serves as the collaborative glue, creating the critical, translational linkages needed between all of these skillsets, ensuring that communication and progress are systematically made. Without the Catalyst, the project goals can be lost and this lack of cohesion can result in project failure.

The Humanist, or specifically here, the Art Historian, is the content domain expert who understands the context around objects, knows where relevant information can be located, and is aware of what is already known and what would be interesting to the field. In the context of Digital Art History, we imagine two principal constituencies here: first, academics operating within the Anglophone university system, and second, museum professionals whose approach to their collections fall under the broad category of "humanistic."[17]

The Technologist is the software development expert with the training and resources available to generate and extract information by appropriately transforming and manipulating data.[18] A Technologist's ability to participate in the core work of art history is predicated on his or her ability to manipulate information, and the discrete, physical entities at the heart of art history provide a unique opportunity for quantification and analysis. Typically, this involves a deep understanding of the existing technological state of the art, an understanding of domain-specific techniques, and customizing or creating new software as part of a digital workflow.

The Data Steward is responsible for ensuring that the essential character of the historical evidence is not lost throughout the process of converting primary source material into computable information, and also that this data will be suitable for the technological processes that it will undergo.[19] This role requires a strong working knowledge of the techniques of both art history and software development, as the Data Steward is responsible for communicating the restrictions and caveats that this conversion creates. By designating this role as the party responsible for surfacing both technological and historical assumptions throughout the process of preparing the data for computation, we make explicit the requirement to observe and discuss the constraints and limitations of this entire process. The individual responsible for this role may be responsible for the actual labor of transforming the data (including data entry), or they may oversee those who do, but they must be sufficiently aware of both the technical and humanist cultures to make explicit the assumptions of one to the other, and then to explicitly call out and document these assumptions to maintain the validity of the process.

The Catalyst is responsible for recognizing the existence of a problem space shared by a technological and a historical question, for initiating and maintaining the flow of the project, and for identifying the team members whose domains and skills are appropriate to address it. This role requires competency and literacy in all three fields represented by the Humanist, Technologist, and Data Steward, as well as a strong professional network that spans these domains. It does not require that the Catalyst be an expert in these areas, or be uniquely competent to solve the problem. It only requires that they are capable of seeing that there is a problem that could be solved, that there are people who are capable of solving it, and that the opportunity is presented effectively to those prepared to join the team.[20]

The Catalyst should not simply be viewed as a project initiator, however. This role also ensures that the holistic goals of the project are maintained over time. Domain experts in any field have a tendency to focus on the needs of their domain to the exclusion of others, and when the needs of two domains conflict, it becomes essential for someone to have the authority to assess and referee. This process of determining where the inevitable compromise occurs requires the same skills as those needed for initiating the project, as well as a strong understanding of what will jeopardize overall success, and what is merely an inconvenience.

It is also inaccurate to reduce the role of the Catalyst to that of a project manager. They are not there simply to ensure the health of the project. Catalysts are direct and engaged members of the team who have a stake in the problem itself. Indeed, in the ideal model, they will be the very member of the team who catalyzed the entire collaboration around a shared question of interest. This role can be taken up by someone aligned with the humanities, computing, or data science, but no matter their home discipline, they will have stakes in the collaboration that extend beyond management and logistics. They are not imposed on the collaboration, they form an essential part of it.

A Model of the Space of Collaboration

In his landmark work of philosophy in computer science entitled, "The Limits of Correctness," Brian Cantwell Smith presents a model of the relationship between lived human experience and computation that we take as foundational to our project.[21] In this piece, Cantwell Smith argues that information systems can only be "correct" insofar as they reliably reflect their design goals. They can never be provably correct in the way that their designers want them to behave in the real world. There is, in his assessment, an essential disconnect between true, human lived experience and the model of reality that exists within the computer, the latter being produced by reducing the world to structured data and algorithmic procedures. Cantwell Smith's formulation essentially describes a computational process. We have adopted and transformed his model to describe the way that knowledge can be produced through the circulatory process of an explicit, targeted simplification of the human experience, followed by a computational analysis of that simplification and a humanistic interpretation of that analysis. In the digital humanities, this chain of activities is a systemic whole, and we find Cantwell Smith's model a productive way to describe the challenges we have encountered while operating within it.

The collaborative roles presented in this paper cover all of the components of this cyclical model of computation and interpretation. Drawing on a figure presented in Cantwell Smith's original essay, we have produced an illustration that renders visible the distribution of the commitments held by each of the roles across this model (fig. 1).

The Humanist maintains responsibility for the left side of the diagram, which encompasses the situated truth of the human experience. Both at project inception and at every successive interpretive stage, the humanist ensures that the ambiguity of lived human experience is accounted for. The right side of the diagram is the Technologist's domain. This role focuses on the ways that humans can work creatively within the limitations set by digital computers to approach a problem made up of a series of specifications, algorithms, and data sets. The technologist ensures that the overall problem at hand is computable and that the technology implemented responds appropriately to the questions being asked. At center, then, the pivotal duties of the Data Steward are thrown into sharp relief, as this role has the responsibility for producing and maintaining both the humanistic and computational integrity of the simplified representation of the "world as data." If the data does not adequately reflect lived, human experience (the domain of the humanist), any computational techniques that are applied (the domain of the technologist) can never succeed. If, on the other hand, the data is insufficiently simplified, computational techniques will be stymied by exceptions and special cases, hindering the production of any analysis that will be useful to a humanist. The Catalyst, represented here at the base of the figure, serves as the binding glue for all three roles, maintaining the problem space of the entire collaboration, serving as a translator between disciplines, and focusing on making sure that all three major components of a digital humanities collaboration—humanist ideology, effective data stewardship, and technological rigor—are in balance and heard equitably across the team for the duration of the project.

Four Roles, Not Necessarily Four People

It is important to note here that we are talking about roles, not people. Two or more of these roles can be performed by the same person. However, each role requires specific, unique skills, and the domain knowledge required to perform all four roles is rarely found within a single individual. Additionally, if a single person assumes multiple roles it is essential to realize that this person will exert more effort and more time, particularly if they must acquire domain knowledge that they do not already have.

In some cases, a researcher might attempt to fulfill all four roles for themselves: the lone-wolf approach. The short-term benefits to this tactic might make it seem a practical choice for researchers working on obscure topics. However, limiting the domain expertise also often means limiting the effective scope of the outcomes.[22] For example, one of the authors (Lombardi) chose to explore computational approaches to the analysis of medieval iconography as a research team of one, using the works of art indexed by Index of Christian Art as a dataset.[23] In particular, he devised a search algorithm to identify saints with extremely different rates of reproduction before and after the Black Death in Tuscany, aiming for a technical proof of concept. As a trained computer scientist, Lombardi served ably as the Technologist, writing his own data mining process to aggregate the data into a useful format and perform the analysis. He also strived to fulfill the role of Humanist by developing an art-historical approach based on selected readings informed by his graduate degree in medieval history. The role of the Data Steward on this project was implicitly taken up by the generations of librarians who produced The Index of Christian Art, but no conversations with the current stewards of this data were made possible. Finally, as the sole participant in the project, Lombardi served as his own Catalyst, driving his project to its conclusion: a proof of concept demonstrating the technique and its potential.

The reception of this work among art historians reveals many of the problems with the lone-wolf approach. Without the guiding hand of expert knowledge in art history, Lombardi had difficulty framing the work in a form that was accessible to that audience. Technical proofs of concept have little relevance to art historians, and thus the result of the initial work was, not surprisingly, dismissed as trivial and already-known. Second, early presentations of the work demonstrated opportunities for significant improvement in the project's structure. Several art historians suggested the specific use of ICONCLASS, the classification schema for Christian iconography, as an important metadata repository for such a project. Had this knowledge been available earlier in the project, the work would certainly have progressed more quickly and effectively. Third, review discussions of the project revealed a potentially more relevant audience for the work: economic historians. Since the Index of Christian Art includes detailed information regarding medium, the long-term analysis of iconography and its translation from one medium to another could provide potentially useful information regarding market trends. Sustained dialogue between subject matter experts in the fields of art history and technology produced these insights. Ideally, the project would have included the full team of experts at the time of its inception to provide the checks and balances necessary to uncover these opportunities earlier in the process.

Indeed, we argue that it is very rare that these roles can be performed at the expert level by the same person. To excel in these roles requires specialized training and expertise developed over time, and the education required to obtain those skills is sufficiently orthogonal that it is rare that any one person will be fully expert in all, or even two. While programming is a skill that can be picked up readily, for example, and it is easy to learn the basics of art history, expertise in either field requires years of learning and practice, and to take the time to master one inevitably involves falling behind in the other. This is not to say that it is not valuable for these fields to learn something from one another, indeed it is utterly critical to a successful collaboration. Between these roles, therefore, there must be a strong understanding of how domain knowledges and problem spaces overlap. One of the fundamental differences between the work of the Art Historian and of the Technologist is the contrast between the quest for truth and for facts. The humanist's interest is in narratives that reveal the human condition, and are prepared to propose and evaluate questions that will reveal those truths. A Technologist's interest is in using his or her abilities in the logical manipulation of data to use computers to convert enormous quantities of data into new, previously unknown facts.[24]

Relatedly, it is critical to recognize that the formalization of a question occurs at different levels for the Art Historians and the Technologists, and that the process of refinement takes place in two distinct languages: code and discursive language. For the historian, the formalization takes place through the writing of a compelling narrative that addresses the hypothesis' place in the whole of history. Technologists formalize hypotheses through the development of executable code. While the Art Historian may strive for elegance of diction and expression, the Technologist must make his or her result formal in the precise mathematical sense. This distinction also appears in the identification of the source material. The force of an Art Historian's intuition is capable of concealing to a great degree the ambiguous complexity of their information whereas the Technologist requires pristine, quantified data that can be put into a computable format. In both cases, the Technologist's requirements are stricter than the Art Historian's, and the Art Historian may push back on this state of affairs on philosophical grounds.

It can be tempting to delegate the role of Data Steward to either the Art Historian or, more commonly, the Technologist. While both Technologists and Art Historians have a deep understanding of the limitations and the needs of their own home disciplines, if either is solely in charge of the data transformation pipeline, the temptation will be to skew the formation of the data to meet their personal needs alone. When—as regularly happens in Digital Art History projects—the majority of the time spent on a project is actually spent on data cleanup and transformation, and when the differing requirements of the Art Historian and the Technologist are foreign to one another, the temptation is always there to ignore the needs of your collaborator, cut corners, and shape the data so that it more closely fits only your own requirements. Having a designated Data Steward who understands the needs of both, but who is dedicated to maintaining the integrity of the pipeline, ensures that neither the Art Historian nor the Technologist compromises the other's constraints for the sake of expediency. Even when a dedicated, professional data steward is unavailable, knowing that the explicit role exists will help ensure that the constraints from both sides are respected.

The work of catalyzing a project can be highlighted easily. While it is clear that there is great potential for productive collaborations between Technologists and Art Historians, these collaborations are to date rare despite the obvious benefits that they can bring, mainly because there are few opportunities for experts in these two fields to come together. Because experts in one domain are often by nature unaware of the problems or the opportunities in the other's field, there is not an intrinsic motivation for them to seek one another out. Even when someone discovers an interesting avenue for research that they believe could have applicability in the other's field, without the domain knowledge to evaluate relevance, the proposed research is more likely to be viewed as irrelevant or trivial by scholars in that domain.

Additionally, it is exceptionally hard to evaluate expertise across the domains. Working with these human complexities is also the work of the Catalyst. Technologists can be unaware of the various types of Art Historians that exist, and even if they can determine that a specific individual has expertise in a subfield, they are completely unqualified to judge the quality of that expertise. The same is equally true of Art Historians: Technologists can be viewed by these scholars as interchangeable technicians, possessing intimidating but undifferentiated skills. It is possible for the Catalyst role to be filled by the Art Historian, the Technologist, or even the Data Steward, but it requires a very generous soul to agree to compromise his or her own indicators of success to meet the needs of another, and it can be helpful to have this authority imbued in a person whom all collaborators trust to hear and understand their needs and positions.

It has been our direct experience that the work of both the Data Steward and the Catalyst is frequently treated as “invisible” labor, left out of grant proposals and performed without credit. However, we argue that this work is essential to the success of a project, and that failure to acknowledge, plan for, and credit this work significantly increases the likelihood of project failure. Even in projects where multiple roles are performed by the same individual, identifying that multiple roles exist and must be performed forces that individual to consider which role they are performing, and increases the likelihood of empathetic communication.

When a collaboration is able to have each of the four roles functioning, the work can grow in interesting and somewhat unexpected ways. One such example is the Art Tracks project at Carnegie Museum of Art (CMOA),[25] in which two of the authors, David Newbury and Tracey Berg-Fulton, collaborated as the Technologist and Data Steward, respectively.[26] Art Tracks was initially born out of hallway conversations between Jeffrey Inscho and Louise Lippincott, colleagues of Newbury and Berg-Fulton’s at CMOA. The original goal of the project was to build an interactive map showing the movement of Impressionist artworks through space and time using the artworks’ provenance as the underlying data. However, the team soon discovered that building such a map using provenance information alone was more difficult than anticipated. The data lacked structure and regularity of expression, and thus a computer could not parse the data consistently to generate acceptable visualizations. Standardized, structured data was needed for the technology to work, but producing such standardization at the moment of data creation would have required museum staff to completely change the way they composed provenance.

This stumbling block could have been the sign for the Technologists and Humanists to retreat to their respective disciplinary camps, bend the situation towards their disciplines, or give up on the venture entirely. Instead, a collaborative project, complete with a number of researchers filling distinct disciplinary roles, emerged. At that moment, Jeff Inscho served as the Catalyst, bringing a complete team together. Lulu Lippincott and Costas Karakatsanis provided humanistic insight into the meaning and structure of provenance text, and Berg-Fulton worked with Newbury to ensure the standardization was appropriate for both the human and the computer. The group agreed upon and created a modified standard for composing provenance, using precise art-historical terminology to describe transactions while also providing formal, semantic definitions to the words selected. To minimize the need for change to standard museum practice, the complete Art Tracks team worked collaboratively to develop a computer-assisted workflow to translate traditional provenance into structured data with a minimum amount of human labor.

Unfortunately, Inscho had left the project early on for new opportunities, causing the team to temporarily lose sight of their overarching goals. Keeping the team oriented towards a common goal is one of the most critical responsibilities of the Catalyst, as it ensures that the final product, as amorphous as it can be at times, aligns to grant guidelines (if any) and institutional goals. This role was eventually picked up by Newbury, who, in addition to serving as Technologist, had to learn how to support the project as part of the strategic vision of the institution. The importance of the role of the Data Steward was also highlighted by his effort. Identifying that the process of transforming the shape of the provenance data was not an ancillary effort to Art Tracks, but instead constituted the bulk of the work of the project, was the key insight that allowed Art Tracks to succeed. Developing and executing this newly-understood focus required the expertise of the entire team. Newbury, functioning as the Technologist, developed software to assist Berg-Fulton, functioning as the Data Steward, to validate the effectiveness of this new standard in both the Humanist and Technology domains. The standardized data then enabled visualizations that allowed Berg-Fulton and Lippincott, functioning as Art Historians, to discover errant data and gaps of ownership in the provenance text.[27]

Each team member's contribution was often proscribed by the limits of his or her home field of inquiry, but their disciplinary formations also allowed them to provide unique insight into the project. For instance, Newbury's technological expertise enabled him to approach provenance as structurable data, but the scope of his involvement was limited by a lack of historical context. Newbury frequently asked Lippincott and Berg-Fulton questions like "What question do you wish you could ask?" rather than "What is a question that can be answered?" While the latter is a valid question, it is limited in its ability to expand scholarship and understanding, and would essentially be providing a parlor trick for the Technologist and the exploration of the information would be rather flat and ultimately uninteresting. By pushing to explore the questions that had not yet been asked because of what the Art Historians perceived as unconquerable complexity, the collaborators began to form around a problem of sufficient difficulty, novelty, and intellectual value for all. In this process, all collaborators were given agency to shape the project, their subject expertise respected and exercised, and the project continued successfully in terms of institutional buy-in, continued grant funding, and the impact of its art-historical research.

Differing Motivations and Rewards

Any successful collaboration in Digital Art History necessitates a reconciliation not only of approaches, but also the more fundamentally human question of motivation. While this certainly touches upon issues like temperament and individual curiosity, these human characteristics remain deeply idiosyncratic and are difficult to account for. Nevertheless, we would like to address the more formal questions of motivation that are connected to the institutions and intellectual networks that the collaborators are likely to inhabit. We have identified three areas where divergent motivations might become an impediment to collaboration, and by signaling these possible "pressure points," we hope to give potential collaborators a framework that they can use as the starting point for an earnest conversation about what motivates a particular collaboration.

First is the question of disciplinarity. Disciplinary expertise is real and hard-earned through study and practice; differing disciplinary knowledges must be respected by all collaborators. The individuals involved in such collaborations will, almost by definition, be extremely intelligent and accomplished within their fields of expertise. The strong disciplinary formation of each participant, however, will sometimes make it difficult for collaborators to recognize the importance of compromise, and that different intellectual traditions require different—but not incommensurable—approaches.[28] A strong commitment to epistemological modesty is required from all involved. We have found that the most concrete way to show respect toward the expertise of our collaborators is to gain facility with their domain(s) of expertise. This is a painstaking process. The endgame is not to preempt the expertise of others or to comprehensively retrain oneself, but rather to be able to recognize and articulate the stakes of what constitutes an "interesting question" in another field of study. Only when collaborators focus in on something that can be considered "important" in all participating fields will a collaboration reach escape velocity.

Second is the issue of incentives. Finding a problem that is interesting or important to all parties is essential to helping bridge the gap between the incentives of the various collaborators, however, collaborators must also find a set of problems that provides adequate professional and/or monetary incentives for all parties as well. This will be particularly important for the Technologist, whose skillset can command a market price well beyond what an academic collaborator can offer using traditional sources of funding for humanistic research. However, the pressures exerted by this funding gap can be lessened if the collaborators feel that they are working together to address major issues in each other's domains of knowledge. Somewhat counterintuitively, we believe that such collaborations can offer an attractive reward structure for Technologists, as these professionals can be offered a great amount of intellectual freedom to pursue large and important questions. If the team can work to develop a project that allows the Technologist to pursue problems and solutions that are of interest, monetary compensation can become a less pressing issue. This collaborative, mutually-beneficial act of project creation is fundamentally different from the "work for hire" model that frequently employs Technologists, even in remunerative and prestigious jobs. The work offered by these other industries is rarely as engaging as that presented by Humanists, and is often controlled by the whims of distant project managers. Humanists can do well to recognize that they can attract technologists into a collaborative problem space by offering freedom from a few capitalist constraints, although this definitely means sharing intellectual ownership over the project.

Third, it is essential to find a way for all collaborators to accrue reputational enhancement and professional advancement from this collaboration. Similar to the question of incentive, the problem of divergence of professional reward structures is not insurmountable, but collaborators must remain gimlet-eyed about how to make professional recognition available to all participants throughout the duration of the collaboration. The primary point of conflict here emerges from how the peers and professional institutions assess performance within a given field. For the tenure-stream academic, professional rewards are closely correlated to the number of publications produced. While there does seem to be a growing acceptance of scholarship published by multiple authors, the default assumption remains the single-authored study, making these types of collaborations tricky.

Moreover, there is pressure for tenure-stream academics to publish their results as quickly as possible (within the constraints of the academic publishing model) in order to have tangible evidence of progress toward completion of any given project. For Technologists, however, publications are not as central to their evaluation as professionals. Instead, evaluation occurs at the project level. Unlike the academic, who is encouraged to publish and move on, the ideal project for the Technologist is sustainable over a prolonged period. Reputation accrues to those projects that perdure and iterate, ideally occupying an ever-expanding problem space. Such open-ended efforts are difficult for academics to justify to their institutions, much as academic publications are pushed to the edge of the Technologist's professional reward structure.

The Data Steward and Catalyst occupy an even more fluid professional space, and their rewards will depend even more strongly on their precise roles within their institutional structures. For example, a museum database administrator acting in the role of Data Steward is unlikely to accrue much professional gain from publishing. However, his or her participation in a successful, published collaboration may lead to future employment. Similarly, Catalysts may be employed as academics (either inside or outside the tenure stream), grant-funded positions, or museum professionals, and the benefits they gain from collaborating will change accordingly. The ideal set of collaborators will be aware of these divergent reward structures and plan in advance to produce a series of deliverables that will help all collaborators demonstrate professional progress to their institutions and benefactors.[29]

Disciplinary Respect

This proposed approach to collaboration in Digital Art History establishes a process for identifying the common motives that sustain ambitious work at the intersection of art history and technology. However, we find that, above all, respect is the foundation of any successful collaborative effort. For practitioners of these disciplines to collaborate effectively, each must resist the temptation to compress the amount of knowledge, tradition, and expert practice in other disciplines. Each discipline has its own breadth and depth that must be respected. Technologists cannot obtain the expert knowledge of an Art Historian by cribbing ideas from popular texts in art history, and Art Historians do not become expert Technologists by taking a six-week programming course on the Internet or at a DH workshop. While collaborators certainly could perform the physical task of data entry, that is only one facet of the Data Steward's discipline, and treating the curation of data as a task to be done "as time permits" is done at great peril. The work of the Catalyst, so easily dismissed, thus emerges as central: he or she works as the guardian of the project, ensuring that all collaborators recognize the strengths of the other disciplines and the limitations of their own, so that everyone can best work towards their goals.

A failure to appreciate the richness of other disciplines is an all too common theme in interdisciplinary research. In the realm of technology, this disposition frequently takes the form of technological immodesty, the belief that all problems are ultimately technical problems.[30] For example, Lazer et al. cite Google Flu Trends (GFT) as an example of "big data hubris," the notion that large volumes of data can replace traditional data collection and analysis.[31] Despite the media attention, GFT has performed rather poorly by "persistently overestimating flu prevalence" and missing the 2009 influenza A-H1N1 pandemic altogether.[32] In short, the GFT team undervalued the knowledge and practices of epidemiologists and overestimated the capabilities of big data analysis in this domain.[33] Without a Catalyst encouraging cross-disciplinary dialogue, technical projects can miss the critical perspectives offered by other disciplines.

Humanists' dismissiveness of technical approaches to their subjects demonstrates a similar lack of interdisciplinary appreciation. A common refrain among humanists is that technology succeeds only in telling us what we already know. Matt Jockers, for instance, questions the logic of such objections: "Why should further confirmation of a point of speculation engender a negative response? If the matter at hand were not literary, if it were global warming, for example, and new evidence confirmed a particular 'interpretation' or thesis, surely this would not cause a thousand scientists to collectively sigh and say 'Duh.'"[34] Again, the Catalyst can prompt the interactions and exchanges across disciplines necessary to push past the initial reactions preventing dialogue. Without mutual respect, interdisciplinary collaboration will fail to produce the sustained dialogue required for ambitious research.

Sustained Dialogue

We would like to draw attention to the fact that the collaborative framework outlined here also requires a commitment to sustained dialogue. Dialogue is an intrinsic good in academic settings. Even without any tangible research benefit, dialogue across disciplinary boundaries produces insight and perspective, and we have much to gain from it. Each discipline provides important challenges to the other's world-view. For example, Technologists frequently base their arguments on virtual evidence derived from models and simulations.[35] Virtual evidence informs disciplines ranging from biology and medicine to literary history and music, and yet such evidence commands relatively little respect in the field of art history.

What is exceptional about art history that excludes this type of evidence from serious consideration? Because of the reticence regarding master narratives such as those proposed by Winckelmann, as discussed above, Art Historians prefer to scope their arguments and studies to specific contexts. The theory of the universal machine notwithstanding,[36] in practice, many Technologists design systems highly dependent on context and targeted to specific audiences as well. In fact, computer science has entire branches of knowledge such as human-computer interaction dedicated to this type of study.[37] Why do Technologists believe that their methods are universal for art history when they have decided that in so many other areas context is crucial? By fostering such dialogue, Art Historians and Technologists can gain important insights into their own work and practices.

Indeed, the debates in Digital Art History also have important contributions to make to other academic dialogues, such as the philosophical differences regarding the nature of evidence in research currently taking place in applied statistics. The field of statistics is currently flowering due to the intense cross-fertilization of ideas among statisticians, computer scientists, physical, natural and social scientists, digital humanists, and all others who are interested in big data.[38]

Humanists and art historians have important perspectives to bring to this conversation regarding the negative disciplinary impact that can be caused when assuming that all objects of study are best treated as quantitative data.[39] The statistician Herbert Weisberg fired an important salvo in this debate arguing that medical clinicians often must use logic that departs from classical statistical thinking.[40] He argued that clinicians are experts not due to their ability to predict, but rather because they are masters at wading through ambiguity. If art-historical work similarly and necessarily departs from the typical assumptions of applied statistics, and also works with high degrees of ambiguity, then sustained dialogue with Technologists will highlight these differences. The role of ambiguity and certainty in the research traditions of Art Historians and Technologists varies significantly and fascinatingly. These diverse viewpoints on knowledge production have much to contribute to the larger debates about applied statistics in our time.

Develop Shared Understanding

Mutual respect and sustained dialogue are the necessary prerequisites for producing the shared understandings required for robust interdisciplinary research projects. The scope of this endeavor includes not only developing a consistent view of project goals and objectives, but also appreciating the diversity of motivations animating the many contributors to such projects. Why is developing a shared understanding so difficult in this domain? In an effort to build bridges among such stakeholders in the Pittsburgh Digital Humanities community, researchers from several disciplines gathered to review projects that are currently situated at the intersection of art-historical and technological research.[41] The Next Rembrandt project (https://www.nextrembrandt.com/) served as a particularly good example of the perils and pitfalls at the heart of developing shared understanding. The project used a variety of techniques from engineering and machine learning including facial recognition to train a computer to simulate a Rembrandt painting: “the next Rembrandt.”

When the assembled group, which consisted of Humanists, Technologists, Data Stewards, and Catalysts, watched the promotional video documenting the computational techniques involved in producing the simulated painting, the art historians at the meeting burst into a fit of laughter at the summary of the computer’s insight into Rembrandt’s work. The Technologists appeared to have shown, through all of their intensive work, that the typical Rembrandt painting is a portrait of a Caucasian, middle-aged male with facial hair wearing dark clothing with a collar and a hat. The art historians had trouble seeing the need for complex technology to deduce what college students routinely recognize in Art History 101. After pushing through the immediate reaction to the project, the group distilled the essence of the objection to the approach: aggregates held little interest for these Art Historians. Each painting has a unique value and history; this simulation, which appeared like a deus ex machina to solve an unsolvable problem, has no history. From the Art Historian's point of view, the project offered little more than a compelling example of technological immodesty.

The Technologists in the room, however, saw something rather different in the project. First, the achievement, stated in machine learning terms, sounded much more satisfying. Technologists trained a computer to extract information, albeit simple, from a database of images with Deep Learning techniques.[42] That the approach could deduce what college students routinely recognize in Art History 101 is a technical achievement even if it is of little interest to Art Historians. Second, the Technologists were less likely to see this one "new" Rembrandt painting as the goal of the project. Instead, machine learning and many other computing disciplines routinely create new simulated test data to improve the effectiveness of testing procedures, especially in fields of study with limited available data such as image processing. From their perspective, creating a "new Rembrandt" was understood as a neat way of simulating data for further testing and research as well as validating that they were able to understand enough of what makes a Rembrandt a Rembrandt to effectively mimic one.

Eventually, the Art Historians and Technologists found some common ground as both groups found that ING's marketing campaign and its many citations in the popular press skewed the importance of the stated achievements by presenting a technical achievement as a development of significance to art history. The dialogue produced some shared understanding including the fact that the project had greatly differing value to each community and popular discussions of the project frustrated attempts to build common ground across disciplinary boundaries.

From Shared Understanding to Empathy

We have identified several points of tension within the professional structures of interdisciplinary collaborators. By indicating these potential choke points, we have advisedly not sought to offer solutions, but rather to call attention to issues we have seen arise in our own collaborations. If collaborators approach these issues in good faith and are willing to propose solutions, then sustained collaboration becomes possible. We suggest disciplinary respect, sustained dialogue, and the intention to develop a shared understanding as the path forward.

Despite the many challenges to their collaboration, Art Historians, Technologists, Data Stewards and Catalysts have excellent opportunities for conducting research in an interdisciplinary framework. The concrete, tangible subject matter of art history and the Art Historian's reverence for materiality fit more comfortably with the Technologist's model building instincts than it might at first appear. In fact, the catalogues raisonnés familiar to Art Historians demonstrate a high degree of familiarity and comfort with metadata, a necessary prerequisite for data modeling, a knowledge which can serve as a starting point for dialogue with Technologists and Data Stewards. For this reason, the metadata produced by Art Historians may be a more natural point of origin for humanistic approaches to data than the models of raw text driving literary research in the digital humanities.

Moreover, both Art Historians and Technologists have long interacted with the knowledge of many other disciplines. In particular, many Art Historians, especially in the field of Technical Art History, have thought deeply about the role that all technologies play in the form and content of artistic productions. Materiality, metadata, and interdisciplinarity, therefore, provide a reasonable foundation for a framework of collaboration among participants fulfilling these four critical roles. To borrow the language of criminology, researchers seeking projects at the intersection of art history and technology clearly have the means and the opportunity to collaborate if only they can find a motive to do so.

In circumstances where long-term mutual respect and sustained dialogue promote deep, shared understanding, we see the potential for something even more in these projects: the growth of empathy. As scholars and human beings, we expect humanistic endeavors to increase our capacity for empathy, and, far from lessening this effect, digital art history has the ability to amplify it. Given that the process advocated here involves four different roles, ideally filled by four different people, each participant in the team must develop the imagination required to view the project from another's perspective. This model can help make it possible for the participants to understand and accept the many differences in motivation and incentive that drive their peers to participate in the project. We believe that this empathy creates the context for integrating insights at the boundaries of disciplinary knowledge.

Art historians today are uniquely positioned to work on a massive scale, which would have been unimaginable even for art historians as ambitious as Winckelmann and Riegl. Undertaking such analyses will necessarily involve collaboration between humanists and technologists. The nature of the questions we propose to ask remains quite close to the sort of research undertaken by previous generations of art historians. It is humanistic research. However, when augmented with computing power, certain aspects of humanistic inquiry are transformed. It is not feasible for a single scholar, toiling away in solitude at his or her desk, to undertake analysis on this scale. Humanists must reach out an open hand to technologists who are invested in uncovering historical truth. The converse is also true. Technologists working on their own can develop computer programs that will analyze massive amounts of data beyond what any art historian previously thought possible. However, without seriously engaging the discipline of art history, even an infinite amount of computing power is likely to only confirm what we already know. From both sides, such lone-wolf behavior is unlikely to bear meaningful fruit. Instead, this sort of ambitious research requires conscious, thoughtful multi-party collaboration, that extends even beyond the notion of the "humanist-technologist" dyad. We have outlined why we believe that, for these projects to be effective, they cannot rely solely on technological solutions, but rather must be founded in the most humanistic of tools: empathy and respect. Far from de-humanizing the humanities, these projects can, and ought, to be high-touch interactions, where sustained dialogue across communities can create new knowledge about ourselves and our pasts using data at scales unimaginable by our predecessors.

Notes

[1] Author Statement: Authors are listed in alphabetical order. Each author contributed equally to this piece of writing, in all of its aspects. Berg-Fulton (National Kidney Foundation) most often inhabited the role of Data Steward. Langmead (University of Pittsburgh) most often inhabited the role of Catalyst, with a side of both Art Historian and Data Steward. Lombardi (University of the Virgin Islands) most often inhabited the role of Technologist, with a side of Catalyst. Newbury (J. Paul Getty Trust) most often inhabited the role of Technologist. Nygren (University of Pittsburgh) most often inhabited the role of Art Historian.

[2] The production of this essay has been catalyzed by a series of gatherings and events that have taken place at the University of Pittsburgh over the past few years, beginning with the "Computational Visual Aesthetics" conference organized by Alison Langmead and Christopher Nygren, which was held at the School of Information Sciences on November 13, 2015 (https://sites.haa.pitt.edu/cva/). The conversation then continued during spring 2015 in a series of follow-up events held within the Department of the History of Art and Architecture at the University of Pittsburgh. The collaborators on this paper have continued to meet consistently since that time to clarify, refine, and publish this work. The authors wish to thank everyone who participated in these events, especially Adriana Kovashka, Erin Peters, and Benjamin Tilghman.

[3] For one of the most thoughtfully crafted discussions of the field of the digital humanities at the present moment, please see the collection of essays found in Matthew K. Gold and Lauren F. Klein, eds., *Debates in the Digital Humanities*, 2nd edition (Minneapolis: University of Minnesota Press, 2016), http://dhdebates.gc.cuny.edu/debates/2.

[4] James Cuno, "How Art History Is Failing at the Internet," *The Daily Dot*, November 19, 2012, http://www.dailydot.com/via/art-history-failing-internet/.

[5] Johann Joachim Winckelmann, *History*

of the Art of Antiquity, translated by Harry Francis Mallgrave (Los Angeles: Getty Research Institute, 2006), 76.

[6] On Winckelmann's assertions of autoptic authority, see Alex Potts, *Flesh and the Ideal: Winckelmann and the Origins of Art History* (New Haven and London: Yale University Press, 1994), 11-46.

[7] For the most concise analysis of Winckelmann's impact on subsequent generations, see Alex Potts' introduction to Winckelmann, *History of the Art of Antiquity,* esp. 28-35.

[8] For Riegl's contrasting definitions, see Alois Riegl, *Problems of Style: Foundations for a History of Ornament*, translated by Evelyn Kain (Princeton: Princeton University Press, 1992), 4 and idem, *Late Roman Art Industry*, translated from the original Viennese edition with foreword and Annotations by Rolf Winkes (Rome: Giorgio Bretschneider, 1985), 9.

[9] Jaś Elsner, "From Empirical Evidence to the Big Picture: Some Reflections on Riegl's Concept of Kunstwollen," *Critical Inquiry* 32 (2006): 741-766, cited at 741.

[10] Erwin Panofsky, "The History of Art as a Humanistic Discipline," in *Meaning in the Visual Arts* (Chicago: University of Chicago Press, 1983), 1-25, cited at 9-10.

[11] Donald Preziosi, *Rethinking Art History: Meditations on a Coy Science* (New Haven and London: Yale University Press, 1989), 16.

[12] Max Marmor (responding to Hubertus Kohle), "Art History and the Digital Humanities: Invitation to Debate," *Zeitschrift für Kunstgeschichte* 79 (2016): 151-163, cited at 155.

[13] Within the field of the digital humanities, there have been a number of publications that discuss the issue of collaborations and interdisciplinary research. On this subject, see for example, Cathy Davidson and Danica Savonick, "Digital Humanities: The Role of Interdisciplinary Humanities in the Information Age," in *The Oxford Handbook of Interdisciplinarity*, 2nd ed. (Oxford: Oxford University Press, 2017): 159-172. This essay focuses on the institutional impediments to interdisciplinary work rather than the interpersonal negotiation of the responsibilities within the collaboration, which is our focus here. Please see also, Christine Borgman, "The Digital Future Is Now: A Call to Action for the Humanities." *Digital Humanities Quarterly* 3 (2009): http://www.digitalhumanities.org/dhq/vol/3/4/000077/000077.html. Borgman's work emphasizes, as we do, the importance of empathy in collaborations as well as the importance of different disciplinary reward structures within cross-disciplinary projects. On the ways that digital humanists have come to define the notion of "team" in an academic environment that traditionally prizes individual research, see Lynn Siemens, "'It's a Team if You Use ''Reply All:''' An Exploration of Research Teams in Digital Humanities Environments," *Literary and Linguistic Computing* 24, no. 2 (2009): 225-233.

[14] For more information on this from an art-historical point-of-view, see Lev Manovich, "Data Science and Digital Art History," *International Journal for Digital Art History* 1 (June 2015): 13-35, http://dx.doi.org/10.11588/dah.2015.1.21631.

[15] Martin Hilbert provides an excellent overview of potential failure states of data analysis without sufficient context in "Big Data for Development: A Review of Promises and Challenges," *Development Policy Review* 34 (January 2016): 135–174, doi:10.1111/dpr.12142.

[16] Perhaps the foundational discussion of how disciplinary practices and assumptions unconsciously inform scholarly observation and description remains Bruno Latour, "Circulating Reference: Sampling the Soil in the Amazon Rainforest," in *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge and London: Harvard University Press, 1999), 24-79.

[17] This is not to suggest that scientifically-minded museum employees, such as conservators, cannot engage in useful collaborations with technologists. Indeed, many already collaborate with technologists in their work. However, we are here focusing on those scholars who concentrate more specifically on interpretive work outside of a conservation studio.

[18] When we talk about Technologists, we would like to emphasize that we are defining a role different from "Computer Scientist." Computer scientists are interested in producing advancements in state-of-the-art computer science, which traditionally involves the development of new algorithms and techniques.

While this is an essential role in the larger academic world, it is rarely one where fruitful collaboration between equals is possible with the humanities, due to the institutional challenges discussed throughout the document. Instead, we refer to Technologists as the role capable of using or extending existing technology and tools, including mathematics and statistics, to transform and manipulate information.

[19] In the information sciences, data stewardship roles can be assigned to individuals with many different job titles, including that of "informationist." For more on the data stewardship functions of informationists on interdisciplinary teams, see Elizabeth Whipple, Jere Odell, Rick Ralston, and Gilbert Liu, "When Informationists Get Involved: the CHICA-GIS Project," *Journal of eScience Librarianship* 2 (2013): 41-45.

[20] For a related take on this translational role, please see Scott Weingart, "Lessons From Digital History's Antecedents," *The Scottbot Irregular*, October 30, 2016, http://scottbot.net/lessons-from-digital-historys-antecedents/.

[21] Brian Cantwell Smith, "The Limits of Correctness," *ACM SIGCAS Computers and Society Newsletter* 14-15 (January 1, 1985): 18-26.

[22] The difficulties of the lone-wolf approach have been analyzed by David McBee and Erin Leahey, "New Directions, New Challenges: Trials and Tribulations of Interdisciplinary Research," in *Investigating Interdisciplinary Collaboration: Theory and Practice Across Disciplines* (New Brunswick, NJ: Rutgers University Press, 2017), 27-46.

[23] The Index of Christian Art is now known as the Index of Medieval Art. Further information can be found at https://ima.princeton.edu/. Thomas Lombardi, "Interdisciplinary Approaches to Metadata," Computational Visual Aesthetics Workshop (Pittsburgh, PA, November 13, 2015), https://sites.haa.pitt.edu/cva/interdisciplinary-approaches-to-metadata-tom-lombardi/ and "Interdisciplinary Approaches to Metadata," professional paper given at Keystone DH 2016, Pittsburgh, PA, 2016, http://keystonedh.network/2016/.

[24] Our aim here is not to resolve the long-standing philosophical question of the relationship between "truth" and "fact." We are acutely aware that the etymological root of "fact" (Latin: *factum*) implies agency. Our belief is that the rigorous application of computing technology will allow us to cast a fresh glance on historical data, which we hope to be able to convert into a truthful narrative of the facts. For greater detail on our use of the term "fact," see Bruno Latour, *On the Modern Cult of the Factish Gods* (Durham: Duke University Press, 2010). For the distinction between Truth and truthfulness in the enterprise of history, see Bernard Williams, *Truth and Truthfulness: An Essay in Genealogy* (Princeton and Oxford: Princeton University Press, 2002).

[25] Please see the IMLS grant documentation for "Art Tracks: Provenance Visualization Project," 2013, found at https://www.imls.gov/grants/awarded/ma-10-13-0337-13.

[26] Tracey Berg-Fulton, David Newbury, and Travis Snyder. "Art Tracks: Visualizing the Stories and Lifespan of an Artwork," in *Proceedings of Museums and the Web* 2015, Chicago, Illinois, April 8-11 (MW2015), published January 15, 2015, http://mw2015.museumsandtheweb.com/paper/art-tracks-visualizing-the-stories-and-lifespan-of-an-artwork/.

[27] Art Tracks Project, "The CMOA Digital Provenance Standard," draft version 0.2, published October 14, 2016, http://www.museumprovenance.org/reference/standard/.

[28] See Latour, *Pandora's Hope*.

[29] For a discussion of differing reward structures within academia and their implications for a variety of research products, see Christine Borgman, *Scholarship in the Digital Age: Information, Infrastructure, and the Internet* (Cambridge, MA: MIT Press, 2007), esp. Chapter 8, "Disciplines, Documents, and Data."

[30] Neil Postman, *Technopoly: The Surrender of Culture to Technology* (New York, NY: Vintage Books, 1993). For an excellent socio-technical take on technologically-focused, interdisciplinary collaborations, please see Caroline Haythornthwaite, Karen Lunsford, Geoffrey Bowker, and Bertram Bruce, "Challenges for Research and Practice in Distributed, Interdisciplinary Collaboration," in *Research and Practice in Distributed, Interdisciplinary Collaboration*, ed. Christine Hine (Hershey, PA: IGI Global, 2006), 143-166. The conversation

about interdisciplinary collaborations produced directly within the fields of information and computer *science* is small, and heavily focused on education and collaboration software.

[31] David Lazer et al., "The Parable of Google Flu: Traps in Big Data Analysis," *Science* 343, no. 6176 (March 13, 2014): 1203, doi:10.1126/science.1248506.

[32] Lazer et al., "The Parable of Google Flu: Traps in Big Data Analysis."

[33] The natural and social sciences also write about the function of interdisciplinary work in their fields, focused mainly on how the scientific disciplines work together. For a particularly sweeping overview of these issues, see Scott Frickel, Mathieu Albert, and Barbara Prainsack, eds., *Investigating Interdisciplinary Collaboration: Theory and Practice across Disciplines* (New Brunswick, NJ: Rutgers University Press, 2017). This book raises, among many other important points, the critical issue of disciplinary hierarchy and power asymmetry within the natural and social sciences. This agonistic understanding of collaborative work provides an interesting counterpoint to the model presented by the current paper.

[34] Matthew L. Jockers, *Macroanalysis: Digital Methods & Literary History* (Urbana, Chicago and Springfield: University of Illinois Press, 2013), 31.

[35] Please see, for example, Gordon Bell, Tony Hey, and Alex Szalay, "Beyond the Data Deluge," *Science* 323, no. 5919 (2009): 1297–98, doi:10.1126/science.1170411 or Aimee Kendall Roundtree, *Computer Simulation, Rhetoric, and the Scientific Imagination: How Virtual Evidence Shapes Science in the Making and in the News* (Lexington Books, 2013).

[36] A. M. Turing, "On Computable Numbers, with an Application to the *Entscheidungsproblem*," *Proceedings of the London Mathematical Society* (1936), 230–65.

[37] The HCI literature is far too extensive to be summarized here. Those looking for a gentle introduction should consult "The Encyclopedia of Human-Computer Interaction" (Interaction Design Foundation, n.d.), https://www.interaction-design.org/literature.

[38] Galit Shmueli, "To Explain or Predict?" *Statistical Science* 25, no. 3 (2010): 289–310.

[39] On this subject see for example, Johanna Drucker, "Humanities Approaches to Graphical Display," *Digital Humanities Quarterly* 5, no. 1 (2011): http://www.digitalhumanities.org/dhq/vol/5/1/000091/000091.html.

[40] Herbert I. Weisberg, *Willful Ignorance: The Mismeasure of Uncertainty* (New York: Wiley, 2014).

[41] These events began with the "Computational Visual Aesthetics" conference organized by Alison Langmead and Christopher Nygren, held at the School of Information Sciences on November 13, 2014 (https://sites.haa.pitt.edu/cva/), and continued in a series of follow-up events held within the Department of the History of Art and Architecture in the Spring Term of 2015. The discussion of the "Next Rembrandt Project" took place on April 8, 2016.

[42] On Deep Learning see for example, Li Deng and Dong Yu, "Deep Learning: Methods and Applications," *Foundations and Trends in Signal Processing* 7, no. 3–4 (2014): 197–387, doi:10.1561/2000000039.

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Workshops

Summer School on Digital Art History (DAHSS). Data-Driven Analysis and Digital Narratives

Nuria Rodríguez Ortega

University of Málaga

The Summer School on Digital Art History (DAHSS) is an ongoing joint initiative of the University of Málaga and the University of California, Berkeley. In 2015, both institutions signed a memorandum of understanding for the development of training activities in the field of Digital Art History and Visual Culture: DAHSS is the first outcome of this collaboration. Later on, other institutions, such as the Ludwig-Maximilian University in Munich and the University of Western Ontario in Canada, joined this project, enriching their benefits and expanding its scope.

Why DAHSS? The so-called "digital turn" has configured new modes of access, production, representation and distribution of knowledge. The digital turn implies, therefore, new ways of thinking and understanding, and also new ways of creating, recreating, communicating, representing, and interpreting. Being aware of this new scenario, DAHSS is rooted in the need to provide art historians and analysts of visual culture with innovative training contexts that take into account the material and technological conditions of our contemporary world, and that also contribute to critical reflection of how these conditions are modeling new epistemic, interpretative and methodological paradigms. Facing this complex scenario implies, in turn, the implementation of learning strategies based on transdisciplinary collaboration, stimulation of creativity, and promotion of disruptive thinking in order to question established assumptions and conventions. In other words, DAHSS is a response to the challenge of reinventing the practices of Art History and Visual Culture Studies within the framework of the digital realm. Our ultimate goal is to establish a permanent seminar that serves as a bridge between a plurality of backgrounds and disciplines, able to configure a transnational scenario for critical reflection, ground-breaking learning and cooperative work. Fortunately, it seems that this objective has a way of being fulfilled if we consider the progression occurred between the first and second iterations of the program.

The first edition took place in September 2016, and what began as a workshop with a reduced and local scope has experienced an important quantitative and qualitative leap in the second edition, expanding the number of applications, the variety of disciplinary backgrounds and the national and institutional diversity of participants. Only 40% of the applications could indeed be accepted, resulting in a final group of 23 participants coming from 14 different countries.

Why the topic of Data-Driven Analysis and Digital Narratives? DAHSS has tried to answer a double-sided question, crucial to the emerging field: in the two editions that have happened so far: How might the ability to access and process hundreds of thousands of data tell new stories about artistic culture? And how might we present these new stories in unprecedented narrative models? Not by chance one of the aspects of digital culture that requires more attention is the enormous amount of images, materials and data of all nature that, thanks to the incessant digitization effort carried out by GLAM institutions, together with the proliferation of open data and LOD initiatives, are at our disposal to be used for many different purposes. Further questions arise: How to use this material to generate new knowledge in the field of artistic and visual culture? How does the possibility of processing hundreds of thousands of data imply a paradigm shift with respect to interpretive models and traditional research practices?

Likewise, digital media—transitive, interactive and hypermedia by nature—requires a refounding of the discursive models and of the forms of representation that, up to now, have been determined by the formats of the printed culture and the book. The need to refound the writing practices and the discourse models that have governed historical-artistic knowledge so far demands an adequate understanding of the potentialities of digital languages. In this sense, the creative practices of new media artists or the proposals developed by electronic literature can inspire new models of narratives and stories.

In accordance with its objective of setting up training contexts based on creativity, innovation and disruptive thinking, DAHSS17 put different teaching strategies into play, combining theoretical exchanges and critical discussions with practical sessions (lab-based sessions) through which participants worked collaboratively in joint assignments. Lab-based sessions followed Design Thinking methodologies for rapidly prototyping projects. The development of prototypes is useful for the acquisition and practice of digital and technical skills. Moreover, they also serve as catalysts to foster critical reflections about the new epistemic conditions associated with digitality and its effects on artistic and visual culture. In DAHSS17, the shared discussion expanded in a Facebook group, which is still working today and is becoming a meeting point to share news, initiatives and reflections related to Digital Art History. The DAHSS17 program was completed with the participants' lightning talks, which gave us the opportunity to know their backgrounds as well as their ongoing research projects.

The first three days of DAHSS17 were devoted to discuss a variety of problematic issues which were introduced by the instructors through provoking and suggestive presentations. Greg Niemeyer (University of California, Berkeley) addressed a twofold reflection: on the on hand, in his presentation "Parsing Networks" he took as base the "circulating reference" concept proposed by Bruno Latour to explore the process through which the materiality of the phenomena empirically observed is transformed into a new materiality by means of the aggregation of layers of interpretation. This process formalizes and progressively abstracts the empirical reality to build a new one: the dataset that we will finally manage. The critical question that immediately emerged was how to go from data—understood as an abstraction and formalization of empirical phenomena—to transformative actions that reconnect with them; in other words, how to go from theoretical formalization to practice; or how to make data-driven approaches an effective tool to face the challenges of a changing world. This last question led us to consider the need of building predictive models that help researchers to envision the future in order to provide better solutions to the next problems that will beset us.

On the other hand, given that socio-cultural phenomena do not progress in an unique manner and they are complex, the need to overcome linear narratives to develop multiple narratives was addressed in a second phase. Therefore, the central question that focused the debate was: How might we interrogate datasets in order to obtain a plurality of narratives? In turn, a series of connected reflections came up: assuming that our observations of the world are embedded in the building of data models, what do they mean in cultural terms? How might we interrogate the arguments and assumptions embedded in data models? How might we build more "neutral" data models? Is that possible in some way?

As an alternative path for analyzing socio-cultural phenomena and systems in terms of complexity and fluidity, especially in the context of the liquid modernity (Baumann) of the 21st century, Greg Niemeyer proposed the notion of "morphogenesis"—already raised by Alan Turing—in his presentation "Towards Morphogenic Design". The morphogenetic approach focuses attention on "how" simple forms become complex forms, rather than "why". It is also an ontological question to the extent that, from this point of view, things and creatures are not defined by categories, but rather by the waves that give rise to their forms. While traditional perspectives describe structures and creatures in terms of categories of classification, morphogenesis proposes to think of data (and socio-cultural phenomena) as waves that

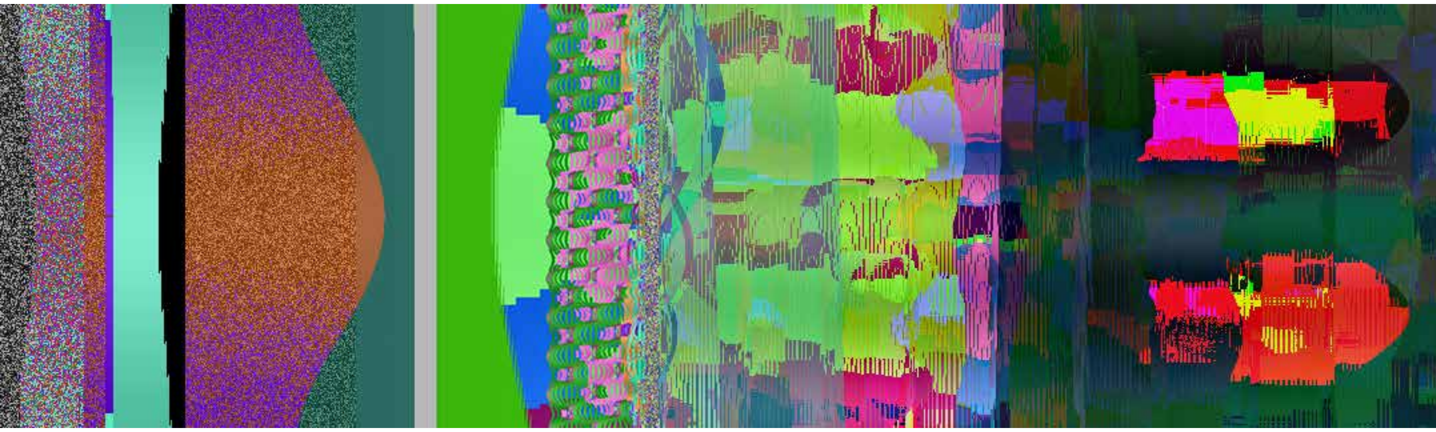

Figure 1: Greg Niemeyer, Paul D. Miller, *Supraliminal* (screenshot).

collide amongst themselves, resulting in a diversity of forms. To illustrate this issue in a practical way, Greg Niemeyer showed Supraliminal[1], a project developed in collaboration with Paul D. Miller consisting in a 360 degree video installation that generates visual and sonic patterns based on the principles of morphogenesis (fig. 1).

Naturally, the matter of data brought about other controversial issues, such as the bias of datasets, the existence of black holes, differences in access, inequalities in open data policies, etc.

Harald Klinke's presentation (LMU) posed the problem from its foundation, that is, he launched the crucial question of what is, in reality, Digital Art History: can we say that it exists as something independent or different from the traditional Art History? Are these two labels—traditional and digital—actually defining two different ways of practicing and understanding Art History? To answer this intellectual challenge, Harald Klinke referred to the mechanisms traditionally used in art-historical research (comparison, observation, discovery of similarities and differences, classification, etc.) to reflect on how they are transformed when carried out through computational methods. Since one of the contexts where this shift is most noticed is when processing the huge image collections now available, the debate of how to deal with these new resources centered most of the discussion. Likewise, the problems associated with the practice of Digital Art History were also addressed: the abundance of information and the need for a critical filter; the problems of unbalances and underrepresentation in digital cultural heritage; the need to understand the logic of computational methods in order to propose meaningful interpretations; the transit from individual to collaborative and interdisciplinary work; the change in the authorial and recognition models, etc. In short, participants faced the fundamental question of what it is to be an art historian in the 21st century.

Justin Underhill (University of California, Berkeley) focused on image processing and 3D laser scanning techniques. His presentation revolved around a fundamental idea: if the medium shapes the way in which we see, the digital artifacts (images, 3D models, etc.) are—therefore—powerful tools for shaping our understanding of visual culture and also heuristic tools to clarify issues related to the artistic production processes that were hitherto impossible to address. This lesson had an on-site demonstration at the Málaga Cathedral. On Wednesday morning, we moved to the city center to visit the Cathedral and to carry out a scanning session. Once all the captured data was processed, we were able to visualize the 3D reconstruction of the building and to discuss the advantages and disadvantages of this technique[2].

On Wednesday, the formation of the working groups took place. At this point, we were all aware of the critical moment that we had in front of us since the effectiveness of the rest of the summer school depended on the success of this operation. We decided to rely on the Design Thinking strategies. Taking a starting point a small set of key questions that had emerged in the discussions of the previous days, the participants gradually added new questions on issues that had aroused their interests (fig. 2). These questions, grouped into semantic clusters, served as the basis for the distillation of the three projects that were finally proposed to be developed during the following days. Once the projects were decided, each participant joined the most interesting one by him/her.

On the last day, the three projects, tutored each by one of the instructors, were publicly presented.

1. Matching China, led by Greg Niemeyer, set out to explore different narratives through gamification processes as a means of challening narratives based on linear logics usually used by museums and cultural institutions (chronological, stylistic, etc.). The result is Matching China[3], an interactive game that examines how different narratives influence our ways of seeing. At the beginning of the game, a series of images of heterogeneous blue-porcelain objects pass before the eyes of the gamers combining different settings (random, chronological, subjective, with associated information, without information, etc.). Subsequently, gamers must match fragments of the objects with the figure to which they belong (fig. 3). The hits scored are used to reflect about what kind of settings are best remembered by participants, and, therefore, whether the use of certain logics determines the cognitive experience of the viewer.

2. Modeling the *Music Lessons*. Veermer's IKEA, guided by Justin Underhill, set out to explore the potential of 3D modeling techniques to foster

Figure 2: Research questions' panel (https://goo.gl/nXPG2i).

speculative hypotheses about two-dimensional representations. In particular, the project focused on the painting *The Music Lesson* (ca. 1660) by Johannes Vermeer. The final result was a 3D artifact that reconstructs the geometry of the room depicted and the different objects included in the scene. This 3D artifact allows us to speculate about the techniques used by Vermeer in the projection of the two dimensional space, the point of view adopted by the painter but also about the changing effect of the natural light when this invades the scene through the windows at different times of the day[4].

3. Data Analysis and Visualization, leaded by Harald Klinke, set out to delve into the opportunities provided by data analysis and visualizations to produce new art-historical knowledge. Both open datasets and datasets belonging to participants' personal projects were used. It is interesting to note that, during the exploration process, datasets were conceived as research objects per se. In contrast to traditional approach that usually departs from questions previously established, datasets were analyzed in order to find out which new and unexpected questions emerged as a function of configuration, structure, volume, data types, etc.

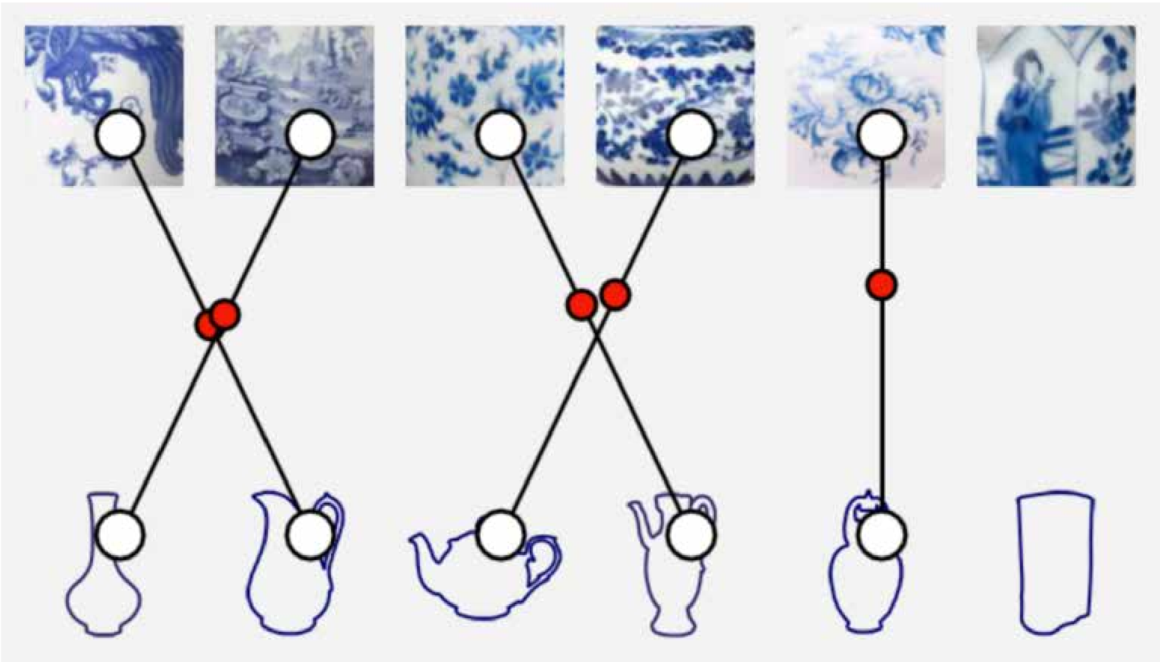

Figure 3: Matching China interface (screenshot).

Finally, I presented my own experiment, Words-Images Game, whose objective was to explore the nature of the words used to describe certain images in order to discover whether any pattern can be traced depending on the nature of the image we are seeing. Each of the participants provided 7 words of their choice to describe each of the 7 images selected by me (all of them paintings of the 20th century). The results demonstrated a tendency to use words that identify (nominate) the objects represented when figurative images are described, while the words related to the description of the visual qualities—which, for obvious reasons, are prevalent in the non-figurative images—remain marginal. Therefore, the predisposition of figurative images to activate the cognitive mechanism of identification—the first step of the Panofskian iconographic method—seems to relegate the appreciation of the visual qualities (form, color, light, etc.) to a second register.

And now, what is the next? We are already working on the DAHSS18 with the ambition of improving the training strategies, expanding the scope with new topics and making the community of Digital Art History practitioners grow.

The entire DAHSS17's documentation can be found at: http://historiadelartemalaga.uma.es/dahss17/en/

Figure 4: Clustering artists in the Met Museum tapestry collection foremost shows us the overrepresentation of designers in tapestry research @rudyjosbeerens.

Notes

1 http://www.supraliminal.org/ [Viewed: 20/12/2017]. See Greg Niemeyer's explanation at: https://goo.gl/3bwDTa [Viewed: 20/12/2017].
2 See Justin Underhill's explanation at: https://goo.gl/nc2ScS [Viewed: 20/12/2017].
3 http://matchingchina.org/ [Viewed: 20/12/2017].
4 See video at: https://goo.gl/sV6rmB [Viewed: 20/12/2017].

Coding Dürer: International Interdisciplinary Hackathon for Art History and Information Science

Sonja Gasser

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A highly interdisciplinary field such as digital art history requires specialized skills. For sophisticated projects, a fruitful collaboration between scholars in the humanities and scientists with a technological background is crucial. When the methods of art history encounter current topics in computer science, differing concepts of research come together, which results in the application of mixed methods. Researchers trained in one field often need the expertise of those in the other to successfully complete a digital humanities project that convinces from the conceptual, the content-related but also technological aspects.

The organizational structures at universities rarely facilitate collaboration across different faculties. For that reason, Harald Klinke (Digital Art History[1], Ludwig-Maximilian University Munich (LMU)) and Sonja Gasser (Digital Humanities Lab[2], University of Basel; Digital Art History LMU) decided to organize an event that gives the participants the opportunity to work interdisciplinarily. Thanks to the generous funding of the VolkswagenStiftung within the workshops and summer schools' funding line "'Mixed Methods' in the Humanities?"[3], this five-day "Coding Dürer" Hackathon[4] could take place in Munich—with 40 participants as well as five invited speakers from various countries of Europe and the USA—from March 13th to 17th 2017.

The event follows from previous initiatives, such as the Summer School "Computing Art—A Summer School for Digital Art History" in Heidelberg 2015,[5] and the Summer Institute "Digital Collections—New Methods and Technologies for Art History" in Zurich and Lausanne 2016, which brought together researchers from mainly German-speaking countries.[6] In contrast to these previous summer schools, the international group at "Coding Dürer" included a range of participants, from BA students up to professors. Most importantly, it was not just restricted to scholars from the discipline of art history. In addition, computer scientists and others anywhere in between were involved. Outside of academia, it is characteristic to find this mix of people at open cultural GLAM-hackathons such as "Coding da Vinci"[7] in Germany, which inspired "Coding Dürer".

Coding
DÜRER 13.–17.03.2017
Munich, Germany
International Interdisciplinary Hackathon
for Art History and Information Science

The main intention of Coding Dürer was to bring art historians and computer scientists together to enable them to collaborate face to face. Although both groups often generate worthwhile ideas for utilizing cultural data, they often do not have the chance to interact in everyday academic contexts. All participants arrived with a deep interest and prior experiences in the fields of art and technology, some of them even with training in both. The exchange was very fruitful for both sides. Many technicians were happy to have capable interlocutors whose background in art history allowed them to answer historically specific questions about the data. Being familiar with the content and meanings of a particular data set is not only a prerequisite to contextualize and interpret it correctly, but also for having good ideas for data processing projects. Art historians with a strong interest in digital humanities often have a good understanding of technology, but not sufficient capabilities to apply it. Therefore, they enjoyed having team members, who were able to set up complex systems, apply computer scientific methods and realize interactive applications. Moreover, being an expert in one particular area and having a general understanding of other areas is necessary to smoothly overcome differences in doing research between the two disciplines. The technologists realized that the art historians were able to precisely describe what they wanted in terms of technological functionalities, which facilitated coding and implementation.

Most of the available time was reserved for working on self-organized group projects. Due to the limited period of five days, it was intentionally an experimental setting with an open outcome. At the beginning of the event, everybody presented his or her ideas and told the others about their research skills. With the help of a big post-it cloud on the wall, the groups formed almost automatically. This was the starting point for successful discussions and collaborations in the teams on a democratic basis and led to results that many teams did not anticipate.

It was very important that the participants could be part of an interdisciplinary exchange. Additionally, the inputs from five renowned invited speakers throughout the whole week offered a welcome insight into particular research projects and developments in the field. Nuria Rodríguez Ortega reflected profoundly on software, tools and methods to analyze and visualize data. Lev Manovich explained via livestream how cultural analytics allow to handle a big amount of images and to draw conclusions on society. Anna Bentkowska-Kafel set out that there is already a history of the still emerging digital art history, while Justin Underhill presented impressive examples of art historical reconstruction. Mario Klingemann spoke about his experiences as an artist who works with algorithms and data. The speakers were on site for the entire event and joined also one of the seven groups.

The discussions in the groups or in plenum were very vivid. The interdisciplinary exchange yielded many insights. It also allowed participants to find out that certain terms with highly divergent meanings and discursive histories exist in both disciplines, such as 'similarity' and 'image', with highly divergent meaning. At the end of each day, the groups reflected in plenum on the progress of their project. It was interesting to see how the projects developed, to learn what was successful, and what obstacles the teams had to overcome.

The success of the event was partly due to the participants, a group of open-minded people with varied

Figure 2: Participants of the hackathon "Coding Dürer".

backgrounds. The participants were selected from the astonishingly big number of 159 applications. This makes it evident that there exists a community—by the way, a very gender balanced one—for the topic. Therefore, summer schools, workshops or hackathons are a suitable way to foster and cultivate this community. In the future, more long-term projects will allow for outcomes that go far wider than those realized within only five days. Thus, it is necessary to establish environments and projects at universities that facilitate and document interdisciplinary collaborations. The "International Journal for Digital Art History"[8] is an optimal outlet for digital art historians to communicate on such projects, initiate debates and discuss the theoretical implications of their research methods.

At the Hackathon, the public presentations of functional prototypes were broadcasted via live stream and attracted also a worldwide audience. Before, during and after the event, the interaction on Twitter[9] was very active. The Coding Dürer website documents the hackathon, the group projects and remains a valuable resource for digital art history with a list of collected tools and a table of data resources accompanied by explanatory blog posts. The participants, speakers and organizers were all very satisfied with the event. It was a good opportunity for digital art historians to network in real time. One will see, what will arise in the future from the contacts made during Coding Dürer.

Notes

1 http://www.kunstgeschichte.uni-muenchen.de/forschung/digitalekg/
2 http://dhlab.unibas.ch/
3 https://www.volkswagenstiftung.de/en/funding/mixed-methods-in-the-humanities
4 http://codingdurer.de/
5 See Peter Bell, "Computing Art. A Summer School for Digital Art History" in: *International Journal for Digital Art History,* No. 2, 2016, p. 216–218, http://dx.doi.org/10.11588/dah.2016.2.24760.
6 http://digital-collections.online/
7 "GLAM" stands for "Galleries, Libraries, Archives and Museums"; https://codingdavinci.de/
8 http://dah-journal.org/
9 https://twitter.com/hashtag/codingdurer

Addendum

In the second issue of this journal, Figure 8 is missing from the article by Babak Saleh and Ahmed Elgammal. It is reproduced here.

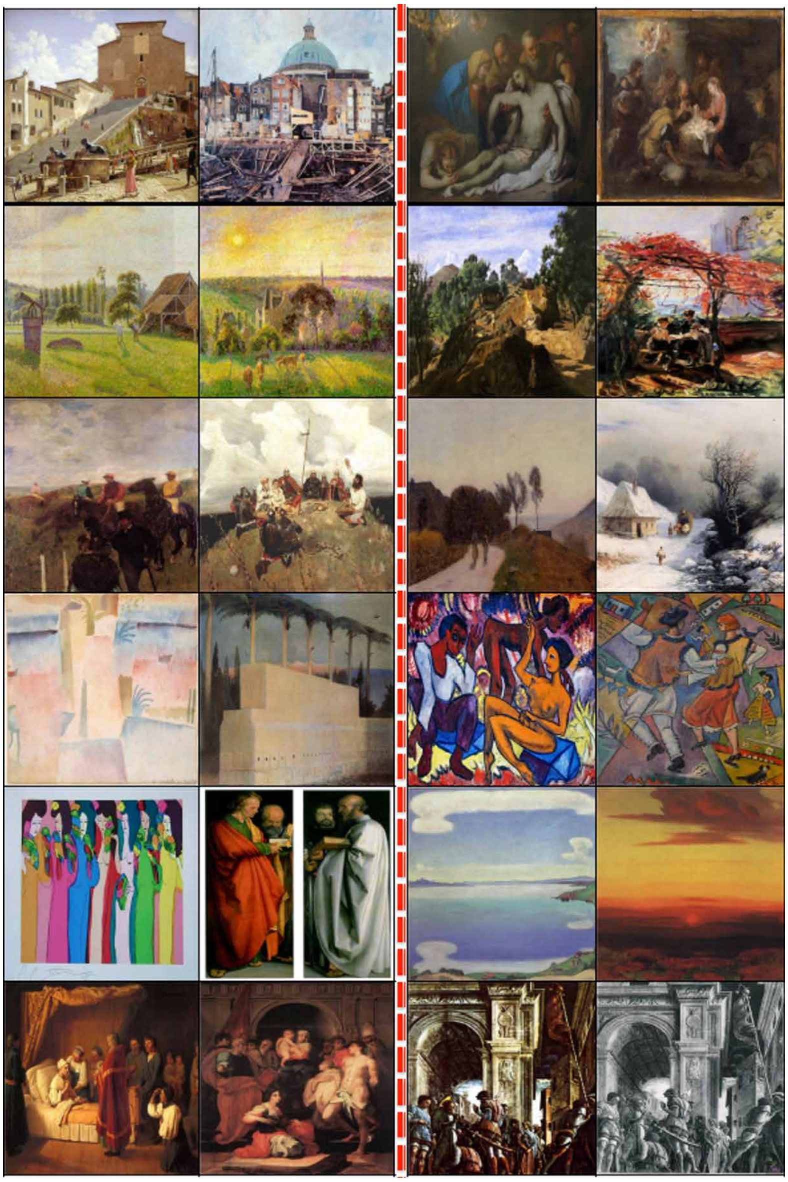

Figure 8: Sample output for the tasks of image search. In each pair, the image on the left is the query and image on the right is the closest match, but not from the same style (LMNN plus feature fusion).

Call for Manuscripts #4:

Digital Transformation of Institutions

Digital Art History is often described as a methodological addition to Art History. Moreover, it includes a profound transformation of its institutional framework: server rooms replaced the slide libraries as the former center of art historical departments, museums are concerned with digitizing their collections and making them accessible via virtual exhibitions, and conservators facing challenges preserving digital art with its soft- and hardware.

The transition from analog to digital pictorial transcription has transformed art history and its archives in profound and unexpected ways. The objects of our study, once physically circumscribed by the walls of the slide library, are now widely available. The advent of image retrieval platforms like ArtStor and Google Image Search, not to mention countless museum databases, present new challenges and opportunities for cataloguing and visualizing data. The photographic practices of museum visitors have likewise been transformed by the integration of digital photography, cellular phones, and social media. Additionally, art historical publishing and pedagogy continue to be mostly constrained (in the English-speaking) world by antiquarian protocols governing copyright and image clearance.

For the upcoming issue of the DAH-Journal we ask for contributions on the following topics:

– How are analog institutions transforming and which digital tools steer this transformation? What practices persist, which one are eliminated?

– What nascent digital methodologies do museums and archives utilize to engage visitors, organize metadata, and document collections?

– How might digital publishing, artmaking, and experimentation challenge and change art-historical research?

– What are digital opportunities to develop and document archives of underrepresented, neglected, or ephemeral traditions of image-making?

The fourth issue's featured author will be Johanna Drucker, who is currently the Martin and Bernard Breslauer Professor in the Department of Information Studies at the Graduate School of Education and Information Studies at UCLA.

We welcome articles from art historians, curators, conservators, artists, information scientists, and authors from other related disciplines who are concerned with questions around this topic. To send in articles, please register first at http://dah-journal.org/register.html and then submit articles by September 30, 2018 (6,000 words max.). For more information please visit "Information for Authors" on our website http://www.dah-journal.org/authors.html

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