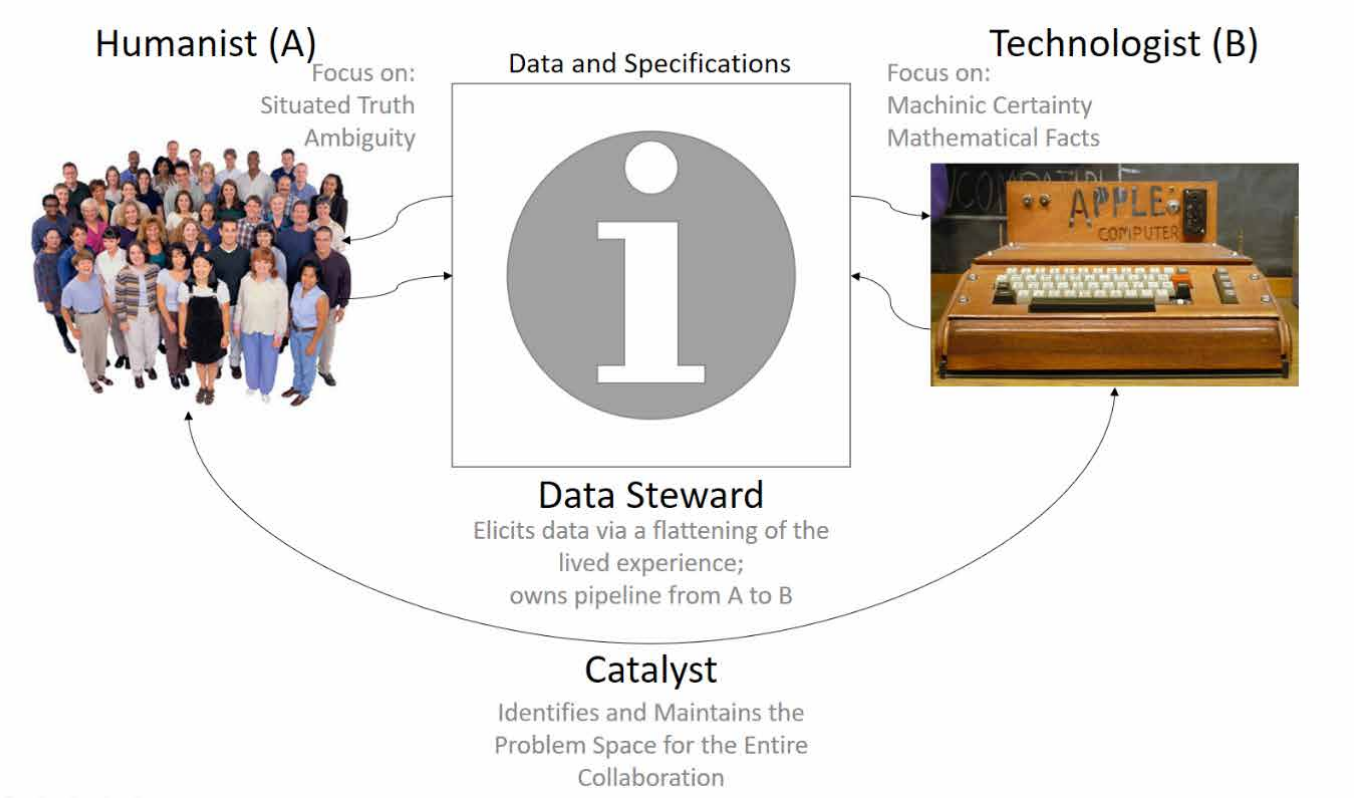

Figure 1: A Model of the Collaborative Universe in the Digital Humanities, based on a figure from Brian Cantwell Smith, “Limits of Correctness” (1985).

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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 de-

scribes 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 under-

standing 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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