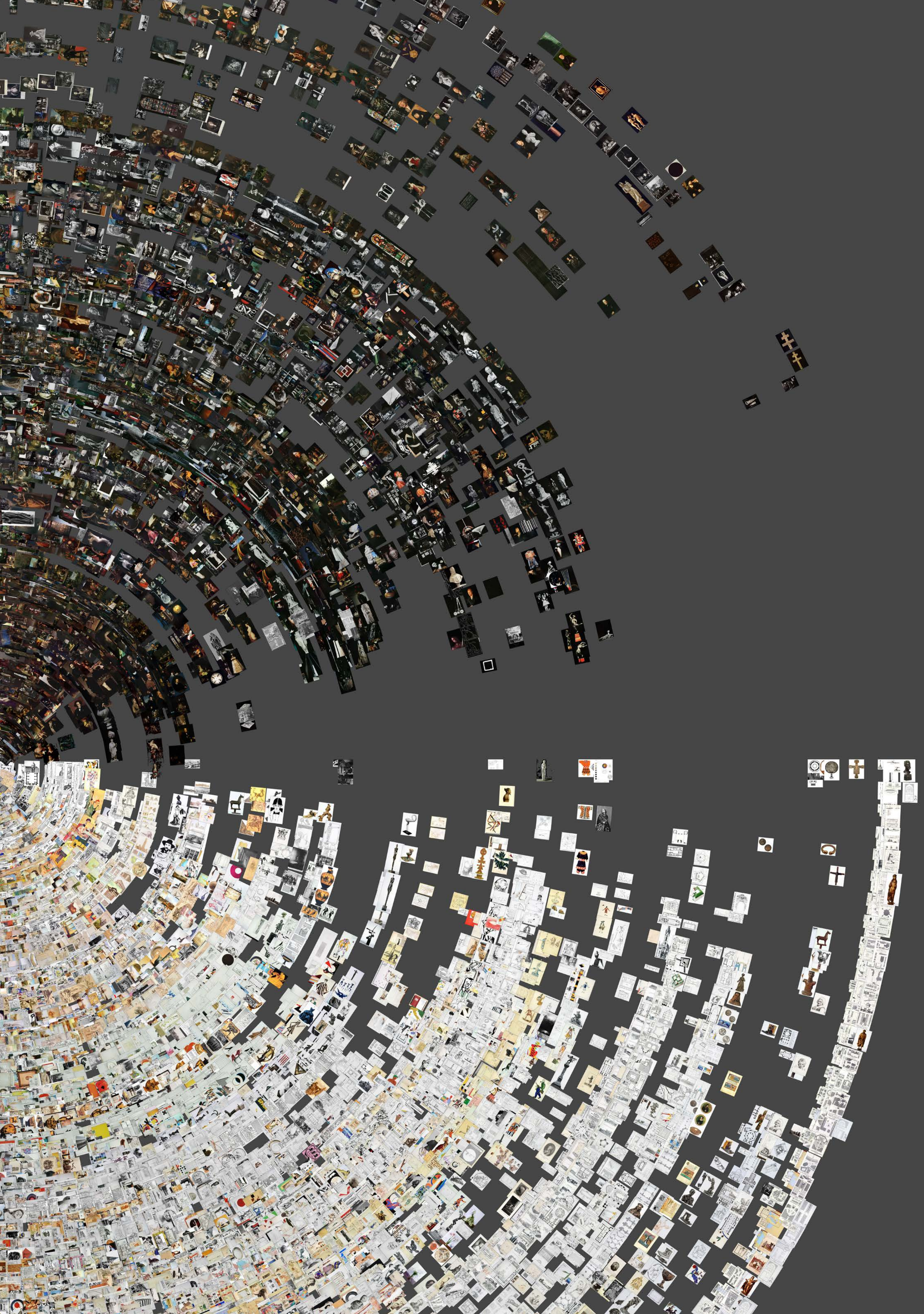

Big Image Data within the Big Picture of Art History

Harald Klinke

Abstract: The use of the computer in Art History is changing the approach towards our objects of research. Now, we are able to compute more images than a human can see in a lifetime. That, in turn, calls for a new definition of the role of the researcher and the tools being used. The access to large amounts of visual data stands in a tradition of conventional methods of Art History, but also augments them with quantity. This article proposes a theoretical model on which to build an understanding of the meta image with which we interactively derive our conclusions.

Keywords: Big Data, Digital Humanities, Distant Viewing, Information, Media, Meta Image, Methodology, Qualitative/quantiative Research, Semantic Gap

The digitalization of Art History is creating enormous opportunities. Among the most striking is that we now have the opportunity to not only look at a single work of art—or the comparison of two—but that we are also able to compare more pictures than a human can look at in a lifetime. This concept is called Big Image Data (BID).

Taking a look at our discipline's methodology, the first systematic approach that comes to mind is Erwin Panofsky's iconography and iconology.[1] According to him, and in contrast to all other disciplines in the Humanities, art historians take the visual record seriously and derive knowledge from it by reconstructing an artwork's meaning layer by layer. The goal here is to embed the individual object into its cultural and historic context. Art History is, thus, an empirical science that gathers and interprets visual data. This is one reason why Art History is, in German-speaking countries, also called "Bildwissenschaft," the science of pictures. It should be noted that Panofsky knew that starting with the visual phenomenon does not allow the exclusion of any written records. It is only natural that scholars in front of a work of art will acquire knowledge from books and compare their findings with those of other scholars, and then add to this shared knowledge through future publications.

Figure 1: About 60.000 images taken from the Artemis database (LMU Munich) sorted by average brightness using ImagePlot developed by the Software Studies Initiative

Another art-historical method comes to mind: the side-by-side comparison of pictures as established by Heinrich Wölfflin.[2] What has been done with originals and painted or printed copies before the advent of slide projections turned into a central method in our discipline through the use of double slide projectors. Comparisons make clear the differences as well as the similarities of the studied objects. The findings can then be discussed and converted into insights, such as the question of the object being an original or a copy, questions of dating (*Datierung*), or authorship attribution (*Handscheidung*).[3] A slide library containing hundreds of thousands of high resolution color images is a powerful means of navigation through the history of art.

Both methods show that no other discipline looks at pictures as systematically as Art History. They also show that individual scholars and their visual experiences acquired over the years are at the center of this kind of research. In both cases, researchers need a mental archive of images in order to identify figures by their attributes and to select objects for comparison. Would it not be great to go a step further and use computers to be able to consult a much greater variety of artworks, to use algorithms to recommend further works that might be of interest to the researcher? Would it not be great to let the computer do the work of sifting through a great number of artworks in order to deliver meta information on an enormous corpus of images?

This capability is exactly what the Digital Humanities promise. As the Natural Sciences have used computers to yield unprecedented insights that were not possible before, such as the sequencing and analysis of the human genome, the Humanities are able to make the computer a tool for their research, too. Ever since Roberto Busa created a lemmatization of the works of Thomas Aquinas using IBM computers in 1951,[4] text-based Humanities have developed many software tools to obtain an overview of text corpora employing statistical methods, to uncover semantic structures via text mining, and to develop new insights into language using Corpus Linguistics. The visual sciences, the foremost being Art History, started to integrate computational methods in the early 1980s,[5] but progressed slowly for several reasons.[6] The most important reason is that images are much harder for a computer to process. This might seem to be an odd statement, especially since digital images consist of nothing beyond a string of information units called bits like all other digital media. But this matrix of pixels does not “mean” anything to the computer at first.

While one string of ASCII characters[7] in a text can be compared to another (search), they can be summed up in a corpus (frequency distribution) or become the basis of statistical calculations (text mining). A string of pixels on a display is nothing more than a sequence of brightness values on the visible light spectrum (red, green and blue) at first. However, we are able to calculate and use these color values as the criterion to sort images[8] in a process involving these "low level features" of images (see figure 1). This process, however, is limited in its epistemic potential.[9] In contrast, "high level features" are what those pixels represent; the content of the images. Between both of these lies the "semantic gap," where high level features are perceived by humans with ease, whereas the computer still struggles. Information Science—Computer Vision in particular—is working on this problem via pattern recognition, deep learning, and other approaches, but there is still much research to do.[10] As research is carried out, it will increasingly provide the means to work with images that Art History can use for its own purposes.

At this point, we have to distinguish two concepts. Reading a book of literature and writing about it has been called "close reading." Having all works of an author in a digital format and comparing them to those of another author by means of statistical analysis is an example of "distant reading."[11] It offers the possibility to use computers to work with data in order to analyze a greater number of books in a matter of seconds than an individual could hope to read in a lifetime. These concepts can also be applied as standard methods of study for Art History, where "close viewing" describes the study of individual reproductions of artwork. In the same vein, "distant viewing" describes what algorithms are increasingly able to offer: examining an infinite number of images at once and deriving meta information from that corpus of images.[12] Dealing with a massive amount of data is a tremendous challenge for Art History. The good news is that there is no need to start from scratch. Other disciplines have dealt with images before: medical applications deal with images, such as high quality x-rays. Biology has developed software to handle pictures produced by microscopy in order to quickly discover clusters or count cells. Astronomy, Geology, and other similar disciplines incorporated such tools into their daily practices long ago. In particular, one field of Information Science has advanced quickly of late: Big Data.

Big Data has been a buzzword for a few years now. In 2012, it was identified as the biggest trend by Bitkom—the German IT Trade Association—and in 2014, Big Data was the theme of the CeBit trade fair. The reason for this recognition is that it promises unprecedented insights into social behavior and new possibilities for business models. At the same time, it stokes fears of surveillance and espionage. Big Data seems to be defined as the collecting and analyzing of data, with the ultimate result and goal to make money; Facebook, Apple, and Google come to mind when discussing Big Data. With data, companies not only know what we do, but also things that we *might* do.[13] Some say that data is the new raw material.[14] And the massive amount of data is not the problem, but the solution.

Big Data, first of all, is an Information Science concept. Only in combination with business does it become a concept for profit maximization. It has the potential, in combination with science, for "knowledge maximization." Moreover, it can become a fruitful tool in the Digital Humanities. While "data" is generally used here to denote values, such as sensor results, the challenge for disciplines like Art History that use images is figuring out how to gain knowledge from a mass amount of visual data. How can we understand the hidden connections between images on a macro scale? How do we deal with what could be called Big Image Data?

What is a Digital Image?

Large amounts of images can be a treasure trove. An art-historical image database can represent a relevant section of art history for specific research questions. But before we are able to unearth such a treasure, we first have to understand what kind of data digital images are. If we want the computer to help us generate art-historical knowledge, we have to go a bit further and ask what an image is, generally speaking.

"What is an image?" was the central question posed in Gottfried Boehm's 1994 publication that spurred Visual Studies. His thoughts were based on the assumption that we are living in a time when we use images in a quantity unprecedented in human history (and that is truer than ever today, 22 years later). Since we have sciences for language, there must also be a science for images (*Bildwissenschaft*).[15] So again, what is an image?[16] An initial approach to answering this question could be to name the objects that we include under the term "image." The history of art knows many such objects, and paintings are only one of them. Photography has arguably been the most important revolution for images. One can incorporate not only artistic productions, but also the broad field of amateur photography. In addition, technical images have to be added because they are mainly used in the natural sciences. Effigies, wax figures, and other such items are also undoubtedly understood as images.[17] Finally, so-called internal or mental images are also a part of the Visual Studies, even if they are of a fundamentally different nature than the aforementioned external images. As a matter of fact, in the English language we sometime prefer to call external images "pictures."[18] The two are closely tied together, as pictures cannot be sufficiently explained without images.

In addition, the term "picture" refers to another important concept. The conventional panel painting has, for centuries, dominated European art history. Following its example, art theories have been developing since the Renaissance. But only with the invention of photography—and with approaches to make them theoretically comprehensible—a new concept has become necessary: the concept of the medium. The term "medium" here denotes the carrier of an image that makes the visual phenomenon possible by its physical configuration.[19] The term is necessary in photography to make clear the relationship between originals and copies. A photograph allows for the production of a series of positives from one negative. Unlike reproduction graphics, the first and the hundredth copy do not differ appreciably. This has been made possible by using a specific medium—chemical photography, in this case. The distinction between image and medium makes clear what is new about photography and its demarcation from painting. A picture became not only something that could represent something else (a distinction between the picture and what is pictured, see figure 2), but it could also appear with different characteristics in its production, distribution, and reception. It is noteworthy that after nearly 100 years of image-making practices with photography, these crucial concepts were discussed for the first time in 1936 by Walter Benjamin.[20] This opened up the opportunity to make the new image phenomenon tangible; make us able to conceive a history of visual media and media theory.[21]

Today, we are living in a time where revolutionary changes in the hegemony of visual media are being made again. A new visual medium has joined its peers and, similar to photography, challenges other media in their artistic standards and continues to drive the democratization of image production and lets the flood of images skyrocket. This new visual medium is the digital image.

The advent of the digital image—just think of the spread of digital photography—challenges the older media at least as radically as photography did in the 19th century. It represents a new challenge to conceptual tangibility, just as photography did. At the same time, it is itself the driving force to develop new ideas about what images are. Just as the photograph required the concept of media, the digital image requires new terminology in order to make its unique ontology understood, as well. The difficulty in making digital

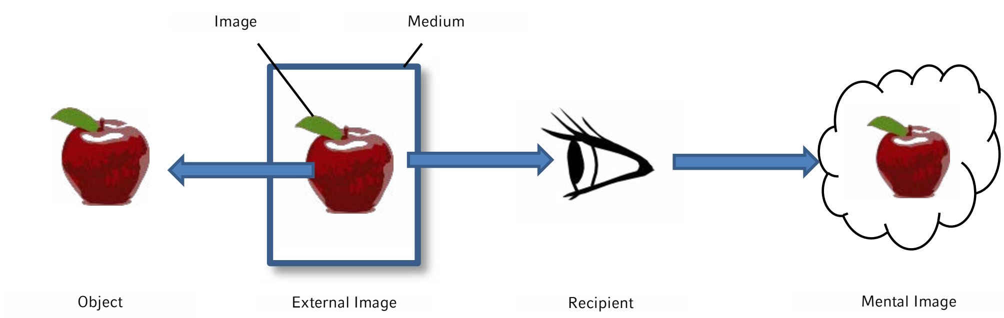

Figure 2: Scheme of image and medium

images understandable comes from the fact that the concepts developed for the older image media must now be challenged: What is the image of a digital image? What is the medium of a digital image? The distinction of image, what is being pictured, and the medium no longer seems sufficient. Therefore, the digital image can only be understood when new terms are introduced.

A few specific examples will make it easier to grasp what has been introduced by the digital image. The simplest example of a digital image is probably the digital photograph. It is noteworthy that even especially high-priced digital cameras today imitate the mostly conventional Single Lens Reflex camera (SLR) in design. The film has been replaced by an image sensor, such as a CCD chip. The advantage of this technique is the immediate consideration of the result on a screen, so much so that in compact cameras, the optical viewfinder has largely been phased out in favor of a visual display. The revolution of photography was, at one time, the chemical fixation of the volatile image of the camera obscura. Today is quite similar, where digital image captures can be displayed on a pixel matrix (see figure 3).

Another example of a digital image is when you work in a graphics program, such as Adobe Photoshop, on a computer. The image is visible on the display and can be changed using a graphical user interface that is controlled by mouse and keyboard peripherals. The possible changes to brightness and contrast, to collage or "paint," have replaced the conventional processes used in a darkroom.[22] The "retouched" image can subsequently be sent or shared via email or social networks and made available to other viewers.

A third common form of the digital image is—as opposed to digitized—the computer generated image (CGI) as used in computer games (first-person shooters, for example), movies, or design software. The on-screen visible

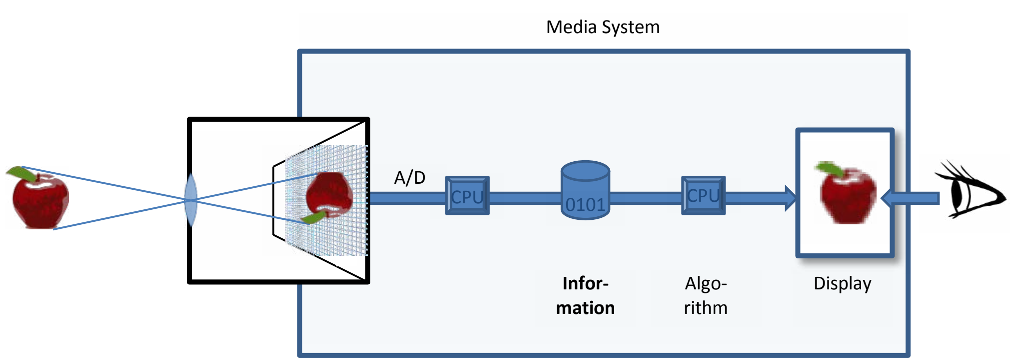

Figure 3: Basics of digital photography

image is now generated based on data and algorithms devised through computational steps. In addition, this allows for manipulation of the image by the recipient (now called the “user”) in real time.

These are all undoubtedly examples of images, and there is something they all share: the visible and the object being pictured. Also, digital images represent something visible by means of the image carrier (the medium). Yet, it is clear that we are dealing with a special picture system here whose unique ontology becomes clear when examining the differences with older picture systems. The “image” on a camera’s memory chip is itself not visible, comparable perhaps to an exposed roll of film in a sealed opaque cartridge, carrying the latent images only. And yet the “latency” of digital images on the chip is different because it is made visible through a different process than chemical photography. In image processing, it is clear that the image can be changed with more ease than performing the same changes in a darkroom. It can be copied without loss and can become visible anywhere in the world almost simultaneously. Finally, computer generated imagery does not need to be in direct proportion to the visible reality; rather, it can be created and modified in real time. This can be done with such quality that the impression of immersion may occur, which was not previously possible with any other visual medium.[23]
If one examines the “image” in the strict sense (what is visible with the help of a medium that has a reference to something), the question arises: what is the medium of the digital image? It is certainly not the display alone. In digital cameras, the memory chip and the files it contains are important elements. When one thinks of Internet applications, it is clear that the display unit and the file do not even need to be in one place. The file is located on a remote server and can be fetched via the network at any time.

Strictly speaking, the CCD chip converts the local brightness values of RGB colors via an analog/digital converter into numbers, which are then compressed using a processor and written to a file (such as the JPEG format) where they can ultimately be presented as on/off states. In reverse, the data is read, decompressed, and outputted as the brightness values of the three primary colors on a display. Any alterations via imaging software takes place only indirectly on the display (the graphical user interface is the interface between users and the data; between man and machine).[24] In fact, the database is changed by a computational process. For example, brightening an image corresponds to the addition of a value to each RGB value of the pixel matrix, darkening an image is a subtraction, and contrast enhancement is actually a stretching of the histogram. The image is finally generated by calculating the numerical values of the individual pixels. In other words, the computer knows no image, only numbers. It does not “see”—it only calculates.[25]

The system, as described, makes it clear that we have to add a new concept to image and medium: the concept of information. The science of digital images must be understood as information theory of images. The individual bits of memory contain the information that must be interpreted by applications to provide meaningful messages. A string of bits, like 01000001, can be interpreted as a decimal (65) or—according to the ASCII table—the letter "A" or a brightness value of a pixel. In this way, not only numbers and letters, but entire pictures, sounds, and myriad pieces of data can be coded in binary, processed, and transported as a signal.

But that is not the image. It is the information that is later turned into an image through hardware and algorithms; in other words, by an overarching system that may be referred to as a medium. This process is called "visualizing." The information can be displayed using a computer screen, two screens, be presented as printout, etc. These are only different forms of visualization of the same information.

The question "where is the image in a digital medium?" can now be answered: it is not in the memory storage device. The information stored by the memory device is required to represent something through the use of the medium. The medium—the system that makes the information visible—can be labeled as a computer, which is designed according to the von-Neumann principles. A von-Neumann-computer consists of controller, arithmetic unit, memory, input unit, and output unit components.[26] Every digital camera, smartphone, and laptop consists of memory, a processor, and a display. The seemingly placeless image, e.g. a picture posted on Facebook, can be retrieved from different places, uploaded, and downloaded. Such images basically consist of a string of bits in a file format, such as JPEG, it is located on an Internet server and is transferred on demand to the local machine. The file is interpreted there by using programs and made visible by the graphics and display hardware as an "image." This entire system can be called the medium, and therefore its task is to visualize the string of bits.

If we have thus defined and distinguished information and media, what then is the "image"? In summation, the distribution of brightness of the red, green, and blue values on a screen's pixel array results in an impression of contiguous areas, which are detected as objects based on one's experience with the real world. In other words, an "image" of something. Consequently, the "image" is the visual phenomenon as perceived by the viewer.[27] More specifically, it is the light projected on the retina, which is then converted into nerve signals and—preprocessed by the metathalamus— perceived in the visual cortex.[28] In short: what is visible is the visual phenomenon. In order to avoid obfuscating the term "image," the following descriptors should be used: information, media, and visual phenomenon.

These terms enable a clear description of the digital images. A digital camera generates information that can be visualized on a display or photo printer. The image processing program changes the information (via a graphical user interface), which is then sent and displayed on devices. To "send a picture" is colloquial and actually means to transmit information signals that are interpreted and displayed on the device as a visual phenomenon recognizable by humans. Computer games generate sequences of bits using data and algorithms. These bits are visualized using the medium and are perceived as visual phenomenon.

These terms can be applied to more than digital images. With conventional panel paintings, there was no need to question the medium because the visible phenomenon was inseparable from the physical medium.[29] Image reproducibility extended the medium's properties and allowed for the new concept of the new visual medium to form. The term "medium" can then be traced historically back to the paintings: the medium "painting" consists of pigments with a binder (e.g. oil) and applied to a substrate (wood or canvas). Because of this material configuration, a visual phenomenon can be experienced, which creates the impression to refer to objects outside of the picture itself.

Accordingly, in photography, there was no need to question the information because the image information was irrevocably connected with the image carrier. Image data processing systems introduced new complexities to what the information entails. It called for precise descriptions and a more comprehensive understanding of this new imaging system. This concept of information can also be traced back historically. As stated above, the information is hidden behind the visual phenomenon and defines the brightness and color distribution for the output device. Viewed as a whole, these pieces of information coalesce to form a visual impression—specifically, the brightness values of RGB subpixels. The values associated with each cell of the matrix are not permanently fixed, because the brightness on a display can

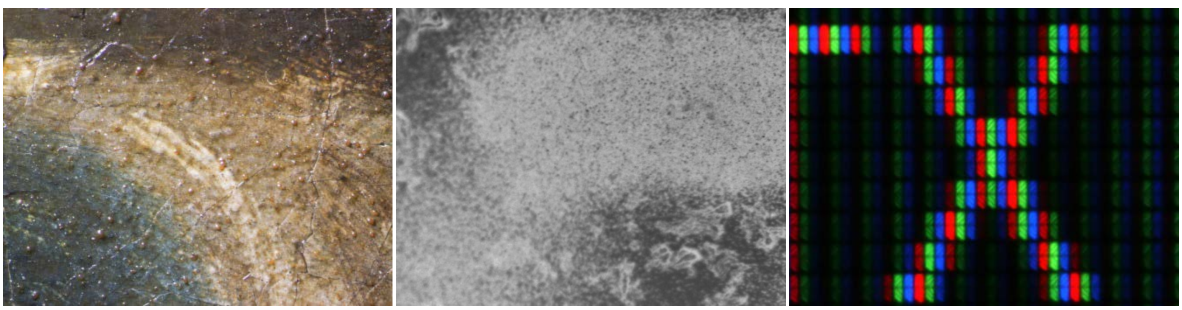

Figure 4: Pigments of a Painting, Silver Nitrate of a Daguerreotype, Pixels of an LCD Display

Source: Micrograph. Light micrograph. Macro shot of an LCD display shift at any point and is controlled by the display's underlying operating system. In a painting, these pieces of color information are also present. However, their values are determined by the artist using a brush in the form of bound pigments and are no longer changeable after the drying process. The information is thus firmly connected to the image carrier. The situation is similar with photography: silver nitrate is changed via light exposure by different degrees. Each silver nitrate molecule at any point is a carrier of brightness information that will convey the overall visual impression (see figure 4). Again, the information is fixed to the medium. Only in the digital imaging medium are these elements separated and act as properties of the new medium that has added new features and options to it. The separation of "information" and "media" makes variability, processing ability, and lossless copying possible—these basic characteristics distinguish the digital image from the conventional image.

The introduction of the concept of "information" in image science has further advantages: the above triad of information, media, and visual phenomenon stands in a hierarchical relationship with one another. The media system requires information to create a visual phenomenon. This can be represented as follows:

3. Visual Phenomenon
2. Media System
1. Information

In computer science, this is called a layer model. Among the best-known layer models is the OSI model, which refers to seven perspectives on technical structures in telecommunications. In it, the lowest layer of the physical layer—copper cable or electromagnetic waves—transmits the bits in the form of signals. The higher layers assure the correct transmission between sender and receiver through a series of transmission protocols.[30] A similar layered model can be applied to visual media.

It should be noted that the first layer consists not only of bits, but also of data formats including compression. The second layer consists of the elements of von-Neumann computers, including memory, on which information is stored, processed, and outputted (e.g. displayed). The third layer consists of the observable phenomenon that is purely optical.

On this foundation a system of human perception can be built: an image is only an image when it is viewed by a recipient. Higher layers describe the steps of assigning meaning. For this, a proven model of additional layers that we can make use of already exists: Erwin Panofsky describes a three-stage general epistemology of visual perception when discussing iconology and iconography. Accordingly, first the objects are named (in his example serving Christian iconography: man, knife), and then the overall image is identified (Saint Bartholomew) and finally placed in its cultural and historical context.[31]

What Panofsky fails to describe is that before the cognitive process—which relies on cultural experience—can begin, the sensation must first be pre-processed to distinguish shades and surfaces in order to identify areas as connected objects. This requisite edge detection, contrast enhancement, and reduction of information already happens in part inside layers of the retina and the metathalamus.[32] This pre-processing is necessary to distinguish a human from an object based on the amount of stimuli in a visual phenomenon and can be added to Panofsky's description as layer zero. In this way, we obtain the following layer model:

3. Iconological Interpretation
2. Iconographic Analysis
1. Pre-iconographic Description
0. Object Recognition

Since the structured image description as shown here is only complete with a description of the image medium, these two layer models can stacked upon each other:

7. Iconological Interpretation
6. Iconographic Analysis
5. Pre-iconographic Description
4. Object Recognition
3. Visual Phenomenon
2. Media System
1. Information

This model describes the picture medium and its reception by the viewer in full and is applicable not only to the digital image, but any image phenomena. It is the relationship between the visual phenomenon caused by a physical configuration and the viewer that constitutes what is called an "image." It is the human being who perceives images and fills them with meaning, and it is the human being who creates images in order to visually communicate ideas. With the digital image, it becomes clear: to talk about images, one must connect four terms into a relationship: recipient, visual phenomenon, media system, and information. In short, an "image" consists of multiple interconnected parts.

What is Big Data?

Having defined the term "image," the question remains: what is "Big Data" and how can we use it, especially Big Image Data (BID), for science? Big Data simply sounds like a lot of data. The image database Prometheus (University of Cologne) contains 1.5 million images,[33] Art Store contains 2 million,[34] Google Cultural Institute contains almost 5 million,[35] and the Artigo project (University of Munich) has generated about 8 million tags so far.[36] A heap of data, however, does not yet represent knowledge. We have to distinguish pure signs, such as bits or bytes that can be interpreted; data, or unstructured facts about certain occurrences in the real world; information, or contextualized, relevant meaning; and knowledge, or understanding through experience (see figure 5).[37] The interpretation of results is still exclusive to humans, but computers can help us with the steps leading to that destination.

Since Big Data promises to acquire new relevant knowledge, it refers to data on one hand, and the analysis of that data on the other. For example, the warehouse chain Target employed a marketing strategy aimed at pregnant women as their target market and tried to address their needs earlier on in their pregnancy than competitors. By analyzing the patterns in a customer's purchase history, a woman's pregnancy and her child's birth date could be predicted, sometimes even before the women knew, it seems.[39] Such patterns are derived from a combination of age, place of residence, and purchase history. This analysis discipline is called "predictive analytics" and shows how knowledge about the future can be generated by using the past and present. An important point should be mentioned here: such predictions are not definitive, rather, they come with a probability. That means the result of such an analysis is not a statement of fact, but is instead a fuzzy projection (often with a notably high probability).

In order to generate knowledge from pure data, Big Data is characterized by three Vs: Volume, Variety, and Velocity.[40] Volume allows for the access to a large set of data, and its heterogeneity allows for the drawing from multiple ends in order to find the item

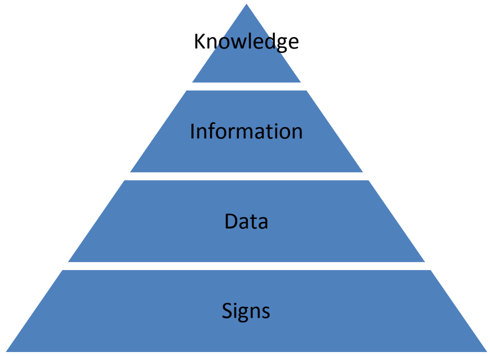

Figure 5: The "Pyramid of Knowledge" as derived from Ackoff (1989)[38]

searched for. Its real-time analysis allows for a higher probability of the prognosis. Thus, Big Data means to acquire, store, and analyze large amount of data that are generated quickly and are not always structured, as with SQL databases. Open source solutions like the Hadoop Framework, or database systems such as Cassandra and MongoDB, were all developed to help analyze such data quickly.

What is Big Image Data

Big *Image* Data, then, is about a special kind of data: visual data. Analysis of it can lead—just like ordinary Big Data—to statistical key figures, diagrams, overviews, or graphs that show structures such as clusters or outliers.[41] Image data visualization is essentially images about images—meta images, perhaps—since they make a digest of many images understandable. How that digest is calculated determines the epistemic content of the image. Similar to text mining, the process could be called image mining, for which algorithms are currently being developed. It is a projection from many to one and, thus, an information reduction defined by mathematical calculations.[42] In short, they reflect other images. Or, in the words of W.J.T. Mitchell, "Any picture that is used to reflect on the nature of pictures is a metapicture."[43]

A few examples of volume in BID: Apple's iCloud solution has over 782 million users (as of February 2016),[44] and its photo sharing function allows users to upload the last 1,000 photos from a device, such as the iPhone, and sync them with other devices. That means up to 782 billion images can be kept in Apple's data centers, such as the one in Maiden, South Carolina. Shortly after the introduction of this service, the 1,000 image limit was lifted. Starting in 2013, virtually all images can be synchronized. Facebook has over 1 billion users and is said to receive about 350 million photo uploads per day.[45] The sheer number of images is not the treasure here, but the variety: GPS location integration, likes, friends, and other contextual data. The velocity is another treasure and includes the real-time acquisition of images, since they are uploaded almost immediately after they are taken on a mobile device.

Big Data content is often acquired in the "Internet of Things" by means of sensors. Visual data is acquired with visual sensors, such as cameras in smartphones. The number of these images is being generated and accumulated like never before in history. Their analysis can generate enormous insights into societal developments and individual habits. Most of all, visual data speaks to what we see, what we show to others, and what we think the world looks like. Art History is still far away from such repositories, but still has to answer how a *Bildwissenschaft* makes use of image analysis technology. So how can Art History acquire data big enough to derive meaningful knowledge about the history of art? How can we utilize the tools information science is offering for our objectives? Digital Humanities promises that the computer can help us reach our epistemic aims better. The computer can support our conventional methods, and with its help, we are able to develop new digital methods. What does this mean for Art History?

Apple and Facebook are presumably interested in understanding customer behavior in order to match advertisements with customer interests. To achieve such an objective, the collected data requires the proper structure, and the challenge comes in how to analyze the data in order to receive meaningful insights. Art History is also interested in human behavior, but on the other hand, it is also interested in image-making processes (as a *homo pictor*),[46] in specific images like art works, and in networks existing between artwork and artist.[47] This means that not only are the number and structure of data relevant, but also their quality.

Therefore, sometimes there is another important fourth "V" added: veracity. Veracity refers to the accuracy of data in relation to the real world. For Art History, this begs the question: how much can we trust a digital reproduction of an artwork? Fact is, a reproduction always bears a difference to the original. But looking at dozens of variations of depictions of the Sistine Chapel in our database makes us wonder if we are able to comprehend the width of that gap. We need to address the integrity of our data. Hence, we must first ascertain what data needs to be acquired to be used as the base for subsequent analyses. If we build on top of our digitized slide libraries, like our art-historical image databases, we also need to address other quality concerns apart from accurate color depiction. The sufficient richness of visual data remains unanswered: paintings are not flat and are therefore not adequately represented in a JPEG-file, but they have a relief structure. Paintings would be more adequately represented with an additional layer of grazing light or x-rays and a 3D model. Such a database for visual computing could be called *Rich Image Data.*

Once the necessary kind, structure, and amount of data have been acquired, how can it all be used to gain knowledge on a higher level? First of all, art-historical research should not be driven by the promises of information technology, but by its very own epistemic goals. Digital Art History should therefore not ask what to do with all those images, rather start with what we want to find out, and then ask how computers can assist us in this task. As a third step, we should ask what data we need, in what kind of structure, what algorithms we should use in order to analyze the data, and what visualizations should be used to show these results and explore the data.

Data analysis for Art History means the introduction of *quantitative* methods into a field that has used exclusively *qualitative* methods throughout its existence. However, these quantitative methods are not a substitute for conventional methods, but an addition. Results of data analysis can help to answer to our research questions, but may also spark new hypotheses that can be followed using a bouquet of methods that Art History has. For some, Big Data seems to be the end of theory but one could also argue that Data Analytics helps us to see the big picture and create new hypotheses for qualitative research.[48] This way, the computer remains a tool in the hands of the researcher, or as Steve Jobs defined the role of the computer to the human, "a bicycle for the mind."[49]

Figure 6 details how the human system (i.e. the researcher) makes use of the computer (denoted as the media system) in order to access visual data. Such meta images from BID are observed by the viewer just like individual images, except they are a digested representation of the amount of data, can be interactive, and reference on visual data. The referenced visual data relates to the individual physical art-historical object, which the art historian likes to place in a cultural context. The goal of that epistemic process is to form an abstract mental representation of developments in the history of art.[50] In this process, the computer acts as a computational co-processor to the researcher's mind. To quote Mitchell once again: "The metapicture is a piece of moveable cultural apparatus, one which may serve a marginal role as illustrative device or a central role as a kind of summary image, [...] that encapsulates an entire episteme, a theory of knowledge. [...] In their strongest forms, [metapictures] don't merely serve as illustrations to theory; they picture theory."[51]

Today, the computer is able to make low-level features computable and is increasingly able to compute high-level features. That is particularly fruitful for Art History when applied to large amounts of images in order to pre-process them, visually examine them in order to create a distant view, to explore them, and to find them. The processing of low- and high-level features usually takes place in the human retina, metathalamus, and visual cortex. With the ability of the computer to process these plain pieces of data into meaningful information while generating meta images, these processes sink on the hierarchy of levels into the realm of the media system. Augmenting the layered model described above with the computer's visual computation abilities leads to the scheme shown in Table 1.

Thus, the computer becomes a powerful tool in the hands of an image researcher because it can help us to access large amounts of visual data. At the same time, it leaves cultural contextualization to the art-historical researcher, who can dive deeper into the individual images. Art is made by humans for humans and the computer

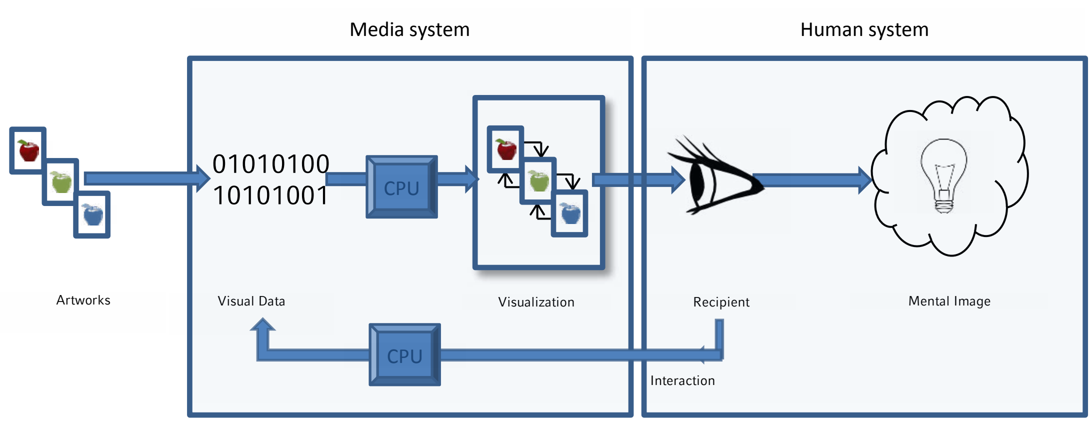

Figure 6: Scheme of the computer as an epistemic tool in the service of image research

can help us cut through the ever-expanding forest of mass visual data. Such digital methods do not replace the human researcher, even if the computer takes over more and more tasks. It helps us to focus on those tasks that we excel in: interpretation, contextualization, and appreciation. The mental archive will remain central and will be extended with computers where applicable. In short, the processing of increasingly larger numbers of images by the computer (*meta* images) allows for deeper interpretation of the individual image by researchers (*mesa* image).

The computer, used as a tool to explore visual data via meta images, puts visualization into a core concept of BID. This concept, visualization, can be added as the fifth "V" in Big Data. The computer and the data it stores are being used via a graphical user interface—an interface between the human and the data. It processes data, reduces information, and transforms it to a dynamic visual phenomenon. This transformation process can apply different algorithms and can be controlled by a number of variables. At the same time, the user interface allows for the manipulation of data via interaction. It allows selection, exploration, and alteration. The human using the system will see, understand, and comprehend the visual phenomenon and then form a mental image of the data, which becomes their structure and meaning. For a long time, Art History has studied the recipient in front of an image. What is being seen is not a passive process, but shaped by previous visual experiences, cultural norms, and expectations.[52] Having the ability to not only contemplate the image, but to also interact with it, makes the viewer an active user and designer of data and allows explorative access to virtually infinite image libraries.

<table>
<tr><td rowspan="4">Human system</td><td>7. Iconological Interpretation</td></tr>
<tr><td>6. Iconographic Analysis</td></tr>
<tr><td>5. Pre-iconographic Description</td></tr>
<tr><td>4. Object Recognition</td></tr>
<tr><td rowspan="3">Media system</td><td>3. Visual Phenomenon of Meta Image</td></tr>
<tr><td>2. Media System (pre-processing, including object recognition and pre-iconographic analysis)</td></tr>
<tr><td>1. Information</td></tr>
</table>

Table 1: Layers in Generation and Understanding of a Meta Image from BID in Computer-aided Art History

BID seems to hold great promise for Art History. The methods that we are about to develop are not only for our own scientific needs, but might also be used to grasp the billions of images that are created outside the artistic realm. The methods can be applied to answer the questions that society has regarding the digital image in general. Who else can make this contribution to society if not the discipline that has for centuries acquired a great historical and visual experience—Art History?

The future form of Art History means more than the analysis of Big Image Data, but at the moment that seems to be the greatest promise *and* challenge for the discipline. More than any other area of the Humanities, Art History deals with images and the analysis of visual data. It is a great opportunity to modernize the discipline. At the same time, we should not forget that, in research, we draw information from multiple sources—not only images. The prototype of an Art History department at a university has historically had two repositories of knowledge: the library and the slide library. While we have digitized the slide library and are discussing how to access its data, the physical book library is yet another source of information. The next step will be to combine and connect both sources of data digitally and make that the basis of our research.

The acquisition of Big Image Data, data analysis, and visualization will open up to new methods in Art History. We need to team up with information scientists, define goals, and develop tools that meet our objectives. Now is the time to develop such new approaches. However, we must remain critical: data analysis does not replace quantitative research; it is an aid to the researcher. Results always need interpretation; they do not replace hypotheses, but are their premise. And statements can only be made based on the data present. Meaning today, we teach our students source criticism, i.e. evaluating a text by asking who has written what, when and why. In the future, we need to add critiquing digital resources to the curriculum—data critique must become a core competence in art-historical studies.

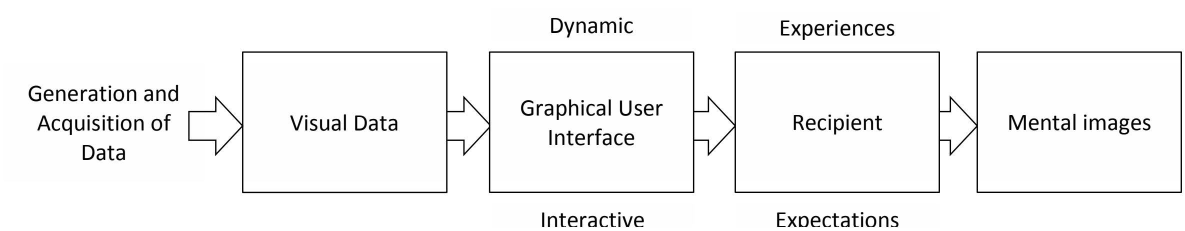

Figure 7: Scheme of a research workflow via a graphical user interface that accesses visual data

We are witnessing a historical shift. Art historians used to be in the position of image recipients. With data visualizations, we have become producers of images ourselves. Which discipline has the toolset to understand what kind of images such visualizations represent, if not Art History? Thus, a critique of the digital image should be included in art-historical curriculums as well—a visual literacy in the digital age, so to speak. And that, too, requires digital competence. If we want to remain a *Bildwissenschaft* in the 21st century, we need to embrace digital methods. Not only to apply them on reproductions of art or popular culture, but also to understand contemporary art that is increasingly digital-born.

Notes

1 Erwin Panofsky, "Iconography and Iconology: An Introduction to the Study of Renaissance Art," in Erwin Panofsky, Meaning in the Visual Arts: Papers in and on Art History (Garden City, NY: Doubleday, 1955), 26–54.
2 Lena Bader and Martin Gaier/ Falk Wolf (eds.): Vergleichendes Sehen (München 2010).
3 See also Udo Kultermann, "Der Dresdner Holbeinstreit," in Udo Kultermann: Geschichte der Kunstgeschichte. Der Weg einer Wissenschaft (München: Prestel Verlag, 1996), 136–141.
4 Thomas Nelson Winter, "Roberto Busa, S. J., and the Invention of the Machine-Generated Concordance," The Classical Bulletin 75:1 (1999), 3-20 http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1069&context=classicsfacpub
5 See Anna Bentkowska-Kafel, "Debating Digital Art History," International Journal for Digital Art History, [S.l.], n. 1, june 2015. ISSN 2363-5401. Available at: <http://journals.ub.uni-heidelberg.de/index.php/dah/article/view/21634>. Date accessed: 19 mar. 2016. doi:http://dx.doi.org/10.11588/dah.2015.1.21634.
6 See Benjamin Zweig, "Forgotten Genealogies: Brief Reflections on the History of Digital Art History," International Journal for Digital Art History, [S.l.], n. 1, june 2015. ISSN 2363-5401. Available at: <http://journals.ub.uni-heidelberg.de/index.php/dah/article/view/21633>. Date accessed: 19 mar. 2016. doi:http://dx.doi.org/10.11588/dah.2015.1.21633.
7 American Standard Code for Information Interchange is a table of characters alongside their numerical repre-sentation. The now widely used UTF-8, which is capable of encoding all possible characters, is fully backward compatible to ASCII.
8 Sorting of pictures according to their median brightness, hue or saturation can easily be done with ImagePlot developed by the team around Lev Manovich: http://lab.softwarestudies.com/p/imageplot.html
9 R. Datta, D. Joshi, J. Li, and J. Z. Wang, "Image retrieval: Ideas, influences, and trends of the new age," ACM Computing Surveys, 40(2):1-60, April 2008
10 See the article by Babak Saleh in this journal.
11 Moretti, Franco and Alberto Piazza, "Graphs, Maps, Trees: Abstract Models for Literary History" (Verso, 2007).
12 K. Bender, "Distant Viewing in Art History. A Case Study of Artistic Productivity," International Journal for Digital Art History, [S.l.], n. 1, june 2015. ISSN 2363-5401. Available at: <http://journals.ub.uni-heidelberg.de/index.php/dah/article/view/21639/15412>. Date accessed: 09 mar. 2016. doi:http://dx.doi.org/10.11588/dah.2015.1.21639.
13 Charles Duhigg, "How Companies Learn Your Secrets," The New York Times Magazine, http://www.nytimes.com/2012/02/19/magazine/shopping-habits.html, Feb. 16, 2012. The story is based on the presentation "How Target Gets the Most out of Its Guest Data to Improve Marketing ROI" by Andrew Pole at Predictive Analytics World Conference in Washington D.C. (October 19, 2010).
14 Craig Mundie in: "Data, data everywhere", The Economist, http://www.economist.com/node/15557443 , Feb 25th 2010, see also Clive

Humby, Address at the ANA Senior Marketer's Summit at the Kellogg School (2006), in Michael Palmer, Data is the New Oil (Nov. 3, 2006), http://ana.blogs.com/maestros/2006/11/data_is_the_new.html.
15 Gottfried Boehm, "Die Bilderfrage," in Was ist ein Bild?, ed. Gottfried Boehm (München, Fink, 1994), 325-343.
16 The following paragraphs have already appeared in German in: Harald Klinke, "Bildwissenschaft ohne Bildbegriff," in Bilder der Gegenwart, ed. Harald Klinke, Lars Stamm (Göttingen: Graphentis Verlag, 2013), 11-28.
17 Hans Belting, Bild-Anthropologie. Entwürfe für eine Bildwissenschaft (München: Fink, 2001), 16.
18 Belting, op. cit., 15.
19 "Es gibt keine Daten ohne Datenträger. Es gibt keine Bilder ohne Bildschirme" (Claus Pias, "Das digitale Bild gibt es nicht. Über das (Nicht-) Wissen der Bilder und die informatische Illusion," Zeitenblicke Bd. 2 (2003), §53).
20 Walter Benjamin, "Das Kunstwerk im Zeitalter seiner technischen Reproduzierbarkeit," in Gesammelte Schriften Bd. 1, ed. Rolf Tiedemann und Hermann Schweppenhäuser (Frankfurt/M.: Suhrkamp, 1980), 431-469.
21 Narrations of a general history of media usually start with the invention of the printing press - a text medium. A history of visual media on the other hand focuses on the visual media and therefore begins with the first human image artifacts (e.g. cave paintings). The history of visual media is also not limited to the history of technology. Rather, it is rather concerned with the examination of the cultural consequences of the development of visual media and the definition of the properties of the medium in its historical context.
22 See W.J.T. Mitchell, "Realismus im digitalen Bild," in Bilderfragen. Die Bildwissenschaften im Aufbruch, ed. Hans Belting (München: Fink, 2007), 237-255.
23 Oliver Grau, Virtual Art. From Illusion to Immersion (Cambridge, Mass: MIT Press, 2003), 15.
24 Margarete Pratschke, "Interaktion mit Bildern. Digitale Bildgeschichte am Beispiel grafischer Benutzeroberflächen," in Das Technische Bild, ed. H. Bredekamp and others (Berlin: Akademie Verlag, 2008), 68-81.
25 See Frieder Nake, "Das doppelte Bild," in Bildwelten des Wissens. Kunsthistorisches Jahrbuch für Bildkritik Vol. 3, No. 2, Digitale Form, ed. Margarete Pratschke (Berlin: Akademie Verlag, 2006), 47ff.
26 The Von-Neumann principle describes a computer, which is universal, i.e. independent of the problems to be processed and controlled by binary coded commands.
27 Edmund Husserl, "Phantasie, Bildbewusstsein, Erinnerungen. Zur Phänomenologie der anschaulichen Vergegenwärtigung," in Husserliana Band 23, ed. Eduard Marbach (Den Haag: Martinus Nijhoff, 1980).
28 See Harald Klinke, "The image and the mind," in Art Theory as Visual Epistemology, ed. Harald Klinke, 1-10.
29 See Belting, op.cit., 38.
30 See Peter Stahlknecht and Ulrich Hasenkamp, Einführung in die Wirtschaftsinformatik 11th ed. (Berlin, Heidelberg, New York: Springer, 2005), 94-97.
31 Panofsky, op. cit..
32 Specifically in the Corpus geniculatum laterale (see Hans-Otto Karnath und Peter Thier, Kognitive Neurowissenschaften, 3rd ed. (Berlin: Springer Medizin, 2012), 36-37.
33 http://www.prometheus-bildarchiv.de/
34 http://www.artstor.org/content/artstor-digital-library-features-benefits
35 https://www.google.com/culturalinstitute/browse/
36 http://www.artigo.org/
37 Jay H. Bernstein, "The data-information-knowledge-wisdom hierarchy and its antithesis," in Proceedings North American Symposium on Knowledge Organization, ed. E. K. Jacob, and B. Kwasnik , Vol. 2 (Syracuse, NY, 2009), 68-75.
38 R. L. Ackoff, "From data to wisdom," Journal of Applied Systems Analysis 15 (1989), 3-9.
39 Charles Duhigg, op. cit.
40 Douglas Laney, "The Importance of ‚Big Data': A Definition," in Gartner, 2012. http://www.gartner.com/resId=2057415.
41 Harald Klinke, "Heinrich Wölfflin in Zeiten digitaler Kunstgeschichte," in Kunstgeschichten 1915. 100 Jahre Heinrich Wölfflin: Kunstgeschichtliche Grundbegriffe, ed. Matteo Burioni and others (Passau, 2015) , 415-421.
42 "Dimension reduction is a projection of a space of many dimensions into a fewer dimensions – in the same way as a shadow of a person is a projection of a body in three dimensions into two dimensions." Manovich,

Lev, "Data Science and Digital Art History." International Journal for Digital Art History, [S.l.], n. 1, june 2015. ISSN 2363-5401. Available at: <https://journals.ub.uni-heidelberg.de/index.php/dah/article/view/21631>. Date accessed: 19 mar. 2016. doi:http://dx.doi.org/10.11588/dah.2015.1.21631., 30
43 William J. Thomas Mitchell: Picture Theory. Essays on verbal and visual representation (Chicago/London: The University of Chicago Press, 1994), 57.
44 "(…) more than 1 billion active devices and 782 million iCloud users" (Juli Clover: Eddy Cue and Craig Federighi Discuss Bloated Software Accusations, Upcoming iTunes Plans, http://www.macrumors.com/2016/02/12/eddy-cue-craig-federighi-bloated-software/ February 12, 2016.
45 Facebook Reports Second Quarter 2016 Results, https://investor.fb.com/investor-news/press-release-details/2016/Facebook-Reports-Second-Quarter-2016-Results/default.aspx.
46 Hans Jonas, "Homo Pictor. Von der Freiheit des Bildens," in Was ist ein Bild?, ed. Gottfried Boehm (München: Fink, 2006), 105-124.
47 Of course one could question if today the differentiation between artistic and general images should be sustained. Lev Manovich recently published a Manifesto in which he argued that there is no need for that anymore. A democratic approach would now be possible in which every image process would be stored through the simple fact that there is enough storage on the servers. And with BID there would be methods at hand that could integrate every one of the billions of images (Lev Manovich: Manifesto for Democratic Art History, http://lab.softwarestudies.com/2016/02/manifesto-for-democratic-art-history.html). But is it just elitism that makes the difference between art and plain images made by laymen? Or shouldn't we think of artists as the ones who are experimenting with new image media and try to test what an image can be? (Thanks to Liska Surkemper for the thoughts on this paragraph.)
48 Liska Surkemper, "Zu einer Theorie vom Ende der Theorie," Archplus, 48 (221), 2015, 66-69.
49 Steve Jobs, in: Memory & Imagination. New Pathways to the Library of Congress, Michael Lawrence Films, 1990
50 A discussion of the concept of the master narrative see: Jean-François Lyotard, The Post-modern Condition: A Report on Knowledge, 1979.
51 Mitchell: Picture Theory, op. cit., 49.
52 Klinke: The image and the mind, op. cit.

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Big Image Data

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