Can Computers Create Art?

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Working draft

January 16, 2018

Abstract

This paper discusses whether computers, using Artificial Intelligence (AI), could create art. The first part concerns AI-based tools for assisting with art making. The history of technologies that automated aspects of art is covered, including photography and animation. In each case, we see initial fears and denial of the technology, followed by acceptance, and a blossoming of new creative and professional opportunities for artists. The hype and reality of Artificial Intelligence (AI) tools for art making is discussed, together with predictions about how AI tools will be used. The second part concerns AI systems that could conceive of artwork, and be credited with authorship of an artwork.

Recent advances in artificial intelligence for making images have come at a staggering pace lately; along with them, so have come fears about Artificial Intelligence (AI). AI artists are being trained to produce their own art, we are told. In typical news media hype, new neural network algorithms will revolutionize everything and automate everything, thus saving lives and making it easier for people to express themselves, but maybe they will put human workers out of work and, while they’re at it, rob us of our humanity?

Beyond the hype, confusion about how technology influences art pervades serious discussions. Professional artists often are concerned that computers might put them out of their jobs, a concern I’ve heard for decades. Computer scientists often view artists in a way that borders on mysticism, though some recent AI efforts have proclaimed lofty ambitions for how machine learning will impact art.

Some researchers present their algorithms as themselves artists (or intended to be), e.g., [1, 42]. And, I was recently contacted by a prominent social psychologist who, inspired by recent results with neural networks, wished to conduct experiments to assess whether ordinary

∗This essay expresses my own personal opinions and does not reflect those of my employer.
†This manuscript is in preparation for submission to the journal Arts, Special Issue on “The Machine as Artist (for the 21st Century)” (http://www.mdpi.com/journal/arts/special_issues/Machine_Artist), by invitation. Please send comments to hertzman@dgp.toronto.edu. However, I cannot promise to respond to all feedback.
people might be willing to buy artwork made by a computer, and, if so, why. It was assumed that computers were already happily making their own artwork.

On the other hand, whenever I have informally asked friends or colleagues the question of whether computers can create art, the answer is usually a decisive “No.” Art requires human intent, inspiration, a desire to express something. Thus, by definition, there is no such thing as art created by a computer... why would anyone worry?

In this essay, I will tackle the question of “Can Computers Create Art?” There are several related versions of this questions worth discussing. First, to what extent will computers replace professional artists or make their technical skills obsolete? Second, can we imagine a future scenario in which a computer is itself considered the author of an artwork? Will AI change our understanding of what art is?

Given the emphasis on intent as the role of the artist, it is conceptually worthwhile to separate the creation of art into execution versus intent. “Execution” refers to the application of technical skill required to go from an idea to an output, e.g., the ability to paint a picture of a particular subject in a particular style. “Intent” refers to the conception of the idea and the goals of the work, together with the high-level decision-making during an iterative process. The “Intent” is not just the original conception of the work, because most art is iterative: often, an artist will emerge from the process with something very different from their original idea. For example, a painter might begins with a vague idea, rough a sketch, modifies it, paint more, steps back to assess their work so far, change the idea based on how the painting is evolving, and continues to iterate. This separation of decision-making from execution is sometimes artificial, but useful for this essay so that we can discuss their automation separately.

One of my main themes is that technological innovation ultimately benefits art and artists. Sadly, art and science are often viewed as being separate, or in even opposition or competition \[54\]. I describe several previous times in history when artists feared new technologies, when, in fact, these new developments ultimately had the effect of dramatically expanding the opportunities for artists. Often, artists are important contributors to these innovations; artists and technologists have much in common, as tinkerers, experimenters, and explorers. Rather than being a foe, technological development stimulates so much of the continued vitality of art. I see every reason to believe that AI technologies will do the same.

**Part 1: Execution**

I now focus on two related questions: given instruction and guidance, can machines create artwork as well as humans? That is, can they replace the technical skills of paid professionals? And, if so, should human artists — particularly, commercial and professional artists like illustrators and designers — worry about their job security?

For example, consider an art director who must come up with an original magazine cover each month, or original book covers for new novels. Normally, they might start with a rough idea, hire a professional designer or illustrator to explore related ideas and execute on the design brief. In the hypothetical AI-driven world, they would enter their idea into a software
package that would execute the idea, and the art director could explore or iterate on different ideas with the software package. The art director performs the high-level decision-making: they decide on the underlying concept, and must have some level of taste and discernment in selecting amongst options. But their need to hire a professional designer is replaced by the computer. There are analogous possibilities in many other work-for-hire scenarios, like the studio musicians performing in a rhythm section in an album recording, or actors performing in a film. There are more far-out scenarios, e.g., where the film script itself is automatically generated [25]. Is this realistic?

I argue that, throughout history, technology has expanded creative and professional opportunities for artists dramatically, by providing newer and more powerful tools for artists. The advent of new technologists often cause fears of displacement among traditional artists. In fact, these new tools ultimately enable new artistic styles and inject vitality into art forms that might otherwise grow stale. These new tools also make art more accessible to a wider sections of society, both as creators and as consumers. These trends are particularly visible in the past two centuries since the Industrial Revolution. Furthermore, I argue that these trends will continue for the foreseeable future with AI technologies.

1.1 How photography became an artform

"From today, painting is dead!" - Paul Delaroche, painter, at a demonstration of the daguerreotype in 1839

For lessons from the past about AI and art, perhaps no invention is more significant than photography [1]. Prior to the invention of photography, realistic images of the world could only be produced by artists. In today’s world, we are so swamped with images that it is hard to imagine just how special and unique it must have felt to see a skillfully-executed realistic painting. The technical skills of painting and other visual arts were inseparable from other creative aspects. Photography automated a task that had previously been solely done by artists, that is, reproducing images of the real world.

In 1839, the first two commercially-practical photographic processes were invented: Louis-Jacques-Mandé Daguerre’s dagguereotype, and William Henry Fox Talbot negative-positive process. They were mainly presented as ways to produce practical records of the world. Of the two, the daguerreotype was more popular for several decades, because Talbot’s process was restricted by patents. Improvements to Talbot’s method eventually made the daguerreotype obsolete and evolved into modern film processes.

One early use for the daguerreotype was to produce souvenirs for tourists: within ten years, daguerreotypes of Roman ruins completely replaced the etchings and lithographs that tourists had previously purchased. As the technology improved, photography became indispensable as a record of engineering projects, disappearing architectural ruins, and documentary purposes, such as Matthew Brady’s photographs of the horrors of the American civil war.

Portraiture was a main driver for adoption. Then, as today, people enjoyed possessing pictures of their friends, loved-ones, and ancestors. Portrait painting was only available to

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1Except where noted, the historical information from this section is distilled from Rosenblum [51].
Figure 1: (a) A traditional silhouette portrait. (b) Daguerreotype portrait of Abraham Lincoln, 1846. Photographic techniques like this completely displaced previous portraiture techniques.

Aristocrats and the very wealthy; even today, portrait painting is a symbol of great wealth and status. In the 18th century, a number of inexpensive methods were developed, such as the silhouette, a tiny black representation of an individual’s outline (Figure 1(a)), typically hand-cut by an artisan out of black paper. The daguerreotype offered an economical way to create a realistic portrait (Figure 1(b)). It was very slow and required locking the subject’s head in place with a head brace for several minutes, while the subject gripped their chair tightly, so as not to flutter their fingers. Nonetheless, numerous daguerreotype studios arose and became commonplace as technologies improved; recognizing its potential, many portraitists switched to this new technology. Portrait painters even adopted photography as a helpful crutch for painting. Photography has largely replaced most older forms of portraiture, such as the silhouette, and no one seems to particularly regret this loss. As much as I appreciate the mystery and beauty at looking at old etchings and portraits, I’d rather use my mobile phone camera for my own pictures than to try to draw everything by hand.

“Is photography art?” This question was debated for many decades, coalescing into three main positions. Many people believed that photography could not be art, because it was made by a mechanical device rather than by human creativity. Many artists were dismissive of photography, and seemed threatened by it [33]. A second view was that photography could be useful to real artists, but should not be considered as equal to drawing and painting. Finally, a third group, relating photography to established forms like etching and lithography, felt that photography could eventually be as significant an art form as painting.

Photography ultimately had a profound and unexpected effect on painting [33]. Though some painters put more or less emphasis on realism versus expressionism, painters’ mimetic abilities had been improving over the centuries. Many painters of the 19th century, such as the
Pre-Raphaelites like John Everett Millais and Neoclassicists like Ingres, painted depictions of the world with dazzling realism, more than had ever been seen before. However, as cameras became cheaper, lighter, and easier to use, they grew widespread among both amateurs and professionals, and realistic imagery became commonplace by the end of the 19th century. If photorealism could be reduced to a mechanical process, what is the real value of art? This question drove painters away from faithful reproduction toward greater abstraction, through movements such as Symbolism and Tonalism, as in the atmospheric scenes of James MacNeill Whistler. Early Modernist painters were inspired by types of images created by photography in many different ways. For example, Edvard Munch’s wrote “The camera will never replace the painter as long as it cannot be used in Heaven or Hell;” but he experimented with photography extensively, including as a reference for his paintings, as well as capturing scenes from life. Symbolists like Odilon Redon and Paul Gauguin, on the other hand, were inspired by the way that photography changed how one thought about the notion of what is visible. One can argue, in fact, that photography was one of the major catalysts of the modern art movement: its influence led to decades of vitality in the world of painting, as artists were both inspired by photographic images and pushed beyond realism.

The Pictorialist movement, begun around 1885, was an attempt to firmly establish photography as an art form. Pictorialists introduced much more artist control over the photographs, often manipulating their images in the darkroom. Other times, they used highly-posed subjects, similar to those seen in conventional paintings. Many of their works had a hazy, atmospheric work similar to Tonalism (e.g., Whistler’s paintings), that deliberately softened the realism of high-quality photography. Today, many of these works seem evocative but also very affected in their emulation of the painting styles of the time. They pursued various strategies toward legitimization of their work as art form, such as the organization of photographic societies, periodicals, and juried photography exhibitions. Their works and achievements made it harder and harder to deny the artistic contributions of photography; culminating in the “Buffalo Show,” organized by Alfred Stieglitz at the Albright Gallery in Buffalo, NY, the first photography exhibition at an American art museum in 1910. Photography was finally established as an art, and free to move beyond the pretensions of Pictorialism.

This story provides several lessons that are directly relevant for AI as an artistic tool. At first, photography, like AI, was seen by many as non-artistic, because it was a mechanical process. Some saw photography as a threat and argued against its legitimacy. Photography did displace old technologies that had fulfilled non-artistic functions, such as portraiture’s social function. Some artists enthusiastically embraced the new technology, and began to explore its potential. As the technology improved, and became more widespread over nearly a century, artists learned to better control and express themselves with the new technology, until there was no more real controversy over the status of photography. The new technology made image-making much more accessible to non-experts and hobbyists; today, everyone can experiment with photography. Furthermore, the new technology breathed new life into the old art form, provoking it toward greater abstraction. Wherever there is controversy in AI as an artistic tool, I predict the same trajectory, until AI tools are fully recognized as artists’ tools, and, likewise, AI tools may stimulate traditional media as well, e.g., the New Aesthetic.
Figure 2: The interplay of painting and early photography. (a) By the 19th century, Western painters had achieved dazzling levels of realism. (b) Early cameras took low-quality (though evocative) pictures. This daguerreotype took over ten minutes to expose. (c) However, camera technology steadily improved, capturing greater and greater realism. (d) This challenged painters to create works that were not about hyper-realistic depiction, such as Whistler’s Tonalist Nocturne. (e) The Pictorialist photographers attempted to establish photography as an art form by mimicking the styles and abstraction of painting. Works: (a) Ophelia, John Everett Millais, 1851 (b) Boulevard du Temple, Daguerre, 1838; (c) Portrait of Sarah Bernhardt, Félix Nadar, 1864; (d) Nocturne in Blue and Gold: Old Battersea Bridge, James MacNeill Whistler, c. 1872-1875; (e) Morning, Clarence H. White, 1908
1.2 The technology of live-action cinema

The story of filmmaking and technology also has important lessons about how artists and technologists can work together, each pushing the other further. Most of the early photographers were, by necessity, both artists and technologists, experimenting with new techniques driven by their art or to inspire their art. But, in film and animation, the interaction has been much more central to the art form.

The history of film is filled with artist-tinkerers, as well as teams of artists and technologists. Eadweard Muybridge invented the first camera for capturing motion. The Lumière Brothers created the first short film, a simple recording of workers leaving their factory, but also experimented with a wide range of camera technologies, color processing, and artistic ways to use them. The stage magician George Méliès filmed fantastical stories like *A Trip to the Moon*, employing a wide range of clever in-camera tricks and techniques to create delightfully inventive and beguiling films. Walt Disney employed and pushed new technologies of sound and color recording, and drove other innovations along the way, such as the multiplane camera. Many of Orson Welles’ innovative film techniques were made possible by new camera lenses employed by his cinematographer Gregg Toland. The introduction of the Steadicam in 1975 enabled directors to create a much more first-person sense of movement. George Lucas’ team for Star Wars was an early developer of many new visual effects on a shoestring budget (think of Ben Burtt hitting telephone guy-wires to create the “blaster” sound effect), as well as an early adopter of digital film editing. Digital and computer graphics technology, have, obviously, revolutionized film storytelling since then, with directors like Michel Gondry and James Cameron pushing the technology further into unforeseen directions. In each case, we see technologies rapidly adopted by directors to create new storytelling techniques and styles, transforming the medium over and over.

1.3 3D computer animation: a tight collaboration

3D computer animation as an artform was pioneered by Pixar Animation Studios, and that success is due to the close collaboration of artists and engineers [49]. It all began with Ed
Catmull, an animation enthusiast who received a PhD in computer science in 1974. In his thesis, he invented several core techniques that every major 3D computer graphics system uses today. During his time in graduate school, he quietly set a goal for himself: to make the world’s first computer-animated film [6]. Consequently, he founded the Lucasfilm Computer Division, and hired a team of brilliant engineers to invent computer systems to be used for film-making. However, none of this group could animate, that is, bring a character to life through movement. Hence, Catmull recruited John Lasseter, an animator trained deeply in the Disney tradition. Through tight collaboration between Lasseter and the technical staff, they were able to invent new technologies and discover together how computer animation could start to become its own art form. This group spun out as Pixar, and, over the following years, invented numerous technical innovations aimed at answering the needs set out by Pixar’s artists; in turn, the artists were inspired by these new tools, and pushed them to new extremes, and so on. One of their mantras was “Art challenges technology, technology challenges art” [6].

Pixar, by design, treats artists and engineers both as crucial to the company’s success and minimizes any barriers between the groups. When I worked there as a visiting research scientist during a sabbatical, despite my technical role, I had many energizing conversations with different kinds of artists, attended many lectures on art and storytelling, sketched at a life drawing session, watched a performance of an employee improv troupe, and participated in many other social and educational events that deliberately mixed people from different parts of the company. The relationship is not symmetric: “Story is King” and all decisions ultimately come down to the needs of directors and the animators that execute on their vision. However, the culture is one of tremendous respect between the groups. This is the culture that, though it still has some flaws to address, achieved so many years of technical and creative innovation, and, ultimately, commercial and artistic success.

Animation provides another case study of artists’ fears of new technology. In the early, pre-Pixar days, Catmull’s group made many attempts to interest Disney animators in their work [49]. Alvy Ray Smith later said: “In those early days, animators were frightened of the computer. They felt that it was going to take their jobs away. We spent a lot of time telling people, ‘No, it’s just a tool—it doesn’t do the creativity!’ That misconception was everywhere” [48]. It is a common misconception that computer animation just amounts to the computer solving everything; like a programmer presses a button and the characters just move on their own. In reality, computer animation is extraordinarily labor-intensive, requiring the skills of talented artists (especially animators) for almost every little detail. Character animation is an art form of extreme skill and talent, requiring laborious effort using the same fundamental skills of performance — of bringing a character to life through pure movement — as in conventional animation [37]. Even simulated scene elements, like water and cloth, involve laborious manipulation and adjustment in order to get the “look” just right.

Moreover, traditional cel animation jobs did not even last at Disney. Disney Feature Animation underwent a renaissance in the early ’90s, starting with The Little Mermaid. Then, following some changes in management, the Disney animation began a slow, sad decline. After releasing duds like Brother Bear and Home on the Range, management shut down all cel animation at Disney, and converted the studios entirely to 3D computer animation. Following
Disney’s acquisition of Pixar several years later, they revived Disney’s beloved cel animation productions. The result, a charming and enjoyable film called *The Princess and The Frog*, performed so-so at the box office, and, moreover, the animators’ creative energy was focused on the newer 3D artform [6]. Today, traditional cel animation at Disney is dead [5]. Today, computer animation is a thriving industry, and it thrives in many more places than cel animation ever did: at many different film studios, in visual effects for live-action films, in video games, television studios, web startups, independent web animators, and many more. There are now more types of opportunities for animators than ever before. The story here is not the destruction of jobs, but the evolution and growth of an art form through technology.

Each of these stories contradicts the popular notion of art and technology operating in conflict, when, in fact, the opposite is usually true. My current employer is Adobe Systems, a company with the primary mission of creating new technology for artists and designers.

### 1.4 Procedural artwork

In the art world, there is a long tradition of procedural artwork. Jean Arp created artworks governed by laws of chance in the 1910s (or so he claimed), and, beginning in the 1950s, John Cage used random rules to compose music. The term “Generative Art” appears to have originated in the 1960s. Starting in the 1970’s, fine artist Harold Cohen began generating realistic paintings using a program he wrote called AARON [7]. Since the 1980s, many current artists, such as Karl Sims, Scott Snibbe, Golan Levin, Scott Draves, and Jason Salavon, produce abstract artworks by writing computer programs that produce either static images, or interactive artistic experiences in installation works (Figure 4). In Sims’ and Draves’ work, the artwork “evolves” according to audience input. The popularity of the Processing computer language for artists speaks to the growth of this area.

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2Traditional animation styles are more vibrant in countries like Japan and France that, unlike Americans, do not believe that animation is “just for kids.” Even so, their visual styles of have evolved considerably due to computer technology.
In each of these cases, despite the presence of procedural, emergent, and/or crowdsourced elements, the human behind it is credited as the author of the artwork, and it would seem perverse to suggest otherwise. The human has done all of the creative decisionmaking around the visual style, of testing and evaluating alternative algorithms and so on.

1.5 State of the art: computer science research

Recent developments in computational artistic image synthesis are quite spectacular. But they should not be mistaken for AI artists.

Non-Photorealistic Rendering (NPR) is a subfield of computer graphics research [52] that I have worked in for many years. NPR research develop new algorithms and artistic tools for creating images inspired by the look of a conventional media, such as painting or drawing. Paul Haeberli’s groundbreaking 1990 paper [26] introduced a paint program that began with a user-selected photograph. Whenever the user clicked on the canvas (initially blank), the system placed a brush stroke with color and orientation based on the photograph. In this way, a user could quickly create a simple painting without any particular technical skill (Figure 5(a)). In a follow-up paper, Pete Litwinowcz automated the process entirely, by placing brush strokes on a grid [40]. My own first research paper arose from experimenting with modifications to his algorithm: the method I came up places long curved strokes, beginning with a large strokes that were then refined by small details [27] (Figure 5(b)). The algorithm was inspired by my experience with real painting, and the way artists often start from a rough sketch and then refine it.

This type of artistic algorithm design reflects the majority of computer graphics research in this area. The algorithms are automated, but we can explain in complete detail why the algorithm works and the intuitions about artistic process it embodies. This mathematical modeling of artistic representation continues the tradition begun in the Renaissance with Filippo Brunelleschi’s invention of linear perspective, a belief that I have expanded upon more elsewhere [28].

At some point, I found it very difficult to embody richer intuitions about artistic process into source code. Instead, inspired by recent results in computer vision [18], I began to develop a method for working from examples. My collaborators and I published this method in 2001, calling it “Image Analogies” [29]. We presented the work as learning artistic style from example. But the “learning” here was quite shallow. It amounted to rearranging the pixels of the source artwork in a clever way, but not generalizing to radically new scenes or style (Figure 6). Since then, other researchers have improved the method substantially [20], based on the same principle of rearranging patches of pixels.

In 2016, Leon Gatys and his colleagues published a new breakthrough in this space, Neural Style Transfer [21]. Based on recent advances in neural networks, their method transfers certain neural network correlation statistics from a painting to a photograph, thus producing a new painting of the input photograph (Figure 7). The method is still “shallow” in a sense — there is no “understanding” of the photograph or the artwork — but the method was more robust than the classical Image Analogies results in many cases. This paper led to a flurry of excitement...
Figure 5: Painterly rendering algorithms that process an input photograph, using hand-coded rules and algorithms. (a) Paul Haeberli’s interactive painting system [26]. (b) My automatic painting system [27] processes a photograph without user input aside from selecting some parameter settings.

Figure 6: Our Image Analogies algorithm [29], which stylizes a photograph in the style of a given artwork; in this case, Van Gogh’s *Starry Night over the Rhône*. 
Figure 7: The Neural Style Transfer Algorithm [21], which stylizes a photograph in the style of a given artwork; in this case, Van Gogh’s *The Starry Night*. This algorithm has led to numerous new apps and research in stylization.

Figure 8: Images that we generated using a neural network trained on different subsets of a database of artistic imagery [63].

and new applications, including the popular Prisma app and Facebook’s Live Video stylization, as well as many new research papers improving upon these ideas. This work is ongoing to this day.

Another development which received considerable attention in 2015 was the invention of DeepDreams by Alexander Mordvintsev [44], who, developing a visualization tool for neural networks, discovered that a simple activation excitation procedure produced striking, hallucinatory imagery of a type we had never seen before. There are many other current projects, particularly those around Generative Adversarial Networks [24] and Project Magenta at Google [42], that also show promise as new artistic tools. For example, Figure 8 shows images that we generated by visualizing trends learned by a neural network from a large collection of artistic images in different styles. Though automatically-generated, these image abstract visual concepts in a way that appears to be novel.
1.6 Algorithms are artists’ tools

In every technology that we currently employ — whether photography, film, or software algorithm — the technologies and algorithms we use are basic tools, just like brushes and paint. The same is true for the new AI-based algorithms that are appearing. They are not always predictable, and the results are often surprising and delightful — but the same could be said for the way watercolor flows on the page. There is no plausible sense in which current systems reflect “true” artificial intelligence: there is always a human behind the work.

Applying the same standard to the current research in neural networks and neural style transfer, it would seem equally perverse to assign authorship of their outputs to the software itself. The DeepDream software was authored by a human; another human then selected an input image, and experimented with many parameter settings, running the software over and over until obtaining satisfactory results. Indeed, in a recent art exhibition meant to promote these methods and their exploration [61], human artists were credited for each of the individual works. The same process of selection of tools and inputs, adjusting settings and even modifying code, and iterating until a desirable output is produced, occurs in all current computer artworks.

Unfortunately, there has been a considerable amount of media hype around AI techniques; in the news media, algorithms are often anthropomorphized, as if they have the same consciousness as humans (e.g., [64, 17]), typically accompanied by an image of The Terminator. In fact, we have no real idea what consciousness is, or what it would mean to embody it in an algorithm.

Rodney Brooks has written an insightful essay deconstructing common errors in making predictions about AI [5]. One of his key concepts is the notion of “suitcase words.” When we as researchers speak of “training” an algorithm, or an algorithm that “learns,” it is easy to interpret this as being the same thing as human learning. But these word mean quite different things in the two contexts. At present, nearly all “learning” algorithms are essentially data-fitting procedures. The human specifies a set of data to be fit, and a model with parameters to estimate, and the algorithm fits these parameters (usually, with considerable trial-and-error on the human’s part). But the algorithm has learned no general purpose understanding of the world. It is like a tourist in a foreign country that can repeat and recombine a few phrases remembered from the phrasebook, but lacks true understanding of the language or culture that it is visiting.

There are, indeed, fascinating parallels between human learning and machine learning, and it does seem likely that humans are, in some way, machines for optimization of evolutionary principles [3, 36, 60]. But going from these high-level analogies to actual machine intelligence is a problem for which the solution is not even on the horizon.

In short, in our present understanding, all art algorithms are tools for artists; they are not themselves artists. Moreover, we cannot conceive, in any meaningfully-rigorous sense, what it would be for AIs to gain human-level consciousness or independent thought. It is pure science fiction, and we might equally well worry about political structures for colonization of Alpha Centauri.
1.7 Technology helps art stay vital

Rather than being afraid of the new technologies, we should be enthusiastic about the new artworks that it will enable artists to produce. When we think of art of having external influences, we normally think of social or political influences, but ignore the effect of new tools. In contrast, I argue that, in the 19th and 20th Centuries, technological developments have played a pivotal role in advancing art, in keeping it vital and injecting fresh ideas. The stories I gave of photography and cinema include many of examples of this. However, the effect is far more widespread.

In any decade since the 1950s, our most culturally-important works used technology that had only been invented within the previous ten years. For example, most technology used in today’s feature films did not exist ten years ago (e.g., widespread use of HD digital cameras; facial performance capture); the same goes for artworks using smartphones and crowdsourcing; artworks involving white LEDs and Arduino controllers; DJs performing on stage behind their laptops; and so on. Even the most vérité-seeming romantic comedies frequently involve recent digital video editing and digital backdrops.

Conversely, artistic styles that fail to change often become stale and lose their cultural relevance; the adoption and exploration of new technology is one of the main ways that art stays vibrant. For example, the introduction of synthesizer music into 1980s pop music created a new sound that was exciting and modern. The sound diversified as the tools improved, until grunge became popular and made the 80s synthpop sound seem superficial and old-fashioned. Nowadays, a recent revival of 70s and 80s instruments by bands like Daft Punk and LCD Soundsystem seems most exciting at times when they are creating new types of music using old instruments, as com. In contrast, the swing music revival of the 1990s never went anywhere (from bands like Big Bad Voodoo Daddy and Squirrel Nut Zippers) in my opinion, because the bands aped classic styles with classic instruments, without inventing anything particular original themselves.

In each era, radical technological innovations are met by artists with both enthusiasm and rejection. For example, when the Moog synthesizer became popular, it was adopted by big-name bands like Emerson, Lake, and Palmer. Other bands felt that twisting knobs to make music was “cheating;” Queen’s album covers proudly state that the band did not use synthesizers. Robert Moog described one New York musician who said of the instrument “This is the end of the world” [55]. It now seems silly to imagine that people might have ever categorically objected to synthesized music, or to the scratching and sampling of hip-hop DJs, just as it now seems silly that people once rejected waltzing, the Impressionists, and the Rite of Spring as invalid or immoral.

In addition to stimulating for professional artists, new tools make art more accessible to larger portions of society. Photography was accessible only to the most determined early adopters, but has continually become easier, faster, and more compact, to the point where nearly everyone carries a mobile phone camera in their pocket or purse. The same goes for the tools of cinematography (from hand-cranked to cameras to handycams to iPhones), and so on. Modern computers give nearly everyone access to digital equivalents of darkrooms, mix-
Figure 9: Les Paul, inventor of the solid-body electric guitar in 1943; Robert Moog, pioneer of the electronic synthesizer, respectively. Their technologies transformed popular music in ways they could not have foreseen.

ing studios, painting studios, and so on; these were formerly highly-specialized technologies requiring laborious effort.

1.8 The general story of jobs and technology

Concerns of how technology displaces jobs has been around since at least the 19th century, when Luddite protesters destroyed mechanical weaving machines, and, in folk songs, John Henry competed against a steam drilling machine. In general, these disruptions have not led to large scale unemployment: as old roles are erased, many more arise in their stead. And, at any given time, it is very hard to foresee the specifics: it is easy to imagine losing specific jobs, but it takes superhuman imagination to think concretely about how transformative new technologies will create new opportunities. Yet this is the trend: overall unemployment has not continuously risen over the past 200 years, and most of us do jobs that would be hard to even explain to a 19th-century worker.

The real concerns should not be about technology, but whether the economic system shares the benefits of new productivity fairly across society versus concentrating wealth only among the very richest [58]. When displacements due to new technology occur, the solution is social safety nets and better educational foundations (for employment flexibility and retraining). Conversely, a society which fails to distribute wealth and economic gains fairly has much bigger problems than just the impact of AI.

1.9 What does this tell us about the future?

Some general trends around the evolution of technology and art seem to be quite robust. As discussed above, current AI algorithms are not autonomous creators, and will not be in the foreseeable future. They are still just tools, ready for artists to explore and exploit. New developments in these tools will be enthusiastically adopted by some artists, leading to exciting new forms and styles that we cannot currently foresee. It is possible that some tasks performed by human artists will gradually fade out, but these will generally be mechanical tasks that do not require much creativity because they fill societal functions other than artistic expression. Some
traditional arts may fade simply due to seeming old-fashioned; this is the nature of art: nothing is fresh forever, and is not to be blamed on technology. But, conversely, new technologies will enable new styles, aesthetics, and job descriptions. Novices will have access to new simplified tools for expression. Artistic technology is a “imagination amplifier” [8] and better technology will artists to see even further than before.

Aside from general trends, it is hard to make specific predictions about the art of the future. Les Paul, who invented the solid-body guitar in the 1940s, himself primarily performed light pop, country, and showtunes, and could hardly have predicted how the electric guitar would be used by, say, Led Zeppelin, just as it’s hard to imagine Daguerre predicting Instagram. More generally, making predictions about how AI technologies might transform society is very hard because we have so little understanding of what these technologies might actually be [5]. Even the science fiction writers of the 1950s and 1960s completely failed to imagine the transformative power of the Internet and mobile computing [34]; for them, the computers of the future would still be room-scale monstrosities that one had to sit in front of to operate. But they did predict moon colonies and replicants by 2018.

In short, we cannot predict what new inventions and ideas artists will come up with in the future, but we can predict that they will be amazing, and they will be amazing because they make use of technology in new, unpredictable ways.

Part 2: INTENT

I now turn to more philosophical and hypothetical discussion: could we ever say that AI itself created art? Will we ever recognize a piece of software as the author of a work of art?

Hypothetically, if we ever develop AI with human-level artificial intelligence and consciousness, it ought to be able to create art. But, as discussed in the previous section, this scenario is science fiction and we have no idea if this is possible or how it would be achieved. Making meaningful predictions about this world is impossible [5], because we have so little idea of how specifically this AI would actually operate. Moreover, this AI would transform society so much as to make it unrecognizable to us. We may as well speculate about what kind of artwork will be made by outer-space aliens when they come to visit.

Hence, the interesting question is whether there could be computer-authored artwork without human-level artificial intelligence or consciousness.

2.1 What is art?

The answer to whether computers can create art depends on what we mean by “art;” different definitions could lead to different answers. Hence, before tackling the question posed by this essay, it is important to first discuss what we mean when we say “art.”

For art world outsiders (i.e., most people), today’s definition of art seems to involve several overlapping but competing ideas: the image of the artist as lone genius struck by a mystical inspiration (i.e., “it’s art because I made it”); conceptual art, an inscrutable and bizarre enter-
Figure 10: The ever-broadening Western conception of art. (a) In Renaissance art, such as Rafael’s Vatican Palace paintings, beauty, technical skill, and, often, moral/religious instruction are all embodied in an artifact. (b) Modern works defy some or most of these requirements, like Marina Abramović’s performance art *The Artist Is Present* (2010), which is not a physical artifact.

Modern definitions of art. In the modern era, there have been several attempts to form concise definitions of “art” that capture everything that we describe as art, including both representational painting and conceptual art. The prototypical conceptual work is, arguably, Marcel Duchamp’s 1917 “Fountain,” an ordinary urinal that he inverted, signed with a fake name, and submitted to an annual exhibition. The Fountain made a clear statement that the artist’s concept and intent are all that are needed to create an artwork; no technical skill or significant effort are required. In the rest of the century, artists explored this idea and pushed the boundaries of precedent even further. Marina Abramović’s performance artworks produce no physical artifacts, but are still considered artworks that are “exhibited” in fine art museums; conversely,
Robert Smithson’s earthworks exist only in specific locations outside of gallery spaces. Outsider art and folk art are specifically the work of untrained amateurs, such as Grandma Moses and Henry Darger. A current definition of art must include all of these examples... and also, dance, music, literature, and so on.

Modern definitions of art are all meant to cover the same classes of works, and so they may all be valid; indeed, it seems unlikely that there is one single, compact definition [46]. However, some definitions may be more “predictive,” and thus give us more guidance about what might be valid art in the future.

Institutional definitions and an inclusive definition. Of the modern definitions, a good baseline definition of art is the Institutional Theory of art: art is anything that is culturally accepted as art by society’s cultural institutions [11, 13]. A variant on this theory is Levinson’s [38] Historical Definition of art: “a work of art is a thing intended for regard-as-a-work-of-art: regard in any of the ways works of art existing to it have correctly been regarded.” This definition allows for art styles to evolve, but not the mechanisms of appreciation, e.g., a pleasurable drug is not art because it never has been art. Modern theories have the role of the human artist — and their intent — as implicit to varying degrees. The question posed in this essay then comes down to the question of whether computer-authored works would ever be regarded as art.

I will state my own version of this definition of art as: the only meaningful prerequisite for being an artwork in the fine art world is to be some specific expression or activity invented by a human as art. This definition does not require cultural institutions or broad acceptance, merely the statement of a person that their activity is art. This definition includes everything that we currently consider as art. It may be over-broad, but not in ways that matter, particularly for the discussion here. And, by this definition, computers cannot create art, because it assumes a human artist.

This definition of art is extremely inclusive. A five-year old scribbling in crayon is making art. A teenager moodily shooting BBs into a lake could be described as performing art. An angry driver swerving in traffic dramatically could describe their act as art. Of course, just because we could call an activity art does not mean that we want to — my point is that there are few meaningful boundaries for what could be called art. For the teenager shooting BBs into a lake, most people wouldn’t bother to call it art, and there’d be no reason to do so. It would not satisfy the institutional definition of art that I gave above. However, if that teenager happened to have taken a lot of art classes and wanted to sell tickets to their situationist performance about environmental degradation, I would not waste my time denying their work the status of “art.” Instead, if pressed, I would question whether the work was worthwhile on any axis: is it interesting? Is it thought-provoking? Is it impressive? Does it say something interesting about current topics?

I believe that almost all real-life debates about what is or isn’t art are wastes of time. As a rule-of-thumb, if you someone presents a thing as their artwork, then it almost certainly is. The important question is, almost always, not “is it art?” but “Is it good?” How successful is it on different axes, e.g., is it technically impressive? Is it interesting or provocative? Is it beautiful?
Is it amoral? How much money is it worth? etc.

These definitions have the advantage of being broadly true, but have the disadvantage of being so vague as to be almost tautological. Quite understandably, they generally assume that art is the product of a human artist without justifying the assumption. They provide little guidance to the question at hand.

**Cluster Concept.** In search of a more precise definition of art, more recent philosophers have proposed that art can be defined as a “cluster concept.” \[22, 23, 15\]. A cluster concept is defined by a list of properties that a work may have, such as being a source of pleasure, requiring skill, being expressive of emotion, being bracketed off from ordinary life, and so on. In this view, no single property is a requirement for something to be called art, but it must have most of the properties. In addition, these authors also state some additional required criteria for artwork, including being a “product of an action” \[23\] and intended for an audience \[16\].

While none of these authors claim to propose a definitive list of cluster properties, Dutton’s \[16\] is the most comprehensive. Several of his properties relate mostly to technical skill that, in principle, AI could achieve, through improved models and improved training algorithms. However, several of his criteria would be difficult for AI to achieve, particularly Novelty and Creativity, Art Traditions and Institutions, and Imaginative Experience. Novelty and Creativity refers to the ability both to surprise, but also to explore deeper themes in new, unexpected ways. It is not sufficient simply to be novel, but to be novel in an interesting way. Art traditions and Institutions refers to the need to exist within an institutional context; conceptual art gains its value in part from its art historical context. Dutton writes that Imaginative Experience is possibly the most important of his twelve criteria: “objects of art essentially provide an imaginative experience for both producers and audiences. A marble carving may realistically represent an animal, but as a work of sculptural art it becomes an imaginative object. The same can be said of any story well told, whether mythology or personal history.” Additionally, Gaut \[23\] lists as one criteria “being the product of an intention to make a work of art,” implicitly, the intention of an individual or group.

For modern and conceptual art, how that work speaks to current cultural debates is crucial to the artwork. Marcel Duchamp’s Fountain would not have meant anything to a Renaissance noble; if presented as an artwork today, it would seem like a trite stunt. But, in 1917, it had enormous impact on discussions around art and we understand art. Conceptual pieces are significant for their place and time, and would not have been considered serious art at some other time. Many of these artworks attract attention and high prices simply because they provoke discussion and controversy, and pose fascinating riddles about the nature of art. As a recent example, Damian Hirst’s 2017 exhibition “The Wreck of the Unbelievable” left my head spinning for days with different interpretations and assessments, and wondering whether one can simultaneously be an artistic genius and a craven charlatan.

While it’s clear that we can “train” machines in some level of technical skill, all of the above aspects of art seem like they would be very hard for artificial intelligence to be good at, without any human-level understanding of society, culture, and human experience.

Like other modern definitions of art, the cluster criteria are primarily meant to be descrip-
tive: to include the things we current call art and not the things that we do not. They are not precise enough to be predictive, i.e., to answer whether some heretofore unseen new thing would be called art. (In machine learning terminology: these definitions cannot generalize to non-human art, because they were trained only on examples of human activity as art, i.e., they are overfit.) However, they do provide more precise statements of the hurdles for the AI artist.

2.2 Other important cases

Aside from abstract definitions of art, there are a few specific cases of art/non-art that are relevant.

**Not art.** It might seem that, in the art world, anything goes, and anything can be called art. But there are some instructive counterexamples.

Natural processes, including landscapes like the Grand Canyon or the HuangShan Mountains, are not art, even though they may be extraordinarily beautiful and change one’s perspective immensely. Beautiful structures made instinctively by animals, such as honeycombs, are not considered art.

In some cases, higher mammals have been trained to paint, including chimpanzees, elephants, and dolphins \[12\]. Often, the animal’s owner or handler typically steers the process, e.g., stopping the painting when they believe it is done and selecting which works to show. It often seems that the animal is doodling on the canvas while the human is making the editorial decisions that identify lucky doodles to be called artworks. Animal artwork has not had any significant cultural impact or popularity; it seems to have been largely sensational news item. (People for the Ethical Treatment of Animals have recently tried to claim copyright in favor of a monkey, but failed \[43\], as US copyright law only allows humans to claim copyright.) Based on this, together with evidence that human guidance is usually involved, I am skeptical as to whether we should consider any of this to really be art. More likely, it should be considered the art of the zookeeper and not the animal.

Despite attempts to promote animal artwork, human intent seems to be crucial for the time being. However, the discussions around animal artwork are empirical rather than definitional: is the thing that the monkey is doing art? Does the monkey conceive of the artwork as a thing in itself? Does it care about aesthetics, beauty, or visual expression? These are empirical questions. It’s not that the human element is really fundamental, just that we haven’t yet found any creatures (or robots) that seem to be making something that we consider to be real artwork.

**Collaborations and contributions.** In some cases, multiple people are involved in the creation of an artwork, which is instructive for how we might credit humans working with AI or crowdworkers. First, artworks can obviously be collaborations between multiple people. Equal collaborators usually get equal credit (e.g., Leonard Bernstein and Stephen Sondheim); in a more hierarchical relationship, e.g., a movie director and their actors and crew, the director gets authorship, though the contributions of actors and crew get recognized as well. Sometimes artwork involves collaboration with technicians that are not really considered artists themselves,
Crowdworking involves automating requests for many small tasks from online human workers, and has been described as a technique to solve AI-hard problems with human workers, essentially, turning people into algorithm subroutines [39]. Scott Draves’ Electric Sheep artwork runs a genetic algorithm that optimizes procedural patterns, with a fitness signal provided by hundreds of thousands of users voting on which patterns are most appealing [14]. Aaron Koblin’s Sheep Market [32] involved many crowdworkers paid two cents for each sheep drawing. In each case, credit for the artwork goes to the coordinator/creator, not the crowdworkers. (As livestock-themed Internet-scale works go, Ian Bogost’s satirical Cow Clicker video game [59] is also singular.)

An extreme and controversial example is Richard Prince [41], a conceptual artist who directly copies others’ work and regularly sells it for millions; the other photographers that he directly copies do not receive any of the credit or profit (except, potentially, through lawsuits).

These examples all show that, in our current definitions of art, no matter what contributions of the work came from other people or machines, the artist who conceives and directs the work gets ultimate authorship credit. Hence, it is not enough for an AI to create most of the work to be an author of it. Conversely, an AI that directs the work, but relies on crowdworkers to execute the individual tasks, could be considered an artist.

“Art” as colloquial judgment. The term “art” is often used in another way, i.e., to separate good from bad or to elevate the ordindary to be exalted. I recall one of my college art professors, in several instances enthusiastically declaring one amateur or another as “a real artist!” For example, he gave this praise to Scott Weaver, a hobbyist who spent many decades building an awe-inspiring model of the San Francisco Bay Area out of toothpicks and Elmer’s glue. Likewise, one might praise their friend’s drawings by saying “you are a real artist!” In these cases, “art” and “artist” are judgements of technical skill. Paradoxically, this usage is both inclusive — it allows untrained hobbyists to be elevated to the status of artist — but also
elitist because it excludes people based on skill. When spoken by, say, an artist or professor, it furthermore seems meant to elevate the speaker, to show that they are authorized to decide what is or isn’t art.

I think this usage is risky as a definition of art. Here is an analogy. Suppose that it were common, when describing a movie that one does not like, to say that it “wasn’t a movie.” For example, when coming out of, say, “Star Wars I: The Phantom Menace”, most people would say that it wasn’t a movie. A few fans might say that it was a movie, and then they would get into arguments about whether it was or wasn’t a movie. Each person might have their own slightly different idea of what makes something a movie or not. This seems like a confusing and ridiculous argument to have: we should be arguing over whether it was a good movie: whether it was fun, meaningful, exciting, or provocative. When arguing over whether or not something is an enjoyable movie or not, the subjectivity inherent in the question is obvious, but not when arguing whether or not it is a movie at all. Arguing over whether something is or isn’t art seems equally ridiculous.

Using an inclusive definition of art greatly improves communication. For example, getting into debates about whether something is or isn’t art is usually a quagmire. Saying that, say, a work by Thomas Kinkade or Damien Hirst “isn’t art” is phrased as an objective judgement. But it is really a subjective choice, e.g., it asserts that Kinkade or Hirst’s work is unoriginal, cliched, or pretentious. The objective-seeming statement hides the subjective nature of the judgement, and obscures the real reasoning behind the judgement.

2.3 Could the definition change?

“Human intent” is crucial to our current definition of art. But art is culturally defined, and has steadily expanded over the past centuries. The definition could change again.

The fact that there is debate over whether animals’ painting are art, and whether AI could create art, indicates that we are open to the possibility. Perhaps there is a more fundamental definition of art lurking here that could include animals and AIs, if only they were to meet the right prerequisites. The cluster criteria provide some candidates. But, more fundamentally, it seem like underlying consciousness, and a desire to communicate through art, are our prerequisites. As stated above, conscious AI is currently science fiction, and so I consider only whether people might accept art from non-human-level AI.

Indeed, there are a few systems in which the authors of the software, describe the software as the artist, or as software that they hope will be recognized as such, e.g., [19, 10].

The definition of art could change in the following way. Perhaps a curator at a well-known museum would download or otherwise acquire various artifacts from software “artists,” and list the software systems listed as the authors. There would be controversy, and discussion in newspapers and journals. Perhaps other curators and galleries would follow suit. Perhaps people might accept art from non-human-level AI.

An additional disadvantage of art as judgment is that it discourages amateurs from pursuing art as a hobby, without risking the possibility that their amateur watercolor or crocheting isn’t art. Everyone can create art, even if only for their own satisfaction and enjoyment, or for sharing with friends and family; it need not be museum-quality to be a worthwhile activity.
ple would find enough value in these computer-generated artworks, while also being convinced that no human could be rightly given credit for their works. Perhaps gallery owners would find a way to limit supply so that the works could be seen as valuable, and sold to wealthy collectors and museums. This sort of process has happened for things like abstract expressionism, and not for chimpanzee art. Could it happen for computer art?

2.4 Building an Intent Machine

Let us now conduct a thought experiment of building a computer artist. This artist must be able to generate an “intent.” I suspect that actually defining what we mean by intent, in a comprehensive and complete way, is very hard. For some artworks, the intent might be very hard to articulate, or a matter of speculation. However, no artist needs to be able to have every possible intent, so we just need to create a sufficient rich set of “intents.” I will focus on representational painting, in order to narrow the scope of the discussion. (A few previous systems have tried to create intent, e.g., [35]).

I first need to define, in some way, a set of possible intents, and how I’d represent intent in software. Let’s say that the system’s intent can be one of the four possible goals: to depict a specific scene and the feeling that it conveys; to express the artist’s emotional state; to make a statement through the scene (e.g., glorifying nature, portraying the city as exciting or as disgusting); to make a conceptual statement (to glamorize or protest an event, or a concept, or a person). The intent could be represented by a simple data structure (e.g., <mood, serenity>, <glorify, valor>), an English-language sentence (“I wish to express melancholy over human mortality”), or a learned feature encoding (e.g., non-linear embedding) that captures hard-to-articulate concepts inferred by latent variable modeling and weakly-supervised learning. Recent methods that convert from images to English-language descriptions [30] or vice versa [65] could be inspirational here.

As for execution on the intent, there are many options. We could train a neural network model that takes a given “intent” and a photograph, and creates an appropriate painting for simple concepts; or, if this model isn’t good enough, the system could hire a professional through an online crowdworker platform in order to execute on the intent. The input image itself could be automatically selected from online image collections, instead of being provided to the system. The system might also include a classifier or ranker to identify which artworks it produces are the best. Although the synthesis model might not be very good at first, as we have seen, authorship of artwork is defined by the intent and editorial choices, not by execution.

The simplest intent generator would be hand-authored. I could write some lines of code that, given an image, randomly selects which of the four types of intents to apply, and then randomly generates appropriate qualities to go with it (e.g., which emotional state to depict). I might make the sampler conditional on the image content and photographic style.

I could then submit the generated artworks to a gallery or art exhibit, describing the process by which they were created. I highly doubt that people would accept the computer as artist; they would say I am the artist, since I conceived of the system, and designed it with the intent of exploring the boundaries of artificial creativity.
The next step would likely to be train better models of intent. Perhaps I would scrape artist statements from the web, or from analysis of Wikipedia pages, or, more likely, pay crowd-workers to annotate real-world artworks with their intents according to a rubric that I’d specify. I might train a model that infers latent parameters of intent and style that can’t be manually annotated. Even better would be to first generate an overall meta-intent and style, representing this artist’s particular inclinations, and a natural-language “Artist’s Statement” expressing this concept, and then a collection of individual artworks that elaborate on that theme. The system would also need to automatically select starting images from online social images, or, better yet, generate them with a generative model (e.g., a Generative Adversarial Network [24] or Variational Autoencoder [31]). The system could also be refined by using crowd workers to evaluate, label, and score its outputs, in order to improve each step of the process. Many other continued refinements would be possible.

2.5 How good does it have to be?

As one continues to improve this system, is there a point after which viewers — even ones that fully understand the process — will be willing to assign authorship to the software itself? I remain skeptical. I think people are going to set the bar very high for computer artists. It won’t be good enough to paint like humans paint. As suggested by the cluster criteria, computer artists are going to have to show us something truly new, and be good at it, i.e., not just getting lucky once in awhile. It will have to, in some sense, be in-tune with our current cultural concerns. We are going to have to have a sense that there is an agent behind the work that is consciously creating a work of art. This requires human-level AI and consciousness, which again, is science fiction.

One standard for judgment is: does the artificial artist automatically create works that (a) could not be conceived of by the system’s author, or by anyone that understands the algorithms and methodology, (b) are not simply mimickry or interpolation of the training data, and (c) satisfies the aesthetic, conceptual, or other roles of art well enough to be included in galleries or other exhibitions alongside human art? This is a high bar that we are not anywhere near reaching. (A related standard that is more focused on the system’s level of understanding is given by Colton [9].)

Perhaps the system could be trained to extrapolate from current trends. Extrapolation is extraordinarily difficult. A more effective strategy in trendspotting is to identify “influencers” (e.g., cutting-edge artists who are not well-known) and then adopt and explore their styles. It is hard to devise a strategy that does not, in some sense, seem like cheating.

Sometimes people are fooled by shallow AI. The Eliza system is a simple text-based “psychiatrist” program developed in 1964, based on simple pattern-matching and repetition of what the user types [62]. It was meant as a demonstration of the superficiality of the AIs of the time, but became remarkably successful: many people attributed human-like emotions to the machine. Since then, many “chatbots” have fooled humans in online settings. But, once the veil is lifted, it is clear that these chatbots don’t actually exhibit real intelligence.

Likewise, there are attempts to assess creativity of software [50, 9], but, as long as the
algorithm is following rote (or random) procedures that people can understand, or that the system’s author could easily conceive of within their framework, it is hard to see how the system will be accepted as an artist.

Almost every experiment that I have proposed in the previous two sections is something that we could, more or less, implement with existing technology. It would certainly be fun to try this out, and that’s the only way to find out how good it really is. But I doubt that the outcome will be an “artist” anytime soon.

Computational theories of creativity are fascinating to consider, and some lovely results have come from this [19]. But “creativity” is a another “suitcase” word: the computer’s creativity cannot simply be automatically equated with human creativity to grant computers autonomous authorship.

Conclusion

One of my main goals in this essay has been to highlight the degree to which technology contributes to art, rather than being antagonistic.

Fears of new technology seem to be human nature. I suspect many people view the “normal” state of things as being how they were when they came of age, and they view any significant change as scary. Yet, nearly all of our familiar modern technologies were viewed as threatening by some previous generation.

The fear of human-created life has been with us for a long time. Notably, 18th-century scientists discovered electricity. As they searched to understand it, they discovered the life-like effect of galvanism, i.e., that the muscles of animals such as frogs could be stimulated by electrical currents. Had the secret of life been discovered? This inspired Mary Shelley’s novel Frankenstein; or The Modern Prometheus in 1813, in which a scientist uses modern science to create new life [53]. Today, the story is vivid and evocative, but, intellectually, we recognize it as preposterous. The fear of AI is essentially the same irrational fear; SkyNet is Frankenstein’s monster, but with neural networks as the Promethean spark instead of galvanism. At present, the autonomous AIs of The Terminator are only slightly more plausible than its ability to travel backwards in time.

There are real dangers to current AI technologies, particularly, misuse of big data and machine learning that inadvertently magnifies existing inequality and unfairness in our social and governmental structures [47, 4]. These are problems not with technology per se, but with how it is used by humans and organizations.

Every time I see an artist create something wonderful with new technology, I get a little thrill: it feels like a new art form evolving. Danny Rosin’s Wooden Mirror, Jason Salavon’s The Top Grossing Film of All Time, 1 x 1, Bob Sabiston’s Snack and Drink, Michel Gondry’s Like A Rolling Stone, Kutiman’s ThruYOU, Amon Tobin’s Permutation, Ian Bogost’s Cow Clicker,

4In fact, Frankenstein is presented as a cautionary tale about the quest for knowledge in general. Victor Frankenstein tells his story as a warning when he learns that Captain Walton is himself driven by an obsessive quest for knowledge, even though it is entirely unrelated to Frankenstein’s experiment.
Christian Marclay’s video installations, Íñigo Quilez’s procedural renderings, and Wesley Allsbrook’s and Goro Fujita’s Virtual Reality paintings are a few examples of artworks that have affected me this way over the years.

Art maintains its vitality through continual innovation, and technology is one of the main engines of that innovation. Occasionally, the avant garde has tremendous cultural impact: electronic music and sampling was once the domain of experimental electronic and musique concrète pioneers, like Wendy Carlos and Delia Darbyshire. Likewise, at one time, computer-animated films could only be seen at obscure short-film festivals. Today, we are seeing many intriguing and beguiling experiments with AI techniques, and, as artists’ tools, they will surely transform the way we think about art in thrilling and unpredictable ways.

Acknowledgements. TBD

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