Computational Beauty: Aesthetic Judgment at the Intersection of Art and Science

Emily L. Spratt[†] and Ahmed Elgammal[‡]

[†] Dept. of Art and Archaeology, Princeton University, NJ, USA
[‡] Dept. of Computer Science, Rutgers University, NJ, USA

Abstract. In part one of the *Critique of Aesthetic Judgment*, Immanuel Kant wrote that " the judgment of taste... is not a cognitive judgment, and so not logical, but is aesthetic.[1]" While the condition of aesthetic discernment has long been the subject of philosophical discourse, the role of the arbiters of that judgment has more often been assumed than questioned. The art historian, critic, connoisseur, and curator have long held the esteemed position of the aesthetic judge, their training, instinct, and "eye" part of the inimitable subjective processes that Kant described as occurring upon artistic evaluation. Although the concept of intangible knowledge in regards to aesthetic theory has been much explored, little discussion has arisen in response to the development of new types of artificial intelligence as a challenge to the seemingly ineffable abilities of the human observer. This paper examines the developments in the field of computer vision analysis of paintings from canonical movements with the history of Western art and the reaction of art historians to the application of this technology in the field. Through an investigation of the ethical consequences of this innovative technology, the unquestioned authority of the art expert is challenged and the subjective nature of aesthetic judgment is brought to philosophical scrutiny once again.

Keywords: Computer Vision, Aesthetic Judgment, Aesthetic Theory, Critical Theory, Formalism

1 Introduction: Aesthetics, between Computer Science and Art History

Since James Gibson's pioneering research on two-dimensional imaging for statistical pattern recognition, which brought the computer from a type-writing calculator to an image processing machine, Computer Vision Science has developed into an independent field of study within the quickly evolving domain of Artificial Intelligence. While developments within Computer Vision have mainly derived from the impetus of Defense technology, in the last twenty years, the application of this research in the interpretation of two-dimensional images has arisen, creating a new branch of study. For example, Computer Vision utilizes algorithms for different object-recognition-related problems including: instance recognition, categorization, scene recognition and pose estimation, to list a few

critical developments. At this point in time, computers can examine an image and recognize distinct objects and even categorize the scenes they occupy. Cultural and historical inferences about an image may slowly become determinable by computers, yet, the complexities of these types of higher-level perceptions are currently possible only in the realm of human cognition.

Due to the significant advances in Computer Vision research in the analysis of art, we would like to suggest that the time has come to make an overall evaluation of the possibilities of aesthetic interpretation that the computer offers to date. While academics in the humanities have remained largely skeptical of the use of Computer Science to perform tasks that involve subjective interpretations of qualitative data, we seek to demonstrate how one intersection of the arts and sciences can be more fruitfully navigated, that of Computer Vision and Art History. Rather than relegating the aesthetic interpretation of art by computers solely to computer scientists, let us determine how machine based analysis of art functions in comparison to human judgment by considering the voices of art historians and others representatives from the humanities who have shed much ink exploring this subject. This collaborative approach thus harkens a re-evaluation of the philosophy of aesthetic theory as it has been applied in Art History in light of the scientific developments not only within Computer Vision but also in relation to Neurobiology. Indeed, Computer Vision challenges the art historian's very conception of the processes of aesthetic judgment and what may be regarded as objective or subjective mental processes if a computer has the ability to perform similar tasks.

Through examination of the innovations and histories of Computer Vision and Aesthetics as a philosophical discourse, that has been utilized in Art History, we will question both how notions of authority in aesthetic judgment and the processes of aesthetic interpretation itself have been constructed over time. While the art historian, critic, connoisseur, and curator have long held the esteemed position of aesthetic judge, their training, instinct, and "eye," part of a seemingly inimitable cognitive process that occurs upon artistic evaluation, these new developments in Computer Science challenge the very tenets of aesthetic theory and call for their reevaluation. Similarly, this paper calls for a more critical explanation from computer scientists to make clear to members of the humanities how aesthetic judgments are being programmed into machines and to what end. Through a collaborative approach, we aim to begin to bridge the gap between Computer Science and Art History fostering research that will yield fruitful applications of Computer Vision in the analysis of art and theoretical reconsideration of aesthetic judgment itself.

In this paper, we will question the capability of a computer to make aesthetic judgments. We will consider the degree to which computers can aid specialists within Art History and examine whether Computer Vision can offer unique insights to art historians regarding iconographic and stylistic influence. We also will examine the degree to which art historians would be open to using new technologies advanced by these developments in Computer Science and offer suggestions as to how to foster collaboration between the fields. Through the

initiation of a multidisciplinary discussion about these interrogations, this investigation is, to our knowledge, the first of its kind. The paper's structure is as follows: Section two provides a literature survey of the research developments in Computer Vision regarding the analysis of art. Art Historians' responses to these developments are addressed in section three. A philosophical review of the concept of aesthetic judgment follows in section four, and its implications are discussed in section five. In conclusion, section six provides a discussion about the present and future interaction between Computer Science and Art History.

2 Computer Analysis of "Visual Art" a Short Survey of Recent Innovations in the Field

The field of Computer Vision is focused on using computers to understand images and videos. Given the context of the application of this research, these interpretations have the capacity to yield highly variegated meanings. Through the relatively short history of the Computer Vision field (only a few decades), scientists have addressed a wide spectrum of problems ranging from the recognition of objects in an image, the analysis of activities, gestures, facial expressions, object interactions, and the ability to recover three-dimensional forms of representations from a two-dimensional image Within the Computer Vision field, in the last two decades there has been increasing interest in the area of computer-based analysis of Art. The research is comprised of the development of several programming tasks including: the automatic classification of art work to identify the artist, the retrieval of stylistically similar images of paintings, the classification of style, the quantification of artistic similarity, and the ability to predict a painting's date of production. In this section we survey some of these new developments, targeting non-experts in the field of the computer analysis of Art. For a more comprehensive survey for the research in this area prior to 2009, we refer the reader to the survey by Stork [2].

Most of the research concerning the classification of paintings utilizes low-level features, or simple diagnostic measures, such as the appearance of color, shadow, texture, and edges. Lombardi [3] has presented a study of the performance of these types of features for paintings to identify artists. Several features such as color, line, and texture were surveyed for their accuracy in classification of a given painting to identify its artist among a small data set of artists. Several machine learning techniques were used for classification, visualization, and evaluation. Through this research, the style of the painting was identified as a result of the computer's ability to recognize the hand of the artist. For example, recognition that a painting was attributed to Claude Monet signaled an association with Impressionism. A Bag of Words (BoW) approach (typically used for object recognition) with low-level features of color and shades to identify the painter among eight different artists was utilized by Khan et al. [4]. Similar experiments with low-level features were conducted in [5, 6].

Computerized analysis of brush strokes in images of painting has extensively been studied by different researchers, e.g. [7–13]. Brush strokes provide a signa-

ture that can help distinguish the artist. The analysis typically involves texture features that are assumed to encode the brush stroke signature of the artist. Recently, Li et al [13] proposed a method based on the integration of edge detection and clustering-based segmentation for brush stroke analysis. Using these features they found that regularly shaped brushstrokes are tightly arranged, creating a repetitive and patterned impression that can represent, for example, Van Gogh's distinctive painting style, and help to distinguish his work from his contemporaries. This research group has analyzed 45 digitized oil paintings of Van Gogh from museum collections. Due to small number of samples, and to avoid overfitting, they state this problem as hypothesis testing rather than classification. In essence, they hypothesize which factors are predominant in Van Gogh's style by comparing his oeuvre to his contemporaries and tested them by statistical approaches in addition to the analysis of brushstroke features.

The problem of annotating digital images of art prints was fruitfully addressed by Carneiro et. al. [14]. In that work an image of an art print was automatically annotated to one of seven themes (e.g. annunciation) as well as existence of 21 specific symbols or objects (e.g. Angel, Christ, Mary etc.). These computer scientists have proposed a graph-based learning algorithm based on the assumption that visually similar paintings share the same types of annotation. The dataset used contained images of print arts from the fifteenth to seventeenth century, annotated by art historians, and focused exclusively on religious themes. In [15] the analysis of print art images was extended using a larger dataset (PRINTART) with global semantic annotation (e.g Holy Family), localized object annotation (e.g. a bounding box around a Christ child), and pose annotation (e.g. bounding boxes around the head and torso of Mary). The research of Carneiro et al. [15] demonstrated that the low-level texture and color features, typically exploited for photographic image analysis, are not effective because of inconsistent color and texture patterns describing the visual classes in artistic images. An approach denoted as "inverted label propagation" was proposed and shown to produced the best results on the PRINTART dataset.

In the research of Graham et. al., [16] the question of finding the way we perceive two paintings as similar to each other was posed. Toward this goal, they collected painting similarity ratings from human observers, and used multidimensional scaling (MDS) methods to find the most correlated factors with human ratings. They analyzed two sets of images, denoted as landscape art and portraits/still lives. The analysis demonstrated that similarities between paintings can be interpreted in terms of basic image statistics. For example for landscape paintings, the gray-level statistics were shown to highly correlate with the similarity ratings. Regarding the category of still lives and portraits, the most important visual clues about their degree of similarity were determined to be semantic variables, such as the representation of people in a given composition.

The question of ordering paintings according to their date of production was posed by Cabral et al [17]. They formulated this problem by embedding paintings into a one-dimensional manifold (i.e. linear ordering), and tried utilizing two different methods. In the first, they applied unsupervised embedding using

Laplacian Eignemaps [18]. To do so, they only needed to employ visual features and defined a convex optimization to map paintings to a manifold. This approach is very fast and does not need the input of human expertise, but its accuracy is, unfortunately, low. The second method took into account the fact that, since some partial ordering on paintings is available by experts, this information could be used as a constraint and could allow the incorporation of Maximum Variance Unfolding [19] in order to find a proper space, which subsequently captured a more accurate chronological ordering of the paintings.

Unlike most of the previous works that focused on inferring the authorship of the artist from the painting, the research of Arora et al [20] approached the problem of the classification of style in paintings into classes that are recognized in the History of Art. They defined a classification task between seven painting genres: Renaissance, Baroque, Impressionism, Cubism, Abstract, Expressionism, and Pop Art. In their research, they approached the problem as a supervised classification problem and presented a comparative study evaluating generative (topic models) versus discriminative (classifier-based) models, as well as low-, intermediate-, versus semantic-level features. For the semantic-level features they used the Classeme features [21], which encodes an image in terms of the output of a large number of week classifiers, that are trained using images retrieved from Internet search engines, with an accompanying term list. The result [20] was particularly interesting; the research yielded that the semantic-level discriminative model produced the best classification result of 65% style classification accuracy, which was about 10% better than the next best compared model. Indeed, the use of verbal descriptors that are associated with the visual content of a painting led to a greater accuracy of classification than stylistic analysis alone. This result highlights the importance of encoding semantic information for the task of style classification and for the analysis of art in general.

The problem of discovering similarities between artists and inferring artistic influences was addressed by Abe et al [22, 23] by defining similarity measures between artists over a dataset of 66 artists and 1,710 paintings, spanning from the fifteenth to twentieth century. Based on the results of the research of Arora, [20] they also used the Classeme features [21] to encode the similarity of paintings. Artist-to-artist similarity was encoded with variants of the Hausdorff distance (a typically used distance measure between two sets of points). This similarity measure was used to construct a directed graph of artists encoding both artist-to-artist similarity and temporal constraints, and that graph was used to discover potential influences. They evaluated their results by computing the recall of their retrieved top-k potential influences against ground-truth influences collected from art historical sources. Figure 1 illustrates an example of similar paintings detected by the approach of [22, 23]; Frédéric Bazille's *Studio 9 Rue de la Condamine* (1870) and Norman Rockwell's *Shuffleton's Barber Shop* (1950). Not surprisingly, this type of comparison would not be cited in art-historical sources as the connection between the paintings is purely formal and coincidental. The artist graph was also used to achieve a visualization of artistic similarity (termed "map of artists") using a graph embedding procedure.

Fig. 1. An interesting computer recognized example of artistic influence, from Abe et al [22] is Frédéric Bazille's *Studio 9 Rue de la Condamine* (left) and Norman Rockwell's *Shuffleton's Barber Shop* (right). The composition of both paintings is divided in a similar way. Yellow circles indicate similar objects, red lines indicate composition, and the blue square represents similar structural element. The recognizable objects, – a fire stove, three men clustered, chairs, and window are seen in both paintings along with a similar position in the paintings.

Most the aforementioned research uses the analysis that Computer Vision provides to perform tasks implicitly related to aesthetic judgment on its most basic level. There also has been recent research which has developed algorithms to make explicit types of aesthetic judgment of images that evaluate the beauty of an object e.g. [24].

3 Perspectives from the Field of Art History: Does Computer Vision Pose a Threat?

Unfortunately, these developments in Computer Vision are not widely known or fully understood in the humanities and thus indicate the disjuncture between the fields of Art History and Computer Science and a larger fracture between the Arts and Sciences. While there has been some positive reception of the use of Computer Vision research in Art History, it remains limited and often confined to the domain of art conservation and connoisseurship. Not only is there a general unfamiliarity with the developments of new technologies like those in Computer Vision and their potential use value in the humanities, there is much trepidation about their implementation. While computer scientists tend to assume that their work will facilitate art historical research, art historians who are made aware of the capabilities of Computer Vision typically recoil at the prospect of such a collaboration.[1] Although art historians are generally skeptical of allowing computers to perform tasks that have been traditionally reserved

[1] Indeed, this response is reflective of apprehension regarding the digital humanities on a larger scale. These anxieties are well expressed in, Stephen Marche, "Literature is not Data, Against Digital Humanities," [25].

for trained specialists and deemed capable for only human comprehension, to date, there has been to our knowledge, no exact measures of this implicit distrust in the sciences to produce knowledge of a subjective nature. While the digital humanities project has been met with criticism we are unaware of any surveys gauging its extent. Given the radically divergent assumptions and misperceptions between Computer Scientists and Art Historians, we composed two surveys: one for art historians and the other for computer scientists to capture a base-line measurement of the current opinions on this specific example of the digitization of the humanities. While early results from the surveys have confirmed the aforementioned assumptions, by the end of August of 2014 we will have obtained complete results in a sample group that includes Princeton University, Rutgers University, Pratt University, and New York University.

Indeed, the key survey question, which inquires how art historians could use Computer Vision to better understand paintings, aroused a strong territorial response from the field of Art History. Rather than further this sequestration, the authors of this paper have been trying to build a bridge between the disciplines, investigating and analyzing the consequences and perceived threat that the use of AI in domains traditionally understood to be reserved for humans pose. What does it mean when an art historian, who is trained to evaluate art, or even a novice admirer of art is faced with a machine that can perform a similar task? Since the very nature of our ability to aesthetically comprehend and judge beauty is the determining factor in what most people would describe as distinguishing us from machines, this type of computer science threatens our own conceptions of human identity[26]. While it is important to recognize these anxieties, we would like to propose that understanding some of the philosophical origins of how we have come to regard aesthetic judgment may more precisely explain why it is that persons not trained in computer science perceive these developments as a threat. Computer Science, neither our friend, nor foe, presents to the humanities a challenge: is intangible, or sensory knowledge really intangible if a computer can perform processes that manifest the same results that a human would produce?

4 Aesthetic Judgment: Between Philosophy and Art History

The concept of sensory knowledge derives from a long tradition in European theology, philosophy, and psychology, although, it was not until the 18th-century that this type of knowing began to be perceived in a positive light [27]. Predominantly on account of Alexander Gottlieb Baumgarten's Aesthetica, published in Latin 1750, the notion that there was a type of knowledge distinct from that of logic or reason, gained acceptance [28]. He termed this knowledge as *analogon rationis*- or analogue of reason, which had its own perfection distinct from logic. In consequence to this theory, it came to be argued that there should be two kinds of corresponding sciences of knowledge: that of logic and that of aesthetics. Baumgarten's philosophy provided the foundation for Immanuel Kant's theories

on aesthetics and the immediate background for the *Critique of Judgment* published in 1790 [1, 27].

The key to Kant's discourse was his rooting of the condition of aesthetic discernment in a subjective, non-logical process. Indeed, the philosophy of aesthetics from Baumgarten to Deleuze, not necessarily including the branch of philosophy that Hegel directed aesthetics, places aesthetic comprehension in the realm of subjectivity. Kant articulated the conditions of this type of reasoning in the *Critique of Judgment*, locating aesthetic understanding in moral philosophy and the principles of universality[1]. In part one of the *Critique*, Kant explains the processes of analysis that is required for the interpretation of art. He writes:

> If we wish to discern whether anything is beautiful or not, we do not refer the representation of it to the Object by means of the imagination (acting perhaps in conjunction with understanding) we refer the representation to the Subject and its feeling of pleasure or displeasure. The judgment of taste, therefore, is not a cognitive judgment, and so not logical, but is aesthetic- which means that it is one whose determining ground cannot be other than subjective.[1]

Despite the focus on the subjectivity of aesthetic interpretation through individual judgment, Kant goes on to explain that the judgment of taste is also universal. He considers this in regards to the knowledge of how things are, or, their "theoretical knowledge," and to how things should be, or their "morality."[27] Kant argues that judging art is like judging the purposiveness of nature, as both can be examined in terms of beauty, either natural or artistic. While the philosophical relationship of nature and art remain outside the confines of this paper, it is important to take note that art was largely evaluated in terms of its faithfulness to imitating nature until the modernist revolution led to the questioning of these very premises.

Just as nature was valued in terms of its purposiveness and its ability to manifest this quality in its appearance, so too was art through its references. In this sense, Kant's perception of the quality of art is bound to the principles of the Romantic Movement, "the world being the Artifact of a divine Artificer[27]-p65." Positioning himself against classical rationalism, that beauty is related to a singular inner truth in nature, Kant instead suggests that beauty is linked to the infinite quality of the human imagination yet grounded in finiteness of being. In this sense, the universality of taste also related to a type of collective consciousness that stems from God's universal creation. Kant further related aesthetics and ethics, positing that beautiful objects inspire sensations like those produced in the mental state of moral judgment, thus, genius and taste could be related to the moral character of an artist or viewer. How moral values can raise or lower the aesthetic value of art is, indeed, a subject of philosophical scrutiny to this day [29].

The direction that Kant steered Aesthetics has had a pervasive influence in Philosophy into the contemporary period as Gilles Deleuze's conception of a transcendental empiricism demonstrates in its use of Kantian notions of sensibility. While Art History has a tradition of intellectual borrowings for its theories and

methodologies, its montage nature as a discipline, incorporating the perspectives of diverse fields in the humanities such as Philosophy, Comparative Literature, Anthropology, Archaeology, and Psychology, to name a few, has allowed for its inherent flexibility in critical interpretations that rarely produce a singular analysis of Art. Indeed, parallel interpretations of a given object are implicitly understood to exist stemming from a wide range of theories and methodologies such as formal analysis, studies in iconography, conservation history, connoisseurship, Marxist theory, feminist theory, or social history, to list just several art historical perspectives all of which may overlap or exclude each other.

Although the birth of Art History is usually associated with the Renaissance and Giorgio Vasari's writing of the Lives of the Most Excellent Painters, Sculptors, and Architects, first published in 1550, how we define the origins of the discipline differs greatly according to the artistic tradition being considered thus nuancing any standardization of what is meant by art historical analysis. In the West, Greek philosophers such as Plato and Aristotle could be credited with engaging in an early form of art history, commenting at length on the faculties of observation gained through sight and the physical drives associated with seeing [30]. Indeed, throughout the history of the discipline, Art History has been directly influenced by the sciences to varying degrees over time and according to geography, yet never to the exclusion of philosophical approaches to the interpretation of art. For example, Carl Linnaeus (1707-1778), the founding father of modern taxonomy who drew heavily from Francis Bacon's (1561-1626) scientific method of empiricism, may be credited with establishing the foundations for the classification of artifacts in museums through his organization of natural history objects in Uppsala, Sweden concurrently with philosophical developments in the History of Art [31, 32].

As Eric Fernie has pointed out, "it is no exaggeration to say that . . . the first thorough reassessment of the techniques and standards of connoisseurship since they were established by Vasari," however, were addressed by Giovanni Morelli (1816-1891) [33]. While the period from the sixteenth century to the end of the nineteenth century witnessed many methodological developments in the History of Art, these contributions were largely philosophical and less emulative of the direction Linnaeus took the interpretation of museum worthy objects. Morelli's innovation was to focus on methods of connoisseurship that privileged direct engagement with a work of art that allowed for a very precise type of visual investigation. For instance, the rendering of a detail such as an ear or the shape of a fingernail could reveal the true authorship of a painting [34]. By contrast, to more philosophically minded art historians less concerned with issues of attribution, the concept of aesthetic appeal lay in the synthesis of form and content.

Morelli writes in a dialogue from his book, *Italian Painters*, 1890, "Art connoisseurs say of art historians that they write about what they do not understand; art historians, on their side, disparage the connoisseurs, and only look upon them as the drudges who collect materials for them, but who personally have not the slightest knowledge of the physiology of art."[35] Morelli and later,

the Vienna School of Art History, which was heralded by Alois Riegl's (1858-1905) contributions on the history of ornament in terms of form (as opposed to history or philosophy) underscore the strictly material interpretation that the History of Art also accommodates. Not surprisingly, the legacy of the theories of art espoused by Morelli and Riegl find immediate application to the world of connoisseurs, conservators, and museum associates. In the same vein, this types of materialist inquiry opened theoretical ground for philosophical consideration of the history of art measured through the development of form itself, devoid of its socio-historical constraints.

While space does not permit a complete analysis of the history of Art History and its entanglement with the sciences both in terms of the faculties of vision and aesthetic judgment along with the field's engagement with scientific methodologies, this review highlights the sustaining influence of science in the arts and its philosophical inspirations. If we were better able to understand the capabilities of Computer Vision technology, why wouldn't art historians consider the philosophical implications of this modern-day science on aesthetic theory?

5 The Implications of Aesthetic Philosophy and Art History

The machine's ability to make an aesthetic judgment about a painting, and, then, compare it stylistically, to other paintings, demonstrates that logic is at work in the complicated algorithms that comprise the AI system. These processes are all clearly imitative and objective at the point of the computer program training period; once the machine reaches the automaton level, the question of subjectivity enters. In this sense, are computers programmers like blind watchmakers, to use Richard Dawkin's famous metaphor of the evolution of the universe and the free-will debate[36]? Are computers comparable to humans with genetic codes that predetermine outcomes, which are then shaped by the environment?

While the research on the similarities between neurobiology and computer systems is burgeoning, we are reminded of the origins of the field of Computer Science itself. Fortunately, a new area of research: *neuroaesthetics*, has begun to explore the seemingly parallel nature of these processes[37]. For example, we know that it is the prefrontal cortex that is involved in aesthetic judgment and that this unique feature of our executive brain functioning distinguishes us from our primate ancestors. Nonetheless, the questions remain the same: if we are able to create artificial intelligence that performs types of reasoning that we have long considered subjective, we are either more machine-like than we admit, machines have more human potential than we estimate, or these processes are, in fact, tangibly measurable and, in fact, objectively determined. In essence, the debate moves to the question of determinism and free will. While most people would agree that a computer, even one that has reached automaton status and has the ability to learn from its environment is not free, we are less willing to concede the notion of human freedom when we too are ultimately bound by our genes and environment. For the 18th century philosophers, reasoning, particularly in

the domain of subjectivity, was tied to God through morality and universality in terms of the decisions we are perceived to *freely* make. Are these philosophies not still debated today but in different terms?

We would like to suggest that how we understand Aesthetic Judgment can still be tied to the 18th and 19th- century philosophical tradition yet we need to better interpret how these "subjective" processes work, if they even are subjective, and integrate new scientific developments, such as those in neurobiology and computer science into our conceptions of how knowledge is produced. Fortunately, significant inroads have already been made on this front within the field of art history such as Michael Baxandall's well known consideration of the "period eye" and the processes of visual interpretation on a biological level [38]. John Onians summarizes the history of biological inquiries of the interpretation of art in his introduction to Neuroarthistory ([37] p 1-17). Nonetheless, it is a paradox that developments in computer science could have pushed the humanities to re-evaluate its most basic premises: for art history this is how we determine that something is beautiful and/or important, and, how objects are interrelated. Have the advances in science not provided a platform in which we can begin to understand cognition, as it is applied to aesthetics, in a radically different way than 18th- and 19th- century philosophers conceived these processes? We easily discredit the idea of humors as ruling temperaments of the body but know that Kant considered them viable and one of them as an indication of the absence of temperament[39]-p79. We still read Kant for his interpretations of physical and psychological states, yet not on his theory of the phlegmatic humor.

Science is obviously not the only domain from which to take direction. Let us heed caution from the aesthetic critics such as Julius Meier-Graefe who, in 1904, explored the problem of the dominancy of paintings in the history of art in his response to Modern Art and the new mediums the movement favored [40]. That a machine has the ability to examine paintings does not mean that it has the capacity to understand sculpture, installation art, performance art, or land art. What would a computer make of the Christo and Jeanne-Claude installation of the wrapped Reichstag (Figure 2)? Both three- and two- dimensional computer vision programs would be able to determine the sharp edges of the building and sense its occupation of a large amount of space, either in reality, or, as it appears in a photo, yet, how would the significance of the wrapping of such a canonical architectural form loaded with symbolism be readily understood and quantified for qualitative analysis by a machine? When computer scientists one day will simulate the human brain, will the machine understand the Christo and Jeanne-Claude installation? Will machine aesthetic judgment be any different than human aesthetic judgment? Who shall we give the authority to make that judgment? These are important considerations to make in our society as it adapts to the advances in artificial intelligence. Norbert Wiener's famous remarks on the effects of what he termed, "cybernetics," in the world, remains so relevant today. In 1950 he perceptively wrote that, "the machine, which can learn and make decisions on the basis of its learning, will in no way be obliged to make such decisions as we should have made, or will be acceptable to us. For

Fig. 2. Wrapped Reichstag, Berlin, 1971-95 Christo and Jeanne-Claude, Photo: Wolfgang Volz 1995 Christo

the man who is not aware of this, to throw the problem of his responsibility on the machine, whether it can learn or not, is to cast his responsibility (and we would add, his *freedom* as a human,) to the winds [41]."

6 Within the Limits of Probability: Computer Science and Art History Today

This paper has considered both the limitations of Computer Vision research and its potential for growth in regards to its application for Art History. In conclusion, we would like to underscore the current concerns that this research poses for art historians in its immediate application. We have thus highlighted three main issues that demand further attention: the use of language between fields to describe global and specific concepts, the lack of uniformity in the interpretation of art including the degree to which social context and emotive interpretation versus the autonomy of form are valued, and the separate developments within Computer Science and Art History regarding aesthetic interpretation.

Firstly, there is alarming discomfort in the globalizing language that Computer Scientists use to describe their research. Rather than make claims about a computer's ability to analyze Art at large, specificity as to what can be analyzed and what has been analyzed would assuage philosophical anxieties about the ontological nature of man versus the machine [42]. In this paper, we have been careful to describe computer analysis of what computer scientists call "Visual Art," a term that is not readily utilized in Art History, as an analysis of paintings from some of the canonical movements in art through history in the Western tradition. Instead of framing computer vision research in broad and global terms that are unsupportable (from the humanities' perspective), demonstrating the potential of this technology through specific examples allows art historians to consider its value in ways that don't interfere with their critical approach of analysis. If we can shift the onus of interpretation to the art historians, computer scientists would likely find art historians more willing to collaborate,

ensuing more fruitfully applied research. While Computer Vision research has been instrumental in art conservation applications, it has not been utilized by art historians for more aesthetically based interpretations.

We would therefore like to propose that computer scientists collaborate with art historians on specific projects. Research that concerns the analysis of a multitude of images related to one artist or movement could be facilitated by the current capabilities of Computer Vision technology. The ability to compute perspective coherence, lighting and shading strategies, brushstrokes styles, and semantic points of similarity could, for example, aid the analysis of a large group of Italian drawings with unclear authorship. Recent collaborations of this nature have already been initiated and should continue (e.g. [13, 43]). While this type of collaboration lies in the domain of connoisseurship more than what one would term Art History, it seems clear that working within the realm of current Computer Vision technology capabilities is the best way to build a collaboration between the fields that would eventually ignite a more philosophical understanding of these methods and their bearing on aesthetic theory.

The second issue that comes up regarding the immediate application of Computer Vision research in the domain of aesthetics concerns the way the social history of an object and the emotional engagement to Art is calculated. In Art History, the degree to which the context in which a work of art is produced should matter. How can a computer quantify the social history of a painting or the material means of its production? It is exactly this point that the critical theorists of art raised more than a century ago regarding the nature of art "as both context-bound yet also irreducible to its contextual conditions."[44] To quote Michael Podro, "Either the context-bound quality or the irreducibility of art may be elevated at the expense of the other. If a (theorist) diminishes the sense of context in his concern for the irreducibility or autonomy of art, he moves towards formalism. If he diminishes the sense of irreducibility in order to keep a firm hand on extra-artistic facts, he runs the risk of treating art as if it were the trace or symptom of those other facts[44]." If art is treated autonomously, as having an independent progression in the realm of form, its history is purely stylistic. For the critical theorists, before form could independently hail meaning for the modernists, this extreme was considered an aesthetic failure, as judgment requires morality and thus was tied to value-based interpretations of art at the level of object analysis [44].

In essence, there is no singular "correct" interpretation of a work of art within Art History as multiple theories and methodologies place differing emphases on style, content, and context. To date, Computer Vision research offers predominantly stylistic interpretations of paintings that only recently have begun to include iconographic considerations. While these tools have allowed us to categorize paintings into broad genres and chronologies, Computer Science is currently unable to offer more immediate associations regarding the specific social history of an object and the degree of influence that these conditions shaped the final product. In the same vein, certain periods or genres are more amenable to some theoretical approaches than to others. For example, Abstract Expres-

sionism, which is highly concerned with the role of form over content, naturally accommodates the high degree of stylistic interpretation that Computer Vision offers. Within Modern Art, Computer Vision research might have the potential to offer unexpected insights on the level of style.

Due to the use of broad data sets, it is not surprising that Computer Scientists have noticed some far-reaching stylistic influences. For instance, Automatic Influence Detection demonstrated the ability to detect less overt connections between artists such as Eugene Delacroix's not so widely known influence from El Greco both in terms of color and expressiveness [22]. While this observation highlights the remarkable subtleties of interpretation that Computer Vision is capable of generating, this type of analysis is of less use to an art historian than a more specific study such as what an analysis of Kazimir Malevich's fairly uniform appearing Suprematist paintings might reveal in regards to style.

The last critical issue that emerges concerns the way we locate and attribute the onus of interpretation in Computer Vision analysis. To what degree can we ascribe the detection of influence or artistic merit to a machine when it was the computer scientists that wrote the programming that associated certain visual components with particular markers of identity? At what point in the process of "training" the program to make its own judgments does the machine develop autonomy, if ever? If computer scientists can be charged with owning the responsibility of artistic interpretation at the level of programming input, why wouldn't art historians be involved at this level of the research? While there is no question that programs have demonstrated the ability to take on an autonomous quality based on what they have been "taught," are these innovations so advanced at this point in time that we can consider them on par to human judgment? Unfortunately, the aesthetic interpretation in Computer Science is developing in isolation from the aesthetic discourse from Philosophy and Art History. If the humanities were able to more clearly understand the use-value of Computer Vision research in a non-threatening manner and art historians were able to collaborate with computer scientists as machine-based aesthetic interpretation develops, both fields would benefit.

That a computer is able to measure art aesthetically challenges the field of Art History to reexamine its own aesthetic constructs. David Hume pontificated that "beauty is no quality in things themselves: it exists merely in the mind which contemplates them; and each mind perceives a different beauty[45]." If the interpretation of art lies in the eyes of the beholder and is thus a subjectively determined process that is associated with feeling, how can we understand the development of autonomous aesthetic evaluation from a computer without re-evaluating the processes of human aesthetic judgment and emotion? Awareness of these concepts could equally steer the direction of Computer Vision in terms of its abilities to provide immediate practical applications to the field of Art History rather than taking on the uncomfortable guise of a virtual art historian.

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