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RYAN ABBOTT

Can an AI System Be Given a Patent?

By Jared Council

Wall Street Journal | Oct. 11, 2019
https://www.wsj.com/articles/can-an-ai-system-be-given-a-patent-11570801500

An artificially intelligent system purportedly has created two new products. Now patent offices must decide if it can be named as the inventor.

See also in the TTI/Vanguard archive:

- Edward Feigenbaum: *Artificial Intelligence: Then, Now, and WOW*, San Francisco, California, December 2013.

RICH DEMILLO

Richard DeMillo on the Trials and Triumphs of Helping to Protect U.S. Elections from Hacking

By Michelle Hampson

AAAS | September 20, 2019
https://www.aaas.org/membership/member-spotlight/richard-demillo-trials-and-triumphs-helping-protect-us-elections

When Richard DeMillo first began his career in computer science in the 1970s, the concept of cybersecurity did not exist. Fast forward to today and you will find him, along with other top computer scientists across the United States, fighting to counteract cyberattacks that threaten the country's democracy. As demonstrated all too clearly in the last two federal elections, electronic voting systems are vulnerable to hacking and pose a serious threat to the integrity of the U.S. electoral system.

See also in the TTI/Vanguard archive:

- Avi Rubin: *Electronic Voting and Security*, Austin, Texas, February 2004.
- Richard DeMillo: *Virtual Blight*, Atlanta, Georgia, February 2008.
- Rich DeMillo: *Computer Research Association (CRA) Grand Challenge Research*, Austin, Texas, February, 2004.
- Judith Estrin: *Facing Up to the By-Products of Digitization*, Berkeley, California, March 2019.

GEORGE FRIEDMAN

From: *The Storm Before the Calm*
By George Friedman

Penguin, February 2020
https://www.penguinrandomhouse.com/books/252382/the-storm-before-the-calm-by-george-friedman/

The Constitutional Convention invented the American government. It was an invention in two ways. First, it created a government where none had existed. Second, it created a machine, the machinery of government, which had sprung from the minds of the founders. Unlike other governments, it had no past. This government came into existence through design, architecture, and engineering. The machine was built on two principles. First, the founders feared government, because governments tended to accumulate power and become tyrannies. Second, they did not trust the people, because the people—in pursuing their private interests—might divert the government from the common good. Government was necessary, and so of course were citizens, but both had to be restrained in such a way that the machinery of government limited their ability to accumulate power. The founders had created such a machine.

See also in the TTI/Vanguard archive:

- Thorvaldur Glyfason: *From Crowd to Constitution: The Case of Iceland*, Washington, D.C., May 2012.

STEVE GLENN

Amazon invests in prefab startup focused on smart home tech
By Patrick Sisson

Curbed | Sep 25, 2018
https://www.curbed.com/2018/9/25/17899200/amazon-alexa-prefab-construction-startup

Could this investment in California-based Plant Prefab be a new avenue for Alexa expansion?

See also in the TTI/Vanguard archive:

- George Berghorn: *Building Buildings with Reusability in Mind*, Berkeley, California, March 2019.

PETER HANFORD

Wayland Additive Moves into New Facility for Development of Its Neutral Beam technology

By Daniel O'Connor

TCT | 11 December 2019
https://www.tctmagazine.com/3d-printing-news/wayland-additive-moves-into-new-facility/

Wayland believes it has, thanks to the developments of the team of electron beam experts, developed the most stable metal additive manufacturing process yet, thanks to the fundamentals of their Neutral beam technology "NeuBeam." Wayland has also developed very sophisticated in-process monitoring capabilities, giving end-users insight into cause and effect from parameter inputs.

See also in the TTI/Vanguard archive:

- Julia Greer: *Materials by Design: 3-D Nano-Architected Metamaterials,* San Francisco, California, December 2015.
- Nick Pinkston: *Designing for Manufacturability Inside Your CAD Software,* Detroit, Michigan, May 2015.

SARAH KAUFMAN

The Most Futuristic Developments We Can Expect in the Next 10 Years

By George Dvorsky

Gizmodo | October 24, 2019
https://gizmodo.com/the-most-futuristic-developments-we-can-expect-in-the-n-1838676080

Making predictions is easy; it's getting them right that's tough. That said, some tangible trends are emerging that should allow us to make some informed guesses about what the future will hold over the next 10 years.

See also in the TTI/Vanguard archive:

- Peter Calthorpe: *Redesigning City Streets and Mass Transit with AVs in Mind—and Vice Versa,* Berkeley, California, March 2019.

ADITI KUMAR

Brace for the Digital-Money Wars

By Paul Vigna

Wall Street Journal | Dec. 7, 2019
https://www.wsj.com/articles/brace-for-the-digital-money-wars-11575694806

Digitizing the Chinese yuan—and eventually the dollar—would open new fronts in the fight over privacy and trade.

See also in the TTI/Vanguard archive:

- Bill Maurer: *Understanding Money*, Pittsburgh, Pennsylvania, October 2012.
- Bill Schafer: *Enabling Sustainability with Blockchain Technology Accessed by Mobile Devices,* Boston, Massachusetts, April 2017.

FRANCIS MCINERNEY

The Edgeless Cloud and Flatnets

By Francis McInerney

State of the Edge | December 26, 2019
https://www.stateoftheedge.com/blog/the-edgeless-cloud-and-flatnets/

The math of Cloud Inflation says that, at some point, your smartphone becomes my server. So, forget everything you hear about edge servers harnessing the Cloud; the cloud has no edge. There is absolutely no reason why each home in the world should not become a combination cell tower, data center and blockchain revenue engine scaling with Moore's Law and the Memory-Density Curve. When this happens, the Cloud loses its edge. Whence, the Edgeless Cloud.

See also in the TTI/Vanguard archive:

- Jags Kandasamy and Sek Chai: *AI Everywhere—Even at the Edge*, San Francisco, California, December 2019.
- Brewster Kahle: *Locking the Web Open: A Call for a Decentralized Web,* San Francisco, May 2016.

SCOTT ROSS

Old Musicians Never Die. They Just Become Holograms.

By Mark Binelli

New York Times | Jan. 7, 2020
https://www.nytimes.com/2020/01/07/magazine/hologram-musicians.html

A start-up called Eyellusion produced "Dio Returns." It's one of a handful of companies looking to mold and ultimately monetize a new, hybrid category of entertainment—part concert, part technology-driven spectacle—centered, thus far, on the holographic afterlives of deceased musical stars. Eyellusion also toured a hologram of Frank Zappa in the spring, in a show overseen by Zappa's son Ahmet. The tour kicked off in April at the Capitol Theater in Port Chester, N.Y., about an hour north of Manhattan in Westchester County. A few hours before the show, I talked to the owner of the venue, the 47-year-old concert promoter Peter Shapiro. In 2015, he was a producer of the Grateful Dead's 50th-anniversary "Fare Thee Well" concerts. The five shows grossed more than $50 million, becoming, according to Billboard, "one of the most successful events in live-music history."

See also in the TTI/Vanguard archive:

- Jeri Ellsworth: *3-D Augmented Reality Game System,* San Francisco, California, December 2013.

TOM ROBINSON

Time for the Human Screenome Project

By Byron Reeves, Thomas Robinson, and Nilam Ram

Nature | 16 January 2020
https://www.nature.com/articles/d41586-020-00032-5

To understand how people use digital media, researchers need to move beyond screen time and capture everything we do and see on our screens.

See also in the TTI/Vanguard archive:

- Adam Gazzaley: *Distracted Mind: Ancient Brains in a High-Tech World,* Boston, Massachusetts, April 2017.
- Ingo Deutschmann: *Behavior Biometrics: Continuous Authentication for Mobile and Web Transactions,* Washington, D.C., September 2016.

GINNY RUFFNER

"Ginny Ruffner: Reforestation of the Imagination" Transforms the Renwick Gallery into a Post-Apocalyptic Haven of Hope

Smithsonian | June 21, 2019
https://www.si.edu/newsdesk/releases/ginny-ruffner-reforestation-imagination-transforms-renwick-gallery-post

In collaboration with animator and media artist Grant Kirkpatrick, Ruffner brings to life a colorful world where glass stumps suddenly sprout mythical flora that have adapted to their surrounding conditions in unexpected, beautiful and optimistic ways. By transforming the gallery into a multi-dimensional experience, "Ginny Ruffner: Reforestation of the Imagination" calls into question the very notions of reality and fantasy, of concrete and abstract, and of desolation and hope.

See also in the TTI/Vanguard archive:

- Mira Calix: *In Art We Trust,* Jersey City, New Jersey, October 2013.

KARIN STRAUSS

Demonstration of End-to-End Automation of DNA Data Storage

By Christopher N. Takahashi, Bichlien H. Nguyen, Karin Strauss, and Luis Ceze

Nature | 21 March 2019
https://www.nature.com/articles/s41598-019-41228-8.pdf

Synthetic DNA has emerged as a novel substrate to encode computer data with the potential to be orders of magnitude denser than contemporary cutting-edge techniques. However, even with the help of automated synthesis and sequencing devices, many intermediate steps still require expert laboratory technicians to execute. We have developed an automated end-to-end DNA data storage device to explore the challenges of automation within the constraints of this unique application.

Our device encodes data into a DNA sequence, which is then written to a DNA oligonucleotide using a custom DNA synthesizer, pooled for liquid storage, and read using a nanopore sequencer and a novel, minimal preparation protocol. We demonstrate an automated five-byte write, store, and read cycle with a modular design enabling expansion as new technology becomes available.

See also in the TTI/Vanguard archive:

- Sri Kosuri: *Bio<->Technology,* San Diego, California, February 2015.

CLAYTON WOOD

Secretive Seattle Startup Picnic Unveils Pizza-Making Robot—Here's How It Delivers 300 Pies/Hour

By James Thorne

GeekWire | October 1, 2019
https://www.geekwire.com/2019/secretive-seattle-startup-picnic-unveils-pizza-making-robot-heres-delivers-300-pies-hour/

Picnic—previously known as Otto Robotics and Vivid Robotics—is the latest entrant in a cohort of startups and industry giants trying to find ways to automate restaurant kitchens in the face of slim margins and labor shortages. And its journey here wasn't easy. "Food is hard. It's highly variable," said Picnic CEO Clayton Wood. "We learned a lot about food science in the process of developing the system."

See also in the TTI/Vanguard archive:

- Daniela Rus: *The Robots Are Coming,* Boston, Massachusetts, April 2014.

ETHAN ZUCKERMAN

Mistrust, Efficacy and the New Civics: Understanding the Deep Roots of the Crisis of Faith in Journalism

By Ethan Zuckerman

Aspen Institute, 2017
https://assets.aspeninstitute.org/content/uploads/2017/07/zuckerman.whitepaper.FINAL_.pdf

Addressing mistrust in media requires that we examine why mistrust in institutions as a whole is rising. One possible explanation is that our existing institutions aren't working well for many citizens. Citizens who feel they can't influence the governments that represent them are less likely to participate in civics. Some evidence exists that the shape of civic participation in the US is changing shape, with young people more focused on influencing institutions through markets (boycotts, buycotts and socially responsible businesses), code (technologies that make new behaviors possible, like solar panels or electric cars), and norms (influencing public attitudes) than through law.

See also in the TTI/Vanguard archive:

- Ethan Zuckerman: *Can Movements Move Media?,* Washington, D.C., May 2012.
- Ethan Zuckerman: *Fiji Water, Chinese Routers, and Ghanaian Geeks: Or How I Learned to Stop Worrying and Love the Future,* Miami, Florida, July 2005.
- Ethan Zuckerman: *Which People and Which Technologies: Geekcorps,* Atlanta, Georgia, November 2000.
- Judith Estrin: *Facing Up to the By-Products of Digitization,* Berkeley, California, March 2019.
- Roger McNamee and Jonathan Taplin: *A Conversation about Devices, Addiction, Children, and Happiness,* Los Angeles, California, March 2018.
- Jonathan Taplin: *Move Fast and Break Things: How Facebook, Google, and Amazon Cornered Culture and Undermined Democracy,* Boston, Massachusetts, April 2017.

Can AI Receive A Patent?

A filing lists an AI system as the inventor, raising all sorts of issues

By Jared Council

GIULIO BONASERA

If an artificially intelligent system creates a new product, should patent offices recognize it as the inventor?

That's the question at the center of a case making its way through patent offices in the U.S., Europe and the Middle East, one that business leaders and lawyers say is posing fundamental questions that could alter how centuries-old patent systems around the world operate.

The case involves an AI expert, a professor and a group of attorneys who filed two patent applications over the past year, designating an AI system as the inventor behind each. But the patent laws in some of the jurisdictions where the applications were filed only recognize "natural persons" or "individuals" as inventors.

The inventions are a specially shaped container lid designed for robotic gripping and a flashlight system for attracting human attention in emergencies. The group says both were created by an AI system called Dabus (short for "device for the autonomous bootstrapping of unified sentience"), which was built by Stephen Thaler, founder and chief executive of **Imagination Engines** Inc. of St. Charles, Mo.

Mr. Thaler has spent at least a decade developing Dabus, which was built to ingest data about a range of subjects—including fractal geometry and flashing light patterns—and conceive ideas for products it hadn't seen before. The group says Mr. Thaler has no background in developing container lids or flashlight systems, didn't conceive of those two products and didn't direct the machine to invent them—so it's improper to list him as the inventor.

Ryan Abbott, a law and health-sciences professor at the University of Surrey in the U.K. who is leading the group, says: "If I teach my Ph.D. student that and they go on to make a final complex idea, that doesn't make me an inventor on their patent, so it shouldn't with a machine."

U.S. response

The case has drawn business interest partly because patents that list the wrong inventor—or exclude an inventor—could be deemed unenforceable.

In addition to Dr. Abbott and Mr. Thaler, the group behind the case includes four patent lawyers from the U.S., U.K., Germany and Israel. Between October 2018 and August 2019, the team filed patent applications with the U.K.'s Intellectual Property Office, the European Patent Office, the Israel Patent Office and the U.S. Patent and Trademark Office listing Dabus as the inventor.

In August, the U.S. patent office sent a letter stating that the applications wouldn't be considered unless the applicants listed the inventors involved by their legal names. Later that month, Dr. Abbott and his team filed a response requesting that the office recognize Dabus as the inventor because there was no human inventor. It also asked that Mr. Thaler be granted ownership rights to the inventions.

Dr. Abbott says the applications represent a test case that has implications for fairness, innovation and business certainty. It is unfair, he says, for people who don't themselves invent to be acknowledged in the same way as people who do. Also, if companies see risks in seeking patents for AI-generated inventions, they may be less inclined to use AI in that manner.

"If Watson and DeepMind become not just competitive with a human inventor, but outperform a human inventor, you would want to be using them in R&D," he says, referring to AI platforms owned by International Business Machines Corp. and Alphabet Inc., respectively.

"But if [patent offices] are going to say you can't patent anything that comes out of them, you're probably not going to get that, or not going to get it as much."

Parallels to monkey case?

In an interview, U.S. patent office Director Andrei Iancu wouldn't comment on what's next for this case but said his office is working to formulate policy positions on the issue, and that the judicial and legislative branches ultimately will have to decide whether patents can recognize AI systems as inventors. "Technology is moving very fast, and we need to get ahead of it," he says.

The U.S. patent office in late August requested public comment on AI, with one objective being to consider "whether new forms of intellectual-property protection are needed." One of the questions it poses is: "What are the elements of an AI invention?" The deadline for public comment is Nov. 8.

Corey Salsberg, vice president and global head of intellectual-property affairs at Novartis AG, says his company is interested in the Dabus case because Novartis uses AI to winnow down chemical compounds that could be used in developing new drugs.

He says the case has some parallels to the "monkey selfie" case earlier this decade, in which an Indonesian macaque took pictures of itself on unattended cameras belonging to photographer David John Slater, who later claimed ownership of the photos. Groups including People for the Ethical Treatment of Animals contested that ownership, saying the copyrights should belong to the monkey.

Ultimately, neither Mr. Slater nor the monkey got those rights, as the U.S. Copyright Office said in 2014 that only photographs taken by humans can be copyrighted, and the U.S. Ninth Circuit Court of Appeals said in a separate decision last year that animals can't sue for copyright infringement.

Mr. Salsberg's stance is that regardless of whether an AI system gets credited as the inventor or the person behind it does, the patent should be awarded—unlike in the monkey case.

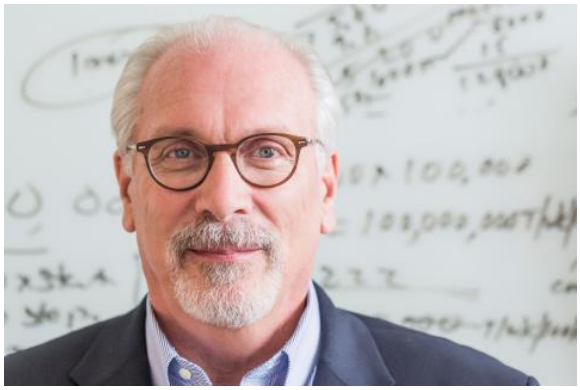
"What would be a problem is [a patent office saying] you're not going to get a patent because we believe the AI did the work that a human normally would have done," he says. "So no one gets the patent. That's the outcome we're most concerned about."

Mr. Council is a reporter for WSJ Pro Artificial Intelligence in New York. Email him at jared.council@wsj.com.

Richard DeMillo on the Trials and Triumphs of Helping to Protect U.S. Elections from Hacking

By Michelle Hampson
September 20, 2019
https://www.aaas.org/membership/member-spotlight/richard-demillo-trials-and-triumphs-helping-protect-us-elections

When Richard DeMillo first began his career in computer science in the 1970s, the concept of cybersecurity did not exist. Fast forward to today and you will find him, along with other top computer scientists across the U.S., fighting to counteract cyberattacks that threaten the country's democracy. As demonstrated all too clearly in the last two federal elections, electronic voting systems are vulnerable to hacking and pose a serious threat to the integrity of the U.S. electoral system.



DeMillo specializes in evaluating existing voting technologies for vulnerabilities, as well as evaluating security measures that could help make elections more secure. For example, he recently assessed whether an approach by voters to confirm their electronic votes could be successful (it's not). For DeMillo, these issues cut close to home. As a cybersecurity researcher and Distinguished Professor of Computing at the Georgia Institute of Technology, he resides in a state that's widely considered by experts to have the most outdated and vulnerable electronic voting infrastructure. When electronic voting systems first became an option in the early 2000s, Georgia was among the first states to adopt the technology – an action with severe repercussions that persist today.

"The technology was not ready and it had not been evaluated from the point of view of election security. It was different place and time – the Internet was not as ubiquitous as it is today, so the idea that someone from Russia or somewhere else could infiltrate our election system wasn't well understood," explains DeMillo. "So since the first voting machines first came live 2003, there has been a consistent push on the part of – at first a small group and then a growing group – of scientists and activists to at least confront the weaknesses of the election system."

In 2002, he left his position as Chief Technology Officer for Hewlett-Packard and became the Dean of Computing at Georgia Tech. While holding this position, he was asked to help conduct a confidential assessment of the vulnerabilities of Georgia's voting infrastructure;

that assessment revealed many human-associated weaknesses related to poor training and management practices. DeMillo says that when he and his colleagues sought to assess the voting machines, they were directed by the Secretary of State to stop, as well as redact any references to the machines in the original report.

After that, DeMillo continued his research on cybersecurity and in 2004 was honored as an AAAS Fellow. His focus on election infrastructure fell dormant – until the 2016 federal election. As it happens, one of the voting tech centers he was asked to stop investigating back in the early 2000s, at Kennesaw State University, was hacked during the 2016 election.

Unfortunately, the hacking at this tech center was just one example. Numerous reports show that Russians hackers succeeded in infiltrating voting infrastructure across the United States during that election, as well as the 2018 mid-term election. Although reports suggest that no votes were directly changed, the hackers very well could have altered voting records if they chose to, a concern that remains widely unaddressed as the 2020 election approaches.

DeMillo says the solution is to forgo the use of all machines for voting, with the exception of votes from people with disabilities who require the technology. "The root of the problem is inserting computers where they are not needed into a process that's extraordinarily difficult to manage. So the solution is to get as many computers out of the election process as you can," he emphasizes. "In the U.S.'s case, that means moving from ballot machines to hand marked paper ballots."

Along with a handful of other cybersecurity experts, DeMillo has been working hard to convey these vulnerabilities to the public and government in the hopes of spurring a shift away from electronic voting systems. This involves undertakings such as providing testimonies in court and posting on social media.

He says that often these efforts are analogous to the challenges that climate change scientists face, where the science is complex and must be communicated to the public, while scientists must keep pushing the frontiers of knowledge forward. Similarly, researchers in this field often encounter resistance from decision-makers. For these reasons, DeMillo says the cybersecurity community often looks to climate scientists for inspiration on how to implement policies.

Despite efforts by researchers and activists to reembrace paper ballots, the Georgia government just recently authorized $150 million towards new voting electronic voting machines, which critics say will still harbor vulnerabilities to hacking.

However, DeMillo says that scientists are having an impact on the situation in Georgia, by supporting fact-based policy-making and legislating. A more recent court ruling by a federal judge mandates that, if the newer voting machines are not ready by the 2020 federal election, Georgia must adopt a paper-based voting system. DeMillo acknowledges that cybersecurity is a difficult career to pursue, both technically and politically, but it can be rewarding.

In the cyber world, he notes, there is always someone looking to exploit tools. "As a cyber security researcher, you get to not only confront those people actually and virtually – you get to invent technologies and do the math that prevents them from succeeding in what they want to do," he says. "In most of science, your adversary is a natural process and you're trying to figure out what's going on. In cybersecurity, it's an adversary who thinks and is there to outsmart you. And that intellectual challenge makes it a really rewarding area to work in."

The American Regime and a Restless Nation

On the last day of the Constitutional Convention, right after adoption, a woman waiting outside the old Pennsylvania State House asked Benjamin Franklin whether the nation would be a monarchy or a republic. His answer was "A Republic, if you can keep it." The Constitutional Convention invented the American government. It was an invention in two ways. First, it created a government where none had existed. Second, it created a machine, the machinery of government, which had sprung from the minds of the founders. Unlike other governments, it had no past. This government came into existence through design, architecture, and engineering.

The machine was built on two principles. First, the founders feared government, because governments tended to accumulate power and become tyrannies. Second, they did not trust the people, because the people—in pursuing their private interests—might divert the government from the common good. Government was necessary, and so of course were citizens, but both had to be restrained in such a way that the machinery of government limited their ability to accumulate power. The founders had created such a machine.

The founders were trying to invent a machine that restrained itself, thereby creating a vast terrain in American life that was free from government or politics. They sought to create a sphere of private life in which citizens would pursue the happiness that had been promised in the Declaration of Independence. The private sphere would be the sphere of commerce, industry, religion, and the endless pleasures that were the domain of private life. The most important thing about the machine they invented was the degree to which it was restrained from intruding on the things they held most important, the things that were not political.

It is one thing to invent a machine and another to make it run without extensive maintenance. The solution for this invention was to make it inefficient. The balance of powers that were created achieved three important things: first, it made the passage of laws enormously difficult; second, the president would be incapable of becoming a tyrant; and third, Congress would be limited by the courts in what it could achieve. The founders' remarkably inefficient system of government did what it was designed to do; it did little, and the little that it did, it did poorly. The government had to protect the nation and maintain a degree of internal trade. But it was private life that would create a cycle of creativity that would allow society, economy, and institutions to evolve at remarkable speed yet not end up tearing the country apart, save for some near misses. This is why Benjamin Franklin left the Pennsylvania State House in Philadelphia both confident and cautious. He knew that the regime was designed to balance powerful and dangerous forces, and he knew that it was a new and untried form of government.

This was not simply a matter of the legal phrases contained in the Constitution. It was even more a matter of creating and enshrining moral principles, some only implicit and others clearly stated. Limits on society, both public and private, can be imposed not by political fiat or documents but by rendering the extraordinary moral vision as merely the common sense of the nation. The moral principles were complex and sometimes at odds with each other, but they had a common core: each American ought to be free to succeed or fail in the things he wished to undertake.

This was the meaning of the idea of the right to pursue happiness. The state would not hinder anyone. A person's fate would be determined only by his character and talents. The founders did more than separate the state and private life. They created an ongoing tension between them. Visit a meeting of any local public school board, where the realities of the government meet the needs of the people. The desire not to have increased taxes—but to deliver increased services—confronts a government that constantly seeks to expand its power and funding, without committing itself to any improvements. The pressure accumulates on the democratically elected members of the school board who are caught in between. This is the microcosm of the tension, which leads from the local level to Washington.

The Republic, in principle, was not wedded to any particular place or people. The founders saw it as the form of government and society that was the most natural and moral. It could have been an ideal form of government anywhere. The Republic could have failed in the United States, yet whether it was in existence elsewhere or nowhere, in the eyes of the founders it would still have remained the most just of political orders.

This meant that the regime was unique. It was not connected solely to the people who lived in America. It was theirs if they kept it and belonged to others if they chose to have a regime like this. That made the United States radically different from other nations, which are rooted in a common history, language, culture, and place. For example, France and Japan are deeply tethered to their past. America is rooted in an invention, a form of government designed with a moral and practical end, but not, in principle, rooted in the American people. Hence Franklin's warning. The very concept of the American republic is artificial, unconnected to the past.

The regime is called the United States. The country is called America. The regime and the country are linked by the country's accepting the principles of the regime. It need not do so in order for America, the country, to exist. Americans could have chosen to switch to a different form of government—a monarchy, for example—and the country would have remained America. But we would no longer have been the United States, in the full institutional and moral meaning of the term. The United States of America is the place where the principles of the regime govern the country. This is a very different understanding from what exists in most other countries, and it has profound, and sometimes not recognized, consequences.

You can say that you are a citizen of the United States, but you cannot say I am a "United Statian." The language doesn't permit it. Your natural relationship is to America, your homeland. Saying you are American is easy. But your love of the land and of the people, and your relationship to the United States, are very different things. One of the constant challenges of the Republic is to keep the two aligned, for our natural inclination is to love our home, and loving the Republic is an intellectual exercise. The two need not be one, but the American founding is designed to make certain that there is no unbridgeable distinction. Mostly it works. When it doesn't, there is tension.

Shortly after the Declaration of Independence was signed, Thomas Jefferson, John Adams, and Benjamin Franklin formed a committee to design a great seal for the United States. Given that the United States had been plunged into war by the signing of the declaration, this would not have seemed a priority. What these three men knew, however, was that the United States was a moral project and moral projects require icons, things that define the moral mission and carry with them a sense of the sacred. It took years to produce the Great Seal. In 1782, Charles Thomson, secretary of the Continental Congress, was asked to take this project to conclusion. He did, and the final product now rests in several places, as sacred in American life as the Republic's principles. The most important place you will find it is nearest to the hearts of Americans: the dollar bill.

Inventing the government was the preface to inventing a nation. Governments can be machines, but nations have to accommodate the actual lives of people. People don't live abstract lives. They live real ones, within nations, and those nations give them a sense of who they are. Partly it has to do with the government. Partly it has to do with the principles of the nation, the things that tell us what kinds of people we are and ought to be. There can be weighty tomes written on this subject, but Jefferson, Adams, and Franklin provided the nation with a great seal that was to be a prism through which we looked at ourselves and that explains why we behave as we do. The Great Seal is symbolic and the symbols must be decoded. But in those symbols, we can find what they thought Americans should be and what citizenship in the United States must be.

We should take the Great Seal seriously because of the three men who called it into being. They not only were among the most extraordinary members of a group of extraordinary men but also represented all the major factions of the revolution. Jefferson was a democrat. Adams was a Federalist. Franklin was an iconoclast, and perhaps best represented the American spirit. He was a serious man. He was not a sober one. Franklin was a party of one and represented the people who loved the country, but he understood that decency required humor. It is amazing that three minds such as these—a philosophical genius, a legal genius, and a genius at living well—were able to share a single vision of who we were and who we must remain.

On the front of the seal is the eagle, said to represent the strength of America. Benjamin Franklin actually objected to the choice of the eagle, explaining his rationale in a letter to his daughter:

For my own part I wish the Bald Eagle had not been chosen the Representative of our Country. He is a Bird of bad moral Character. He does not get his Living honestly. You may have seen him perched on some dead Tree near the River, where, too lazy to fish for himself, he watches the Labour of the Fishing Hawk; and when that diligent Bird has at length taken a Fish, and is bearing it to his Nest for the Support of his Mate and young Ones, the Bald Eagle pursues him and takes it from him.

Franklin is said to have preferred the turkey, a more honest bird. He most likely couldn't tolerate the cliché of an eagle. Franklin was being funny, but he was also making the serious point that symbols matter.

On the banner, next to the eagle are the words E pluribus unum, meaning "From many, one." It was said at the time to refer to the thirteen colonies, the many joining together and being one. Over time, however, history has given a different meaning to the phrase. Once the waves of immigration washed across the United States, the motto was used to refer to the manner in which the many cultures that had come to America had become one nation. It is unlikely that the founders ever envisioned the diversity of immigration, although the Constitution clearly anticipated it because it set the rules for naturalization. The Scots-Irish—Protestant Scots from Ireland who arrived after the English—were loathed as violent and unassimilable. It is an old story in the history of American immigration. The Great Seal is fixed in principle. It evolves in practice. Out of many, one, turned out to be the basis on which the American people were founded, but never easily. Here we are, 250 years later, and the principle of immigration still tears at the nation.

But the original meaning of E pluribus unum pointed at another, deadly problem that led to the Civil War. It is easy to forget how different the colonies were from each other and how aware they were of their differences. Rhode Island differed from South Carolina in geography,

customs, and social order. Those differences endure today, but as a shadow of what they once were. E pluribus unum was chosen as a motto not because the new states had much in common but because to some extent they regarded each other as strange and exotic foreigners. Today we may not be strangers, but a New Yorker is frequently exotic to a Texan, and vice versa. The tension endures.

On the back of the seal is an unfinished pyramid, an interesting choice for an emerging modern country in a time when pyramids had not been built for many centuries. But its symbolism is powerful. A pyramid is a massive undertaking, involving the wealth and resources and labor of a nation. It is a unifying principle. The pyramid ties the Republic for which it stands and the people who built it into one. It tells us that the Republic is not simply a concept but the product of a people, and that ties the Republic to a nation.

The seal also signifies that the Republic is a work in progress and must evolve through the intense labor of Americans. The people endlessly build the pyramid on the land. A pyramid has a shape that compels the work to proceed in a certain way. You make the brick, you make the mortar, you lay the brick in an endless cycle. The pyramid gives labor its form and its predictability. Labor also has its moments of crisis and of success. This describes what American life will be like.

Above the pyramid are the words Annuit coeptis, meaning, "He has favored our undertaking." "He" is assumed to be God. Yet it was decided not to use the word "God." There is a great controversy in America between those who argue the United States is a Christian country and others who claim that it is completely secular. The creators of the seal clearly understood this issue. Whether they compromised or whether they were unanimous, there is no mention of Christ or even God in either the Declaration of Independence or the Constitution. Yet there is a clear reference to something beyond humanity who judges and favors the undertaking, a providence, as it is called in the Declaration of Independence. The founders could have referred directly to Christ, or they could have avoided any reference to the divine. They did neither. They did not simply embrace the secularism of the Enlightenment nor the religiosity of England. They refused to name the providential force, but they made it clear that there was one. The ambiguity was, I think, deliberate. It developed a creative tension that endures.

Beneath the pyramid is the third motto on the seal: Novus ordo seclorum, which means a "new order of the ages." This is how the founders viewed the founding of the United States. It was not simply a new form of government but a dramatic shift in the history of humanity. That was radical enough. However, Charles Thomson, who crafted the phrase, said that what it represented was "the beginning of the new American era." The most reasonable way to interpret this is that a new age has begun, and America would be at the center of the new age. There was nothing reasonable about this assertion at the time. In fact, if was downright preposterous. America was in its infancy, sharing a world filled with countries that had existed and evolved for centuries, if not millennia. The age that Europe had defined was far from over, and a new age, transcending the European age, was not yet visible.

Amazon invests in prefab startup focused on smart home tech

Could this investment in California-based Plant Prefab be a new avenue for Alexa expansion?

By **Patrick Sisson** Sep 25, 2018

A Plant Prefab home in Santa Monica, California. *Plant Prefab*

Amazon has made its first foray in prefab construction, investing in a company known for sustainable construction and smart home technology.

Today's announcement of Amazon's investment in Plant Prefab, a startup based in Rialto, California, comes on the heels of the company's announcement of a new line of Alexa-enabled smart home devices, suggesting a potential new avenue of smart home development, experimentation, and expansion.

Amazon already has a deal with Lennar, the nation's largest homebuilder, to pre-install Alexa in all the company's new homes.

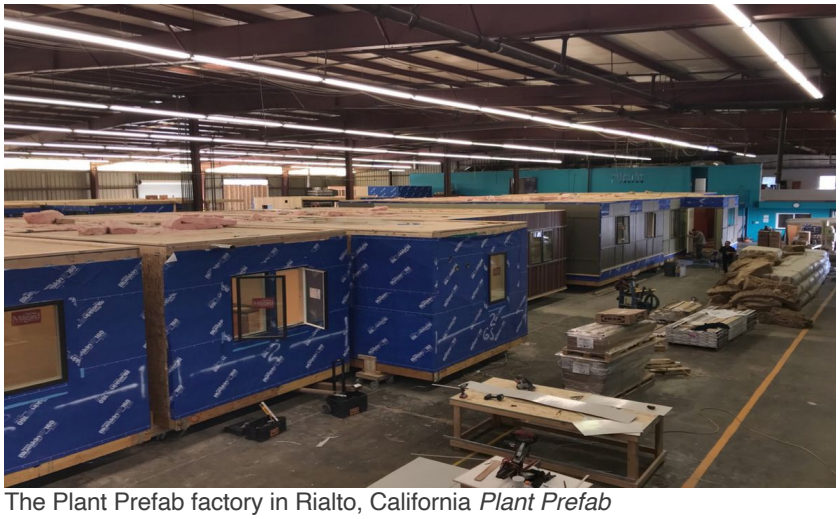
While Amazon has plenty of construction needs, between current expansion in Seattle, future construction of its HQ2, as well as continued expansion in warehouse and logistics space, one of its primary focuses has been getting Alexa, its smart assistant, in more homes. Plant Prefab CEO Steve Glenn told Curbed he wasn't able to discuss any specific plans, the press release announcing the deal focused on smart home technology.

Plant Prefab's factory in Rialto, California. *Plant Prefab*

"Voice has emerged as a delightful technology in the home, and there are now more than 20,000 Alexa-compatible smart home devices from 3,500 different brands," said Paul Bernard, director of the Alexa Fund, in a statement. "Plant Prefab is a leader in home design and an emerging, innovative player in home manufacturing. We're thrilled to support them as they make sustainable, connected homes more accessible to customers and developers."

Glenn said the new $6.7 million Series A funding round, which also includes investments from Obvious Ventures and other private investors, will support expansion and talent acquisition for the company, including senior hires and new factories operating on the company's patented Plant Building System. The company current operates out of a 62,000-square-foot facility in Rialto.

Plant Prefab claims to be the first home factory in the nation focused on sustainable construction, materials, processes and operations, and many of its homes are LEED certified. Plant Prefab says its approach reduces construction time by 50 percent and cost by 10-25 percent in major cities. The company has partnered with some of the industry's leading architects and designers, including Ray Kappe, Kieran Timberlake, and Yves Behar.



The Plant Prefab factory in Rialto, California *Plant Prefab*

In 2016, Plant Prefab was spun out of LivingHomes, a design and development company that designed and built dozens of award-winning prefabricated homes and accessory dwelling units (ADUs), including the nation's first LEED Platinum home.

The company believes factory-built homes can address the challenge of affordability with online technology, new building systems, and automation.

"In the housing-crunched major cities like Los Angeles, New York, and San Francisco, along with areas like Silicon Valley, it takes too much time to build a home from groundbreaking to occupancy, and labor shortages, construction delays and increased construction costs are exacerbating this trend even further—and making homes increasingly less affordable," says Glenn in a statement.

11 December 2019 12:13

Wayland Additive moves into new facility for development of its Neutral Beam technology

by Daniel O'Connor

One of the most exciting meetings at this year's Formnext was not on the booth of an exhibitor but in a tucked away meeting room off the show floor. **Wayland Additive** isn't ready to exhibit its metal additive manufacturing technology, but it is prepared to talk about it to a select few.

On the back of a £3 million Series A funding round led by **Longwall Ventures** in September, Wayland has now moved into a new facility that will house the entire team from R&D to machine assembly.

The new facility is just five miles down the road from **Reliance Precision** in Huddersfield, where Wayland's story started. The 99-year-old engineering firm tasked its then Technical

Director, now CTO at Wayland, Ian Laidler with exploring current metal additive manufacturing systems.

Ian's vast experience in the semiconductor industry and electron-beam lithography led him towards electron-beam technology for it's superior material properties and industrial productivity. However, his research showed some flaws in the technology which he and his team believed they could solve.

Over the last three years, Ian and his team have been developing a new electron beam manufacturing technology with the help of Innovate UK grants before separating as a company and launching Wayland.

Wayland sees one key area of attack for the market as a reduction in post-processing steps such as powder recovery, Wire EDM support/build plate removal and stress relief. A video it has been able to show users of other metal technologies of a free-flowing powder removal from a lattice structure has been something of a revelation to some. With alternative electron beam additive processes, features like internal channels have been difficult or impossible due to the pre-sintering of the powder cake.

Wayland believes it has, thanks to the developments of the team of electron beam experts, developed the most stable metal additive manufacturing process yet, thanks to the fundamentals of their Neutral beam technology 'NeuBeam'. Wayland has also developed very sophisticated in-process monitoring capabilities, giving end-users insight into cause and effect from parameter inputs.

However, Wayland is not a company here to make bold claims and deliver nothing, CEO Will Richardson is keen to stress that the company is in this for the long-term. Wayland will start by engaging its highly-trained application engineers with end-users to create legitimate business cases for the owning of machinery. In 2021, the company will build a maximum of six machines and work with the customers on optimising both applications and machinery.

GIZMODO

DECADE'S END

The Most Futuristic Developments We Can Expect in the Next 10 Years

George Dvorsky
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With the decade winding down it's time for us to set our sights on the next one. The 2020s promises to be anything but dull. From the automation revolution and increasingly dangerous AI to geohacking the planet and radical advances in biotechnology, here are the most futuristic developments to expect in the next 10 years.

Making predictions is easy; it's getting them right that's tough. That said, some tangible trends are emerging that should allow us to make some informed guesses about what the future will hold over the next 10 years.

A new industrial revolution

Of great concern, of course, is the pending automation revolution and the associated onset of technological unemployment. Indeed, the coming decade will involve considerable disruptions to the global workforce, the result of steady improvements in robotics and artificial intelligence.

For example, research from 2018 predicted the loss of 75 million jobs around the world by 2022 as a result of automation, with an associated creation of 133 million jobs over the same period, for a net increase of 58 million jobs. This rather sizable swing in vocations will require significant re-training and other major adjustments. A likely trend in the 2020s, for example, will be jobs involving centaurs, that is, human-AI collaborations.

P. W. Singer, author of Ghost Fleet, LikeWar, and the upcoming book Burn-In: A Novel of the Real Robotic Revolution, says we should focus less on a revolt of the robots and more on the onset of a robotics revolution.

"We're entering an industrial revolution akin to the rise of the steam engine and factories," explained Singer in an email to Gizmodo. "A wave of automation and AI is hitting across all sectors of society, applied everywhere from the farm and home to the battlefield. There will be incredible efficiency gains and pathways taken that humans could never have done on their own."

It's worth pointing out that the outmoding of specific jobs to robots and AI will primarily be done for economic reasons. If business owners can save money, even if it involves the massive displacement of workers, it's something they'll likely consider.

Singer said people have already forgotten about the traumas inflicted by the previous industrial revolution, but we're already witnessing the disruption of jobs and roles, the altering of vote politics, the emergence of thorny legal and ethical questions, and new politics and ideologies.

"Remember, the last industrial revolution also brought everything from our conception of modern capitalism to ideologies of socialism, communism, and fascism, which we spent the next few centuries shaking out," said Singer.

Society readjusts to new normal

For every action there is a reaction, which means we're going to spend a good part of the 2020s finding new ways to adapt, recover, and take full advantage of the ensuing social and technological changes. That will involve adjustments to new modes of work, altered socioeconomic dynamics, and novel ways of living and moving in our environment.

Roman Yampolskiy, an AI researcher at the University of Louisville, says the capability gap between people and machines will only increase in the next 10 years.

"Machines will become capable of driving unsupervised, generating captivating news articles, and fully automating many jobs, including basic secretarial work, and investing," Yampolskiy told Gizmodo. "At the same time, and as a side effect of such progress, the cognitive gap between people and machines will also increase," meaning that the degree of intelligence separating AI from humans will get increasingly bigger—and not in a way that favors humans.

According to Lyndsay Wasser, a co-chair of McMillan's Privacy and Data Protection Group and its Cybersecurity Group, the impact of widespread autonomous vehicles, or AVs, will be "enormous."

"A number of industries will be affected, and job losses are inevitable, including both directly impacted organizations, such as taxi and tow truck companies, and associated industries like auto insurance, gas stations, and parking facilities," explained Wasser in an email to Gizmodo.

The widespread introduction of AVs will also impact on how people and households approach transportation, she said.

"The cost of owning an AV makes it unlikely that most lower and middle income families will purchase such a car in the near future," said Wasser. "However, many consumers will likely forego ownership in favor of vehicle sharing ecosystems. Although there are many predicted benefits associated with AV's—such as improved safety and mobility for persons who are unable to drive—the technology is associated with significant risks. In particular, an AV could be used as a weapon if a malicious hacker or cyberterrorist gains control of the vehicle. The volume of data generated by AVs also gives rise to real privacy concerns. Although some commentators and regulators have espoused the benefits of voluntary industry codes, I predict that some governments will move toward specific laws to regulate this transformative industry."

Likewise, Sarah Kaufman, the Associate Director of the NYU Rudin Center for Transportation, believes much of the 2020s will be characterized by the rise of AVs.

"Everyone and everything will move in fleets," Kaufman told Gizmodo. "Fleets of taxis, UPS trucks, bikes and drones. No vehicle ownership in cities. Instead people will travel as part of a larger intelligence network tracking that person's calendar, mood, physical makeup, and travel needs: they will be matched to the right vehicle."

For example, Kaufman predicts that phones will say things like, "You ate too much pizza last night: you're biking to work today," or "Since you're taking your kid and her three friends to hockey practice, use this SUV."

All vehicles on the street will detect each other and move in perfect concert to avoid collisions and conflicts, she said. Sure, they'll move more slowly, "but safely and specific to users' needs," she said.

The 2020s could also see a dramatic change in how we live.

"Twenty-first century RVs will sit at cities' edges," Kaufman told Gizmodo. "They will become the new home offices, as younger generations are priced out of permanent homes, increase the number of freelance positions, and exist wherever internet access is available. Every home will be an office, and vice versa."

Like a rolling stone, these mobile pioneers of the 2020s will "relocate regularly," whether it be towards the Silicon Valley of the moment, to steer clear of climate-change damaged locations, or to the next desert-based music festival, she said. The "new home/office RVs will permit a nomadic life that will breathe new life into cities as populations ebb and flow, experiencing their offerings for the first time," predicted Kaufman.

Deepfakes, people hacking, and other scary tech

"Our ability to tell if something is an AI generated fake news story or a deep fake video will be no better than random guessing," said Yampolskiy. "This will have an unprecedented impact on our democracy and social cohesion as well as privacy, safety, and security issues. An explosion of social engineering attacks fueled by advanced chat bots, using realistic, and familiar voices combined with personalized profiling will target billions of users."

Singer expects to see a surge in people-hacking, in contrast to the hacking of computer networks. This will be done, he says, by driving viral ideas through likes, shares, and outright lies. Russian meddling during the 2016 U.S. election was a test of what its operatives could get away with, he said, but the big takeaway was that "it works and is effective," according to Singer. The 2020s will be a test to see if the U.S. and other targeted countries "can change their calculus and push back on this," he said. This will include "companies taking on more responsibilities for toxic forces on their platforms... democracies developing strategies to better defend their population from digital threats," and citizens "not falling for the same old crap again and again," said Singer.

Frighteningly, however, this won't be simple or easy given that hackers will increasingly leverage their powers with AI during the 2020s.

Finn Brunton, associate professor of media, culture, and communication at New York University, foresees two near-term technologies taking shape.

"First, the ability to generate mostly-synthetic or wholly-synthetic video—of which deepfakes are the early stage work—will get cheaper and easier fast, which, combined with image classification of existing libraries of images and video, means that you can produce custom, targeted video—to say nothing of pictures—for very small audiences, even one-offs, more or less on demand," Brunton told Gizmodo.

Some of these fakes will be crude, he said, but plenty of people will still fall for these tricks.

This development, says Brunton, "will be exacerbated by bot and algorithm driven subcultures and consensus." Instead of messing around on Twitter to manipulate public opinion, actors bent on persuasion will "create, reinforce, and amplify small isolated subcultures to push their ideas and beliefs further and further in the directions their creators want to see them go." To which he added: "This portends the emergence and proliferation of strange new militant cults—[possibly armed with] DIY drone bombs—bubbling up out of isolated individuals who neither have nor need a strong connection to empirical reality."

Grimly, this reminds me of one of my own predictions for the 2020s: We could witness the first assassination of a high ranking politician or otherwise important public figure at the hands of a remotely operated, or possibly autonomous, drone. On a somewhat related note, the issue of autonomous killing machines for use in warfare will emerge in the 2020s as a contentious, hot-button, in terms of whether such devices should be allowed.

Inching closer to artificial superintelligence and the bursting of the AI bubble

AI is poised to be increasingly unpredictable—and in some cases unexplainable and incomprehensible, both to the general public and to experts, according to Yampolskiy. Accordingly, an ongoing issue during the 2020s will be in addressing the black box problem, that is, acquiring a coherent understanding of an artificially intelligent system in terms of how and why it reaches its conclusions. This challenge will only get worse as the decade progresses, which is frightening because we'll eventually be out of the loop in terms of AI decision making, potentially leading to huge problems and possibly even large scale disasters.

On the topic of dangerous AI, it's highly unlikely that artificial general intelligence (AGI) or artificial superintelligence (ASI) will make an appearance during the 2020s, but it's a possibly that can't be discounted outright.

By AGI, computer scientists mean an artificial intellect with a broad range of capabilities, rather than a lone core competency (e.g. bots that can only play chess or poker). Put another way, an AGI would be similar, though not identical, to human intelligence in terms of its adaptability, flexibility, and power. By comparison, ASI would be an order, or several orders, more intelligent than human-level intelligence, particularly in terms of speed, power, capability, and reach. We might be able to control an AGI, but our pending ability to constrain an ASI once it emerges remains an open—and very troubling—question. AGI may not appear during the 2020s, but we should prepare accordingly just in case.

In 1999, futurist Ray Kurzweil famously predicted that a superintelligent machine wouldn't appear until sometime around 2045 to 2050—a prediction I still believe is within the realm of possibility. For it to suddenly emerge in the 2020s would require a rather massive technological leap, in which cognitive scientists and/or computer scientists would have to suddenly stumble upon the magic formula that conjures not just AGI, but ASI as well.

That said, the advent of AGI will herald the emergence of ASI shortly thereafter, due to the ease at which a machine, whether an emulation of the human brain or a series of complex algorithms, can be modified and improved even further. Importantly—and perhaps frighteningly—artificial intelligence, and not humans, will most likely be the architects of these next-level thinking machines. As I've argued before, ASI will give birth to itself.

Consequently, a growing social awareness about the dangers posed by powerful AI will emerge during the 2020s—a phenomenon that will likely be compared to today's burgeoning environmental movement and the global struggle to tackle climate change. Douglas Vakoch, an astrobiologist and president of METI (Messaging Extraterrestrial Intelligence), says that, as computers gain in power and become more human-like in both function and form, "we will feel ever more threatened, afraid that our technological children will surpass us, and perhaps even destroy us," he told Gizmodo in an email.

Jaan Tallinn, a computer programmer, founding member of Skype, and co-founder of the Centre for the Study of Existential Risk, doesn't expect the coming decade to be "drastically different" than the last one.

"I would expect the backbone of 2020s technology be defined via gradual improvements in some fundamental and commercially valuable technologies, such as biotechnology, nanotechnology, and AI," explained Tallinn in an email to Gizmodo. "With that said, when considering potential risks from future technology, one should not be content with merely analyzing what's likely to happen—instead, one should look at what's possible, even if unlikely."

Items high on Tallinn's concern list for the 2020s includes sudden breakthroughs leading to uncontrollable, runaway AI, the misuse or accidents involving synthetic organisms, and technological miniaturization enabling "new ways for non-state actors to cause large scale damage without attribution," he said.

"This will probably also be the last decade in which we can learn to control AI," said Yampolskiy, "as it becomes more capable it will take on progressively more responsibilities for managing our daily lives."

Robin Hanson, an associate professor of economics at George Mason University and a research associate at the Future of Humanity Institute of Oxford University, is predicting a different kind of decade, in which the fascination with AI will experience somewhat of a downturn.

"Interest and concern regarding automation and AI has gone in big up-and-down cycles and we seem to be nearing the peak of the fourth such cycle since one peaked near the 1930s," Hanson told Gizmodo in an email. "So an easy prediction for the next decade is that we will more clearly see that this cycle is past its peak. There will be talk of how AI has been overly-hyped and a reduction of investment and media talk. There will be fewer AI conferences, startups, and students enrolling in AI degree programs."

Hanson expects a new cycle to emerge again, peaking around 2050.

Let's hack the planet

Artificial intelligence will get scarier during the 2020s, but so will climate change. By the 2020s we should, sadly, witness an increasing number of related discomforts and disasters, from more heatwaves and droughts through to rising sea waters, storms, floods, and wildfires.

There's a very good possibility that the nations of the world will continue to fail to meet their climate targets and that the status quo approach to the environment will reign. In the place of internationally binding agreements and treaties, it's likely that we'll embark upon our first clumsy efforts to fix the environment through other means, namely the futuristic—and potentially risky—prospect of geoengineering. Proposed solutions include efforts to increase the reflectivity of clouds, the construction of giant space reflectors, ocean fertilization, introducing stratospheric aerosols, among other ideas. The trouble with geoengineering, however, is that we could completely screw it up and damage the climate even further. Also, once we start we won't be able to stop. Fair to say, we should expect to see the prospect of geoengineering and proposed schemes to be actively debated during the 2020s.

The possibility exists, of course, that the world will get its act together and work to reduce carbon emissions, but as Jamais Cascio, a distinguished fellow at the Institute for the Future, explained to Gizmodo, the effects of this won't be immediately obvious due to a phenomenon known as "climate lag."

"One of the complexities of the climate issue that we'll start to confront over the next ten years is the lag—technically, 'hysteresis'—between reductions in carbon emissions and temperature changes," said Cascio. "Thermal inertia, soil carbon, and a whole mess of complex systems make temperatures slow to react to carbon levels. We could cut all carbon emissions today and we would very likely see continued temperature increases for the next couple of decades."

This is an obvious environmental problem, he said, but it's also a political problem.

"What do you say to citizens who have agreed to make big changes in their lives, even sacrifices, with seemingly no beneficial results?" he said. "Saying 'It could have been worse' rarely works, and saying 'Trust me, your kids will love it' isn't any better, either."

Better, more powerful biotech

Biotechnologies will continue to advance during the 2020s. It will likely take another generation or two before we see genetically modified "designer babies," but important advances in this area should occur in the next 10 years. As it stands, scientists in the U.S. and elsewhere can genetically modify human embryos for experimentation, but the cells must be destroyed within a few days. Don't expect this to change in the 2020s, but the 2030s could be a different story.

Personalized medicine, also known as precision medicine, should finally make its appearance in the 2020s, in which healthcare professionals will tailor treatments and therapies—whether genetic, environment, or lifestyle related—to the needs of specific individuals. This will be done primarily through genetic analysis, with advances in AI pushing this prospect forward; machine learning algorithms will detect patterns in large datasets, allowing healthcare practitioners to devise individualized treatments, instead of our current one-size-fits-all approach.

The CRISPR gene-editing tool will continue to make waves—and headlines—in the coming decade.

In an email to Gizmodo, Jennifer Doudna, co-inventor of CRISPR-Cas9 and biochemist at UC Berkeley, said that, within the next 10 years, "we could see new CRISPR-based individualized medicines and approaches to treat and potentially cure the most intractable genetic diseases, including sickle cell disease and cystic fibrosis." In agriculture and related fields, researchers will apply CRISPR technology "to grow more nutritious and robust crops and to establish 'gene drives' to control the spread of infectious diseases such as malaria and Zika virus," said Doudna.

Indeed, the 2020s could witness the first gene drives, in which scientists attempt to genetically modify wild organisms, such as mosquitoes. But to "ensure responsible development of these wide-ranging applications," Doudna said it'll be "vital to continue public discourse about uses and regulation" of these powerful technologies.
New views of space—and our place within it

Finally, the next decade will see a dramatic increase in our understanding of the cosmos—and possibly even extraterrestrial life. Next generation telescopes, like the James Webb Space Telescope and the European Extremely Large Telescope, are poised to redefine our knowledge of the galaxy. And as Vakoch explained to Gizmodo, advances in computing power will provide a big boost to SETI.

We'll soon be able to "scan the heavens for signs of intelligent life at an accelerating pace, as we sift through the cosmic static for radio signals that stand out as distinctly artificial," he told Gizmodo. "By the end of the decade, humanity will complete a survey of a million nearby stars, finally observing enough targets to have a realistic chance of finding ET if it's out there, trying to make contact," he said, adding: "The odds of discovering we're not alone in the universe have never been better."

The 2020s will likely feature a volatile mixture of the very good, the very bad, and the very weird. Without a doubt, the next decade will be anything but dull.

THE WALL STREET JOURNAL.

Brace for the Digital-Money Wars

Digitizing the Chinese yuan—and eventually the dollar—would open new fronts in the fight over privacy and trade.

ILLUSTRATION: MIKEL JASO

By Paul Vigna

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https://www.wsj.com/articles/brace-for-the-digital-money-wars-11575694806

THE NOT-TOO-DISTANT FUTURE—The National Security Council holds an emergency meeting. North Korea has launched a missile, capable of carrying a nuclear warhead within range of U.S. forces in Guam. At this rate, North Korea could land a nuke on the U.S. mainland in less than a year.

The shocking advance in capability despite heavy trade sanctions is due to a stream of money that the U.S. and its allies cannot monitor—a cryptocurrency. But it's not one of the risky ones celebrated by overnight millionaires and largely avoided by serious investors, it's a new one, with the stamp of legitimacy: the digital yuan.

The scenario above is fiction, but it isn't fantasy. If China digitizes its currency, as it plans to do, and the North Koreans use it to finance their missile program, it's a flow of money that circumvents U.S. sanctions. That would force the U.S. to grapple with its own now-antiquated currency. If the U.S. follows suit, digitizing the dollar in order to maintain its global economic dominance, it would also find itself in possession of a potentially powerful surveillance tool.

While bitcoin, the first successful cryptocurrency, was created to maintain anonymity in transactions, future digital currencies will be the opposite of anonymous.

And just as every transaction involving a digital yuan would be trackable by China, every digital dollar changing hands would be visible to the U.S., its issuing government. Banks might still manage the flow of money, but they will no longer be the record-keepers they once were.

"The fundamental nature of money is really changing," said Neha Narula, the director of MIT Media Lab's Digital Currency Initiative.

Dr. Narula played the president's "cyber czar" in an enactment of the hypothetical North Korea scenario staged last month at Harvard's Kennedy School. "Digital Currency Wars" also featured former Treasury Secretary Lawrence Summers as well as Ash Carter and Gary Gensler, all of whom have served in presidential administrations. (The presentation can be seen in its entirety here.)

We are moving rapidly into a new monetary era. Countries and companies are looking at digital money as the new standard for their monetary systems and a replacement for actual cash.

Some of the benefits include faster, cheaper payments, a greater ability to root out money launderers, and a more open, inclusive financial system. Digital money is also going to provide new abilities to law enforcement and governments that will almost certainly open up another front in the fight over privacy.

"Privacy is one of the defining problems of our times," said Emin Gün Sirer, chief executive of blockchain-based startup Ava Labs and a professor of computer science at Cornell University, and it will be with money, too. In practice, he said, it's almost impossible to create a form of digital money that doesn't identify its users.

What we think of as "money" is actually an extraordinarily complex network of thousands of commercial banks and central banks. The system works, but is costly and relatively inefficient because everybody is working off their own balance sheets. Digital money would create a system where everybody using a particular currency is working off the same balance sheet.

The idea of bitcoin, unveiled 11 years ago, was to compress the cumbersome functions of the modern financial system to enable money to move anywhere around the world, in minutes, for virtually no cost. If you've ever tried to send even $10 across a border, you can appreciate the allure in this.

But bitcoin was just Act One. Act Two began this summer, when Facebook uncovered its proposed cryptocurrency, libra. This wasn't some loose confederation of cypherpunks and antibankers. Suddenly, one of the world's biggest, most powerful (and most controversial) companies was saying it was going to *make* money.

A flurry of action followed. The U.S. Congress convened hearings and wrote bills to stop libra from launching. Regulators leaned on some of its original supporters to back out. The Bank of England's Mark Carney suggested an international cryptocurrency should replace the dollar as the world's new reserve currency. The Chinese went further. They took their own efforts into overdrive, and are widely expected to launch a digital version of the yuan in the coming months.

"This is more than just Venmo, more than just PayPal," said Aditi Kumar, executive director of Harvard's Belfer Center for Science and International Affairs, and playwright of "Digital Currency Wars." "This is an entirely new way for countries to operate in the world," she added. "It will make one or two actors all-powerful in the monetary system."

The digital yuan China is planning is in fact a complete inversion of the bitcoin model. All of the data created would be centrally housed and become part of China's surveillance state.

Money has always been a powerful, blunt instrument. It's an imposition not just of will, but of values. After World War II, the dollar became the foundation of the international monetary system. That gave the U.S. government a special tool. The U.S. has used its control over the dollar-based finance system to impose sanctions such as the ones on North Korea.

As the U.S. share of the global economy shrinks and that of countries like China and India expand, countries are actively seeking alternatives to the dollar.

In the fictional North Korea missile crisis, China would be tacitly allowing the financing of Pyongyang's nuclear program to go through, because the government would be able to see where each digital yuan goes. That's an extreme, and entirely hypothetical, scenario, of course, but it's an example of the leverage China would have over every transaction on its system. The only question is how heavy-handed the Chinese would be in using it.

While the Chinese model might be the far end of the spectrum, cryptocurrency has been moving in that direction. While bitcoin was designed to mimic the anonymity of cash in a digital setting, all its transactions are public, and therefore trackable. And Facebook's libra would log transaction data, while recording user identities in a separate database. A central concern in Congress is what Facebook would do with that information.

Say the Federal Reserve digitized the U.S. currency. It could track how every dollar in circulation is spent. That might give it a great advantage in trying to figure out how the economy is growing, and where stimulus efforts would best be directed. But say people in government wanted to lock down some group or activity. They could do that, too. The role of banks would likely change considerably as well, though whether they gain or lose with a digital dollar would depend on how the government issued it.

Whether the U.S. will feel pressure to shift to digital still isn't clear. There are proponents and opponents of cryptocurrencies in Congress. The Fed has examined the idea of creating a digital dollar, but that's all it's done.
At Harvard, Mr. Summers and his fellow stage actors spent some time debating this point. Some felt the U.S. should get in the game, others believed all they needed to do was make improvements to the existing system.

People need to start thinking about this now, Harvard's Ms. Kumar said. China's digital yuan will be a real-world proof of concept. The West will need to respond in some way. "Are we prepared for that?" she said. "Not just technically, but legally? Can we protect privacy in this new world?"

STATE OF THE EDGE

The Edgeless Cloud and Flatnets

https://www.stateoftheedge.com/blog/the-edgeless-cloud-and-flatnets/

By Francis McInerney

Managing Director of North River Ventures

December 26, 2019

The math of Cloud Inflation says that, at some point, your smartphone becomes my server. So, forget everything you hear about edge servers harnessing the Cloud; the cloud has no edge.

There is absolutely no reason why each home in the world should not become a combination cell tower, data center and blockchain revenue engine scaling with Moore's Law and the Memory-Density Curve. When this happens, the Cloud loses its edge. Whence, the Edgeless Cloud.

Edgeless elements will be meshed together in topologically flat networks, or "Flatnets." These are virtualized, blockchain-fueled, wireless systems growing in power outside the existing telecommunications network. Flatnets make the Cloud edgeless with no near, no far, no inside, no outside. And open a whole new set of revenue opportunities. In short, Flatnets are the first end-to-end redesign of the telecommunications systems that connect us since Bell founded AT&T in 1877.

Instead of paying carriers for access every month, blockchain will allow users to make money from access and content on scalable, meshed data centers that they control. Think of the Mississippi changing direction and flowing North to the Atlantic through the Gulf of St. Lawrence. Its entire ecosystem will be different.

Thus, in the process of becoming an edgeless, virtualized network, the Cloud dissolves all the phone, cable and cell companies worldwide, every company in their ecosystems and all their shareholders and employees. Uber on steroids

Flatnets are the logical outcome of applying Moore's Law and the Memory-Density Curve to the FCC's 1976 Carterfone decision. This ruling, which made it legal to connect third-party devices to the phone

system, opened the market to customer-premises equipment. Unshackled from Ma Bell, and with no restrictions on the processors and software that users could connect to the network, the power of user devices exploded. By projecting those trends into the future, we could map with precision the day when network polarity would reverse— when there would be more computing, networking and storage outside the network than on it— and with it the network's revenue streams.

We have seen the effects of these trends for years in Wi-Fi. Because it is extremely capital-efficient, Wi-Fi has gobbled up large parts of the "App Delivery Membrane" and sucked all the growth out of cell nets. Most cellular networks are in revenue decline. Capital-efficient flatnets in the Edgeless Cloud will eat up the rest.

How?

In two steps, the first already taken and the second almost complete.

In the first step, we are already seeing companies deploy distributed data centers and sophisticated cloud provider services at cell towers, all connected on their own fiber backhaul. When you realize that these clouds host the bulk of the world's content, the impact of Flatnets hits home hard.

In the second step, we will attach meshed Flatnets to this structure. A member of our FutureCreators program has just been granted a patent covering blockchain on all wireless devices. Mississippi reversal-style, this will unleash huge new revenue flows for the owners of these tower-connected data centers and edge cloud services.

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Francis McInerney, Managing Director at NRV, has been building businesses since the 1980's. He is the Business Model Sherpa for the Zettabyte era.

Comment

Time for the Human Screenome Project

Byron Reeves, Thomas Robinson & Nilam Ram

To understand how people use digital media, researchers need to move beyond screen time and capture everything we do and see on our screens.

There has never been more anxiety about the effects of our love of screens — which now bombard us with social-media updates, news (real and fake), advertising and blue-spectrum light that could disrupt our sleep. Concerns are growing about impacts on mental and physical health, education, relationships, even on politics and democracy. Just last year, the World Health Organization issued new guidelines about limiting children's screen time; the US Congress investigated the influence of social media on political bias and voting; and California introduced a law (Assembly Bill 272) that allows schools to restrict pupils' use of smartphones.

All the concerns expressed and actions taken, including by scientists, legislators, medical and public-health professionals and advocacy groups, are based on the assumption that digital media — in particular, social media — have powerful and invariably negative effects on human behaviour. Yet so far, it has been a challenge for researchers to demonstrate empirically what seems obvious experientially. Conversely, it has also been hard for them to demonstrate that such concerns are misplaced.

A major limitation of the thousands of studies, carried out over the past decade or so, of the effects of digital media is that they do not analyse the types of data that could reveal exactly what people are seeing and doing on their screens — especially in relation to the problems that doctors, legislators and parents worry most about. Most use self-reports of 'screen time'. These are people's own estimates of the time they spend engaging with screens or with platforms that are categorized as 'smartphone', 'television', 'social media', 'political news' or 'entertainment media'. Yet today's media experiences defy such simplistic characterization: the range of content has become too broad, patterns of consumption too fragmented[1], information diets too idiosyncratic[2], experiences too interactive and devices too mobile.

Policies and advice must be informed by accurate assessments of media use. These should involve moment-by-moment capture of what people are doing and when, and machine analysis of the content on their screens and the order in which it appears.

Technology now allows researchers to record digital life in exquisite detail. And thanks to shifting norms around data sharing, and the accumulation of experience and tools in fields such as genomics, it is becoming easier to collect data while meeting expectations and legal requirements around data security and personal privacy.

We call for a Human Screenome Project — a collective effort to produce and analyse recordings of everything people see and do on their screens.

Screen time

According to a 2019 systematic review and meta-analysis[3], over the past 12 years, 226 studies have examined how media use is related to psychological well-being. These studies consider mental-health problems such as anxiety, depression and thoughts of suicide, as well as degrees of loneliness, life satisfaction and social integration.

The meta-analysis found almost no systematic relationship between people's levels of exposure to digital media and their well-being. But almost all of these 226 studies used responses to interviews or questionnaires about how long people had spent on social media, say, the previous day.

The expectation is that if someone reports being on Facebook a lot, then somewhere among all those hours of screen time are the ingredients that influence well-being, for better or worse. But 'time spent on Facebook' could involve finding out what your friends are doing, attending a business meeting, shopping, fundraising, reading a news article, bullying, even stalking someone. These are vastly different activities that are likely to have very different effects on a person's health and behaviour.

Another problem is that people are unlikely to recollect exactly when they did what[4,5]. Recent studies that compared survey responses with computer logs of behaviour indicate that people both under- and over-report media exposure — often by as much as several hours per day[6–8]. In today's complex media environment, survey questions about the past month or even the past day might be almost useless. How many times did you look at your phone yesterday?

The US National Institutes of Health (NIH) is

A participant in a traditional Chinese opera competition plays on her phone.

THOMAS PETER/REUTERS

currently spending US$300 million on a vast neuroimaging and child-development study, eventually involving more than 10,000 children aged 9 and 10. Part of this investigates whether media use influences brain and cognitive development. To indicate screen use, participants simply pick from a list of five standard time ranges, giving separate answers for each media category and for weekdays and weekends. (The first report about media use from this study, published last year, showed a small or no relationship between media exposure and brain characteristics or cognitive performance in computer-based tasks[9].)

Digital life

Instead, researchers need to observe in exquisite detail all the media that people engage with, the platforms they use and the content they see and create. How do they switch between platforms and between content within those? How do the moments of engagement with various types of media interact and evolve? In other words, academics need a multidimensional map of digital life.

To illustrate, people tend to use their laptops and smartphones in bursts of, on average, 10–20 seconds[10]. Metrics that quantify the transitions people make between media segments within a session, and between media and the rest of life, would provide more temporally refined representations of actual use patterns. A session begins when the screen lights up and ends when it goes dark, and might last less than a second if it entails checking the time. Or it could start with a person responding to their friend's post on Facebook, and end an hour later when they click on a link to read an article about politics.

"In today's complex media environment, survey questions about the past month or even the past day might be almost useless."

Measures of media use must also take account of the scattering of content. Today's devices allow digital content that used to be experienced as a whole (such as a film, news story or personal conversation) to be atomized, and the pieces viewed across several sessions, hours or days. We need measures that separate media use into content categories (political news, relationships, health information, work productivity and so on) — or, even better, weave dissimilar content into sequences that might not make sense to others but are meaningful for the user.

To try to capture more of the complexity, some researchers have begun to use logging software. This was developed predominantly to provide marketers with information on what websites people are viewing, where people are located, or the time they spend using various applications. Although these data can provide more-detailed and -accurate pictures than self-reports of total screen time, they don't reveal exactly what people are seeing and doing at any given moment.

A better way

To record the moment-by-moment changes on a person's screen[2,11], we have built a platform called Screenomics. The software records, encrypts and transmits screenshots automatically and unobtrusively every 5 seconds, whenever a device is turned on (see go.nature.com/2fsy2j2). When it is deployed on several devices at once, the screenshots from each one are synced in time.

This approach differs from other attempts to track human–computer interactions — for instance, through the use of smartwatches and fitness trackers, or diaries. It is more accurate, it follows use across platforms, and it samples more frequently. In fact, we are working on software that makes recordings every second.

We have now collected more than 30 million screenshots — what we call 'screenomes' — from more than 600 people. Even just two of these reveal what can be learnt from a fine-grained look at media use (see 'Under the microscope' and All in the details').

This higher-resolution insight into media use could help answer long-held questions and lead to new ones. It might turn out, for

UNDER THE MICROSCOPE

Recordings of smartphone use by two 14-year-olds living in the same northern California community reveal what can be learnt from a fine-grained analysis of media use (see 'All in the details').

Dose. A typical question that researchers might ask is whether study participants are 'heavy' or 'light' phone users. Both adolescents might have characterized their phone use as 'substantial' had they been asked the usual survey questions. Both might have reported that they used their smartphones 'every day' for '2 or more hours' each day, and that looking at their phones was the first thing they did each morning and the last thing they did every night.

But detailed recordings of their actual phone use over 3 weeks in 2018 highlight dramatic differences[2]. For participant A, median use over the 3 weeks was 3.67 hours per day. For participant B, it was 4.68 hours, an hour (27.5%) more.

Pattern. The distribution of time spent using phones during the day differed even more. On average, participant A's time was spread over 186 sessions each day (with a session defined as the interval between the screen lighting up and going dark again). For A, sessions lasted 1.19 minutes on average. By contrast, participant B's time was spread over 26 daily sessions that lasted, on average, 2.54 minutes. So one of the adolescents turned their phone on and off seven times more than the other, using it in bursts that were about one-third the length of the other's sessions.

These patterns could signal important psychological differences. Participant A's days were more fragmented, maybe indicating issues with attentional control, or perhaps reflecting an ability to process information faster.

Interactivity. Both adolescents spent time creating content as well as consuming it. They wrote text messages, recorded photos and videos, entered search terms and so on. On a questionnaire, both might have reported that they posted original material 'sometimes' or maybe 'often'. But the screenshot data reflect patterns of interactivity that would be almost impossible for them to recall accurately.

Participant A spent 2.6% of their screen time in production mode, creating content evenly throughout the day and usually within social-media apps. By contrast, participant B spent 7% of their total screen time producing content (and produced 2.5 times more). But they did so mainly in the evening while watching videos.

Content. During the 3 weeks, participant A engaged with 26 distinct applications. More than half of these (53.2%) were social-media apps (mostly Snapchat and Instagram). Participant B engaged with 30 distinct applications, mostly YouTube (50.9% of the total).

Zooming deeper into specific screen content reveals even more. For participant B, on average, 37% of the screenshots for a single day included food — pictures of food from various websites, photos of B's own food, videos of other people eating or cooking, and food shown in a game involving the running of a virtual restaurant.

In a survey, both adolescents might have reported that they used 'a lot' of apps, and might have given the names of some of them. But the content of their media diets would be impossible to capture. **B.R. *et al.***

instance, that levels of well-being are related to how fragmented people's use of media is, or the content that they engage with. Differences in brain structure might be related to how quickly people move through cycles of production and consumption of content. Differences in performance in cognitive tasks might be related to how much of a person's multitasking involves switching between content (say, from politics to health) and applications (social media to games), and how long they spend on each task before switching.

The Human Screenome Project

So, how can we do better? What's needed is a collective effort to record and analyse everything people see and do on their screens, the order in which that seeing and doing occurs, and the associated metadata that are available from the software and sensors built into digital devices (for instance, on time of day, location, even keystroke velocity).

In any one screenome, screenshots are the fundamental unit of media use. But the particular pieces or features of the screenome that will be most valuable will depend on the question posed — as is true for other 'omes'. If the concern is possible addiction to mobile devices, then arousal responses (detected by a change in heart rate, say) associated with the first screen experienced during a session might be important to measure. If the concern is the extent to which social relationships dictate how political news is evaluated, then the screenshots that exist between 'social' and 'political' fragments in the screenome sequence might be the crucial data to analyse. (News items flagged by a close friend might be perceived as more trustworthy than the same news obtained independently, for example.)

How can researchers get access to such high-resolution data? And how can they extract meaning from data sets comprising millions of screenshots?

One option is for investigators to collaborate with the companies that own the data, and that have already developed sophisticated ways to monitor people's digital lives, at least in certain domains, such as Google, Facebook, Amazon, Apple and Microsoft. The Social Science One programme, established in 2018 at Harvard University in Cambridge, Massachusetts, involves academics partnering with companies for exactly this purpose[12]. Researchers can request to use certain anonymized Facebook data to study social media and democracy, for example.

Largely because of fears about data leaks or study findings that might adversely affect business, such collaborations can require compromises in how research questions are defined and which data are made available, and involve lengthy and legally cumbersome administration. And ultimately, there is nothing to compel companies to share data relevant to academic research.

To explore more freely, academics need to collect the data themselves. The same is true if they are to tackle questions that need answers within days — say, to better understand the effects of a terrorist attack, political scandal or financial catastrophe.

Thankfully, Screenomics and similar platforms are making this possible.

In our experience, people are willing to share their data with academics. The harder problem is that collecting screenomics data rightly raises concerns about privacy and surveillance. Through measures such as encryption, secure storage and de-identification, it is possible to collect screenomes with due attention to personal privacy. (All our project proposals are vetted by university institutional review boards, charged with protecting human participants.) Certainly, social scientists can learn a lot from best practice in the protection and sharing of electronic medical records[13] and genomic data.

Screenomics data should be sifted using a gamut of approaches — from deep-dive qualitative analyses to algorithms that mine and classify patterns and structures. Given how quickly people's screens change, studies should focus on the variation in an individual's use of media over time as much as on differences between individuals and groups. Ultimately, researchers will be able to investigate moment-by-moment influences on physiological and psychological states, the sociological dynamics of interpersonal and group relations over days and weeks, and even cultural and historical changes that accrue over months and years.

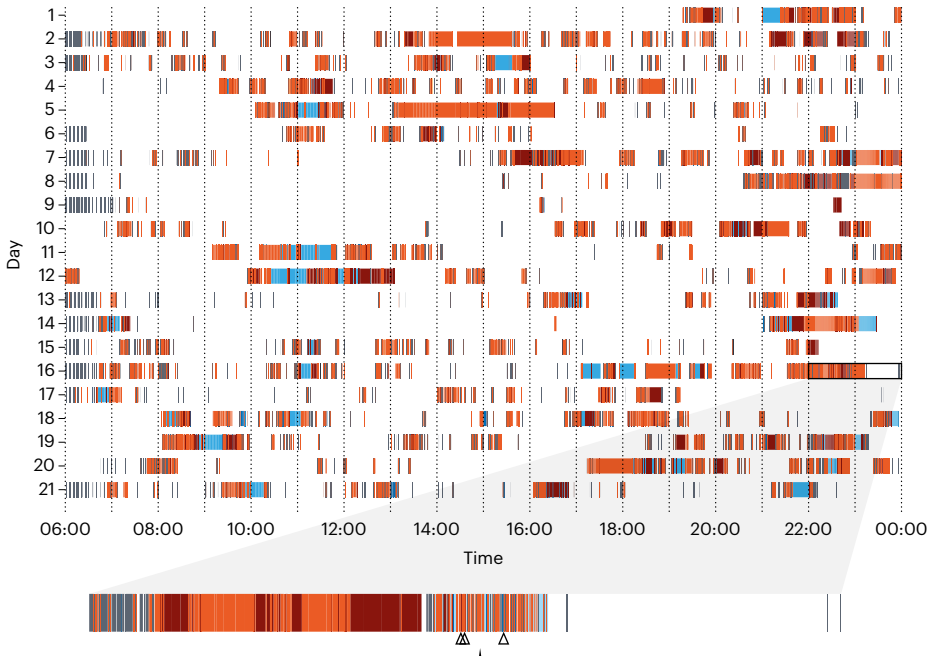
ALL IN THE DETAILS

Recordings of screenshots every five seconds reveal substantial differences in how two adolescents use their smartphones over 21 days (see 'Under the microscope').

Comics · Video players and editors · Communications · Photography · Social · Games · Education · Study · Tools · Music and audio · △ Creating content (not shown on the larger figure)

Participant A

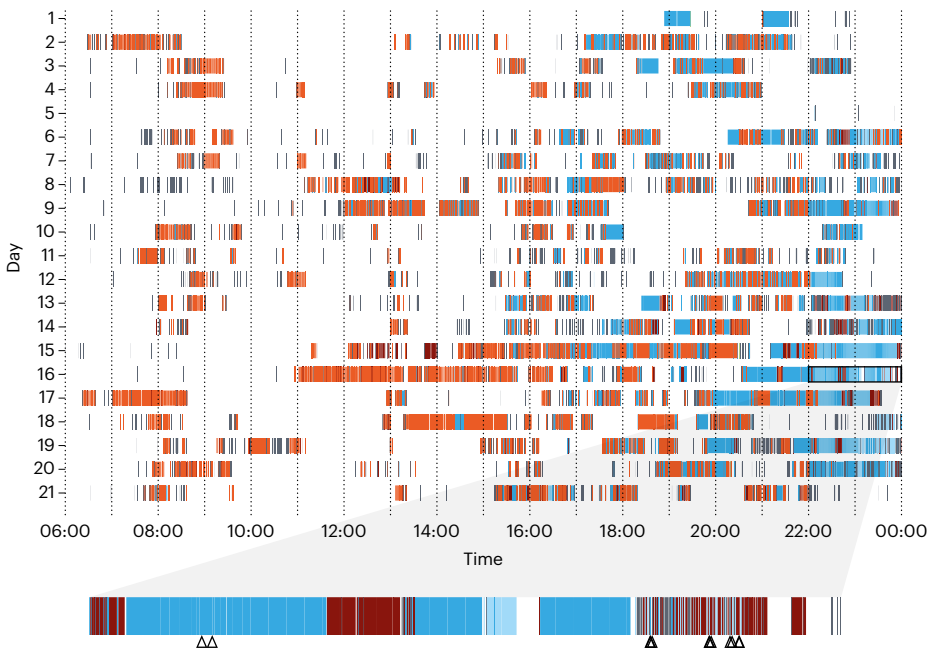
Participant A's time was spread over 186 sessions per day (with a session defined as the interval between the screen lighting up and going dark again). Each session lasted 1.19 minutes on average.



Zooming in on 2 hours of participant A's activity on day 16 reveals more about how they spent their time. More than half of the apps that A engaged with were types of social media (mostly Snapchat and Instagram).

Participant B

Participant B's time was spread over 26 sessions per day, lasting 2.54 minutes on average.



Participant B engaged with 30 distinct applications, mostly YouTube.

Some might argue that screenomics data are so fine-grained that they invite researchers to focus on the minutiae rather than the big picture. We would counter that today's digital technology is all about diffused shards of experience. Also, through the approach we propose, it is possible to zoom in and out, to investigate how the smallest pieces of the screenome relate to the whole. Others might argue that even with this better microscope, we will not find anything significant. But if relationships between the use of media and people's thoughts, feelings and behaviours continue to be weak or non-existent, at least we could have greater confidence as to whether current concerns are overblown.

The approach we propose is complex, but no more so than the assessment of genetic predictors of mental and physical states and behaviours. Many years and billions of US dollars have been invested in other 'omics' projects. In genomics, as in neuroscience, planetary science and particle physics, governments and private funders have stepped up to help researchers gather the right data, and to ensure that those data are accessible to investigators globally. Now that so much of our lives play out on our screens, that strategy could prove just as valuable for the study of media.

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The New York Times

Old Musicians Never Die. They Just Become Holograms.

By Mark Binelli
Jan. 7, 2020
https://www.nytimes.com/2020/01/07/magazine/hologram-musicians.html

In preparation for his first American tour in a decade, Ronnie James Dio spent months sequestered in a modest office suite in Marina del Rey, in Los Angeles. The office was on the second floor of a strip mall, above a vape shop and a massage parlor. I visited at the end of May, only a couple of days before the opening date of the tour, and among Dio's team, there was a tangible air of anticipation. Dio never became a household name, but he is considered one of the great heavy-metal vocalists of all time, up there with Ozzy Osbourne (whom he replaced in Black Sabbath) and metal-adjacent rockers like Axl Rose and Robert Plant. Beginning in the 1970s, Dio took a lead role in codifying a number of his genre's most ludicrous, yet utterly foundational, conventions. He sang of wolves and demons, toured with an animatronic dragon and supposedly introduced the splay-fingered "devil horns" headbanger's salute, which he claimed his Italian grandmother used to flash as an old-world method of warding off the *malocchio* and other forms of bad luck.

Buddy Holly revived as a hologram for a show in Los Angeles.

Opinion among the Dio faithful, nonetheless, was divided on the subject of his "Dio Returns" comeback tour, largely because Dio has been dead for almost 10 years. The Marina del Rey office suite was the site of a visual-effects company creating a Dio hologram. The hologram would tour with a living backing group consisting, in large part, of former Dio bandmates.

If you missed the tour, you might want to take a moment here and call up one of the fan-shot videos posted on YouTube — say, "Rainbow in the Dark," Dio's 1983 hit, filmed at the Center Stage Theater in Atlanta on June 3,

during which the Dio hologram prowls a central portion of the stage, bobbing, weaving, twirling his microphone cord to the monster riffs and occasionally using his free hand to air-conduct his most operatic vocal flourishes. ("His" — would "its" be more apt? Neither word feels quite right.) At one point, the bassist, Bjorn Englen, takes several very deliberate steps to his left, allowing the hologram to dance in front of him and adding to the illusion of a three-dimensional conjuring.

The hologram itself has an uneasy pallor, a brighter shade than the humans onstage but at the same time insubstantial, like a ghost struggling to fully materialize. One crucial decision that had faced the animators was choosing the right age for their creation. Dio in his MTV-era prime tempted them, of course, but then wouldn't it be strange to watch him perform alongside band members who were roughed up by the ensuing years like the rest of us? Then again, Dio's actual age in 2019, were he alive, would be 77, which is not ideal for a heavy-metal frontman. The creative team ultimately settled on a spry, middle-aged Dio, outfitting him in black leather pants, a studded leather wristband and a bell-sleeved white tunic embossed with a silver cross.

A start-up called Eyellusion produced "Dio Returns." It's one of a handful of companies looking to mold and ultimately monetize a new, hybrid category of entertainment — part concert, part technology-driven spectacle — centered, thus far, on the holographic afterlives of deceased musical stars. Eyellusion also toured a hologram of Frank Zappa in the spring, in a show overseen by Zappa's son Ahmet. The tour kicked off in April at the Capitol Theater in Port Chester, N.Y., about an hour north of Manhattan in Westchester County. A few hours before the show, I talked to the owner of the venue, the 47-year-old concert promoter Peter Shapiro. In 2015, he was a producer of the Grateful Dead's 50th-anniversary "Fare Thee Well" concerts. The five shows grossed more than $50 million, becoming, according to Billboard, "one of the most successful events in live-music history." We met at the Capitol Theater bar, which is called Garcia's and serves as a sort of secular reliquary devoted to the Dead's frontman, Jerry Garcia. The décor included one of Garcia's banjos and a Chuck Close-style portrait of Garcia made entirely of Lego bricks. Shapiro, who attended a preview of the Zappa concert, said, "What I just saw felt closer to seeing Zappa than seeing a cover band do it," adding that, based on ticket sales alone, he would definitely book another hologram show. The theater, which holds 1,800 people, was close to sold out for opening night.

"But here's the headline," Shapiro went on. "Look at who's gone, just in the last couple of years: Bowie, Prince, Petty. Now look who's still going but who's not going to be here in 10 years, probably, at least not touring: the Stones, the Who, the Eagles, Aerosmith, Billy Joel, Elton John, McCartney, Springsteen. That is the base not just of classic rock but of the live-music touring business. Yes, there's Taylor Swift, there's Ariana Grande. But the base is these guys."

Shapiro's calculation might be morbid, but he isn't wrong. According to the trade publication Pollstar, roughly half of the 20 top-grossing North American touring acts of 2019 were led by artists who were at least 60 years old, among them Cher, Kiss, Fleetwood Mac, Paul McCartney, Dead & Company and Billy Joel; the Rolling Stones, Elton John and Bob Seger took the top three slots. Using technology to blur the line between the quick and the dead tends to be a recipe for dystopian science fiction, but in this case, it could also mean a lucrative new income stream for a music industry in flux, at a time when beloved entertainers can no longer count on CD or download revenues to support their loved ones after they've died. "If you're an estate in the age of streaming and algorithms, you're thinking: Where is our revenue coming from?" Brian Baumley, who handles publicity for Eyellusion, told me. Some of those estates, Baumley bets, will arrive at a reasonable conclusion about the dead artists whose legacies they hope to extend: "We have to put them back on the road."

Tupac Shakur became one of the earliest test subjects for the new technology 15 years after his murder, when his hologram made a surprise appearance at the 2012 Coachella festival. To actually project a person-size holographic image into three-dimensional space, à la Princess Leia in "Star Wars," would require powerful, prohibitively expensive lasers that would also burn human flesh. The Tupac hologram was created with a combination of C.G.I., a body double and a 19th-century theatrical trick known as Pepper's Ghost, some variation of which has been used for almost all the hologram musical performances of recent years.

As the magician and magic historian Jim Steinmeyer recounts in his book "Hiding the Elephant," John Henry Pepper, the director of the Royal Polytechnic Institution in London, popularized the technology with a dramatization

of a scene from the Charles Dickens novella "The Haunted Man" on Christmas Eve 1862. To call up his ghosts, Pepper projected a bright light onto an actor in a hidden, cutout space beneath the stage, something like an orchestra pit, casting a reflection onto an angled pane of glass. The glass stood upright on the stage but remained invisible to the audience. The spectral image appeared slightly behind the glass, "moving in the same space with the actors and the scenery," Steinmeyer writes. "If all the players were perfectly synchronized, the ghost could interact with the characters onstage, avoiding sword thrusts or walking through walls." Pepper intended the original display, which took place at the Polytechnic Institution, as a scientific lecture, but the audience's riotous response persuaded him to go the magician's route, and soon he began touring the illusion in British and American theaters.

The Tupac hologram performed only two songs, shouting, "What the [expletive] is up, Coachella?" and rapping "2 of Amerikaz Most Wanted" alongside Snoop Dogg. But his digital resurrection worked as a proof of concept. A handful of one-off stunts involving other dead musicians followed: A Michael Jackson hologram performed at the 2014 Billboard Music Awards, and the Mexican pop superstar Juan Gabriel made a holographic appearance at his own memorial concert after his sudden death in 2016. Still-breathing musicians also made use of the technology, including the rapper Chief Keef, who in 2015, as a means of avoiding outstanding legal warrants, beamed a hologram performance from California to a music festival in Hammond, Ind. But the outstanding question remained: Would audiences turn out for an entire hologram concert?

Marty Tudor, chief executive of Base Hologram Productions, is an entertainment-industry veteran whose multifarious career has included, among other things, managing Paula Abdul and Jon Cryer, producing a series of exercise videos with a trainer from "The Biggest Loser" and running an independent record label. When he saw footage of the Tupac hologram at Coachella, Tudor had a hunch that there might be potential for the new technology beyond gimmicky festival cameos.

Tudor took the idea to Brian Becker, the former chief executive of Clear Channel Entertainment, which was the largest events promoter and venue operator in the country during Becker's tenure. For Becker, live entertainment was a family business. In 1966, his father, Allen Becker, a life-insurance salesman from Houston, helped found a regional events-promotion company called Pace Entertainment that eventually became a major national promoter. When Brian joined the company after college, he helped to start Pace's theatrical division, which soon came to dominate, and largely invent, a regional touring market for effects-laden Broadway spectacles like "Cats," "Miss Saigon," "Les Misérables" and "The Phantom of the Opera." The technical innovations of those shows, Becker told me, "evened the score," signaling to regional audiences that they would be seeing a production with all the same bells, whistles and helicopters as a show in New York or London. "We're always cognizant of seams in our industry that might allow us to do things differently," Becker said. After hearing out Tudor's hologram pitch, Becker wondered if the technology might represent such a seam.

In the wake of the Tupac performance, a somewhat motley assortment of newly minted hologram companies were asking themselves the same question, and soon a scramble to lock down exclusive deals with music estates ensued. Digital Domain, the visual-effects house that created Tupac, wound up declaring bankruptcy not long after the Coachella performance, but one of its owners, a Florida investor named John Textor, quickly started a new company, Pulse Evolution, which produced the Jackson hologram and soon after announced that it had also cut hologram deals with the estates of Elvis Presley and Marilyn Monroe, as well as for the band Abba, which broke up in 1982. An eccentric British-Greek billionaire named Alki David, meanwhile, started a rival hologram company, Hologram USA. An heir to a Coca-Cola bottling fortune, David, along with his partners, announced that he would be producing holographic images of Patsy Cline, Billie Holiday and Jackie Wilson, among others. (In September, David and Hologram USA were charged by the Securities and Exchange Commission with "making false and misleading statements to investors and potential investors." David has said he intends to countersue.)

Base Hologram, which was founded by Tudor and Becker, started out by securing rights to produce holograms of Maria Callas and Roy Orbison, debuting each show in 2018 with performances in Europe and America. Orbison's estate, which is controlled by his three sons (via a company called Roy's Boys), approached Base after a deal with another hologram producer fell through, Tudor told me. "Roy was a fairly static live performer — most of the movement you have onstage is him strumming his guitar — so he was the perfect first performer for our purposes," Tudor said. (A 58-date Orbison-Buddy Holly hologram tour began in San Francisco in September.) The Callas

hologram was necessarily more emotive. At a brief demonstration I attended at Sotheby's in New York, the hologram wore a white gown and a long red shawl. After performing *"Melons! Coupons!"* from Act III of "Carmen," a scene involving fortune telling, the hologram tossed a deck of cards in the air, which briefly froze alongside the music before drifting to the ground. "Though a melodramatic touch, it worked," Anthony Tommasini wrote in his New York Times review of the Lincoln Center performance, in which he described the show as "amazing, yet also absurd; strangely captivating, yet also campy and ridiculous." In February, Base will unveil the dead-celebrity-hologram sector's biggest marquee name thus far, at least for a full concert: Whitney Houston, whose tragic, relatively recent death has made the planned tour the most controversial of any on the books. (Shortly after the announcement, Questlove tweeted: "& hell begins.")

Deborah Speer, a features editor at Pollstar, which covers the live-entertainment industry, told me that based on the numbers she has seen for the Orbison and Zappa tours, "obviously, there's a market" for hologram shows. According to the trade publication, the solo Orbison tour grossed nearly $1.7 million over 16 shows, selling 71 percent of the seats available, while Zappa sold an average of 973 seats per show, nearly selling out venues in Amsterdam and London. Whether such tours can cross over from clubs, theaters and performing-arts centers into arenas remains to be seen and will depend largely on the success of bigger-name stars like Houston.

Early one morning in May, I visited a soundstage in the Griffith Park neighborhood of Los Angeles to observe a motion-capture shoot for the Whitney Houston hologram. The soundstage was a cavernous, warehouselike space, moodily lit, aggressively air-conditioned. Several of the Angelenos on hand complained about the cold, including Tudor, who sat in a nearby director's chair wearing a puffy vest over a striped dress shirt and jeans. Fatima Robinson, the director of the production, wore a head scarf and a winter jacket and cupped a rechargeable electronic hand-warming device between her palms. Robinson is a choreographer whose credits include Kendrick Lamar's 2016 Grammys performance, the Weeknd's 2016 Oscars performance, the film version of "Dreamgirls," NBC's live broadcast of "The Wiz" and music videos for Michael Jackson, Mary J. Blige and Aaliyah. Robinson also choreographed Houston herself — the living Houston — in 1993, for the "I'm Every Woman" video. "She was pregnant at the time and in a wonderful place," Robinson told me.

Veterans of pedigreed Hollywood postproduction houses create the C.G.I. holograms in the same way they would make characters like Gollum or Thanos: Motion-capture photography records the performance of a body double, which becomes the basis for a three-dimensional digital model, a block of clay animators proceed to modify — in the case of celebrity holograms, most drastically by augmenting the body double's features with a digitally sculpted likeness of the artist, which can lip-synch to an existing vocal track.

The Houston body double took the stage and began to run through the moves for the first song of the day: "Step by Step," a jaunty, affirmational gospel-dance track from the 1996 soundtrack to "The Preacher's Wife." The double had freckles and wore her hair in dyed cornrows but possessed Houston's approximate build. She wore black tights, a black T-shirt and a baggy white cardigan (costumes created by Houston's former stylist would be worn in a subsequent shoot) and stood atop a sort of oversize lazy susan, which crouching tech guys, who referred to the device as a turntable, slowly spun as she lip-synched to the song.

Robinson sipped tea and watched the pantomime intently. After the first run-through, she said, "We need to go a little slower." The body double had been chosen from a pool of 900 applicants, and she was clearly a talented performer in her own right. (Base requested that The Times not reveal her identity.) "Step by Step" remains an underappreciated Houston song, cloying but oddly irresistible, and as I watched it mock-sung over and over, I felt freshly reminded of Houston's skill at putting over mediocre material, not just in the obvious way — that is, through the power of her voice — but with her presence, that way she had of conveying joy, supreme confidence and the ecstasy of the choir all at once, and at the same time letting us know, even back then, that she wasn't as sweet as her songs' lyrics might suggest. This complexity came through in the body double's performance, in the way she worked her shoulders or flashed a hard look at the nonexistent audience. Houston wasn't much of a dancer, but "she had a serious strut," noted Robinson, who had studied her performances like game tapes.

Lit for the filming, the double cast a horror-movie shadow on the soundproofed wall of the otherwise darkened soundstage. There was something eerie about the way Houston's voice and the mid-'90s dance beat echoed through

the vast space — music being played at club volume to a nearly empty room, with no one dancing, not even the avatar pretending to sing. But despite the workaday setting and the unconcealed artifice, by the third or fourth time I heard the song, I couldn't help feeling … something. Would I describe myself as moved? I'm not sure. But I also found myself wondering if, despite how fundamentally wrong the entire concept for this show felt, there might be some crazy way it could actually work. The future hologram moved her mouth around Houston's voice:

Well there's a bridge
And there's a river
That I still must cross
As I'm going on my journey
Oh, I might be lost

In the final show, Tudor whispered to me, the turntable could be digitally removed or made to look like something else. The creative team hadn't settled on anything yet. But if they wanted to, they could make Houston look as if she were floating on air, spinning, ascendant.

I met Ronnie James Dio once, when he was alive. Tenacious D, the parody band that gave Jack Black his start, had recorded a gently mocking tribute song called "Dio," in which Black demands Dio's cape and scepter and informs him that he's too old to rock ("no more rockin' for you!"). Dio had been a good sport about the whole thing and agreed to make a cameo in the Tenacious D movie, which premiered in 2006 at Grauman's Chinese Theater. I remember standing around the after-party, nursing a drink and feeling awkward, when I spotted Dio, chatting in a corner of the ballroom with his wife. I decided to introduce myself. He was quite short, even for a celebrity, and exceedingly gracious. He told me Black had personally called to pitch the film, insisting that they wouldn't make the movie unless he agreed to "play the part of Ronnie James Dio." Smiling, Dio continued, "Then he said: 'Well, we will make the movie. But it'll be [expletive].' "

Across town in Marina del Rey 13 years later, I sat in the office of Eyellusion's creative director, Chad Finnerty, as he digitally manipulated a photorealistic 3-D image of Dio's face. Finnerty grew up in Pennsylvania with dreams of becoming a Disney animator — old-fashioned cell animation, like what they did on "Snow White and the Seven Dwarfs" — but by the time he graduated from college, the world had gone digital. He spent years working as a C.G.I. animator at Digital Domain, on movies like "Flags of Our Fathers" and "Pirates of the Caribbean: At World's End." When Jeff Pezzuti, a Westchester-based vice president of finance at a cloud-computing consulting firm, decided to start his own hologram company, Eyellusion, he reached out to Finnerty, asking if he wanted to talk. Pezzuti loved heavy metal — he wore a Dio T-shirt for his seventh-grade class picture — and after seeing the Tupac hologram, he wondered, "Can we do something like that in the rock world?" Eyellusion has since received a $2 million investment from Thomas Dolan, whose family owns controlling interests in Madison Square Garden and AMC Networks and whose father founded the New York-area cable-television giant Cablevision.

Finnerty supervised the creation of the Zappa and Dio holograms for Eyellusion. "I'm a bit rusty with this program," he apologized, pecking at his desktop keyboard. Soon a hideously lifelike digital rendering of Dio's face appeared on a large-screen monitor hanging on the wall. For a moment, it bobbed in front of a black backdrop, which made me think of the old "Charlie Rose" set. I briefly thought about pitching a "Black Mirror" episode in which a Charlie Rose-type character interviews the cryogenically preserved heads of rock stars. "We collected all of our data in 2017," Finnerty explained. That's when they filmed the body double and did the facial capture, is what he meant. During the facial capture, hundreds of eye, mouth and facial-muscle movements of a living subject (not necessarily the body double) are recorded. Imagine a puppeteer, Finnerty said, only with thousands of puppet strings to manipulate.

He clicked his mouse, manipulating a digital lever on the screen, and "Dio's" eye suddenly, eerily shifted to the left. You couldn't do this two years ago, Finnerty went on, moving another lever. "Dio's" eyes shifted right, up, down. Finnerty said he had done lots of work on "The Walking Dead," but that was forgiving, because it's zombies. Having a person look real while performing a song for six minutes, with no cutting away or other editing assists that would be available in a film or television show, that was something else entirely.

“Dio” winked, puckered his lips, raised an eyebrow.

I stared at the image’s mottled skin, textured and painted with a level of detail down to the pore. “Hair simulation is the most difficult part of the entire process,” Finnerty said, adding, “My hair guy is also my fire, water and ice guy.” His lighting team had done the skin. Had Dio submitted himself to a full-body scan while alive, the process would have been much easier. Finnerty thought it would be great if more living musicians and actors were proactive about being scanned. Any actor who has starred in a movie involving significant amounts of C.G.I. has already been scanned, he pointed out.

The more bullish hologram boosters envision all sorts of uses beyond the second coming of music deities major and minor. Finnerty just made a hologram for the Ronald Reagan Presidential Library of the former president. Prime Minister Narendra Modi of India has campaigned holographically, and a circus in Germany uses holographic projections of elephants and horses instead of live animals. Base, meanwhile, has cut a deal with Jack Horner, the paleontologist who served as a scientific adviser for “Jurassic Park,” to create dinosaur holograms that will travel to natural-history museums. Imagine, Becker said, a dialogue between holograms of Abraham Lincoln and Martin Luther King Jr. Or a Julia Child hologram teaching a cooking class. Or a Derek Jeter hologram teaching you how to bat.

As for concerts, in the not very distant future, Finnerty predicted, the technology would evolve to the point at which a puppeteer sitting in the wings with a laptop could work the digital strings live — allowing the hologram to react to the crowd or to members of a live band. Imagining this future as he watched “Dio” on his screen, Finnerty referred to him as the “asset,” as in: “This asset is ready for any other adventure we want to put him on. We could beam him into a bar. A coffee house. Not that Dio would play a coffee house.”

Whenever I wondered aloud whether fans might find the shows unsettling or disrespectful, the hologram-industry representative I happened to be speaking to would grow defensive. It’s stagecraft, part of a larger production, the person would tell me. We respect these artists, and we take what we’re doing very seriously. And as these representatives point out, people see tribute acts all the time. An Australian Pink Floyd, Tudor said, just played in Los Angeles! Pollstar’s Speer told me that well over 175 tribute bands reported numbers to the magazine; one of the better performers, “Rain — a Tribute to the Beatles,” often turns up in the top half of the Concert Pulse chart, averaging 1,833 tickets and $95,955 per show over the past three years.

For what it’s worth, the crowd at the Zappa concert seemed utterly charmed — cheering when the hologram Zappa materialized in the center of the stage during the opening number, “Cosmik Debris.” I was sitting about eight rows from the front. It looked like Zappa up there, more or less, though his form radiated the paranormal brightness that holograms can’t help emitting. Eventually, “Frank” addressed the audience: “Good evening. You won’t believe it, but I’m as happy to see you guys as you are to see the show. I’m your resident buffoon, and my name is Frank.” The artificiality of the canned banter had a “Weekend at Bernie’s” aspect to it, making me hyperaware of the sunglasses covering the lifeless eyes of the corpse propped up between living people (in this case, a hot backing band composed predominantly of musicians who had toured with Zappa over the years).

In certain respects, Zappa’s psychedelic jams and goofy, satirical lyrics lent themselves perfectly to the experiment, allowing the creative team to deploy the Zappa hologram judiciously (“like the shark from ‘Jaws,’ ” someone backstage told me) in and around trippy visuals that reminded me of old screen-saver graphics: animated dental floss, a penguin being punished by a dominatrix, Zappa as a leisure-suit-wearing Ken doll.

As I watched the show, my mind drifted, and I began to imagine more dubious ways corporate entities might exploit their particular assets. With artificial intelligence and voice cloning, there would be no reason to limit the shows to recordings made when the artist was still alive. An Aretha Franklin hologram could shush a noisy audience member, banter with her drummer and cover “Shallow.” Chris Stapleton and Sturgill Simpson could form a supergroup with holograms of Merle Haggard and Waylon Jennings. Kurt Cobain, sporting the same faded green cardigan he wore on “MTV Unplugged,” might turn up at a surprise appearance with Billie Eilish at the Grammys. A one-off Beatles reunion in Hyde Park, live Paul and Ringo, hologram John and George. Hologram Biggie takes the Thomas

Jefferson role in “Hamilton.” Bob Marley interrupts his performance of “Exodus” to plug the new season of “Curb Your Enthusiasm.”

On the stage of the Capitol Theater, a grotesque claymation version of Zappa had materialized, and the guy sitting next to me began air-drumming alongside the live percussionists. Before the concert, Ahmet Zappa had pointed me to a passage in his father’s 1989 autobiography in which he seemed to predict the technology that would allow him to return to Port Chester 26 years after his death: a digressive riff about his “idea for a new device, potentially worth several billion dollars,” one that would “generate free-standing 3-d images, in any size (on your coffee table at home, or on a larger scale for theatrical use).” So maybe Zappa would have appreciated his 2019 tour. And maybe holograms will make the leap from ridiculous-seeming technology to ubiquity, like podcasts or e-cigarettes.

Ahmet was 15 when his father received a diagnosis of prostate cancer and was given three months to live. One way to think about the show, he told me, is as “a very childlike way of dealing with loss.” For a couple of hours every night, Frank is up there onstage again, playing with his guys, and Ahmet can almost convince himself that he has his father back. You’d think there would be a market for something like that.

Mark Binelli is a contributing writer for the magazine.

“Ginny Ruffner: Reforestation of the Imagination” Transforms the Renwick Gallery into a Post-Apocalyptic Haven of Hope

Exhibition of Traditional Craft and Augmented Reality Opens June 28

June 21, 2019

https://www.si.edu/newsdesk/releases/ginny-ruffner-reforestation-imagination-transforms-renwick-gallery-post

Ginny Ruffner with Grant Kirkpatrick, *Liriodendrum plausus (Flapping tulip)*, 2017, sculpture (handblown glass with acrylic paint tree rings), island (plywood, low-density foam, fiberglass, epoxy, sand, pebbles, and acrylic paint), and holographic image. Sculpture: 19 x 12 x 9 in. Background: *Bronze Tree* (center island), 2017, plywood, low-density foam, fiberglass, epoxy, sand, pebbles, acrylic paint, bronze, and lampworked glass. Overall: 50 x 63 x 49 in. Installation view at MadArt Studio, 2018. Courtesy Ruffner Studio. Photo by Fiona McGuigan.

Imagine an apocalyptic landscape. It appears barren, devastated and hopeless. It is not. At the Renwick Gallery of the Smithsonian American Art Museum, internationally renowned artist Ginny Ruffner creates a seemingly bleak environment that suddenly evolves into a thriving floral oasis by combining traditional sculpture with augmented reality (AR) technology. In collaboration with animator and media artist Grant Kirkpatrick, Ruffner brings to life a colorful world where glass stumps suddenly sprout mythical flora that have adapted to their surrounding conditions in unexpected, beautiful and optimistic ways. By transforming the gallery into a multidimensional experience, “Ginny Ruffner:

Reforestation of the Imagination" calls into question the very notions of reality and fantasy, of concrete and abstract, and of desolation and hope. The exhibition will be at the Renwick June 28 through Jan. 5, 2020.

"We strive to spark imagination and encourage creative thinking in our visitors with exhibitions that highlight important contemporary issues," said Stephanie Stebich, the Margaret and Terry Stent Director of the Smithsonian American Art Museum. "Ginny Ruffner questions the artificial divide between nature and technology. She unites them in her immersive environment of glass and botanical drawings that spring to life through augmented reality to create a Ruffnerian vision of a regenerative future."

"Ginny Ruffner: Reforestation of the Imagination" is the latest project at the Renwick Gallery to explore an expanded definition of contemporary craft and new technologies. Ruffner is among a vibrant group of artists bringing AR to museum installations. By using this technology as another art media, she transforms visitor experiences. Robyn Kennedy, chief administrator at the Renwick Gallery, coordinated this presentation of the installation, which was first shown at MadArt Studio in Seattle in 2018. "Reforestation of the Imagination" is presented in conjunction with the Renwick Gallery's exhibition "Michael Sherrill Retrospective," which also features botanically inspired sculptures.

The installation consists of five landmasses, each featuring intricate handblown glass sculptures of tree stumps, with painted tree rings that function as discrete QR codes. These five islands surround a sixth landmass that supports a large fiberglass stump sprouting beautifully grotesque bronze and glass appendages. Other than the central stump and the painted shelf mushrooms and tree rings on the surrounding stumps, the scene appears colorless and desolate; however, when viewed through AR's technological lens an alternate landscape is revealed.

Visitors can download the free app "Reforestation" on their phones or use the iPads in the gallery to bring this second reality to life. When the tree rings of a stump are viewed through the device's camera lens, a hologram of a fictional plant appears to sprout from the sculpture. These imagined fruits and flowers have evolved from existing flora, developing dramatic appendages and skills necessary to flourish in this radically different environment. In this reality, tulips develop stem flexibility, pears contain windows to the outside world and flowers take on the form of birds. The installation includes Ruffner's tongue-in-cheek descriptions of her fanciful flora and their remarkable, sometimes humorous adaptations, as well as 19 original drawings by the artist that were the inspiration for the AR images.

"This is nature reimagining itself," said Ruffner. "The imagination cannot be exterminated. It just re-creates itself. To me, 'Reforestation' is about hope."

Ruffner is based in Seattle and trained at the University of Georgia, graduating with a master's degree in fine arts in drawing and painting. She is an artist best known for her elegant sculptures and mastery of glass techniques. Ruffner has had more than 85 solo exhibitions and several hundred group shows, and her artwork can be found in numerous national and international collections. Ruffner has also

lectured and taught extensively and has served as artist-in-residence at schools and universities around the world.

Kirkpatrick, also based in Seattle, received a master's degree in fine arts from the Cornish College of the Arts and is an emerging animator and new-media artist. His interests include the intersection of art and technology, particularly VR/AR, game design and mixed-media work.

Free Public Programs

The Renwick Gallery will host a film screening Thursday, July 11, at 6 p.m. in the Bettie Rubenstein Grand Salon of *A Not So Still Life* (2010; 80 mins.), a documentary that chronicles Ruffner's artistic journey after a life-altering, physically debilitating car accident in 1991. A Q&A with Ruffner moderated by Kennedy follows the screening.

Related pubic programs for the exhibition "Michael Sherrill Retrospective" include a talk with Sherrill Thursday, Sept. 12, at 6 p.m. in the Renwick's Rubenstein Grand Salon and a nature walk with Sherrill, Smithsonian Gardens and the Golden Triangle BID Friday, Sept. 13, at noon to explore landscaping in the Renwick Gallery's neighborhood.

"Field Guide" Publication

The Smithsonian American Art Museum has published an interactive "field guide" to the AR images featured in the exhibition. The booklet, written and illustrated by Ruffner, features pictures of the glass sculptures with the QR code embedded, making them compatible with the "Reforestation" app. It includes Ruffner's 18 original drawings and detailed explanations of the artist's naming conventions for her flowers. The booklet also features an interview with Ruffner in which she discusses her artistic background and her inspiration for "Reforestation of the Imagination." The publication is available for purchase in the museum store and online ($18.95, softcover).

Credit

"Ginny Ruffner: Reforestation of the Imagination" is organized by the Renwick Gallery of the Smithsonian American Art Museum. Generous support has been provided by the Smithsonian American Women's History Initiative, Elizabeth and James Eisenstein, Ed and Kathy Fries, Shelby and Frederick Gans, James Renwick Alliance, Colleen and John Kotelly, Betty and Whitney MacMillan, Jacqueline B. Mars, Kim and Jon Shirley Foundation, and Myra and Harold Weiss.

About the Smithsonian American Art Museum

The Smithsonian American Art Museum is the home to one of the largest and most inclusive collections of American art in the world. Its artworks reveal America's rich artistic and cultural history from the colonial period to today. The museum's main building is located at Eighth and F streets N.W., above the Gallery Place/Chinatown Metrorail station. Museum hours are 11:30 a.m. to 7 p.m. daily (closed Dec. 25). Its Renwick Gallery, a branch museum dedicated to contemporary craft and decorative arts, is located on Pennsylvania Avenue at 17th Street N.W. The Renwick is open from 10 a.m. to 5:30 p.m. daily (closed Dec. 25). Admission is free. Follow the museum on Facebook, Instagram, Twitter and YouTube. Smithsonian information: (202) 633-1000. Museum information (recorded): (202) 633-7970. Website: americanart.si.edu.

SCIENTIFIC REPORTS

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Demonstration of End-to-End Automation of DNA Data Storage

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Synthetic DNA has emerged as a novel substrate to encode computer data with the potential to be orders of magnitude denser than contemporary cutting edge techniques. However, even with the help of automated synthesis and sequencing devices, many intermediate steps still require expert laboratory technicians to execute. We have developed an automated end-to-end DNA data storage device to explore the challenges of automation within the constraints of this unique application. Our device encodes data into a DNA sequence, which is then written to a DNA oligonucleotide using a custom DNA synthesizer, pooled for liquid storage, and read using a nanopore sequencer and a novel, minimal preparation protocol. We demonstrate an automated 5-byte write, store, and read cycle with a modular design enabling expansion as new technology becomes available.

Storing information in DNA is an emerging technology with considerable potential to be the next generation storage medium of choice. Recent advances have shown storage capacity grow from hundreds of kilobytes to megabytes to hundreds of megabytes[1–3]. Although contemporary approaches are book-ended with mostly automated synthesis[4] and sequencing technologies (e.g., column synthesis, array synthesis, Illumina, nanopore, etc.), significant intermediate steps remain largely manual[1–3,5]. Without complete automation in the write to store to read cycle of data storage in DNA, it is unlikely to become a viable option for applications other than extremely seldom read archival.

To demonstrate the practicality of integrating fluidics, electronics and infrastructure, and explore the challenges of full DNA storage automation, we developed the first full end-to-end automated DNA storage device. Our device is intended to act as a proof-of-concept that provides a foundation for continuous improvements, and as a first application of modules that can be used in future molecular computing research. As such, we adhered to specific design principles for the implementation: (1) maximize modularity for the sake of replication and reuse, and (2) reduce system complexity to balance cost and labor input required to setup and run the device modules.

Our resulting system has three core components that accomplish the write and read operations (Fig. 1a): an encode/decode software module, a DNA synthesis module, and a DNA preparation and sequencing module (Fig. 1b,c). It has a bench-top footprint and costs approximately $10 k USD, though careful calibration and elimination of costly sensors and actuators could reduce its cost to approximately $3 k–4 k USD at low volumes.

Before a file can be written to DNA, its data must first be translated from 1's and 0's to A's, C's, T's, and G's. The encode software module is responsible for this translation and the addition of error correction into the payload sequence (see the Methods section and work by Richard Hamming[6]). Once the payload sequence is generated, additional bases are added to ensure its primary and secondary structure is compatible with the read process and the DNA sequence is sent to the synthesis module for instantiation into physical DNA molecules.

The DNA synthesis module is built around two valved manifolds that separately deliver hydrous and anhydrous reagents to the synthesis column. Our initial designs used standard valves, but the dead volume at junction points caused unacceptable contamination between cycles. Therefore, we switched to zero dead volume valves[7]. The combined flow path is then monitored by a flow sensor, whose output is coupled to a standard fitting; the fitting can be coupled to arbitrary devices, such as a flow cell for array synthesis[8] or, in this case, adapted to fit a standard synthesis column. Once synthesis is complete, the synthesized DNA is eluted into a storage vessel, where it is stored until retrieval.

When a read operation is requested, the stored DNA pool's volume is reduced to about 2 μL to 4 μL by discarding excess DNA through the waste port. A syringe pump in the DNA preparation and sequencing module then dispenses our single-step preparation/sequencing mix (Fig. 1d) into the storage vessel; positive pressure pushes the mixture into the ONT MinION's priming port (Figs 1b,c). We chose the MinION as our sequencing device due to its low cost, ease of automation, and high throughput. However, it is neither capable of reading unmodified DNA, nor is it optimized for reading short DNA oligonucleotides[9]. In particular, we have observed that reads shorter than 750–1000 bases tend to get missed or discarded by the MinION's software. To mitigate these limitations, we developed a single-step MinION

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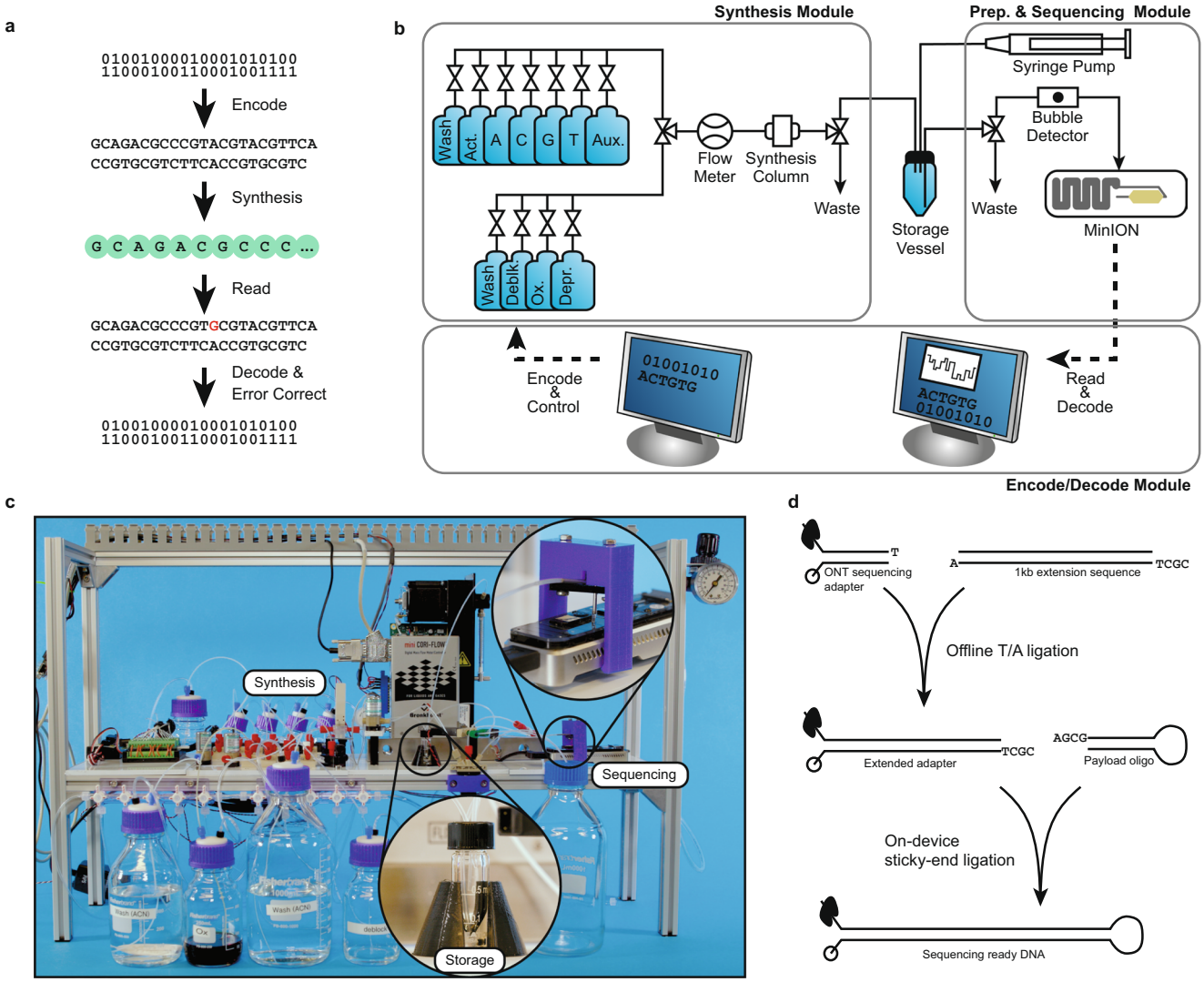

Figure 1. An overview of the write-store-read process. Data is encoded, with error correction, into DNA bases, which are synthesized into physical DNA molecules and stored. When a user wishes to read the data, the stored DNA is read by a DNA sequencer into bases and the decoding software corrects any errors retrieving the original data. (**a**) The logical flow from bits to bases to DNA and back. (**b**) A block diagram representation of the system hardware's three modules: synthesis, storage, and sequencing. (**c**) A photograph showing the completed system. Highlighted are the storage vessel and the nanopore loading fixture. The majority of the remaining hardware is responsible for synthesis. (**d**) Overview of enzymatic preparation for DNA sequencing. An arbitrary 1 kilobase "extension segment" of DNA is PCR-amplified with TAQ polymerase, and a Bsa-I restriction site is added by the primer, leaving an A-tail and a TCGC sticky end after digestion. The extension segment is then T/A ligated to the standard Oxford Nanopore Technology (ONT) LSK-108 kit sequencing adapter, creating the "extended adapter," which ensures that sufficient bases are read for successful base calling. For sequencing, the payload hairpin and extended adapter are ligated, forming a sequence-ready construct that does not require purification.

preparation protocol that requires only payload DNA and a master mix containing a customized adapter (Fig. 1d) with a 1 kbase extension region, T4 ligase, ATP, and a buffer. Each payload sequence is constructed to form a hairpin structure with a specific 5′ 4-base overhang. The customized adapter has a complementary overhang, which aids T4-mediated, sticky-ended ligation. To sequence, the payload and master mix are combined and incubated at room temperature for 30 minutes. Thereafter, the mixture is directly loaded into the MinION through the priming port. Since the introduction of air bubbles causes sequencing failure, we built a 3D printed bubble detector that valves off the loading port immediately after detecting the gas that is aspirated following the sample. This allows the system to load nearly the full sample without damaging the flow cell. Additionally, while not demonstrated here, other research suggests that random access via selective ligation over a small set of sequence identifiers (≈20) can be achieved using orthogonal sticky ends during preparation[10].

Once sequencing begins, the decode software module aligns each read to the 1 k base extension region and the poly-T hairpin. If the intervening region of DNA is the correct length, the decoder attempts to error check/correct the payload using a Hamming code with an additional parity bit; the code corrects all single-base errors and detects all

Figure 2. Synthesis and sequencing process quality. (**a**) Insertion, deletion, and substitution frequency by locus for a synthesized and PCR-amplified 100-mer. Below: An overview of errors. Above: An expanded view of the central 60 bases. The terminal 20 bases come from primers used in amplification and therefore are not representative of synthesis quality. (**b**) Combined write-to-read quality of synthesis, ligation, and sequencing. Bases −60 to −4 (below, grey) are adapter bases. Bases −3 to 0 (below, red) are the ligation scar. Bases 0 to 39 (below, blue) are the synthesized payload region with 8 bases of padding on the 3′ end. (**c**) Distribution of nanopore read lengths with unligated, 1D and 2D read lengths identified.

double-base errors. Once the payload is successfully decoded, it is considered correct if it matches a 6-base hash stored with the data. At this point, sequencing terminates, and the MinION flow cell may be washed and stored for later reuse.

Our system's write-to-read latency is approximately 21 h. The majority of this time is taken by synthesis, viz., approximately 305 s per base, or 8.4 h to synthesize a 99-mer payload and 12 h to cleave and deprotect the oligonucleotides at room temperature. After synthesis, preparation takes an additional 30 min, and nanopore reading and online decoding take 6 min.

Using this prototype system, we stored and subsequently retrieved the 5-byte message "HELLO" (01001000 01000101 01001100 01001100 01001111 in bits). Synthesis yielded approximately 1 mg of DNA, with approximately 4 μg ≈ 100 pmol retained for sequencing. Nanopore sequencing yielded 3469 reads, 1973 of which aligned to our adapter sequence. Of the aligned sequences, 30 had extractable payload regions. Of those, 1 was successfully decoded with a perfect payload. The remaining 29 payloads were rejected by the decoder for being irrecoverably corrupt.

Inspecting the sequencing data indicates that the low payload yield and decode rate was largely due to two factors. The first and primary factor is *low ligation efficiency*. Although chemical conditions should be optimal for T4 ligase, incomplete strands from the unpurified synthesis product likely out-competed full-length strands, leading to a poor apparent ligation rate of less than 10% (Fig. 2c). The second factor is *read and write fidelity*. To interrogate the write error rate, we synthesized a randomly generated 100-base oligonucleotide with distinct 5′ and 3′ primer sequences. The oligonucleotide was then PCR-amplified and sequenced with an Illumina NextSeq instrument to reveal: an error rate of almost zero insertions; <1% substitutions; and 1–2% deletions (Fig. 2a) for most positions, with increased deletions toward the 5′ end due to increased steric hindrance as strand length increases[11]. Literature suggests a nanopore error rate near 10%[9,12], so we also performed a synthesis-to-sequencing error rate analysis on an 89-mer hairpin sequence, encoding "HELLO" in its first 32 payload bases. Figure 2b shows the read error when aligned to the extended adapter and payload sequence. Bases −60 to −1 were directly PCR-amplified from the lambda genome and given a good baseline for nanopore sequencing fidelity under our conditions; bases 0 through +40 come from the payload region and characterize the total write-to-read error rate. The complex combination of these errors — especially deletions and read truncations — causes many strands to be discarded before a decoding attempt is made. Indeed, of 25,592 reads in this new dataset, 286 aligned well in the −100 to −1 region (score > 400) and contained enough bases to attempt decoding. Of those 251 had uncorrectable corruption, 11 had invalid checksum bases after correction, 8 were corrupted but correctable and of those 3 had hashes in agreement, 16 were perfect reads, and 0 were decoded but contained the wrong message.

We demonstrated the first fully automated end-to-end DNA data storage device. This device establishes a baseline from which new improvements may be made toward a device that eventually operates at a commercially viable scale and throughput. While 5 bytes in 21 hours is not yet commercially viable, there is precedent for many orders of magnitude improvement in data storage[13]. Infact, recent storage advances by Erlich *et al.*[2] of 2 Mbytes and Organick *et al.* of 200 Mbytes[3] demonstrate orders of magnitude improvements in the past two years and the underlying physics and chemistry show impressive upper bounds for density[3].

Furthermore, the modules and methods developed here are now being applied to other molecular computing projects internally. For example, by using a non-cleavable linker in the synthesis column and adding a reagent port for chip-synthesized DNA, we can use the same platform to perform a database query in DNA[14]. Additionally, our sequencing preparation protocol and loading hardware can be adapted for use with our digital microfluidics platform[15] and used as a readout for DNA strand displacement reactions.

Near-term improvements will focus primarily on system optimizations in synthesis, cycle count, and cost. Synthesis time can be reduced by 10–12 hours with the addition of heat in the cleave step[16]. Multiple writes (with or without reads) can be achieved by the addition of additional synthesis columns and a fluid multiplexer. Multiple reads can also be achieved with minor modifications (Supplemental Section 1) and exploiting the MinION flow cell's reusability. Additionally, a cost-optimized version could be designed by eliminating the syringe pump and flow sensor, both unnecessary if flow rates are well measured and calibrated. This could save approximately 60% of our current device's

Step	Volume (μL)	Time (s)
deblock	600	50
Act + {A, C, T, G} (1:1)	350	120
Act + Phos. reagent (1:1)*	350	900
Oxidizer	750	10

Table 1. DNA synthesis reagent parameters. *Only performed as final coupling step to add 5′ phosphate.

Reagent	Volume (μL)
Extended adapter	15
T4 DNA ligase (NEB: M0202)	5
DTT-free 10× T4 buffer*	20
ONT RBF	93
Nuclease-free water	64
Total	197

Table 2. Sequencing prep master mix. *DTT-free 1× T4 buffer: 50 mM Tris-HCl, 10 mM $MgCl_2$, 1 mM ATP.

cost at the expense of more laborious operation. Future improvements will focus on bringing storage density, coding, and sequencing yield up to parity with modern manual and semi-automated methods.

Methods

DNA synthesis. DNA synthesis was performed using standard phosphoramidite chemistry[17] without capping. Volumes and times, described in Table 1, used reagents purchased from Glen Research Corporation. For solid support (PN: ML1-3500-5), we used a BioAutomation 50 nmole scale synthesis column containing controlled porosity glass.

DNA cleavage was performed in 32% ammonia at room temperature for 1 hour before eluting. De-protection continued for an additional 11 hours in the same ammonia solution in the storage vessel.

Our system is fluidically configured as in Fig. 1b and electrically configured as in Supplemental Section 2.

Sequencing preparation. The extended adapter was constructed from a 1 kilobase fragment that was PCR-amplified from the lambda genome using hot start TAQ DNA polymerase (NEB M0496) with a Bsa-I restriction site added by the forward primer. The resulting fragment after digestion had a 3′ A overhang and a 5′-GCGT sticky end on the bottom strand. The fragment was then T/A ligated and prepped according to Oxford Nanopore Technology's (ONT) LSK-108 kit protocol, yielding the extended adapter with a four base sticky end.

The extended adapter was then mixed according to Table 2 into a sequencing master mix that is used in automated sequencing prep. Thirty minutes prior to sequencing, the master mix was combined with the hairpin oligo and incubated. DTT was left out of the T4 buffer because it damages the nanopores and causes sequencing to fail.

Nanopore sequencing. Nanopore sequencing was done with an Oxford Nanopore Technologies MinION using an MIN-107 R9.5 flowcell and MinKNOW 18.7.2.0 software. Base calling was performed in 4000 event batches using Albacore 2.3.1. The read length distribution and write-to-read quality test were loaded manually (as described in the instructions for LSK-108 sequencing kits); the end-to-end code, write, read, and decode experiment was loaded automatically from the storage vessel.

Coding and decoding. Prior to coding the user data ("HELLO" in ASCII bytes plus the hash consisting of the right most 12 bits of the SHA256 hash) was passed through a one time a one time pad to increase entropy similar to previous work[3]. One time pads

$$X_1 = (1\,3\,0\,1\,0\,1\,1\,0\,3\,2\,2\,2\,1\,1\,3\,1\,0\,2\,2\,2\,3\,2\,2\,2\,1\,1\,3\,2\,1\,3\,0\,0)$$

and

$$X_2 = (3\,1\,1\,2\,2\,1\,1\,2\,3\,0\,2\,1\,1\,0\,3\,2\,2\,0\,3\,3\,0\,2\,2\,0\,3\,3\,1\,0\,1\,3\,2\,2)$$

were used for the first and second experiment described in this paper respectively.

Data was coded using a two-layer scheme that stored 5 bytes over 32 dsDNA bases with an additional 13 bases of 3′ padding to compensate for lost fidelity near the read end (Fig. 2). The outer layer consisted of a (31, 26) Hamming code[6] over a four-symbol alphabet with a checksum base that detects all two-base read errors and corrects all single-base errors. The following equivalences were made for the sake of algebraic simplicity: A = 0, C = 1, G = 2, T = 3. We used modulo-4 arithmetic and the canonical generator matrix

$$G = (I \; - \; A^T),$$

along with the canonical parody check matrix

$$H = (A \; I),$$

where

$$A = \begin{pmatrix} 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}$$

and I is the identity matrix of the appropriate dimension. To increase error detection, 6 of the 26 data bases stored a 12-bit hash of the payload, which was checked after decoding to ensure data integrity. Source code is available in Supplemental Section 3.

For decoding, groups of 4000 reads were collected and base-called using ONT's Albacore software on 12 CPU cores. Reads that passed QC in Albacore were then aligned to the extended adapter and sequenced for further filtering. Only reads that appeared to have a correctly sized payload region between the adapter sequence and the poly-T hairpin were sent for error checking and decoding.

DNA alignment. All DNA alignment was done using the parasail parasail_aligner command line tool[18] with arguments -d -t 1 -O SSW -a sg_trace_striped_16 -o 8 -m NUC.4.4 -e 4. Alignments to the adapter sequence for decoding used the additional flag -c 20, while payload error analysis used flag -c 8.

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Author Contributions

C.N.T. designed and built the hardware and software, performed all data analysis, and wrote the manuscript. C.N.T. and B.H.N. performed all experiments. B.H.N. advised on protocol development. K.S. and L.C. advised on all aspects. All authors read and edited the manuscript.

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GeekWire

Secretive Seattle startup Picnic unveils pizza-making robot — here's how it delivers 300 pies/hour

BY JAMES THORNE on October 1, 2019

https://www.geekwire.com/2019/secretive-seattle-startup-picnic-unveils-pizza-making-robot-heres-delivers-300-pies-hour/

Picnic's robot delivers freshly sliced pepperoni onto a pizza via a conveyer belt. (GeekWire Photo / James Thorne)

After three years of quietly toiling away on a robotic food system, Seattle startup Picnic has emerged from stealth mode with a system that assembles custom pizzas with little human intervention.

Picnic — previously known as Otto Robotics and Vivid Robotics — is the latest entrant in a cohort of startups and industry giants trying to find ways to automate restaurant kitchens in the face of slim margins and labor shortages. And its journey here wasn't easy.

"Food is hard. It's highly variable," said Picnic CEO Clayton Wood. "We learned a lot about food science in the process of developing the system."

Picnic invited me down to their headquarters in Seattle's Interbay neighborhood last week for a chance to sling pies with their secretive pizza robot.

Walking up to the system, I was taken aback at how unassuming it looked. Picnic's platform had none of the industrial machismo of a Vulcan range. Instead, it looked like a white, kitchen-sized iPhone.

Despite the simple exterior, the component parts were mesmerizing — from the sauce spitting out of a nozzle to the waterfall of diced cheese and individually sliced pepperoni.

Picnic's platform assembles up to 300 12-inch pizzas per hour, far faster than most restaurants would be able to make the dough, bake and serve the pizzas. That speed comes in handy in places where large numbers of orders come in during a rush, such as at a stadium or in large cafeterias. It's also compact enough that it could theoretically be installed in a food truck.

Machines have been making frozen pizzas for years, but Picnic's robot differs in a few respects. It's small enough to fit in most restaurant kitchens, the recipes can be easily tweaked to suit the whims of the restaurants, and — most importantly — the ingredients are fresh.

There are also a few details that may save Picnic's pizzas from tasting as if a robot made them. For starters, the dough preparation, sauce making and baking — the real art of pizza — is left in the capable, five-fingered hands of people. The robot is also highly customizable, comprised of a series of modules that dole out whatever toppings you want in whichever order you choose.

Once an order for a pizza has been made, it enters a digital queue in the platform, which starts making the pie as soon as the dough is put in place. The robot has a vision system that allows it to make adjustments if the pie is slightly off-center. It's also hooked up to the internet and sends data back to Picnic so the system can learn from mistakes.

Picnic's business model is essentially pizza-as-a-service. Restaurant owners pay a regular fee in return for the system and ongoing maintenance as well as software and hardware updates. The startup has launched at Centerplate, a caterer in the Seattle Mariners' T-Mobile Park baseball stadium, as well as Zaucer, a restaurant in Redmond, Wash.

"People are getting more accustomed to the idea of not owning technology because they perceive it to be something that changes quickly. They don't want to buy a major investment and have it be obsolete in three years," said Wood. Picnic's pricing plans, which depend on the volume of pizza being made, are designed to be at or below the labor and waste-related costs that companies can avoid with the system.

The startup has changed names twice since it first came onto GeekWire's radar. Picnic started as Otto Robotics, which caused some confusion with the other Otto, a self-driving car startup, and it later went by Vivid Robotics.

Picnic has also changed CEOs. It was founded and led by Garett Ochs, a mechanical engineer who left a job at Oculus VR to start what would later become Picnic. Ochs resigned last year, and Wood took over the top job.

Wood got his start at Honeywell in the late 90s before taking on several leadership stints at startups including Naverus, WebJunction, Planetary Power, and IUNU. He also is a former CEO at Synapse Product Development.

Draper Associates and Microsoft co-founder Paul Allen's Vulcan Capital funded the company's seed round. Wood declined to discuss Picnic's more recent funding or investors. The company has raised $8.77 million to date, according to PitchBook data.

Robotic chefs have yet to go mainstream, but Little Caesar's has a patent for a pizza-making robot. And Domino's is automating many of its processes, including a pilot for driverless pizza delivery and an experimental drone delivery system. San Francisco-based Zume has raised $445 million with backing from SoftBank to create a pizza robot system and other robotics infrastructure for restaurants.

The good news for Picnic is that there may be room for several such companies in America, where people spend $46 billion annually at pizza restaurants. Down the line, the startup wants to use the same system to assemble salads, bowls and sandwiches.

"The potential for Picnic's technology is broad-reaching for the pizza and other food industries," said Kati Fritz-Jung, a former Little Caesars executive who serves as an advisor to Picnic. "Innovations like this will change the way we approach customer service, product quality, operational costs and overall consumer satisfaction."

Picnic's robotic pizza system is made up of a series of modular components that can be customized for each restaurant. (Picnic Photo)

I have no pride to protect when it comes to my own pizza-making ability, but watching Picnic's various modules layer cheese and slice fresh pepperoni makes me feel a pang of sympathy for Garry Kasparov, the first world chess champion to lose to a computer in a tournament. Picnic's robot is faster and more capable than any entry-level food service employee could ever hope to be.

Maybe that's a good thing, since food service workers can be hard to come by. More than a third of restaurant owners are having trouble filling jobs, especially in the kitchen, according to the National Restaurant Association. And more than 80 percent of workers will change jobs each year, requiring employers to constantly train recruits. Increasing labor costs are also affecting the bottom line for restaurant owners.

"Picnic could help our existing staff work more efficiently, allowing them to do double or triple their customer service load without negatively impacting workflow," said Zaucer co-founder Aaron Roberts. "Our employees feel it's going to help them through the rough spots."

My only job was to place the dough at one end and transfer it to an oven at the other. Even still, I fell behind after only three pies. The experience felt like that episode of *I Love Lucy* with Lucy and Ethel in the candy factory.

In just a few minutes, we had several hot pizzas ready to eat. We were using frozen dough and an electric oven for the demonstration, so my expectations were low. And while the pizzas I made weren't memorable, I couldn't fault the machine: the robot delivered fresh-tasting and meticulously-arranged toppings.

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Mistrust, efficacy and the new civics: understanding the deep roots of the crisis of faith in journalism

Mistrust, efficacy and the new civics:
understanding the deep roots of the crisis of faith in journalism

Ethan Zuckerman, Center for Civic Media, MIT Media Lab

Executive summary

Current fears over mistrust in journalism have deep roots. Not only has trust in news media been declining since a high point just after Watergate, but American trust in institutions of all sorts is at historic lows. This phenomenon is present to differing degrees in many advanced nations, suggesting that mistrust in institutions is a phenomenon we need to consider as a new reality, not a momentary disruption of existing patterns. Furthermore, it suggests that mistrust in media is less a product of recent technological and political developments, but part of a decades-long pattern that many advanced democracies are experiencing.

Addressing mistrust in media requires that we examine why mistrust in institutions as a whole is rising. One possible explanation is that our existing institutions aren't working well for many citizens. Citizens who feel they can't influence the governments that represent them are less likely to participate in civics. Some evidence exists that the shape of civic participation in the US is changing shape, with young people more focused on influencing institutions through markets (boycotts, buycotts and socially responsible businesses), code (technologies that make new behaviors possible, like solar panels or electric cars) and norms (influencing public attitudes) than through law. By understanding and reporting on this new, emergent civics, journalists may be able to increase their relevance to contemporary audiences alienated from traditional civics.

One critical shift that social media has helped accelerate, though not cause, is the fragmentation of a single, coherent public sphere. While scholars have been aware of this problem for decades, we seem to have shifted to a more dramatic divide, in which people who read different media outlets may have entirely different agendas of what's worth paying attention to. It is unlikely that a single, authoritative entity – whether it is mainstream media or the presidency – will emerge to fill this agenda-setting function. Instead, we face the personal challenge of understanding what issues are important for people from different backgrounds or ideologies.

Addressing the current state of mistrust in journalism will require addressing the broader crisis of trust in institutions. Given the timeline of this crisis, which is unfolding over decades, it is unlikely that digital technologies are the primary actor responsible for the surprises of the past year. While digital technologies may help us address issues, like a disappearing sense of common ground, the underlying issues of mistrust likely require close examination of the changing nature of civics and public attitudes to democracy.

Introduction

The presidency of Donald Trump is a confusing time for journalists and those who see journalism as an integral component of a democratic and open society.

Consider a recent development in the ongoing feud between the President and CNN. On July 2nd, Donald Trump posted a 28 second video clip to his personal Twitter account for the benefit of his 33.4 million followers.[1] The video, a clip from professional wrestling event Wrestlemania 23[2] ("The Battle of the Billionaires"), shows Trump knocking wrestling executive Vince McMahon to the ground and punching him in the face. In the video, McMahon's face is replaced with the CNN logo, and the clip ends with an altered logo reading "FNN: Fraud News Network". It was, by far, Trump's most popular tweet in the past month, receiving 587,000 favorites and 350,000 retweets, including a retweet from the official presidential account.

CNN responded to the presidential tweet, expressing disappointment that the president would encourage violence against journalists.[3] Then CNN political reporter Andrew Kaczynski tracked down Reddit user "HanAssholeSolo", who posted the video on the popular Reddit forum, The_Donald. Noting that the Reddit user had apologized for the wrestling video, as well as for a long history of racist and islamophobic posts, and agreed not to post this type of content again, Kaczynski declined to identify the person behind the account. Ominously, he left the door open: "CNN reserves the right to publish his identity should any of that change." The possibility that the video creator might be identified enraged a group of online Trump supporters, who began a campaign of anti-CNN videos organized under the hashtag #CNNBlackmail[4], supported by Wikileaks founder Julian Assange, who took to Twitter to speculate on the crimes CNN might have committed in their reportage[5]. By July 6th, Alex Jones's Infowars.com was offering a $20,000 prize in "The Great CNN Meme War", a competition to find the best meme in which the President attacked and defeated CNN.[6]

It's not hard to encounter a story like this one and wonder **what precisely has happened** to the relationship between the press, the government and the American people. What does it mean for democracy when a sitting president refers to the press as "the opposition party"[7]? How did

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trust in media drop so low that attacks on a cable news network serve some of a politician's most popular stances? How did "fake news" become the preferred epithet for reporting one political party or another disagrees with? Where are all these strange internet memes coming from, and do they represent a groundswell of political power? Or just teenagers playing a game of one-upsmanship? And is this really what we want major news outlets, including the Washington Post, the New York Times and CBS, to be covering[8][9][10]?)

These are worthwhile questions, and public policy experts, journalists and academics are justified in spending significant time understanding these topics. But given the fascinating and disconcerting details of this wildly shifting media landscape, it is easy to miss the larger social changes that are redefining the civic role of journalism. I believe that three shifts underlie and help explain the confusing and challenging landscape we currently face and may offer direction for those who seek to strengthen the importance of reliable information to an engaged citizenry:

- The decline of trust in journalism is part of a larger collapse of trust in institutions of all kinds
- Low trust in institutions creates a crisis for civics, leaving citizens looking for new ways to be effective in influencing political and social processes
- The search for efficacy is leading citizens into polarized media spaces that have so little overlap that shared consensus on basic civic facts is difficult to achieve

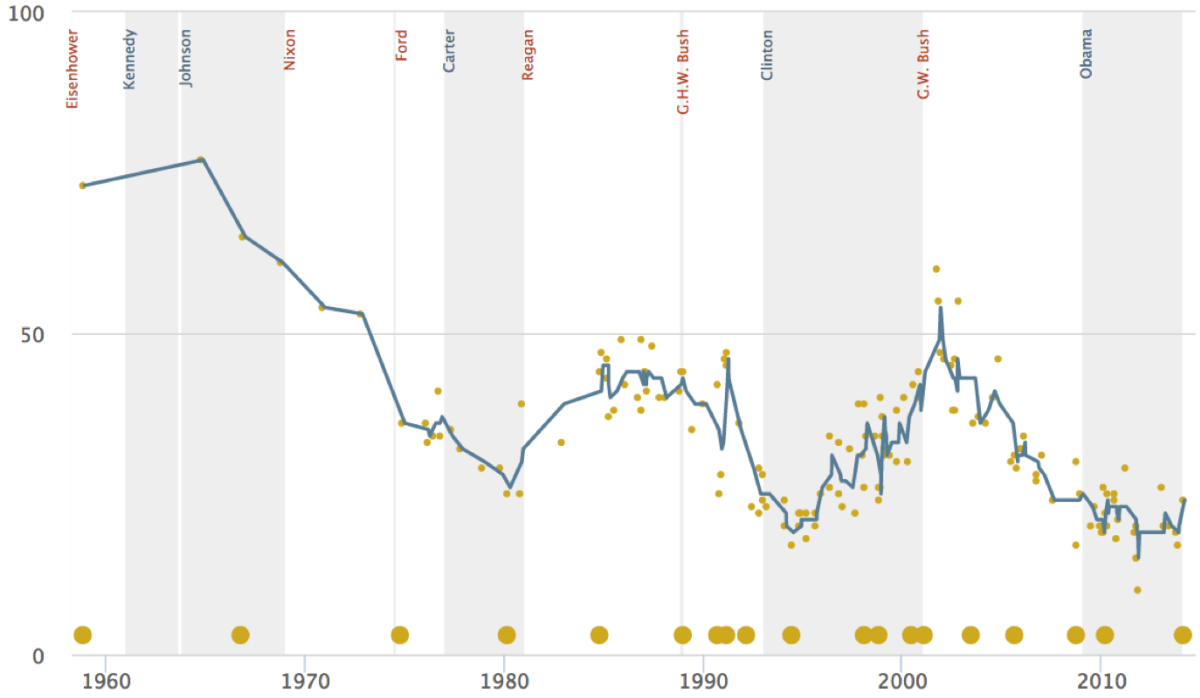
I will unpack these three shifts in turn, arguing that each has a much deeper set of roots than the current political moment. These factors lead me to a set of question for anyone seeking to strengthen the importance of reliable information in our civic culture. Because these shifts are deeper than the introduction of a single new technology or the rise of a specific political figure, these questions focus less on mitigating the impact of recent technological shifts and more on either reversing these larger trends, or creating a healthier civic culture that responds to these changes.

What happened to trust?

Since 1958, the National Election Study and other pollsters have asked a sample of Americans the following question: "Do you trust the government in Washington to do the right thing all or most of the time?" Trust peaked during the Johnson administration in 1964, at 77%. It declined precipitously under Nixon, Ford and Carter, recovered somewhat under Reagan, and nose-dived under George HW Bush. Trust rose through Clinton's presidency and peaked just after George W. Bush led the country into war in Iraq and Afghanistan, collapsing throughout his

[8] Abby Ohiheiser, "The Reddit user behind Trump's CNN meme apologized. But #CNNBlackmail is the story taking hold," The Washington Post 5 Jul. 2017, 27 Jul. 2017 <https://www.washingtonpost.com/news/the-intersect/wp/2017/07/05/the-reddit-user-behind-trumps-cnn-meme-apologized-but-cnnblackmail-is-the-story-taking-hold/>.
[9] "How CNN wound up in a "blackmail" boondoggle," CBS News 6 Jul. 2017, 27 Jul. 2017 <http://www.cbsnews.com/news/how-cnn-wound-up-in-a-blackmail-boondoggle>.
[10] Michael Grynbaum, "The Network Against the Leader of the Free World," The New York Times 5 Jul. 2017, 27 Jul. 2017 <https://www.nytimes.com/2017/07/05/business/media/jeffrey-zucker-cnn-trump.html>.

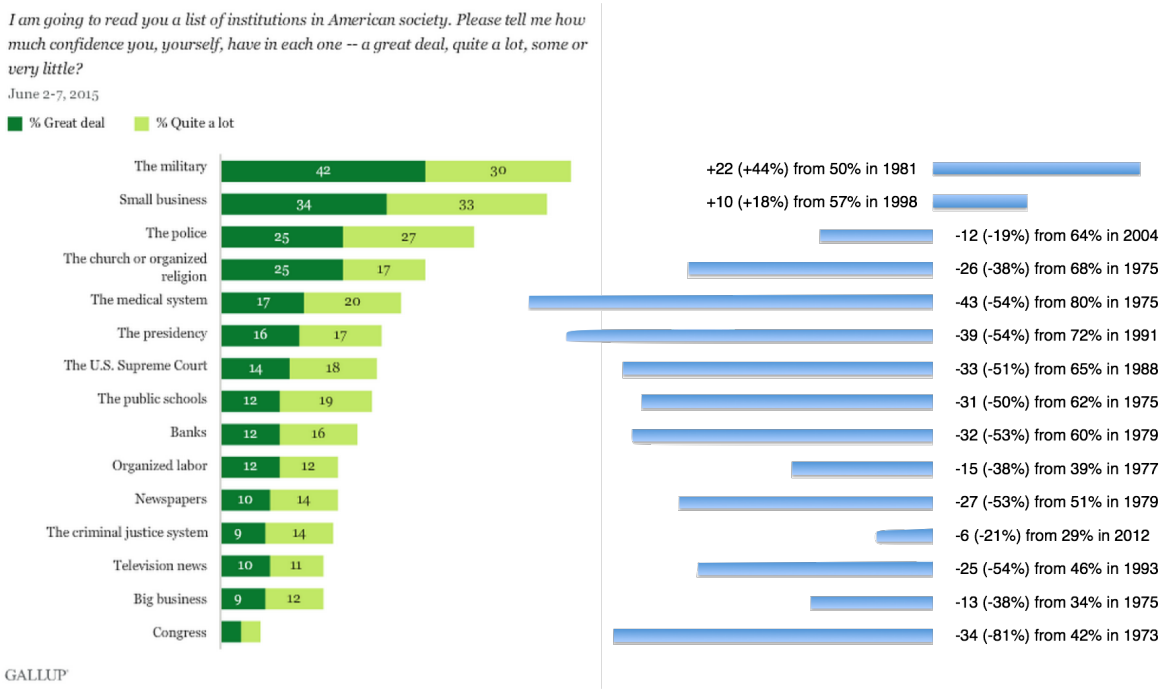
presidency to the sub-25% levels that characterized Obama's years in office. Between Johnson and Obama, American attitudes towards Washington reversed themselves - in the mid 1960s, it was as difficult to find someone with low trust in the federal government as it is difficult today to find someone who deeply trusts the government.[11]



Declining trust in government, especially in Congress - the least trusted branch of our tripartite system - is an old story, and generations of politicians have run against Washington, taking advantage of the tendency for Americans to re-elect their representatives while condemning Congress as a whole. What's more surprising is the slide in confidence in institutions of all sorts. Trust in public schools has dropped from 62% in 1975 to 31% now, while confidence in the medical system has fallen from 80% to 37% in the same time period. We see significant decreases in confidence in organized religion, banks, organized labor, the criminal justice system and in big business. The only institutions that have increased in trust in Gallup's surveys are the military, which faced Vietnam-era skepticism when Gallup began its questioning, and small business, which is less a conventional institution than the invitation to imagine an individual businessperson. With the exception of the military, Americans show themselves to be increasingly skeptical of large or bureaucratic institutions, from courts to churches.[12]

[11] "Public Trust in Government: 1958-2014," Pew Research Center 13 Nov. 2014, 27 Jul. 2017 <http://www.people-press.org/2014/11/13/public-trust-in-government/>

[12] Data and leftmost chart is from Gallup, initially published at http://www.gallup.com/poll/1597/confidence-institutions.aspx. Data on the right is from the author, derived from data sets published at http://www.gallup.com/poll/1597/confidence-institutions.aspx



American media institutions have experienced the same decades-long fall in trust. Newspapers were trusted by 51% of American survey respondents in 1979, compared to 20% in 2016. Trust in broadcast television peaked at 46% in 1993 and now sits at 21%. Trust in mass media as a whole peaked at 72% in 1976, in the wake of the press's role in exposing the Watergate scandal. Four decades later, that figure is now 32%, less than half of its peak. And while Republicans now show a very sharp drop in trust in mainstream media - from 32% in 2015 to 14% in 2016, trust in mass media has dropped steadily for Democrats and independents as well.[13]

In other words, the internet and social media has not destroyed trust in media - trust was dropping even before cable TV became popular. Nor is the internet becoming a more trusted medium than newspapers or television - in 2014, 19% of survey respondents said they put a great deal of trust in internet news. Instead, trust in media has fallen steadily since the 1980s and 1990s, now resting at roughly half the level it enjoyed 30 years ago, much like other indicators of American trust in institutions.

It's not only Americans who are skeptical of institutions, and of media in particular. Edelman, a US-based PR firm, conducts an annual, global survey of trust called Eurobarometer, which compares levels of trust in institutions similar to those Gallup asks about.[14] The 2017 Eurobarometer survey identifies the US as "neutral", between a small number of high trust countries and a large set of mistrustful countries. (Only one of the five countries Eurobarometer lists as highly trusting are open societies, rated as "free" by Freedom House: India. The other

[13] Art Swift, "Americans' Trust in Mass Media Sinks to New Low," Gallup 14 Sept. 2016, 27 Jul. 2017 <http://www.gallup.com/poll/195542/americans-trust-mass-media-sinks-new-low.aspx>.
[14] "Global Results" Edelman 17 Jan. 2017, 27 Jul. 2017 <http://www.edelman.com/global-results/>.

four - China, Indonesia, Singapore and the United Arab Emirates, are partly free or not free.[15] Depressingly, there is a discernable, if weak, correlation between more open societies and low scores on Edelman's trust metric.[16]) As in the US, trust in media plumbed new depths in Eurobarometer countries, reaching all time lows in 17 of the 28 countries surveyed and leaving media contending with government as the least trusted set of institutions (business and NGOs rate significantly higher, though trust in all institutions is dropping year on year.)

So what happened to trust?

By recognizing that the decrease in trust in media is part of a larger trend of reduced trust in institutions, and understanding that shift as a trend that's unfolded over at least 4 decades, we can dismiss some overly simplistic explanations for the current moment. The decline of trust in journalism precedes Donald Trump. While it's likely that trust in media will fall farther under a government that presents journalists as the opposition party, Trump's choice of the press as enemy is shrewd recognition of a trend already underway. Similarly, we can reject the facile argument that the internet has destroyed trust in media and other institutions. Even if we date broad public influence of the internet to 2000, when only 52% of the US population was online[17], the decline in trust in journalism began at least 20 years earlier. If we accept the current moment as part of a larger trend, we need a more systemic explanation for the collapse of trust.

Scholars have studied interpersonal trust - the question of how much you can trust other individuals in society - for decades, finding robust evidence of a correlation between interpersonal trust at a societal level and economic success[18]. The relationship between interpersonal trust and trust in institutions is less clear: Sweden, for instance, is one of the world leaders in interpersonal trust, but one of the most mistrustful of governments and other institutions. Comparing the 2014 World Values Survey measure of interpersonal trust to the 2017 Eurobarometer survey of institutional trust shows no correlation[19]. So while interpersonal trust has dropped sharply in the US (from 48% in 1984 to 31% in 2014, using data from the General Social Survey, the broader world shows fairly stable interpersonal trust. Yet a decrease of trust in institutions is widespread globally, as seen both in the Eurobarometer data and in Gallup OECD data.[20] It's not just that we trust each other less - people around the world appear to trust institutions less.

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[15] Ellen Aghekyan, Jennifer Dunham, Shannon O'Toole, Sarah Repucci, and Vanessa Tucker, "Freedom in the World 2017,"Freedom House 2017, 27 Jul. 2017 <https://freedomhouse.org/report/freedom-world/freedom-world-2017>.

[16] R^2=0.162, unpublished research by the author, correlating 2017 Eurobarometer results and 2017 Freedom in the World study results for all overlapping countries

[17] Andrew Perrin and Maeve Duggan, "Americans' Internet Access: 2000-2015," Pew Research Center 26 Jun. 2015, 27 Jul. 2017 <http://www.pewinternet.org/2015/06/26/americans-internet-access-2000-2015/>.

[18] Manz, Charles C., Paola Sapienza, and Luigi Zingales, "Does culture affect economic outcomes?," The Journal of Economic Perspectives 20.2 (2006): 23-48.

[19] R^2=0.032, unpublished research by the author, correlating 2017 Eurobarometer results and results from waves 5 and 6 from the World Values Survey.

[20] Esteban Ortiz-Ospina and Max Roser, "Trust," Our World in Data 2016, 27 Jul. 2017 <https://ourworldindata.org/trust>.

It's also possible that reduced confidence in institutions could relate to economic stress. As numerous scholars, notably Thomas Piketty, have observed, economic inequality is reaching heights in the US not seen since the Gilded Age. The decrease of confidence in institutions roughly correlates with the increase Piketty sees in inequality, which is stable through the 50's, 60's and mid-70's, rising sharply from there.[21]

We might think of an explanation in which citizens, frustrated by their decreasing share of the pie, punish the societal institutions responsible for their plight. But with this explanation, we would expect to see rising inequality accompanied by a steady drop in consumer confidence. We don't - consumer confidence in the US and in the OECD more broadly is roughly as high now as it was in the 1960s, despite sharp drops during moments of economic stress and a rise during the "long boom" of the '90s and 2000s. It's possible that citizens should be punishing governments, banks and businesses for rising inequality, but consumer behavior and confidence doesn't corroborate the story.[22]

I favor a third theory, put forward by Kenneth Newton and Pippa Norris, called the institutional performance model. Simply put, when institutions perform poorly, people lose trust in them: "It

[21] John Cassidy, "Piketty's Inequality Story in Six Charts," The New Yorker 26 Mar. 2014, 27 Jul. 2017 <http://www.newyorker.com/news/john-cassidy/pikettys-inequality-story-in-six-charts>.
[22] "Consumer confidence index," OECD 2017, 27 Jul. 2017 <https://data.oecd.org/leadind/consumer-confidence-index-cci.htm#indicator-chart>.

is primarily governmental performance that determines the level of citizens' confidence in public institutions."[23] That trust in institutions, easily lost, takes a long time to regain. We might understand the collapse of confidence in US institutions as a set of high visibility crises: Vietnam and Watergate as eroding confidence in the federal government, the Catholic Church sex scandal destroying trust in that institution, the 2007 financial collapse damaging faith in banks and big business.

Newton and Norris developed their theories in the mid-1990s, noting that confidence in public institutions was plumbing new depths. In retrospect, their concerns seem well-founded, as the trends they observed have simply increased over time. In the mid 1990s, Newton and Norris were comfortable positing a relationship between society-wide interpersonal trust and trust in institutions - that relationship is less clear now, because interpersonal trust has remained fairly constant while trust in institutions has decreased. One explanation for the decrease in institutional trust is that institutions have performed poorly, and that citizens are increasingly aware of their shortcomings.

Cultural and technological shifts may have made it easier for institutions to lose trust and harder to regain it. Watergate returned the US press to its progressive-era muckraking roots and ended a period of deference in which indiscretions by figures of authority were sometimes ignored. (It's interesting to imagine the Clinton-era press covering JFK's personal life.) An explosion in news availability, through cable television's 24-hour news cycle and the internet, has ensured a steady stream of negative news, which engages audiences through fear and outrage. The rise of social media fuels the fire, allowing individuals to report institutional failures (police shootings, for example) and spread their dismay to friends and broader audiences. Accompanying the evolution of media technologies is education: in 1971, 12% of Americans had graduated from college, and 57% from high school. By 2012, 31% had college degrees, and 88% had high school diplomas. The citizens of 2017 are better positioned to be critical of institutions than those of 1964.[24]

If we accept any of these explanations for a decrease in trust in institutions, the obvious question emerges: How do we reverse this trend? How do we restore public trust?

It's worth noting that those most concerned with restoring public trust tend to be elites, those for whom existing institutions are often working quite well. Eurobarometer's 2017 report focuses on a widening trust gap between a well-informed 15% of the population and a less informed 85%. The well-informed minority scores 60 on Edelman's trust index, while the less-informed majority is 15 points lower, at 45. The gap between elites and the majority is largest in the US - 22 points separate the groups.[25]

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[23] Kenneth Newton and Pippa Norris, "Confidence in Public institutions: Faith, Culture or Performance?," Harvard Kennedy School Sep. 1999, 27 Jul. 2017 <https://www.hks.harvard.edu/fs/pnorris/Acrobat/NEWTON.PDF>.
[24] "American Adults Better Educated Than Ever Before," The Pew Research Center 10 Jan. 2013, 27 Jul. 2017 <http://www.pewresearch.org/fact-tank/2013/01/10/american-adults-better-educated-than-ever-before/>.
[25] Edelman, op cit.

One approach to institutional mistrust is to try and educate this disenchanted majority, helping them understand why our institutions are not as broken as we sometimes imagine. Any approach is unlikely to reach all citizens - some will remain frustrated and alienated, due to disinterest, misinformation, a healthy distaste for being told what to think, or due to the fact that their mistrust may be justified.

TV commentator Chris Hayes encourages us to recognize that those frustrated with institutions constitute a large and powerful segment of society[26]. He suggests that dividing Americans into institutionalists, who want to strengthen and preserve our existing social institutions, and insurrectionists, who see a need to overhaul, overthrow, replace or abandon existing institutions, is at least as useful as dividing the population into liberals and conservatives. Insurrectionists include progressives (Bernie Sanders), libertarians (Rand Paul) and nationalists (Donald Trump), while both Republicans and Democrats are well represented within the institutionalist camp.

The defeat of a consummate institutionalist - Hillary Clinton - by an insurrectionist outsider suggests a need to take rising insurrectionism seriously. What if our citizens now include a large plurality unlikely to be persuaded to regain trust in our central civic institutions?

How mistrust reshapes civics

Assume for the moment that a large group of citizens is mistrustful of existing institutions. How do these citizens participate in civic life?

Low participation in congressional elections is often offered as evidence of the decline in American civic life. But in 2012, only 35 of 435 congressional seats were considered "swing" districts, where voting margins were within 5% of the national popular vote margin - the remaining 92% of districts strongly favor either a sitting Democrat or Republican.[27] The safety of these districts leads to an extremely high rate of incumbent re-election, 95.9%.[28] Combine the very low chance of making a difference in a Congressional election with extremely low trust in Congress (9% in 2016[29]) and it's easy to understand why many citizens - including some institutionalists - would sit an election out.

When we teach young people how to have a civic voice, we tend to emphasize the importance of voting as a baseline civic responsibility - as the bumper sticker says, "If you don't vote, you can't complain." But at high levels of mistrust, voting doesn't work very well. If we see Congress, the Senate or the presidency as dysfunctional institutions, either unlikely to

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[26] Christopher Hayes, Twilight of the Elites: America After Meritocracy, New York: Crown Publishers, 2012.
[27] Nate Silver, "As Swing Districts Dwindle, Can a Divided House Stand?," The New York Times 27 Dec. 2012, 27 Jul. 2017 <https://fivethirtyeight.blogs.nytimes.com/2012/12/27/as-swing-districts-dwindle-can-a-divided-house-stand/?_r=0>.
[28] Louis Jacobson, "Congress has 11% approval ratings but 96% incumbent reelection rate, meme says," 11 Nov. 2014, 27 Jul. 2017 <http://www.politifact.com/truth-o-meter/statements/2014/nov/11/facebook-posts/congress-has-11-approval-ratings-96-incumbent-re-e/>.
[29] "Confidence in Institutions," 2017, 27 Jul. 2017 <http://www.gallup.com/poll/1597/confidence-institutions.aspx>.

accomplish much[30] or to represent our interests, voting for representatives or encouraging them to advance or support legislation doesn't feel like a powerful way to influence civic processes.

High levels of mistrust present a challenge for protest as well. Unless the goal of a protest - a march, a sit-in, an occupation - is the fall of a regime (as it was with the protests of the Arab Spring), then a protest is designed to show widespread support for a political position and influence leaders. The March on Washington, likely the most remembered event of the civil rights movement as it culminated in Martin Luther King Jr.'s "I Have a Dream" speech, was, after all, a march on Washington. It sought to pressure President Kennedy and Congress to take action on civil rights legislation and is credited with creating the momentum for LBJ to act quickly on civil rights after Kennedy's assassination.

What happens when protesters no longer trust that institutions they might influence can make necessary social changes? The Occupy movement was widely criticized for failing to put forward a legislative agenda that representatives could choose to pass.[31] Occupiers, in part, were expressing their lack of confidence in the federal government and didn't put forth these proposals because their goal was to demonstrate other forms of community decision-making. Whether or not Occupy succeeded in demonstrating the viability of consensus-based governance, the resistance of Occupiers to turning into a political party or advocacy organization shows a deep insurrectionist distrust of existing institutions and an unwillingness to operate within them.

The danger is that insurrectionists will drop out of civic life altogether, or be manipulated by demagogues who promise to obviate the complexities of mistrusted institutions through the force of their personal character and will. The hope is that insurrectionists can become powerful, engaged citizens who participate in civic life despite their skepticism of existing institutions. To make this possible, we need to broaden our understanding of what it means to be a good citizen.

There is a tendency to assume that the actions that constitute good citizenship are stable over time. Good citizens inform themselves about issues, vote in elections, contact representatives about issues they care about and, if they fail to be heard, protest peacefully and non-violently. Michael Schudson argues that this model of citizenship is only one of several that has held sway in the US at different moments in our nation's history. Early in the American republic, "good citizens" would be expected to send the most prominent and wealthy member of their community to Washington to represent them, independent of agreement with his ideology. Later, good citizens supported a political party they affiliated with based on geography, ethnicity or occupation. The expectation that voters would inform themselves on issues before

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[30] Drew Desilver, “In late spurt of activity, Congress avoids ‘least productive’ title,” 29 Dec. 2014 <http://www.pewresearch.org/fact-tank/2014/12/29/in-late-spurt-of-activity-congress-avoids-least-productive-title/>.

[31] Dan Schnur, “What should Occupy Wall Street’s agenda be?,” The Washington Post 21 Oct. 2011, 27 Jul. 2017 <https://www.washingtonpost.com/opinions/what-should-occupy-wall-streets-agenda-be/2011/10/21/gIQA5iTk4L_story.html?utm_term=.ed4a9c67d3f7>.

voting, vote on split tickets making decisions about individual candidates or vote directly on legislation in a referendum was the result of a set of progressive era reforms that ushered in what Schudson calls "the informed citizen".[32]

We tend to see the informed citizen as the correct and admirable model for citizenship a hundred years after its introduction, but we miss some of the weaknesses of the paradigm. Informed citizenship places very high demands on citizens, expecting knowledge about all the candidates and issues at stake in an election - it's a paradigm deeply favored by journalists, as it places the role of the news as informing and empowering citizens at the center of the political process. Unfortunately, it's also a model plagued with very low participation rates - Schudson observes that the voting was cut nearly in half once progressive political reforms came into effect. And while we often discuss civics and participation in terms of the informed citizen mode, he argues that America has moved on to other dominant models of citizenship, the rights-based citizenship model that centers on the courts, as during the civil rights movement, and monitorial citizenship, where citizens realize they cannot follow all the details of all political processes and monitor media for a few, specific issues where they are especially passionate and feel well-positioned to take action.

Young people in particular are looking for ways they can be most effective in making change around issues they care about. Effective citizenship, in which individuals make rational, self-interested decisions about how they most effectively participate in civic life, can look very different from the informed citizenship we've come to expect. Joe Kahne and Cathy Cohen surveyed thousands of youth in California and discovered that while participation in "institutional" politics (rallies, traditional political organizing, volunteering to work with a candidate) is low, there is strong engagement with "participatory politics", sharing civic information online, discussing social issues in online fora, making and sharing civic media.[33] And while young people may not be volunteering for political campaigns, they are volunteering at a much higher rate than previous generations, looking for direct, tangible ways they can participate in their communities.[34]

We are beginning to see new forms of civic participation that appeal to those alienated from traditional political processes. One way to understand these methods is as levers of change. When people feel like they are unlikely to move formal, institutional levers of change through voting or influencing representatives, they look for other levers to make movement on the issues they care about.

In his 1999 book, Code and Other Laws of Cyberspace[35], Lawrence Lessig argues that there are four primary ways societies regulate themselves. We use laws to make behaviors legal or illegal. We use markets to make desirable behaviors cheap and dangerous ones expensive. We use

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[32] Michael Schudson, The Good Citizen: A History of American Civic Life (New York: Simon & Schuster, 2011).
[33] Cathy Cohen and Joseph Kahne, "New Media and Youth Political Action," dmlcentral Jun. 2012, 27 Jul. 2017<https://ypp.dmlcentral.net/sites/all/files/publications/YPP_Survey_Report_FULL.pdf>.
[34] http://civicyouth.org/youth-volunteering-rate-much-higher-than-in-the-1970s-and-80s/
[35] Lessig, Lawrence. Code and Other Laws of Cyberspace. New York: Basic Books, 1999.

social norms to sanction undesirable behaviors and reward exemplary ones. And code and other technical architectures make undesirable actions difficult to do and encourage other actions. Each of the regulatory forces Lessig identifies can be turned into a lever of change, and in an age of high mistrust in institutions, engaged citizens are getting deeply creative in using the three non-legal levers.

In the wake of Edward Snowden's revelations of widespread NSA surveillance of communications, many citizens expressed fear and frustration. The Obama administration's review of the NSA's programs made few significant changes to domestic spying policies.[3637] Unable to make change through formal government processes, digital activists have been hard at work building powerful, user-friendly tools to encrypt digital communications like Signal, whose powerful encryption has now been incorporated into the widely used WhatsApp platform.[38] Code-based theories of change allow programmers and engineers to become powerful social change actors, making new behaviors possible, whether they increase personal privacy or reduce dependency on fossil fuels.

Market-based theories of change use capitalism's capacity for scaling to change the behavior of large groups of people. We usually think of Elon Musk as an inventive entrepreneur and engineer, but it's also possible to think of him as one of the most effective activists working to halt climate change. By building a highly desirable electric car and the infrastructure to charge it at home and on the road, Musk may ultimately reduce carbon emissions as much as legislating global carbon markets. Market-based activists use boycotts, buycotts and social ventures to encourage consumers to make change using their wallets, a technique used since American colonists eschewed heavily taxed British goods, now organized and accelerated through communications networks.

If code-based theories of change are most open to engineers and market levers to entrepreneurs, norms-based theories of change have been embraced by those who make and disseminate media... which in the age of social networks includes the majority of Americans and the vast majority of young Americans. The Black Lives Matter movement is less focused on specific legislative change than on changing social norms that cause many people to see black males, especially young black males, as a threat. Laws are already on the books that should protect black males from police violence. But when a policeman perceives 12-year old Tamir Rice as a threat because he is a young black man playing with a toy, changing the norms of how African Americans are seen by police - and by society as a whole - is a high priority. Online, BLM protesters have focused on making unarmed deaths at the hands of the police highly visible,

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[36] Ackerman, Spencer, “NSA review to leave spying programs largely unchanged, reports say”, The Guardian, 13 December 2013. <“https://www.theguardian.com/world/2013/dec/13/nsa-review-to-leave-spying-programs-largely-unchanged-reports-say>

[37] Bamford, James, “Every Move You Make”, Foreign Policy, September 7, 2016. <http://foreignpolicy.com/2016/09/07/every-move-you-make-obama-nsa-security-surveillance-spying-intelligence-snowden/>

[38] Greenberg, Andy, “Meet Moxie Marlinspike, the Anarchist bringing Encryption to All of Us”, Wired, July 31, 2016. <https://www.wired.com/2016/07/meet-moxie-marlinspike-anarchist-bringing-encryption-us/>

leading to a surge of media coverage in the wake of Michael Brown's death, making these incidents at least 10 times as visible as they were before the Ferguson protests.[39]

Effective citizenship means that people look for the methods of social change they see as most effective. Young people often look for norms-based theories of change, taking advantage of their skills in building and disseminating media. Insurrectionists frustrated with legal institutions or with the behaviors of corporate America look for change through new technology and new ventures.

This shift in citizenship is still emerging. Media often hasn't caught up with the idea that effective civic engagement happens outside the courts, the voting booth and Congress. This understandable overfocus on law-based theories of change leaves those frustrated with institutions frustrated with media as well. For insurrectionists who see Washington institutions as ineffective and untrustworthy, a strong media focus on these institutions can look like an attempt to maintain their legitimacy and centrality.

One of journalism's key roles in an open society is to help citizens participate effectively. From close scrutiny of those in elected office to analysis of legislative proposals to editorial endorsements of candidates for office, news outlets help their customers make civic decisions. If mistrust in institutions is changing how people participate in civics, news organizations may need to change as well. We can recommit ourselves to explaining the importance and centrality of our institutions, but we run the risk of being insufficiently skeptical and critical, and the danger that we lose even more trust from our alienated and insurrectionist readers. Or we could rethink our role as journalists as helping people navigate this emergent civic landscape and find the places where they, individually and collectively, can be the most effective and powerful.

Dueling spheres of consensus

Shortly after the 2016 elections, a friend asked me to lunch. A Trump supporter, he knew we had voted differently in the election, and we both wanted to talk about the future of the country under the new administration. But he invited me specifically because he was angered by an article I'd written that grouped Breitbart founder Steve Bannon with alt-right leader Richard Spencer.[40]

My friend explained that he read Breitbart religiously, not because he supports white supremacy, but because he supports net-zero immigration to the US as a strategy for raising the incomes of white and non-white Americans. Breitbart was the only major media outlet he found seriously discussing that policy stance. "If Bannon is beyond the pale, and Breitbart's

[39] Unpublished research from this author, presented at MIT in Fall 2016.
[40] Ethan Zuckerman, "What happens when you normalize the abnormal,"CNN 23 Nov. 2016, 27 Jul. 2017 <http://www.cnn.com/2016/11/23/opinions/bannon-spencer-white-supremacy-trump-zuckerman/index.html>.

beyond the pale, does it mean that my views on immigration are beyond the pale? And what about the millions of Americans who agree with me?"[41]

Research I conducted with Yochai Benkler and our team confirmed my friend's assertion that Breitbart covered matters of immigration much more closely than other media outlets leading up to the 2016 election, focusing on the issue more than 3x as often as right-leaning outlets Fox News and the Wall Street Journal.[42] Thanks to the strong influence of Breitbart, we speculate, immigration became the most-reported on policy issue in the 2016 election, despite GOP efforts to soften the party's stance on immigration to reach Latino voters.[43]

The move of immigration from the fringe of the news agenda to a central topic is a phenomenon addressed by media scholar Daniel Hallin in his 1986 book, The Uncensored War: The Media and Vietnam.[44] Hallin argues that we should think of potential news stories as fitting into one of three spheres. In the sphere of consensus, there is widespread agreement on an issue or a position (democracy is the best form of government; capitalism is a good way to build an economy) and therefore it's not worth our time to discuss. In the sphere of deviance, there is widespread agreement that a stance is beyond the pale (sexual relationships between adults and minors are natural and should be legal; collective ownership of all goods is the best way to end economic inequality) and also not worthy of discussion. The (sometimes very narrow) sphere of legitimate controversy includes the standard political debates within a society, and journalists are expected to show themselves as neutral on those topics legitimate to debate (tax cuts for the wealthy will lead to economic growth; for-profit insurers will only survive with federally mandated medical insurance).

Lobbyists, activists and PR professionals have used Hallin's spheres to shape what's at stake in public policy debates. Health insurance companies have worked hard to push the idea of single payer healthcare into the sphere of deviance, rebranding the idea as socialized medicine to associate it with a disfavored economic idea.[45] By citing the small number of scientists who do not see evidence that humans are contributing to climate change, advocates have kept the phenomenon of global warming within the sphere of legitimate debate.

While Hallin's Spheres are related to the Overton window - the idea that certain policy prescriptions are so radical that a politician could not embrace them without compromising her own electability[46] - being consigned to Hallin's sphere of deviance has psychological

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[41] Ethan Zuckerman, "Lunch with my friend, the Trump supporter," Ethanzuckerman 9 Dec. 2016, 27 Jul. 2017 <http://www.ethanzuckerman.com/blog/2016/12/09/lunch-with-my-friend-the-trump-supporter/>.

[42] Yochai Benkler, Robert Faris, Hal Roberts, and Ethan Zuckerman, "Study: Breitbart-led right-wing media ecosystem altered broader media agenda," Columbia Journalism Review 3 Mar. 2017, 27 Jul. 2017 <https://www.cjr.org/analysis/breitbart-media-trump-harvard-study.php>.

[43] Jane C. Timm, "Latinos force GOP to negotiate on immigration," 14 Nov. 2012, 27 Jul. 2017 <http://www.msnbc.com/morning-joe/latinos-force-gop-negotiate-immigration>.

[44] Daniel Hallin, The Uncensored War: The Media and Vietnam (New York: Oxford University Press, 1986) pp. 116–118.

[45] Wendell Potter, Deadly Spin: An Insurance Company Insider Speaks Out on How Corporate Pr Is Killing Health Care and Deceiving Americans, (New York: Bloomsbury 2011).

[46] Nathan Russell, "An Introduction to the Overton Window of Political Possibilities,"Mackinac Center for Public Policy 4 Jan. 2006, 27 Jul. 2017 <https://www.mackinac.org/7504>.

implications that falling outside the Overton window lacks. Advance a policy suggestion that is outside the Overton window and you suffer the disappointment that your idea is discarded as impractical. Stray outside the sphere of legitimate debate into the sphere of deviance, and your position becomes invisible to mainstream media dialog. Journalism scholar Jay Rosen observes, "Anyone whose views lie within the sphere of deviance — as defined by journalists — will experience the press as an opponent in the struggle for recognition. If you don't think separation of church and state is such a good idea; if you do think a single payer system is the way to go... chances are you will never find your views reflected in the news. It's not that there's a one-sided debate; there's no debate."[47]

The growth in media diversity brought about by the rise of the internet and social media means that if your ideas are outside the sphere of legitimate debate, you can simply find a media sphere where you're no longer in the sphere of deviance. My friend, frustrated that he could not find media debating his ideas on immigration, began reading Breitbart, where his deviant ideas are within the sphere of consensus, and the legitimate debate is about the specific mechanisms that should be used to limit immigration. He is not alone. While less popular than during the 2016 election, Breitbart is the 61st most popular website in the US[48], close in popularity to the Washington Post. In our data set, which examines how websites are shared on Twitter or Facebook, Breitbart is the fourth-most influential media outlet, behind CNN, The New York Times and politics site The Hill.

The ability to find a set of media outlets compatible with your political views is not new. Even in the days of political pamphlets and early newspapers, it was possible to experience a Federalist or Anti-Federalist echo chamber. The rise of large-circulation newspapers and broadcast media, which needed to avoid alienating large swaths of the population to maintain fiscal viability, led us into a long age where partisan journalism was less common.[49] Even as cable news made partisan news viable again, broadcast news networks and major newspapers maintained aspirations of fairness and balance, attempting to serve the broader public.

Those economic models make little sense in a digital age. As purveyors of wholly manufactured fake news (like the Macedonian teens who targeted content at Trump supporters[50]) know, there is a near-insatiable appetite for news that supports our ideological preconceptions. But it's important to consider that people seek out ideological compatible media not just out of intellectual laziness, but out of a sense of efficacy. If you are a committed Black Lives Matter supporter working on strategies for citizen review of the police, it's exhausting to be caught in endless debates over whether racism in America is over. If you're working on counseling

[47] Jay Rosen, "Audience Atomization Overcome: Why the Net Erodes the Authority of the Press," Huffington Post 14 Apr. 2017, 27 Jul. 2017 <http://www.huffingtonpost.com/jay-rosen/audience-atomization-over_b_157807.html>.
[48] "breitbart.com Traffic Statistics," 26 Jul. 2017, 27 Jul. 2017 <http://www.alexa.com/siteinfo/breitbart.com>.
[49] "breitbart.com Traffic Statistics," 26 Jul. 2017, 27 Jul. 2017 <http://www.alexa.com/siteinfo/breitbart.com>.
[50] Craig Silverman and Lawrence Alexander, "How Teens In The Balkans Are Duping Trump Supporters With Fake News," Buzzfeed News 3 Nov. 2016, <https://www.buzzfeed.com/craigsilverman/how-macedonia-became-a-global-hub-for-pro-trump-misinfo?utm_term=.fb2l4v0vm#.wpjO3LKLr>.

women away from abortion towards adoption, understanding how to be effective in your own movement is likely to be a higher priority for you than dialog with pro-choice activists.

Partisan isolationism is not just purely a function of homophily. The structure of internet media platforms contributes to ideological isolation. While Pariser[51] and others trace these structural effects to Facebook and other highly targeted social media, I argued in Rewire[52] that three different generations of internet media have made it possible to self-select the topics and points of views we are most interested in. The pre-Google web allowed us to self select points of view much as a magazine rack does: we choose the National Review over the Nation, or their respective websites. Unlike broadcast media, which lends itself towards centrist points of view to attract a wide range of ad dollars, narrowcast media like websites and magazines allow more stark, partisan divisions. With the rise of search, interest-based navigation often led us to ideological segregation, either through the topics we select or the language we choose to pursue them - the vegan cooking website is unlikely place to meet conservatives, much as searching for progressive voices on a hunting site can be frustrating. And the language we use to describe an issue – climate change, global warming or scientific fraud – can be thoroughly ideologically isolating in terms of the information we retrieve.

What's different about social media is not that we can choose the points of view we encounter, but that we are often unaware that we are making these choices. Many people joined Facebook expecting the service would help them remain connected with family and friends, not that it would become a primary source of news. As of 2016, 62% of American adults reported getting some news via social media, and 18% reported often getting news through platforms like Facebook.[53] These numbers are more dramatic for young adults, and likely increased during the 2016 presidential election. Because Facebook's newsfeed algorithm presents content to you based on content you've liked and clicked on in the past, it has a tendency to reinforce your existing preconceptions, both because your friends are likely to share those points of view, and because your behavior online indicates to Facebook what content you are most interested in. Eli Pariser calls this problem "the filter bubble", building on earlier work done by Cass Sunstein[54], which recognized the tendency to create "echo chambers" online by selecting media that fits our politics. Pariser argues (controversially) that algorithms used by Facebook and others increase this tendency.

It's worth noting that the filter bubble problem isn't inherent to social media. Twitter has pointedly not filtered their timeline, which avoids the filter bubble, but leaves responsibility for escaping echo chambers to the user. While you can decide to follow a different group of people on Twitter, research from Nathan Matias suggests that even highly motivated people are

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[51] Pariser, Eli. *The filter bubble: How the new personalized web is changing what we read and how we think*. Penguin, 2011.
[52] Zuckerman, Ethan. *Digital cosmopolitans: Why we think the internet connects us, why it doesn't, and how to rewire it*. WW Norton & Company, 2013.
[53] Jeffrey Gottfried and Elisa Shearer, "News Use Across Social Media Platforms 2016," 26 May 2016, 27 Jul. 2017 <http://www.journalism.org/2016/05/26/news-use-across-social-media-platforms-2016/>.
[54] Cass Sunstein, Republic.com, possibly 1999?

unlikely to make major changes in their online behavior in order to combat biases and prejudices.[55]

Our team at the MIT Media Lab is working on Gobo, a new tool that allows you to filter your Facebook and Twitter feeds differently, using natural language processing and machine learning to build filters that can increase or decrease the political content of your news feed, give you more or fewer female authors, or consciously choose to encounter more news outside of your echo chamber. One of the key questions we seek to answer in buiding the tool is whether people will actually choose to use these filters. One hypothesis we hope to disprove is that, despite complaining about filter bubbles, many people seem to enjoy ideological isolation and may choose settings similar to what they encounter online now.

General interest media, like broadcast television and national newspapers, traditionally saw themselves as having a responsibility to provide ideological balance, global perspectives and diversity in their coverage. (Whether they succeeded is another question – I've heard many reports from people of color that they felt invisible in those "good old days" and far more visible in contemporary, fragmented media.) As that business model becomes less viable, because readers gravitate towards ideologically compatible material, it's worth asking whether platforms like Facebook have an appetite for this work.

Thus far, the answer seems to be no. Facebook has assiduously avoided being labeled a publisher, trying to ensure both an escape from legal liability for content it hosts under the Safe Harbor provisions of US internet law, and to prevent itself from being criticized about exercising poor editorial judgement. The problems Facebook is confronted with are serious. Demands that the platform block "fake news" are challenging, given that most of what's called "fake news" is not obviously fraudulent. If Facebook begins blocking platforms like Breitbart, it will be accused of censorship of political content, and rightly so.

One possible escape for Facebook is to eliminate algorithmic curation of newsfeeds, moving back to a Twitter-like world in which social media is a spray of information from anyone you've chosen to pay attention to. Another is to adopt a solution like the one we are proposing with Gobo, and put control of filters into the user's hands. It's an open question whether Facebook would choose a path forward that gives its users more control over their experience of the service.

In considering how platforms enable online discourse, we need to consider the idea that sharing content is a form of civic participation. Part of our emergent civics is the practice of making and disseminating media designed to strengthen ties within an identity group and to distinguish that group from groups that oppose it. Consider the meme-makers competing for $20,000 from Infowars. Many involved don't believe that CNN is ISIS, as one popular meme

[55] J. N. Matias, S. Szalavitz, E. Zuckerman, "FollowBias: Supporting Behavior Change toward Gender Equality by Networked Gatekeepers on Social Media," *In Proceedings of the 20th ACM Conference on Computer Supported Cooperative Work & Social Computing*, ACM Press, 2017.

alleges[56] - as Judith Donath explains, "News is shared not just to inform or even to persuade. It is used as a marker of identity, a way to proclaim your affinity with a particular community."[57]

Donath's insight helps explain why factchecking, blocking fake news or urging people to support diverse, fact-based news is unlikely to check the spread of highly partisan news. Not only is partisan news comfortable and enjoyable (I find it reassuring to watch Trevor Noah or Samantha Bee and assume that friends on the right feel the same watching Fox News commentators), spreading this information has powerful social rewards and gives a sense of shared efficacy, the feeling (real or imagined) that you are making norms-based social change by shaping the information environment.

The research Benkler, I and our team conducted shows how rapidly these partisan ecosystems can come into being. Examining 1.25 million media stories and 25,000 media sources, we gave each media source a partisanship score based on whether people who shared tweets from the Democratic or Republican candidates also shared a story from a source. Stories from the New York Times were more often shared by people who'd retweeted Hillary Clinton than those who'd retweeted Donald Trump, but the effect was much more pronounced with Breitbart: Breitbart was amplified almost exclusively by Trump supporters. Our research shows a tightly clustered set of sites read only by the nationalist right. The vast majority of these sites are very new, most founded during the Obama administration. This community of interest has very little overlap with traditional conservative sources like the Wall Street Journal or the National Review. In our study, those publications are both low in influence and linked to by both the left and right, while the Breitbart-centered cluster functions as an echo chamber.

The emergence of echo chambers like the one around Breitbart further complicates fact-checking. danah boyd explains that in teaching students not to rely on Wikipedia, we've encouraged them to triangulate their way to truth from Google search results.[58] On topics covered heavily in the Breitbartosphere but not addressed in the broader media universe, this leads to a perverse effect. Search for information on Pizzagate as the story was being developed on sites like Infowars and you would likely find links to other far-right sites promoting the story. By the time sites like the New York Times became aware of the story and began debunking it, many interested in the faux-scandal had persuaded themselves of its truth through repetition within a subset of closely related websites, to the point where an unstable individual took up arms to "self-investigate" the controversy.[59]

Hallin's spheres suggests we question whether we are encouraged to discuss a wide enough range of topics within the sphere of legitimate controversy. The problem we face now is one in

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[56] Hrand Tookman, "'CNN is ISIS' Trends On Twitter As Trump Supporters Heckle Network," 3 Jun. 2017, 27 Jul. 2017 <http://dailycaller.com/2017/06/03/cnn-is-isis-trends-on-twitter-as-trump-supporters-heckle-network/>.

[57] Judith Donath, "Why fake news stories thrive online," 20 Nov. 2016 <http://www.cnn.com/2016/11/20/opinions/fake-news-stories-thrive-donath/index.html>.

[58] Danah Boyd, "Did Media Literacy Backfire," 5 Jan. 2017, 27 Jul. 2017 <https://points.datasociety.net/did-media-literacy-backfire-7418c084d88d>.

[59] Matthew Haag and Maya Salam, "Gunman in 'Pizzagate' Shooting Is Sentence to 4 Years in Prison," 22 Jun. 2017, 27 Jul. 2017 <https://www.nytimes.com/2017/06/22/us/pizzagate-attack-sentence.html?_r=0>.

which dialog is challenging, if not impossible, because one party's sphere of consensus is the other's sphere of deviance and vice versa. Our debates are complicated not only because we cannot agree on a set of shared facts, but because we cannot agree what's worth talking about in the first place. When one camp sees Hillary Clinton's controversial email server as evidence of her lawbreaking and deviance (sphere of consensus for many on the right) or as a needless distraction from more relevant issues (sphere of deviance for many on the left), we cannot agree to disagree, as we cannot agree that the conversation is worth having in the first place.

Much as there is no obvious, easy solution to countering mistrust in institutions, I have no panaceas for polarization and echo chambers. Still, it's worth identifying these phenomena – and acknowledging their deep roots – as we seek solutions to these pressing problems. It is worth noting that the research Benkler's and my team carried out suggests the phenomenon of asymmetric polarization – in our analysis, those on the far right are more isolated in terms of viewpoints they encounter than those on the far left. There's nothing in our research that suggests the right is inherently more prone to ideological isolation. By understanding how extreme polarization has developed recently, it might be possible to stop the left from developing a similar echo chamber. Our research also suggests that the center right has a productive role to play in building media that appeals to an insurrectionist and alienated right-leading audience, which keeps those important viewpoints in dialog with existing communities in the left, center and right.

Fundamentally, I believe that the polarization of dialog in the media is a result both of new media technologies and of the deeper changes of trust in institutions and in how civics is practiced. The Breitbartosphere is possible not just because it's easier than ever to create a media outlet and share viewpoints with the like-minded. It's possible because low trust in government leads people to seek new ways of being engaged and effective, and low trust in media leads people to seek out different sources. Making and disseminating media feels like one of the most effective ways to engage in civics in a low-trust world, and the 2016 elections suggest that this civic media is a powerful force we are only now starting to understand.

Closing questions

I want to acknowledge that this paper may stray far from the immediate challenges that face us around issues of information quality, in the service of seeking for their deeper roots. My questions follow in the same spirit. For the most part, these are questions to which I don't have a good answer. Some are active research questions for my lab. My fear is that we may have to address some of these underlying questions before tackling tactical questions of how we should best respond to immediate challenges to faith in journalism.

Trust:

- How long does it take to recover trust in an institution that has failed? What are examples of a mistrusted institution regaining public trust?
- Is the fall in institutional trust an independent or a joint phenomenon – i.e., does losing trust in Congress lessen our trust in the Supreme Court or the medical system
- Is trust in news media higher or lower in countries with strong public/taxpayer supported media? Does trust correlate positively or negatively to ad support? Privacy-invading tracking and targeting?
- If people don't trust institutions, who or what do they trust? How do those patterns differ for more trusting elites and for the broader population?

Participation:

- What forms of participation (from the traditional, like voting, to the non-traditional, like making CNN-bashing memes) are indicators of future civic engagement? Should we be encouraging and celebrating a broader range of civic participation amongst youth? Amongst groups that see themselves alienated from conventional politics?
- Should media attempt to explain and engage audiences more deeply in institutional politics? Will acknowledging the limits of existing institutional politics restore trust in journalism, or damage trust in government?
- Should media celebrate and promote new forms of civic engagement? Will this further decrease trust in institutions? Increase a sense of citizen efficacy?
- What would media designed for increased public participation look like? Are there models in the advocacy journalism space, or in solutions journalism, constructive journalism or other movements?

Polarization:

- Is it reasonable to expect Americans to rely on a single, or small set, of professional media sources that report a relatively value-neutral set of stories? Or is this goal of journalistic non-partisanship no longer a realistic ideal?
- Could taxpayer-sponsored media serve a function of anchoring discourse around a single set of facts? Or will public media be inherently untrustworthy to some portion of American voters? Why does public media seem to work well in other low-trust nations but not in the US?
- Is there a role for high-quality, factual but partisan media that might reach audiences alienated from mainstream media?
- Should media outlets learn from what's consensus, debatable and deviant in other media spheres and modify coverage to intersect with reader's spheres? Is shifting the boundaries of these spheres part of how civics is conducted today?