The Triple Helix at Johns Hopkins University

The Science In Society Review

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About The Triple Helix

The Triple Helix is an international network of undergraduate students that focuses on the dynamic relationship between science, society, and law. We aim to promote education and critical thinking about current developments in science and the implications of these issues within a broader societal framework. The flagship journal of the Triple Helix is the Science in Society Review, which features articles that tackle scientific issues from any interdisciplinary lens including business, law, and ethics. In addition to these publications, the Triple Helix also hosts discussions, lectures, and conferences throughout the semester, so there is always something to look forward to!

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A Letter From the Editors

Dear Reader,

I think it is safe to say that our entry into a new decade has not gone as expected. Every one of us has, in some way, been affected by the ongoing COVID-19 pandemic. Our world has changed beyond what is recognizable: stay at home orders, panic over groceries, and virtual meetings have become the norm. Our response to our altered circumstance has been multi-faceted. Many of us feel mournful for lost opportunities and miss spending time with our friends, even as we fear for our loved ones and worry about economic ramifications. Nevertheless, we have continued to live our lives to the best of our abilities, displaying incredible resilience and adaptability.

At a time like this, the importance of understanding the interplay between science and society is paramount. The divide between academic science, which can seem to exist in an ivory tower divorced from regular concerns, and human society, with its roots in the day-to-day experiences of individuals, may appear to be an unbridgeable chasm. Today, we see in real time the importance of bridging that divide. It is essential that, as a society, we commit to fighting this pandemic; science alone will not be able to save people's lives. However, it is scientific enquiry that will give us the critical information we need to overcome this disease. Both facets are necessary, and neither is sufficient without the other.

The Science in Society Review was established to promote understanding of the impact of science on society, a mission which – though always relevant – seems unusually timely. Our theme for the 2019-2020 journal (chosen well before any whisperings of a pandemic) is "The Art of Science," and seeks to explore how the science can be applied to art, and how artistry is omnipresent in science. From addressing the neurological basis of making and interpreting music to the using artificial intelligence to detect art forgery, the articles in this journal push the limits of what we think of as disparate fields.

Though no single article in our journal addresses the current pandemic, they provide a framework for understanding how thoroughly inseparable science and society are. We would like to thank our writers, our editorial team, our production team, and our executive board for continuing to do the work necessary to bring this journal to fruition, even as our world changes in the extreme. We are incredibly grateful for their dedication to making this journal the best it can be. Working on this journal has shown all of us, repeatedly, that science requires society in order to be meaningful and society requires science to move forward and solve problems. I hope it does the same for you.

Sincerely,

Ananya Reddy & Naomi Doshi
Editors-in-Chief, The Triple Helix at JHU 2020

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THE ART OF SCIENCE
The Gene from the Machine: Creating Art Using Genetic Data

AARUSHI KRISHNAN

ABSTRACT

Genes are the code of the natural world. From the largest blue whale to the smallest bacterium, every bit of life is infused with a code that defines its character. DNA plays such a large role in shaping the world around us that it seems only fair to translate such an important aspect of life into art. Such a creation blends the worlds of science and art, and brings out a number of philosophical questions as well. However, for some, turning genetic code into works of art may seem confusing, even verging on unnecessary. For centuries, art has stemmed from the human mind, with no tools no more advanced than a paintbrush. So, are the works created by expensive laboratory equipment truly art, or are they nothing more than lab results? This article will explore that question, taking into account the different ways and techniques with which genetic art is done as well as the ethical implications of these creations.

At first glance, Children's Mercy in Kansas City, seems like any other pediatric hospital in the world. Colorful toys litter the waiting room, nurses parade each corridor, and the smell of disinfectant is ubiquitous. Looking up at the massive building, sharp-eyed visitors at the hospital might notice that a few windows are colored differently, creating a contrasting arrangement to the otherwise neutral façade of the hospital. However, this isn't just an artistic statement. These colors represent genetic mutations that the children of the hospital suffer from that were painstakingly discovered through DNA analysis.[1] Not quite your typical art project.

Using genetics to create art is a method that's fresh off the press, and its novelty is its true driving factor. This world we live in is ever-changing, and to stay ahead of the game, art

Children's Mercy, Kansas City. The red windows represent genetic mutations that children of the hospital suffer from, and the glowing red staircase (far right) represents a double stranded DNA helix.[7]

must be constantly evolving too. Science-based art seems to be the natural progression-nothing else in this world is moving as fast as the advancements of science. However, this begs the question- how much is too much? Is using important (and expensive) laboratory equipment to create art pieces truly necessary?

Though genetically modified art is still in its early stages, using the natural world as a source of entertainment is no new feat. Science has been fueling our stories for time immemorial- from learning about Franklin and his electricity experiments in elementary school, to watching David Attenborough's fascinating natural world documentaries in our free time, science has always been something that we have been captivated by. In this sense, it can be argued that genetic art is simply a logical progression. If we have been using science as a source of amusement for decades, this novel form of art production is nothing but a newer, refined form of this entertainment.

But what exactly does this "art" entail? The answer may lie in a laboratory in Ottawa. DNA 11, is quite different from all other laboratories in the world. Instead of creating vaccines,robots, or cures to cancer, this lab is the first in the world to create DNA portraits.[4] Owned by two former lab scientists, Adrian Salamunovic and Nazim Amhed, DNA 11 specializes in crafting one-of-a-kind portraits created by analyzing their customers' DNA. The lab sends them state-of-the-art DNA sampling kits, and customers' genomes are obtained from the saliva samples, from which individualized portraits are made.[5] These portraits have obtained a notoriety in the art world- they have been featured in WIRED magazine, the New York Times, MOMA, and even Playboy. Interestingly, these portraits are not just valued for their aesthetic sense- in an episode of CSI: NY, a suspects' DNA was linked to the scene of the crime using nothing other than a portrait of her DNA, createdfrom none other than the humble DNA 11 labs. Currently, business is booming for the labs, which have been estimated to have made a whopping 7.8 million dollars from 2008 to 2018.

Art is made to evoke thought, and the genetic creations created at the Gene Craft Exhibition in Birmingham can certainly be considered thought-provoking. British artist Laurie Ramsell wanted to delve into the similarities she saw between humans and the model organisms geneticists worked with.[2] To do so, she created Homdanio Birminghamensis, a sculpture in the shape of a zebrafish, an animal that is frequently experimented on in labs all over the world. The sculpture was made with bacterial cellulose and the artist's own DNA. The sculpture was created to generate awareness about research into the human genome, but it sparks a deeper question, making viewer and critics wonder what the lim-

Homdanio Birminghamensis, Laurie Ramsell. The Zebrafish sculpted by Ramsell out of her own DNA. [8]

its off animal research truly are. By sacrificing an enormous amount of animals (22 million per year in the US alone)[6] for the sake of human betterment, are we placing a price tag on life? The importance of art is that it makes us ask ourselves the hard questions, and the advent of science-based art only serves to strengthen this issue.

Another creation at the Gene Craft Exhibition drew on human relationships. Gina Czarnecki's Heirloom was a testament to her two daughters.[2] The artists grew her daughters' skin cell tissues onto a glass mask of their face, creating what could be argued as the most realistic masks to ever exist. These art exhibits blur the line between science and art and bring out the true sense of genetic art- pieces that were made to evoke emotion, that were created to produce more questions than answers.

Just how practical is this form of artistic expression, though? The equipment needed to create these pieces are in no way cheap, and the process is time consuming, as well. There is a certain amount of knowledge needed to create these art pieces, which means that often artists team up with scientists to create their work. This is a laborious process, and the end result does not even have any practical use. It would make one question just how important this artwork truly is.

At the end of the day, it is important to clarify whether these genetic manipulations even truly art, or are they simply results from a lab. Beauty is in the eye of the beholder, true, but this form of artistic expression is ethically ambiguous and raises several moral questions, bringing into question whether genetically manipulating living tissue in the name of art is the right thing to do. These art pieces are technically living (or made from living materials) and manipulating life for the sake of our entertainment could border on inhumane. A solution to this dilemma could be setting up an ethics board that oversees genetically manipulated art, similar to the ethic boards that clear laboratory experiments. It may seem counterintuitive to place rules and regulations on art, but the scientific aspect of this art must be handled with tact to ensure that this world of limitless opportunities do not get out of hand.

The reason these artworks receive such notoriety is that they are a flashy new phenomenon. Fusing science with art has previously been unheard of, which is why everyone wants to get a sight of this novelty. But what happens when it stops being a novelty? As time progresses and this science-art hybrid becomes common place, enthusiasm (and not to mention funding) will start to dwindle, and these genetic masterpieces may well become a thing of the past. To overcome this, these artists would have to keep coming up with grander and more technically complex ways of keeping the public entertained. That is the essence of art, after all, and the pieces that stand the test of time are those which has the power to stick in the human mind. As time progresses, who knows what path this art form will take? The world of genes is ever evolving, and the possibilities for the art world are endless.

"Fusing science with art has previously been unheard of, which is why everyone wants to get asight of this novelty. But what happens when it stops being a novelty?"

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A Medicinal Playlist?

ANJU FELIX

ABSTRACT

Music can be any combination of sound and vibration creating a beauty of form. It is an embodiment of expression capable of stirring feelings amongst all listeners. Purely abstract, regardless of the absence of coherent or proper instructions, music somehow causes such a distinct, strong change that begins at the molecular level. What is music to us? Perhaps the steady 4/4 meter of a Bach Sonata, the deep booming sounds of the opera, or even the freestyles of Eminem and company! However, music greatly differs across the world and regionally outside of our western sphere of influence, both structurally and in how it impacts our lives and cultures. Does this cultural shift affect how we perceive music?

Historically, many have attempted to categorize the wide breadth of responses to music. Johannes Tinctoris (1435-1511), a renaissance composer and music theorist, attempted to classify 20 different ways music affects us, most notably with respect to its ability to cure disease. But the most applicable effects today are Musica Deum delectat (religiosity), Musica tristitiam repellit (depression), Musica homines laetificat (joy), Musica aegrotos sanat (therapy), and Musica amorem allicit (sexuality).[1] In order for the brain to perceive this music we hear and conduct these various feelings, the sound waves and frequencies must be transduced into the language of the nervous system: action potentials. The vibrations enter the external ear and travel through the canal to mechanically interact with the tympanic membrane (ear drum).[2] In the cochlea/inner ear, the sound waves will finally be transduced from a physical vibration to neural signals. After the sound waves have been transduced, the information is sent towards the Auditory Cortex where it is consciously perceived by us. Following this process of transduction, music causes further internal, hormonal changes, directly causing emotional and behavioral changes in a listener that can be tested, quantified, and researched through lab techniques and case studies.

In neuromusic research, western classical music is typically used to observe and catalog emotional changes. However, these effects shouldn't be generalizable across music of different cultures due to the drastically different tonalities and structures. Music can generally bubble down to 3 components; melody (overarching theme), rhythm (used to further addinterest and texture), and harmony (used to highlight melody and contribute to tone). How these 3 are interpreted, however, differs greatly between different styles of music.[3] India is often described as a country of colorfulness. Colorful foods, clothing, and even the people! In the arts, the music of India is something especially unique to the land. For example, when comparing the use of harmony in western music vs. Indian music, it is very characteristic for Indian harmonies to consist of repeated combinations of the same tones. Structurally, a musical theme in hindustani or carnatic music is called a Raga, analogous to a western scale. In its most basic, unim-

"Music greatly differs across the world and regionally outside of our western sphere of influence, both structurally and in how it impacts our lives and cultures. Does this cultural shift affect how we perceive music?"

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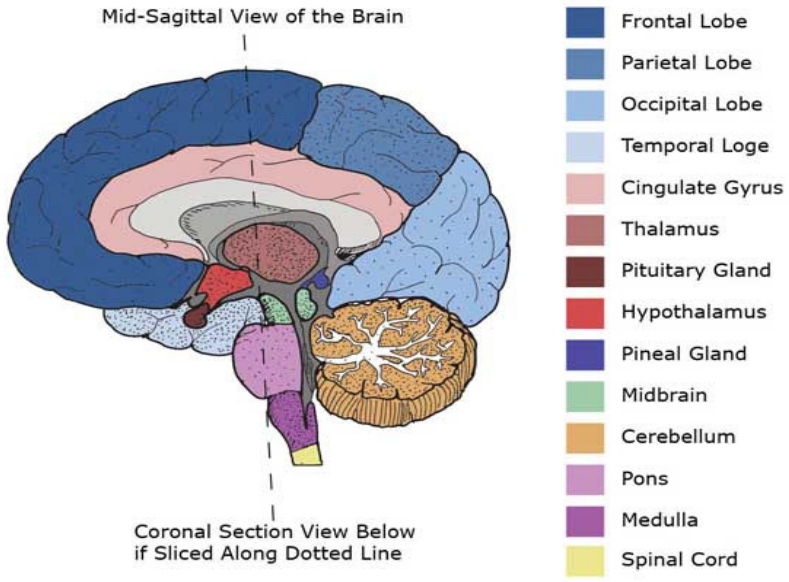
provised form, it consists of 8 ascending notes and 8 descending notes that have various possibilities in terms of tonality (the character of the piece expressed through the notes it contains). These changing tonalities are used to bend the mood and evoke different emotions throughout the musical piece. From here, artists can add gamakas, a form of vibrato (the wavering of pitch), to further add to a listener's experience, and portamento, similar to a crescendo (the piece is played progressively louder) but pitch also increases. Once a pattern/raga is selected, an artist will then improvise the pattern, with performances extended to hours. And the question remains, how does this style affect our brain?

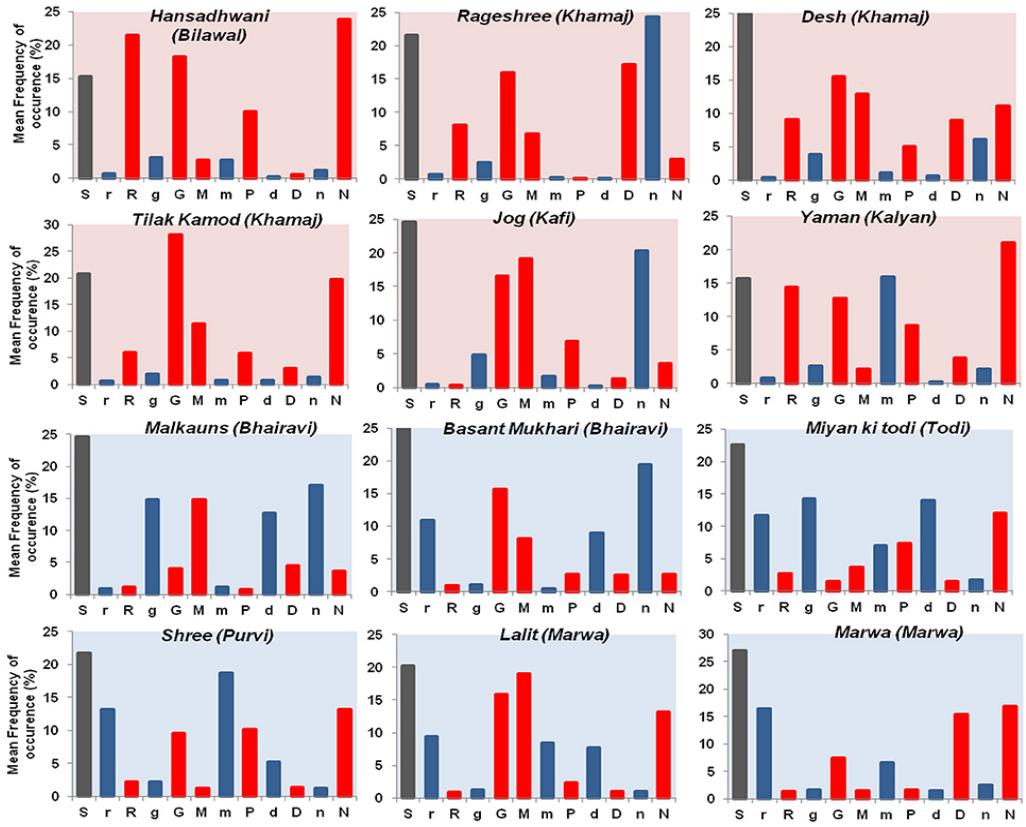
As expected in such an organized, complex organ, certain areas of the brain respond to very specific features in music. The basic, distinct features like timbre, roughness, intensity, etc. of music are translated by the midbrain and then routed towards the cortex by the thalamus. At the cortical level, the auditory cortex handles the more complicated features and even has a component releasing dopamine when stimulated! Determining a melody consists of 3 different phases: detection of stimulus (sound), determining pitch for each segment, and determining the changes in pitches for each segment. This processing begins in the brainstem of the lower brain but is ultimately completed in Heschl's gyrus of the cortex. As these characteristics are processed, they could also give rise to certain physical changes in a music listener. For example, tempo in some cases could influence the cardiovascular system. In ragas, the difference in tonality/agreements of harmony between notes can be directly tested against tempo. This is due to the unique presence of the alaap and gat in classical Indian music, which are the same in tonality, but simply differ in tempo with the gat being substantially faster, introducing a rhythmic component with drums. Most interestingly, acombination of these, tempo, dissonances, changes in instrumentation, etc,. can result in piloerection, better known as goose bumps. Not only is this a physical effect of hearing certain characteristics, but it can also be used as a measure for peaking emotions or sensations. If chills are experienced in response to music, decreased blood flow would be observed in the amygdala and hippocampus. These areas of the brain are especially sensitive to rewards (food, drinks, sex, etc.) and their consumption. Because of this, pleasure evoked by music is associated with a rewards system, playing towards the idea that it is a "natural process" within the body.[4] In addition to physical effects, one's mood could completely change when presented with a to musical stimuli. On the most basic level, due to the release of dopamine, music can have positive effects on mood and overall better social cohesion and cooperation. All in all, the engagement of the neurochemical systems as a result of



To better visualize the different processes/organs of the brain, provided is a color-coordinated map.[4]

listening to music is extremely evident. Firstly, stress itself is the neurochemical response usually associated with high cortisol levels and a poorly maintained homeostatic equilibrium. In general, music causes cortisol levels to lower, leading to a reduction in stress and arousal levels.[5] Because of these general positive reactions, music therapy is often used to mediate certain disorders. One form, known as Guided Imagery and Music (GIM) combines common relaxation techniques while listening to classical music. This type of therapy inhibits the activation of hypothalamic-pituitary-adrenal and cortisol which ultimately results in a decrease in stressors. Because of the nature of the Hindustani/Carnatic style lacking sheet music to learn, this form of music, considering the flexibility of a performer to improvise could be advantageous to providing specific genres and moods to a patient.

Outside of just processing and reacting to characteristics of music, the brain is capable of associating and perceiving emotions tied to it. For ragas, the desired emotional effect is called the rasa, which is intended to effect the bhava, mood, of a listener. Taken from the Natyasastra (200BCE-200CE), a book giving a historical overview of dramatic performance; "Just as noble minded persons enjoying delicious food seasoned with different spices relish the taste with delight, so does the knowing audience relish and savour the experience of emotional states [Rasas] in a performance and are moved by them". There are 9 standard forms of rasas; Sringara (erotic), Vira (Heroic), Karuna (pathetic), Adbhuta (marvellous), Hasya (ludicrous), Bhayankara (terrible), Bibhatsa (disgusting), Raudgra (furious), and Santa (peaceful). These rasas contribute to a distinct bhava which is very specific to the raga. In the words of a mythical sarod player from the Natyastra Epic, compares the emotional flavor of ragas to gustatory taste; "Khansahab would present the audience the distinct form of different ragas.[6] Those who knew how to notate would feel as if they had understood the



Here are graphs of the 12 different ragas cited in the body paragraph. The bars in each chart represent each interval and the color red indicates a happy feeling while blue indicates a sad mood. The color of the backgrounds indicate the general feel of the raga, and this general feel is determined by a majority of either red or blue bars. From these, it is confirmed that more frequencies of minor intervals contribute to a sad mood, likewise with major intervals.[8]

form of the raga fully, but the moment Khansahab began a new raga they would forget the lifeless notational skeleton of the earlier raga. As in a feast, when one forgets an earlier dish the moment one begins to partake of another, and finally remembering only the enjoyment of the whole feast one would remember Khansahab's concert as a whole, as a memorable experience." These different moods are evoked through the possible tonalities and consonances a performer could decide to perform. This is very dependent on the intervals between the notes. Major intervals, Shuddh Swaras, are seen to be associated with positive emotions while minor ones, Komal Swaras, tend to show negative. It is very commonly seen that ragas as a whole are received with listeners exhibiting positive mood if the average frequency of occurrence of major intervals was greater than minor. In a study by Mathur A. of the national brain Research Centre, 12 ragas or varying tonalities and alaap and gat were presented to 122 participants. From here, it was found that tempo and rhythm modulated the level of arousal while tonality determined emotional flavour. When the faster gat form was presented, participants were far more descriptive in terms of the emotions they'd felt (romantic, calm, sad, tension, etc), but with the alaap form, reviews were mostly either calm or sad. Upon acoustic analysis and correlating this with the behavioral ratings given by surveyors, it was concluded that high arousal emotions (happiness/tension) were associated with gat. Through the lens of tonality, it was further confirmed that minor intervals (minor second, etc) predict a negative emotion.[7] In conclusion, it can be said that music of all forms could potentially be extremely impactful in our lives. Through various research techniques, it has been quantified and proven that various inner processes occur as we are stimulated by special patterns of vibrations and frequencies. As a day to day, music can be commonly used to relax and ease stress, so much so that it can even be used in clinical therapy. Perhaps from here, more experimental research can be done in studying specific treamtents through eastern music. Even other cultures' music could be examined; yayue from China, bakhsi from the Middle East, etc. All in all, by understanding the possible reactions to music and the specific ways to induce the hormonal and physical reactions, techniques to better play and produce music could be communicated to all. For example, musicians could learn more efficient ways to memorize, play in an ensemble, interpret lines, music producers could incorporate structures researched that are more favorable to a listening audience, cohesive in instrumentation, or even easier to perform, and music vendors can push labels that appease to dopamine tracks! Regardless, it contrives immense emotion amongst those who pause for a minute and listen.

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THE ART OF SCIENCE
Microbes, Museums, and the Clean Obsession of the Victorian Era

BAYLEIGH MURRAY

ABSTRACT

With more microbial species on Earth than there are stars in the galaxy,[1] wherever you go, you are sure to have innumerable microbial companions hanging on for the ride. Microbes are the smallest unit of life that can be defined. They were the progenitors of all life on Earth and they exist in virtually every environment on the planet: sheltered in the pores of rocks, superheated and compressed in deep sea hydrothermal vents, lying in wait on kitchen countertops, and perhaps most personally, thriving on nearly every part of the human body. As the base of the food chain, if there were no microbes, there would be no Earthly life to speak of. Despite the undoubtedly crucial role microbes play,, there has been a large gap in public understanding of how microbes interact with our bodies, alter climate, and are applied in industry. Luckily, from every problem arises a solution—in this case, museums—which can use art to develop a more microbially literate society.

Among the middle and high class in the Victorian Era, there was a desperate desire to be clean. However, the sanitation and cleanliness rituals of wealthy British Victorians were unable to safely keep up with industrial advancements. With the increasing popularity of dedicated bathrooms and daily washing in tubs sat over gas burners, came a slew of headlines reporting extreme scalding. In an effort to be clean in the most modern way, the Victorians were literally boiling themselves alive.

Misunderstandings about the biochemistry of feces, particularly the release of the highly flammable gas methane by bacteria in feces, led to toilets and sewage systems that were prone to spontaneous explosion. In their homes, Victorians battled against the many pollutants that plagued the outside world: work horse excrement, gas lamp soot, and industrial smog.[3]

And then, just when the Victorians thought that "bad air" was what the only illness-inducing concern, the first microbes were spotted under rudimentary microscopes. At best, they were mysterious and misunderstood advances in science. At worst, they were branded as deadly, invisible assassins.

Riding the waves of fear, newly invented disinfectants flooded the market, champi-

A vintage ad for Lysol exemplifying the "war on germs". Delstein, 2013.[4]

oning claims of scientific support—often before they could be rigorously investigated. However, these products borrowed their disinfecting power from toxicity, and even more concerningly, with products being pushed sooner than regulations could be made, extremely toxic chemicals like caustic soda and arsenic were frequently mistaken for harmless items like sugar or flour in the home and the pharmacy.[3]

Fast-forwarding to the 21st century, while the scientific community has improved the regulations surrounding disinfectants and most people are aware of what microbes are, we still have a ways to go in creating a society that is truly microbially literate—defined by Timmis et al. as "as the ability to understand relevant knowledge about microbial activity, how microbes impact our lives, and how they can be harnessed to benefit society." [2]

Microbial illiteracy, Timmis et al. state, is incredibly prevalent those who do not specialize in microbial science. Similarly, in the "Information Age" widespread information--and misinformation, can give the illusion of competence in and understanding of a very complex system. In light of this disheartening news, the American Museum of Natural History and Artis Micropia both use art and exhibition to help all individuals weigh the microbial information they encounter in their lives.

Micropia is the world's first and only museum that focuses solely on microbes. It brands itself not just as a clustering of exhibits, but as a place to connect scientists, stakeholders, and the public and encourage youth to discover microbiology and pursue STEM fields in the future. It prides itself on revealing the invisible world that so horrified the Victorians and rebranding it as an ocean of possibility. As Micropia most succinctly and poignantly wrote in a press release, microbes can "save us or destroy us."

Artis Micropia's broader goal is to show connections between all living things. Fueled by the looming realities of climate change, the group aims to close the "knowledge gap" between scientists and "the public" through its "microbial zoo." But does the museum truly make a more microbially literate society or is it simply another form of entertainment?

For a piece in the New Yorker, Ed Yong, visited the museum and reported on his experiences. Even before entering the museum, Yong notes the striking visual displays used by the museum. "A large banner draped over the building's two sto-

A picture of The Secret World Inside You Exhibit at the AMNH. AMNH/R. Mickens.[7]

ries displayed a collection of fuzzy colored balls, shaped like a waving person. This towering gestalt figure represented the human microbiome."

As Yong moved through the museum, he encountered a new exhibit built into an elevator. "We looked up to see ourselves reflected in a video feed on the ceiling. As the lift rose, the video zoomed in on our faces, closer and closer, smoothly transitioning from actual video to animations of eyelash mites and skin cells, then bacteria, and eventually viruses."

> "Since the Victorian age, our war with microorganisms—stemming from the view that the unseen creepy-crawlers were enemy combatants, has led to extreme and sometimes deadly behaviors surrounding cleanliness and sterility"
>
> Bayleigh Murray, Page 16

Perhaps one of the most influential exhibits in the museum was a station that allows users to scan through their organs to determine what microbes lived there. "By moving my hand," Yong wrote, "I was able to select an organ and reveal information about its resident microbes—about the denizens of my skin, stomach, gut, scalp, mouth, and nose, and about how they affect my behavior, train my immune system, digest my food, and protect me from disease."

Yong concluded that "Micropia returns its visitors to an unpasteurized era, when invisible organisms were objects of fascination rather than targets for elimination".[5] This attitude is crucial for increasing a person's microbially literacy.

Over three thousand miles away in New York City, the American Museum of Natural History (AMNH) took a similar approach in presenting facts about the microbial world with the exhibit The Secret World Inside You. AMNH scientists Susan L. Perkins, PhD and Rob DeSalle, PhD curated the exhibit to reach the public through more mainstream media. According to Dr. Perkins, who is now the Martin and Michele Cohen Dean of Science and Technology at The City College of New York, "the curation process consisted of three years of meetings with our excellent Exhibitions team, eventually tying in members of the Communications and Education departments as well."

In addition to the exhibit, she and Dr. DeSalle co-wrote the book, "Welcome to the Microbiome," early in the process. This manuscript first began as a template for the exhibit's writing team. Dr. Perkins also developed an interactive game for the exhibit and a card game for the museum's gift shop.

The goal of the exhibit and its associated games was to introduce basic concepts in bacterial biology, explain the function of the microbiome in different organisms, and show how aspects of modernization, such as cleanliness obsession and antibiotic use, have endangered microbiome diversity. According to Dr. Perkins, "the focus was always going to be on the human microbiome, but we decided to concentrate on three primary areas of that—the skin (a story of what the microbiome is and how it is diverse), the reproductive tract (the story of where we get our microbiomes), and the gut (the story of how it shapes things like our immune system, our weight, our moods, etc)."

While the exhibit was geared towards adults, Dr. Perkins states she was surprised at the number of children who were able to benefit from the presentations. "One of the biggest surprises, in my opinion, was the way that even very young children (<5) were fascinated by and understood a lot of the content. The Museum has a large international audience and that was always considered through the development process as well," Dr. Perkins said.

Part of the exhibit included a kiosk survey to get a better understanding of how microbially literate the public was prior to the exhibit. While the results have not been summarized yet, Dr. Perkins summarized that "in a nutshell, the public has a very poor understanding of microbes, what they do, why they need them or how antibiotic use affects them." The main measure of how successful a museum exhibit is happens through metrics such as attendance numbers. However, Dr. Perkins has noted some casual examples of

an increase in microbial literacy that is contrary to most expectations about who can and cannot understand the microbiome. According to Dr. Perkins, the New York State curriculum "suggests that young students cannot grasp the concept of microbes, but we witnessed many behaviors that were contradictory to that viewpoint."

She further explained, "I considered the exhibit a success when I heard a young visitor ask their parent if they could eat more vegetables because they now knew that they were good for their microbiome."

According to Dr. Perkins the reason the exhibit was successful was because of the hands-on way exhibit visitors could interact with concepts related to their microbiomes. "I think that two things about our exhibit helped with literacy a lot. We had this beautiful interactive table with a 14-foot long woman projected along with 17 vignettes to concentrate on three primary areas of that—the skin (a story of what the microbiome is and how it is diverse), the reproductive tract (the story of where we get our microbiomes), and the gut (the story of how it shapes things like our immune system, our weight, our moods, etc)."

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Microbes are not simply organisms that cause disease. They came before us, they outnumber us, and they make our very existence possible. Since the Victorian age, our war with microorganisms—stemming from the view that the unseen creepy-crawlers were enemy combatants, has led to extreme and sometimes deadly behaviors surrounding cleanliness and sterility. Micropia and The Secret World Inside You exhibit at the AMNH use visual displays and games to connect microorganisms to the body, rebranding them as helpful partners in life. With the increase in antibiotic resistance, new studies demonstrating the health consequences of microbiome diversity, and research confirming the role of microorganisms in our changing climate, microbiologists must venture into the world of art to make a more microbially literate world.

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THE ART OF SCIENCE
Increasing Cultural Accessibility for Blind People

ERIC LYNCH

ABSTRACT

Innovative smartphone technology can pave the way to helping blind people enjoy art museums independently. By using location and directional information, the new app helps its user move from exhibit to exhibit and describes the artwork to them. While this experimental app promises a future of increased accessibility in art museums, it does not address major issues the blind community is still facing.

The problems that blind people face have long been publicly known. Losing the ability to see is simply unimaginable for many people. Most people also think it's fairly easy to imagine the problems of the blind; having trouble getting around and not being able to read are commonly thought of as primary issues. Walking sticks, seeing-eye dogs, and braille are just a few inventions that have helped alleviate the issues of the blind and help increase their ability to live independently. However, beyond the immediate physical issues, many people don't anticipate the cultural issues blind people can face. One notable example is that blind people cannot normally interact with visual art. The obvious issue is that blind people simply cannot see the art, what it's depicting, and its beauty. Additionally, though, art museums are typically difficult to navigate for blind people.

A team of researchers from Carnegie Mellon partnered with the Andy Warhol Museum in Pittsburgh to study different ways to help blind people engage with visual art. The researchers note that the desire to increase the accessibility of art museums is "motivated not only by laws (e.g., the Americans with Disabilities Act (ADA)) stating that museums should be accessible to people with disabilities, but also by the interest of blind people in visiting museums and enjoying visual art. Yet, their ability to visit art museums is still dependent on the assistance they get from their family and friends or from the museum personnel." While art museums can currently be navigated by blind people with the aid of another person, a key issue facing blind people is a lack of independence. This problem can only be considered to have been properly addressed once an art museum can be fully enjoyed by a blind person completely on their own. This is especially difficult because "the challenges of an independent museum experience go beyond navigation as the main goal is art consumption or appreciation." Not only does a blind person need to be able to get through an art museum on their own, but they should be able to enjoy the art as much as everyone else can.[1]

> "Lots of research into lowering the cost of visual equipment or increasing the effectiveness of occupational therapy is needed before issues of cultural fulfillment will be brought to the forefront."
>
> Eric Lynch, Page 20

The researchers developed a smartphone app that locates the user within the museum and helps them navigate between exhibits. When the user wants to examine a piece of art, they can turn towards the piece, and the app will then begin telling them about the art. This app is relatively unique due to its ability to smoothly transition between navigation and art appreciation. They then tested this app on participants in the Andy Warhol Museum. Although the researchers were only examining two types of aids, they acknowledge all of the types that have been used to increase accessibility in the past: "guided tours, accessible tactile experiences, and com-

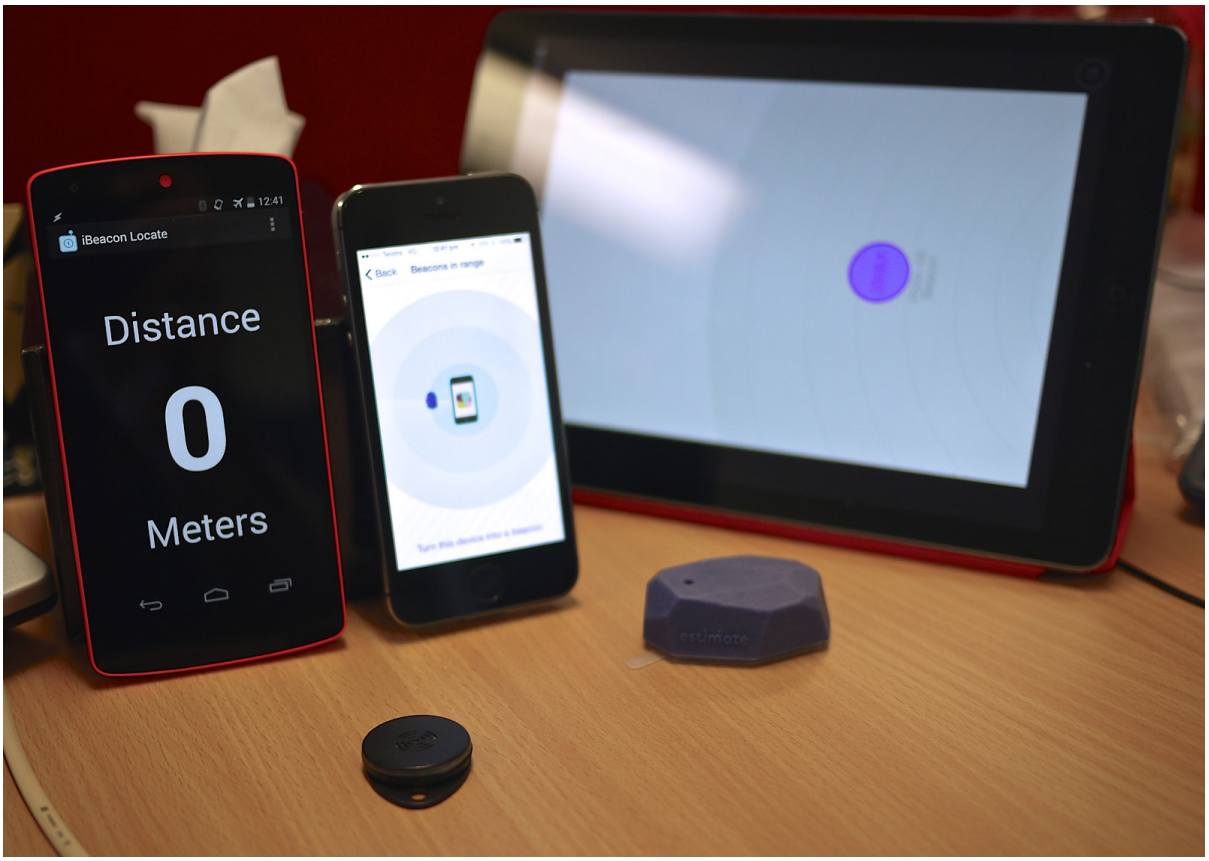
prehensive audio descriptions... Some museums provide specialized tours or workshops, while others allow visitors to negotiate a specific time for accessible visits. Other museums either specialize in tactile art for blind people or provide tactile replicas or reproductions of a subset of their artworks." Being able to touch the art and feel the outlines of what it depicts is an innovative idea that the researchers did not examine in this study. As descriptive as an audio guide can be, being able to feel art may be the best possible way to enjoy the art to the same extent that nonblind people can. They also note that "the use of audio guides, either with proprietary devices or the user's own smartphone, is ubiquitous in museums nowadays. Still, they usually target sighted people and are not designed with accessibility in mind." This is another way that the Carnegie Mellon team's app is unique; it is designed specifically for blind people.

The Andy Warhol Museum, where the experiment was conducted, contains many abstract works of art that can be difficult to describe to a blind person.[3]

This experiment would not have been possible without modern advancements in navigation technology and the prevalence of smartphones. The researchers made use of two important technologies: Bluetooth Low Energy (BLE) beacons and Pedestrian Dead Reckoning (PDR). BLE beacons are used for localization, helping the smartphone understand precisely where the user is with an average error of 1.5 meters and 12.4 degrees. The PDR system uses the smartphone's gyroscope and accelerometer to gauge how fast the user is moving and in what direction. Together, they provide the device with an accurate map of the user navigating through the museum and can tell when they have turned to face a work of art. To determine this turn more accurately, the researchers shared the math they used. The equation utilizes an angle threshold that triggers the device to switch modes when the user turns within 45 degrees of a painting. A series of vibrations and audio instructions help the user if they turn too slightly or too far.

The experiment was conducted on nine blind participants as they used the device to navigate the Andy Warhol Museum. The participants' conclusions were fairly unanimous. The participants were asked to rate a few statements on a five-point scale. A perfect 5.00 was awarded to the statement "I enjoyed being able to listen to audio content." The statement "I would

visit museums by myself if museums provided such an application" scored an average of 4.78 points. In addition to the independence aspect, the researchers found a few other details that the participants valued very highly. They say that "proximity-based art appreciation was found to be important," as many of the participants are quoted explaining how they enjoyed listening to information about the piece of art while they were standing directly in front of it.



The Andy Warhol Museum, where the experiment was conducted, contains many abstract works of art that can be difficult to describe to a blind person.[4]

While blindness as an issue has been in the public eye for decades, perhaps even centuries, the problems blind people face are not always well understood by nonblind people. Working to make art more accessible is an important way to help blind people enjoy and explore their interests. And while this technology is incredibly useful for those blind people who have the time, money, and means to get to an art museum, there are still many barriers blind people must deal with to get to this point. According to a study by Diana M. Zuckerman, "poverty is a fact of life for many blind adults, especially older women. Few blind adults receive welfare. Most blind men in poverty receive food stamps, but most blind women in poverty do not." Additionally, "nearly one in five [blind adults in the U.S.] (19 percent) lives in poverty," and "only 19 percent are currently employed." While blind people are trying to make the best of their situation, their disability makes working and earning income incredibly difficult for some. This also makes independent living complicated because many must rely on family or friends for income or at least for supplemental income. Independence is challenged by the fact that "few blind adults receive the kinds of services that could presumably help them succeed in the work force and remain independent and productive, such as vocational rehabilitation, occupational therapy, or visual equipment." While it is impossible to fault the Carnegie Mellon researchers for working to increase art accessibility, it's a sad reality that for many blind people, basic needs are still not being met. Lots of research into lowering the cost of visual equipment or increasing the effectiveness of occupational therapy is needed before issues of cultural fulfillment will be brought to the forefront.[2]

Nevertheless, this research does some important things. Firstly, it raises awareness. Few people think about the struggle for fulfillment and independence that blind people often struggle with. Some people may even think that existing inventions have already 'fixed' the issues these people face. It's important to continue innovating and show just how accessible the world can be to the blind. Secondly, it elevates the voices of blind people. Carnegie Mellon's researchers prioritized participant testimonies in the results section of the paper. Instead of deciding whether the technology worked from the researchers' points of view, their conclusions were based on how well the blind participants thought it worked. This is important because it lets blind people represent themselves and demonstrate their values. Without doing interviews like this, people working on accessibility technologies would struggle to see what features are the most helpful. For example, one might think that having an audio guide describe the art is sufficient to enjoy an art museum. But this paper shows that facing the painting while it's being described is extremely important too. It also shows that a more human and emotional voice is also highly valued. Although there are almost one million legally blind adults in America, they are still a group whose voice is not often heard. Elevating their voices and learning about their perspectives is key to bringing about new technologies to support them. And when those ideas are kept in mind, scientists can truly make strides to allow blind people to enjoy art to the fullest.

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Quantum Voting: A Political Scheme

HILINA SEIFU

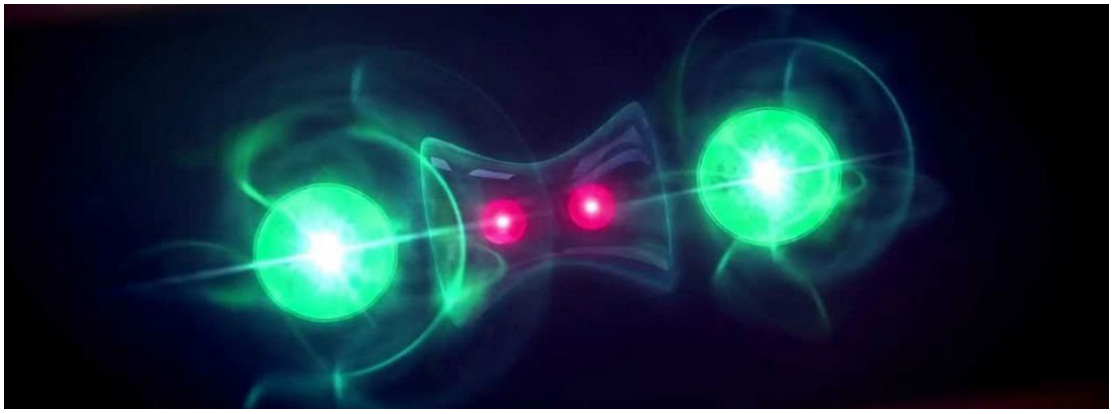
ABSTRACT

The future of the internet is shifting away from classical computing and towards a quantum one, one which makes use of qubits over classical bits. Qubits bring with them many features of the strange quantum world, allowing for a faster and more secure internet. This new method of computing could have a whole host of everyday implications, including secure banking and voting processes.

American politics are, to say the least, a bit tricky, with each election sparking more and more outrage with the current voting and political system. One particular outcry is rooted in America's two-party system, which encourages extremist candidates and forces voters into an ultimatum. Another fear on the mind of most Americans is the vulnerability of elections to foreign hackers. No matter what, changing this certainly will not be an easy feat, but one possible solution might lie in the wacky and weird world of quantum mechanics. Though much of quantum science is still largely theoretical and part of a grand vision of the future, it may very well change the world of computing across many fields, including security, banking, and even politics. Scientists are currently in the process of creating a quantum internet, where all the same functions of our classical internet are performed in the bizarre quantum world. Soon, the days of classical computing might be gone. The nature of politics is currently in flux, and the American political system tomorrow might be entirely unrecognizable from today's. Though the future, as always, is unknown, one thing is certain: current technology and classical computing may not be enough to facilitate this shift.

The quantum internet, as of now, is merely a blueprint. But it is one that becomes more of a reality with each day and each experiment. But what is it? Well, where today's classical computing employs the use of bits, which can either exist in a state valued at either zero or one, quantum computing uses "qubits," which can exist simultaneously as both zero and one through a property called superposition.1 In fact, these have already been used to encode classical information, but this is, hopefully, only the first step before quantum states themselves can be transferred.[2]

These qubits also have the potential for quantum entanglement, where two are tied together and knowing the state of one allows you to



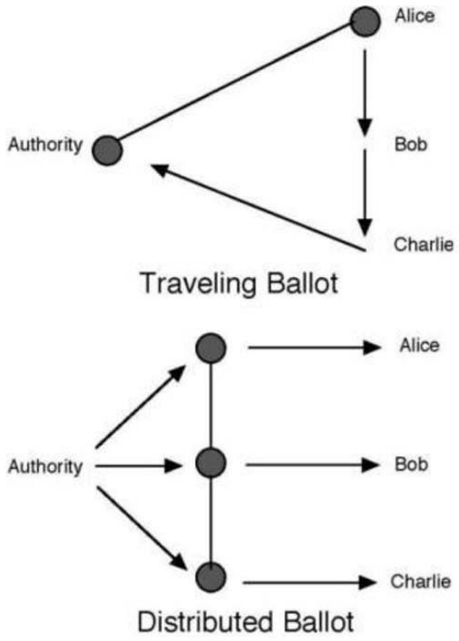
Two Beryllium ions (red) and two Magnesium ions (green) entangled to each other, linking their properties. The entanglement is represented as the hourglass figure.[9]

define and influence the other, even over a great distance.[2] This entanglement is a large part of why it would make a great network: it would allow one to send information, without sending the actual qubit, via a mechanism known as quantum teleportation, whereas in classical computing the physical bit has to be transferred.[2;3] Here, only the quantum state would need to be sent. Another useful feature of quantum mechanisms is known as the "No Cloning Theorem," which means it is impossible to copy an unknown quantum particle without destroying it. This is because reading a quantum state instantly destroys the entanglement in a process known as decoherence.[1] This destruction ensures that only one copy of a quantum state exists at any time.[4]

> "Though much of quantum science is still largely theoretical and part of a grand vision of the future, it may very well change the world of computing across many fields, including security, banking, and even politics"
>
> — Hilina Seifu, Page 22

The Law of Superposition is most commonly known through the tale of Schrödinger's Cat, wherein there is a cat in a box whose state of being is unknown. The uncertainty means that-much like qubits—the cat exists in both states until one checks—it is both dead and alive. But cats are not the only application of this law, rather it might be the future of the American voting process. Two separate units of quantum information would be able to be superimposed in the same qubit at the same time or more than one party may be able to store information in a single qubit. Potentially, this might mean a huge change to the election process. Voters in a single online ballot would be able to select not only a first option for an elected official, but a second, as well, and both could be calculated together.[5] This might be especially useful as the United States shifts away from its two-party system and towards a multi-party system. Today, each party excludes about half of its electorate due to an inability to reconcile the extremes a single party can encompass[6] (Vox- America's two-party system). Nicole Yunger Halpern, physicist at the Harvard-Smithsonian Center for Astrophysics, calls these voters "quantum voters" who could make use of "strategic-voting schemes" which would allow large groups to much more easily reach a consensus.[5]

The practical applications of quantum internet allow for a number of different possible voting schemes—range voting, majority judgment, and approval voting. Both range voting and majority judgment allow voters to independently assign each candidate a number of points on a certain scale, which is then aggregated so that the candidate with the most number of votes wins in range voting. In majority judgment voting, the win goes to the candidate with the highest median number of points. Approval rating employs a different system, allowing voters to give each candidate a thumbs up or a thumbs down[7]. These potential voting systems avoid restricting voters' preferences and allow not only voters' preferences and allow not only their approval to be heard, but their disapproval, as well. American voters would have a greater voice in choosing their representatives and would no



Two possible quantum voting schemes for security: The Travelling Ballot and the Distributed Ballot. Hillery, Mark.[8]

longer have to give their only vote to a poor candidate solely because they are more likely to win.

Quantum mechanics' applications to voting lie not only in the process itself, but the security of it, as well. More specifically, unconditional security of elections in a time when a great fear on many Americans' minds is the possibility of foreign states meddling with and hacking into elections. This is all due to the No Cloning Theorem. No longer having to send information physically promises a much more secure network to the classical one we use now, which is easily susceptible to hackers. However, since physical particles are no longer being transmitted and once the quantum states are read and transmitted they are immediately destroyed, it is virtually impossible for someone to intercept a message encoded in quantum states because the moment they do, it would be destroyed.[1;4]

Quantum entanglement might also be responsible for increasing voter security, in a potential practice known as a traveling ballot scheme. This would make use of two entangled particles, in which the party administering the vote would possess one and the other would go to a single voter. The voter would act on this particle in a manner that corresponds with a vote of either yes or no, before passing it down onto the next voter. This voter would do the same, and so on, and so on, until the last voter, who would pass the qubit back to the vote administrator.[8] Though in classical computing, it might seem risky to hold all of this information in a single bit which is passed around to so many locations, the entanglement ensures that the information on this qubit cannot be viewed without the other since information is stored in the relationship between the qubits, rather than on the qubits themselves. The same practices are applied in the idea of the distributed ballot scheme, in which each voter is given their own qubit, all entangled with each other.

Though quantum voting is still in its very early stages, its potential applications are also very real. With dissatisfaction growing in each election cycle, the American political system is in grave need of help. Whether the solution to this is a quantum internet or another change to these processes, political scientists might find some novel ideas in the world of quantum mechanics.

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THE ART OF SCIENCE

Robocop in the Art World? Using AI to detect Art Forgery

JERRY YANG

ABSTRACT

Detecting art forgery is an often subjective and tedious task. New advances in artificial intelligence to supplement current tools have the potential to revolutionize modern anticounterfeiting forensics. This article will summarize the field and explain two budding areas of focus where traits unique to artificial intelligence can be of use in detecting forgeries.

In 1496, an artist on the streets of Italy was looking for his break. Ambitious but lacking the reputation to break into the fledgling Renaissance art world, he quickly ran out of funds and needed a quick source of money. With few other choices, he forged a statue of a sleeping cupid in the ancient Roman style, artificially aged it by burying it in a vineyard, and then sold it to a local cardinal. Upon learning of the statue's faux origins, the cardinal, rather than becoming enraged, was impressed by this plucky artist's creative abilities. Instead of punishing the artist, the cardinal jumpstarted his career. The artist's name? Michelangelo.[1]

Five hundred years later, forgery remains ever present in the art world. From the antique bronze statues of ancient Greece to avant garde pieces of postmodern painting, forgers and authenticators have and will forever try to get the upper hand over each other. Now, more than ever, art authentication a necessary service. Paintings regularly sell for millions of dollars with new records set every other month. Fakes, on the other hand, are completely worthless and have no resale value resulting in high demand for art authenticators. With this amount of money up for grabs, it's no wonder forgery is so common. By some estimates, 40-50 percent of paintings in auction houses today are frauds. In this view, the art authentication business has one of the highest stakes of any industry.

Further, art authenticators have an even more precarious job than is at first obvious. Much of the process of art authentication relies upon intuition and professional expertise built up over decades of experience. The difference between a masterful forgery and the real painting might be as small as an unusual shade of blue or an uncharacteristic shading style. In a nutshell, it is much like trying to find a hay-colored needle in a haystack without knowing whether the needle is there at all. On top of this complexity, the experts often disagree. A 2018 Russian modern art case resulted in an irresolvable deadlock when the star prosecution and defense expert witnesses had equally prestigious credentials and took exactly contradictory opinions from one another.[2]

> "As with countless other fields, artificial intelligence has the ability to revolutionize the art authentication industry"
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> — Jerry Yang, Page 27

To ameliorate this problem facing expert testimony, multiple techniques based on scientific principles have been brought in to verify the origin of certain pieces of art. High value paintings are routinely screened under x-rays and other spectroscopic techniques to determine the chemical compositions of the pigments used in the paints. Ancient civilizations and early European nations primarily used lapis lazuli to add blue to their paintings. The detection of a synthetic blue dye, first synthesized in the 19th century, is a dead giveaway that something is not right. Afterwards, paintings might be screened

for radioactivity and the products of radioactive decay. Certain radioactive elements do not occur naturally and will only appear in trace amounts in paintings created after the detonations of nuclear weapons in World War II and the Cold War. These are just a few tools among many detectives use to ascertain original from counterfeit.[3] Nonetheless, the process is slow, extremely expensive, and still subject to counterfeiters gaming the process. It is in this modern context that artificial intelligence can help.

An example of a counterfeit painting next to the real painting. Determining which is which is difficult even for a seasoned expert.

In a paper entitled "Picasso, Matisse, or a Fake? Automated Analysis of Drawings at the Stroke Level for Attribution and Authentication", Elgammal et. al propose an AI algorithm that is capable of differentiating between reals and fakes with an average accuracy of over 80% just from a picture of the suspected painting.[4] Instead of looking at chemical data and cross checking it against the potential pigments available to the artist or looking at the style in which the painting was made, the team focused on the unique characteristics of each artist's brush strokes.

Specific attributes such as the shape of the stroke and the pressure applied at different parts of the stroke are unintentional and different across artists and thus present a new vector by which fakes can be identified. The sheer number of strokes in each painting alongside the minuteness of each detail measured presents a massive roadblock to any counterfeiter seeking to evade detection, but it also presents a challenge to any detective seeking to use this method. The amount of information about a painting needed to be gathered and evaluated for this method to work is a task beyond the senses and mental processing power of human beings. At this point, AI algorithms give authenticators the edge. While a human might not be able to count and measure a dozen details of every stroke of a painting to draw an ultimate conclusion about the work's authenticity, a computer can.[5]

Starting with 300 authentic line drawings from a few prominent artists in the early 20th century such as Picasso, Elgammal's algorithm breaks down the line drawings into individual strokes. These strokes are each measured by length relative to the size of the canvas, width of the stroke at various points in the stoke, shape of the stroke and other measurements in the same vein. The information from these strokes are then aggregated using a neural network (a type of

algorithm enabling pattern detection) to create a profile of the artist. Resulting algorithms were tested against 83 line drawings forged by invited artists. Final algorithms returned accuracy rates of between 70-100% depending on the artist targeted. The authors conclude by stating that the study is a proof of concept that stroke characteristics stand as a viable and difficult-to-imitate way of catching 21st century counterfeiters.

However, this new generation of counterfeit detecting artificial intelligences can only process a limited amount of information at a time. This forces detectives to scale down the resolution of paintings and compromise accuracy. An alternative approach pursued by amateur AI enthusiasts Steven and Andrea Frank is based on the idea of entropy. Entropy is the measure of randomness in a system. A totally random system has high entropy while a completely ordered system has very low entropy. In the context of art, a painting with random shapes of random colors scattered across the canvas has high entropy, while an extremely repetitive painting with a limited color scheme has low entropy.

The Franks created an AI algorithm that assigns an entropy measurement to a given painting and then subdivides the painting into chunks each consisting of a few ten thousand pixels. Each of these chunks is assigned an entropy measurement of its own. The chunks with an entropy measurement closest to that of the entire painting are kept and fed to the AI while the other chunks are never processed. This approach ensures that only the information most reflective of the painting as a whole is processed by the AI, thus more efficiently using the computing power available. The end result of this process was an algorithm with the ability to differentiate original from fake 90.4 percent of the time.[7]

As with countless other fields, artificial intelligence has the ability to revolutionize the art authentication industry. While this may at first glance seem like a niche application of AI, the lessons that computer scientists take away from this field have a broad range of applications. The algorithms discussed in this article are trained to recognize the smallest details and use that information to draw a final conclusion. More immediately, similar algorithms could be used to make facial recognition software more accurate as well as detect whether an image or video has been tampered with (otherwise known as a "deepfake"). Beyond that, perhaps the advances in pattern recognition made in this field will be extended to detecting fraudulent irregularities in payments and beyond. After all, the fight against counterfeiting teaches the lesson that sometimes, every small detail counts - a lesson the future of AI stands to gain from. new perspective.

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THE ART OF SCIENCE
Robots Making Art: How Artificial Intelligence is Breaking the Boundaries of Creativity

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ABSTRACT

Artificial intelligence is quickly becoming part of daily life, and the learning process for such programs is improving exponentially. However, the rapid advancement of machine learning has seeped even into the art realm. Artists and computer engineers collaborate to produce autonomously creative computers, AI artists. These computers, by learning from a large set of sample images, can create novel images, paintings, drawings, and other forms of visual art, without human intervention. As such, a new wave of so-called "AI art" is rising, making artists reconsider the very nature of making art and creativity as a form of expression people believe to be unique to humans.

Imagine you are walking around an art museum and you come across a mysterious painting. It depicts a gentleman, his blurry face indistinguishable with wispy brushstrokes, his clothes melting into the dark background, with both sharp and soft edges against a yellowed page. It exudes a sort of tragic nostalgia, reminding you of a photograph recovered from a burning house. You look to the bottom corner and notice this signature:

$$\min_G \max_D \mathbb{E}_x[\log(D(x))] + \mathbb{E}_z[\log(1 - D(G(z)))]$$

Meet GAN, the artist behind that painting, the Portrait of Edmond Belamy, which was sold for $432,500 at an art auction house in New York as one of the first pieces of AI art to be sold.[1] GAN, or Generative Adversarial Network, is among the first computer programs to have its artwork sold, and is also one part of a growing movement that meshes computer engineering with art. Researchers and artists--such as the minds behind GAN, a group called Obvious--are pushing the boundaries of machine learning by programming artificial intelligence (AI) that can create works of art autonomously ("AI art") without human intervention. Such technological advancements are redefining the meaning of art, the nature of the creative process, and the notion of creativity itself. This makes some people nervous. After all, people have a tendency to be wary whenever AI comes a little too close to being human-like, with a lingering fear that robots would eventually make humans obsolete in the cognitive and physical functions that we believe are unique to us. And art seems like a very human thing. However, we should embrace this advancement in machine learning as part of the general evolution of both art and technology, and collaborate with the AI we produce to enhance the visual art form and the creative process. In fact, we should look at AI art not as a threat to the creative process, but as a celebration of human creativity itself.

Portrait of Edmond Belamy, 2018, created by GAN.[1]

AI art has been around for a while. One of the earliest autonomously creative computers, named AARON, was programmed by British artist Harold Cohen back in 1973 and has been developing its artistic abilities since. After painting and attending exhibitions for many years, Cohen was curious about the nature of images.

What exactly is an image? At what point does a set of marks produce an image? Answering such questions brought Cohen to create AARON, a computer that uses ink and fabric dye loaded in a smaller machine to make both abstract and representational drawings on its own based on what it learns from him.[2] It sounds much like AARON is an art student and Cohen is the instructor.

But how does a computer possess such a human ability as developing the skill and aesthetics necessary to create art? GAN, or Generative Adversarial Network, is actually the name of a general framework model developed by Ian Goodfellow in 2014. In GAN, two trained models-- a generative model and a discriminative model--compete head-to-head in a game. The generative model uses a collection of sample data, such as thousands of images of paintings, to produce a new painting of its own. The discriminative model then evaluates the result and determines whether it was created by the generative model or taken from the sample data set. The generative model wins if it can "trick" the discriminative model into indicating that the resulting painting came from the data set, as though the painting was created by a human. Both models develop new methods to try and win the game until the generated painting is indistinguishable from the paintings in the sample set, hence the generative model wins every time.[3] Many programmers use GANs as a foundation of their AI art process. Through GAN, AI learns from analyzing the technique and aesthetic of thousands of human-created images and uses what it knows to create its own works of art. This is similar to how human artists study the

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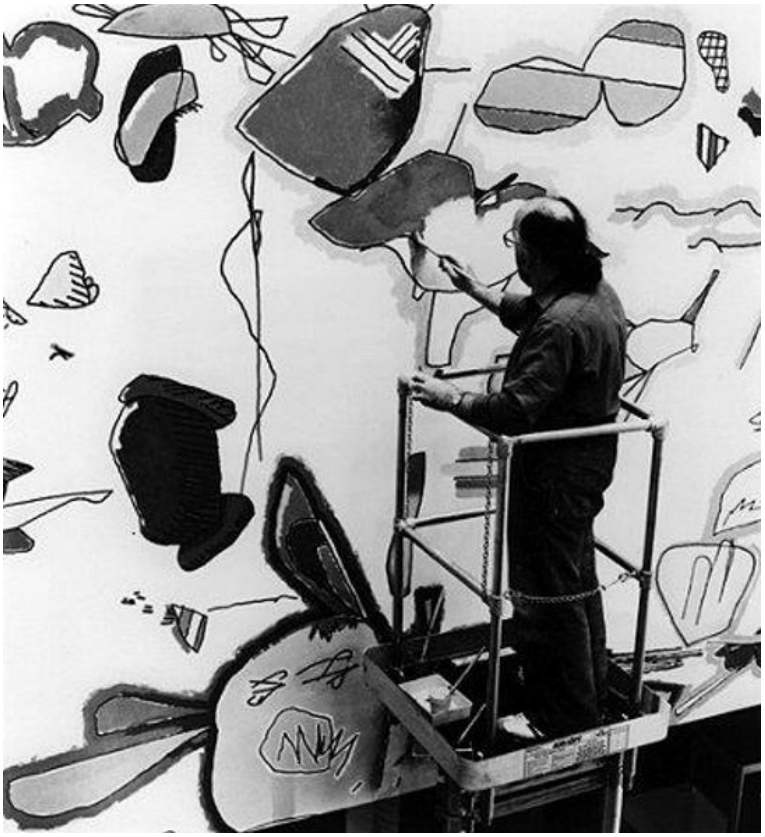

Harold Cohen coloring in the shapes created by AARON in 1982; collaborative effort between a human and an AI.[2]

works of others and draw inspiration from them.

However, learning from other artworks is not enough. The art world appreciates fresh, creative ideas more than counterfeits or cookie-cutter trends. To be truly autonomous, truly creative, AI must create art that is not a mere shadow of human art. Researchers of the Art and Artificial Intelligence Lab at Rutgers University noticed such limitations in GAN, and modified the network to create CAN (Creative Adversarial Network). CAN is a variant of GAN and works the same way, except the generative model becomes creative: it maximizes deviations from established styles, while minimizing deviation from the general art data. In other words, the program develops a style original enough to be psychologically interesting to human observers, but not too radically different from the sample data set that it evokes a negative reaction.[4] It turns out that people cannot distinguish computer-generated art from art made by humans. AICAN is one such CAN program created by the Art and Artificial Intelligence Laboratory at Rutgers University. The researchers of the lab found that 75% of the time, people at an art fair thought that AICAN-generated images were created by a human. Many observers even enjoyed the AI art, calling it "inspiring".[5]

We know how to produce autonomously creative, artistic AIs, but why should we? Does AI art somehow undermine the creative process that human artists experience? Some people in the art world think that, while a convincing replication of art created by humans, AI art is only a replication. For example, science writer David Pogue states that there's something lacking in mass-produced images created by robots that's present in artworks resulting from effort and intention.[6] However, oftentimes the true value of an artwork comes from the viewers' connection to it, how the viewer interprets the colors and forms based on their own experiences and aesthetic tastes. Perhaps it doesn't matter who, or what, produced the artwork. After all, people often cannot distinguish between AI-generated art and art created by humans. Just like a painting made with acrylics isn't any less valuable than a painting made with watercolors, a painting made using computers isn't any less valuable than a painting made using other media. AI can be used as tools for producing new forms of art, and isn't art all about breaking boundaries?

Is AI art really inauthentic? We must ask, what is art anyways? Art is an elusive concept, its definition depends on who you ask and when you ask. The meaning of art and the creative process is ever evolving. AI art is just another step in that process, and it's an important step. Not only does it allow us to think about the very nature of art and what it does for us, but it gives artists a way to express themselves in innovative ways. AI can be used both as an art tool and as a collaborator, just as AARON is for Harold Cohen. In fact, AI art itself-- brought to existence by human minds-- is a testament to how widely the scope of human innovation can expand. Rather than undermine art or creativity, AI art shows just how creative people can be.

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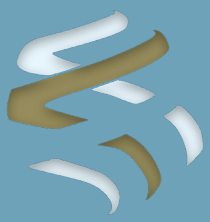

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