The Path Ahead

Fall 2024

Then, Now, & The Future:

Modern Wellness Culture Al and Medicine Laproscopic Surguries **Black Hole Observation** & Many More

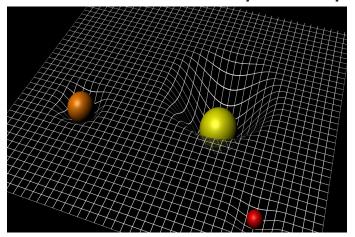


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Publishing Since 1904



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OF THE COLORADO ENGINEER

FALL 2024



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Dear readers,

As the new Editor in Chief for the Colorado Engineer Magazine (CEM), I'm thrilled to introduce a few changes aimed at building our community and increasing our engagement on campus. This term, we took a simple approach to expand our reach: tabling in the engineering lobby, and offering cookies alongside the latest issue of the magazine. This effort, though modest, led to two powerful lessons.

Lesson One: Marketing is everything.

Everyone who grabbed a magazine seemed delighted and wanted to know where to find more issues or when we published. Yet, many didn't even know CEM existed before stopping by. In a digital world brimming with easy-access entertainment, drawing attention requires an initial first spark—something that makes people look up and take notice. Even the most engaging product needs a strong attractor to call attention to itself.

Lesson Two: Monkey see, monkey do.

Initially, despite a table full of cookies, many passersby hesitated, perhaps wary of getting drawn into an unwanted conversation. But once a few brave souls stepped forward and received their cookies and magazines without any strings attached, others quickly followed. It reminded me that taking the first step often feels daunting, but once you overcome that initial barrier, momentum builds naturally.

As you read through this semester's articles, take a moment to reflect on the steps our incredible team took to bring each story to life. We're committed to making CEM a vital part of the engineering community—one step at a time, one reader at a time. Here's to many more steps together.

Aaron Schurman Editor-in-Chief

Our Colorado Engineer Magazine Mission

As staff of the Colorado Engineer, our mission is to inform and educate our readers and reflect pride in CU's College of Engineering & Applied Science world-wide.

Our student-led magazine seeks to provide a voice for CU's engineering students while also carrying on the 100-year CEM tradition: by students for students.

The Colorado Engineer has been reporting on the "latest and greatest" from the engineering, science and technology community since 1904. We were there for the Model T, the jet engine, the IBM PC, the iPod — and we will continue to cover the future of human innovation. Today, we operate with a staff of 10 students and three advisers. We publish the magazine biannually, with a readership of over 8,000 individuals, reaching students at the university, researchers, professors and alumni. If you would like to join our staff or have questions and comments, email us at cem@colorado.edu. Alternatively, check out our website at http://https://www.colorado.edu/studentgroups/colorado-engineer/. We always enjoy hearing our readers' feedback!



THE MAKINGS OF MODERN WELLNESS CULTURE

Holistic Healthcare: Fact or Fiction?

Avery O'Neill

he city of Boulder, Colorado, once a hippie haven, has now morphed into a mecca for those in search of a more holistic and natural way of life. Modern wellness culture has flourished here, from apothecaries offering herbal medicines, to IV oxygen bars, ornaturopathic clinics. The city has much to offer for those in pursuit of nourishment for the mind, body, and spirit.

While the efficacy of some alternative therapies has been supported by scientific evidence, many others have not. This can potentially lead patients down a slippery slope, eventually resulting in a general distrust of scientific institutions and integration of pseudoscientific ideologies. In a highly educated city such as Boulder, where residents have access to an abundance of information, why is it that people are still deciding against evidence-based medicine?

THE PROBLEM LIES IN THE APPARENT AUTHORITY THAT ALTERNATIVE PRACTITIONERS CAN WEILD.

A large part of the problem lies in the apparent authority that alternative practitioners can wield.

The fact that alternative therapies do not need rigorous evidence allows some practitioners to make fantastic claims about their therapeutic potential. While my doctor might say that nothing can be done to address a cold, a naturopath can claim that an infrared auna session will not only cure my cold but also cleanse my body of



support this claim, its validity goes unchecked.

Science, in contrast, is constantly in search of new evidence to update its beliefs and practices. Doubt is woven into the framework. Though this constant updating is necessary for scientific advancement, it can be frustrating for patients.

Take, for example, the constantly changing landscape of nutrition advice. It used to be that everyone knew fat and red meat were the enemy; now, excess sugar and carbs are the problem. This instability has caused many (including myself) to question the authority of nutritional advice.

Alternative medicine does not share this burden of being affected by changing evidence. As a result, its advice and practices can remain static over time – bolstering its apparent authority. This is part of why many alternative practices advertise "natural" solutions with long standing

traditions.

In our current epistemic environment – where fearmongering around health and wellness is constant and unavoidable – it should be no surprise that some find refuge in pseudoscience.

What further complicates the picture is the present difficulty in distinguishing between science and pseudoscience in the first place. When I first set out to write this article, I combed through the webpages of many naturopathic clinics, searching for material that I could easily disprove to support my arguments.

What I actually found was a confusing blend of both legitimate and fallacious claims, and drawing a concrete line between the two was much harder than I had imagined.

"Photobiomodulation Light Therapy", offered at a local naturopathic clinic in Boulder, is a prime example of this. The website describes it as "delivery of multiple photonic wavelengths into the vascular bed of the sublingual region". Stripped of the scientific jargon, what this really means is that a machine will be used to shine light under the tongue. Sounds ridiculous, right?

Turns out, it's not entirely. Photobiomodulation has shown efficacy in clinical studies for the treatment of some neurological and psychological conditions, and it is a growing area of research. (Salehpour et al, 2018). Additionally, the naturopathic clinic's website does provide some information on previous and current studies to support their claims.



Salehpour, F., Mahmoudi, J., Kamari, F. et al. Brain Photobiomodulation Therapy: a Narrative Review. Mol Neurobiol 55, 6601–6636 (2018). https://doi.org/10.1007/s12035-017-0852-4

There is still a problem, however. Much of what the website claims lacks substantial evidence, and at times diverges from the truth entirely. For instance, the website suggests photobiomodulation therapy for the improvement of a wide variety of conditions, from autoimmune disorders to Lyme disease. While research does support some limited benefits of photobiomodulation, there is no substantial evidence that it is effective for the wide range of ailments listed on the website.

MANY NATUROPATHIC
CLININGS USE LIMITED
SCIENTIFIC EVIDENCE &
STRETCH IT TO CREATE A
VENEER OF LEGITIMACY

This clinic – and many others like it - use limited scientific evidence and stretch it to create a veneer of legitimacy around therapies that are, at best, unproven and, at worst, misleadingly marketed as cure-alls. Scientific terminology is appropriated to strengthen this veneer. The resulting mixture of fact and fiction makes it difficult to discern what is real and what is not.

What, then, can we do to block out the noise of pseudoscience?

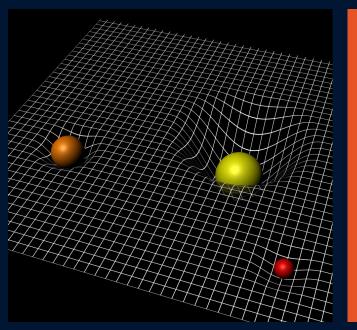
First, we must set realistic expectations for what science and evidence-based medicine can offer. Sure, science is capable of incredible things, but there is still a lot we don't know, especially as it pertains to our own biology. The sooner we accept this fact, the easier it will be to avoid the allure of false cures. Science may not always provide the immediate, definitive answers we hope for. Rather, we must accept the incremental nature of progress.

We must also remain skeptical. Remember that science is where it is today because of skepticism. Healthy skepticism allows us to evaluate claims, explore alternatives, and ultimately choose methods that are grounded in evidence rather than appeal. If wellness is our aim, reality must be our guide.

Ithough modern science has made great strides in its understanding of the physics of our universe, the universe still holds mysteries that remain beyond our understanding. Our current framework rests on the concept of a 4 dimensional spacetime, which bends and warps under the influence of celestial objects and cosmic events. A common demonstration of this warping is placing a rock on a trampoline, causing the fabric distort (see figure right). The history of the universe is difficult to study due to vast timescales, distant and faint objects, extreme early conditions, and the elusive nature of dark matter and energy. These challenges are further complicated by technological and observational limits. One way to chart our progress is by mapping all of the new problems science has encountered as it employs new technologies to explore and refine our fundamental models and theories. An example of this pertains to electromagnetic radiation, or light. Recent breakthroughs in science by CU Boulder's Dr. Joseph Simon, in collaboration with NanoGrav on Pulsar Timing Arrays, and Caltech and MIT's Laser Interferometer Gravitational Wave Observatory (LIGO) have unveiled new information that calls into question many of our assumptions about a 4-dimensional spacetime.

NANOGRAV DETECTS
SUPERMASSIVE BLACK HOLES
BY OBSERVING PULSARS
THROUGHOUT THE GALAXY.

Dr. Joseph Simon is a gravitational wave astrophysicist and Postdoctoral Fellow at the University of Colorado Boulder. Dr. Simon is also a member of the North American Nanohertz Observatory for Gravitational Waves (NanoGrav) with the goal of detecting gravitational waves from supermassive black holes by observing pulsars distributed throughout the galaxy. His current research is using pulsar timing arrays to search for low frequency gravitational waves emitted when two black holes at the centers of galaxies merge.



Visualization of Einstein's Theory of Relativity European Space Agency–C.Carreau

Gravitational waves are ripples in spacetime caused by the acceleration of massive objects, like merging black holes or collapsing stars. These ripples propagate outward, distorting spacetime itself. This distortion stretches and squeezes space time so the distances between objects become warped. When two black holes collide, spacetime ripples, emitting detectable gravitational waves. These waves carry information about the movements of objects in the universe. When space time gets stretched along one axis, it gets squeezed along the other axis. Gravitational waves are polarized similar to how electromagnetic radiation has a plus and cross polarization, which means that the stretching and squeezing happens in different yet predictable ways.

A pulsar is a rotating neutron star that sends pulses of radiation at regular intervals. A neutron star is what is left over after a star collapses and explodes, called a supernova. If the star is massive enough—roughly anything more than two of its solar masses—it will collapse into a black hole; otherwise, it will form a neutron star.

One way to think of a pulsar is as a lighthouse. A lighthouse emits a beam of light that is constantly shining, but the beam is only seen by the observer when it is pointing right at them. These pulsars have strong magnetic fields which funnel jets of particles out along two magnetic poles. Essentially, pulsars are the "cosmic clocks" of the universe, allowing scientists to probe fundamental physics.

UNVEILING COSMIC HISTORY:

BLACK HOLES AS WINDOWS INTO THE UNIVERSE'S PAST

How black holes distort time

Malena Garcia

They are used to test alternate theories of gravity, to explore the limits of nuclear physics and for the detection of low-frequency gravitational waves.

Dr. Simon studies what is specifically called "pulsar timing arrays." Pulsar timing tracks the spin of these "clocks" and as space time stretches and squeezes, the gravitational wave pulses arrive at Earth at different times. The specific pattern of a gravitational wave means that pulsars in one part of the sky will reach Earth at a different rate than pulsars in another section. There is a correlation based on where these pulsars are so the arrival times of each of those pulses can be predicted through general relativity.

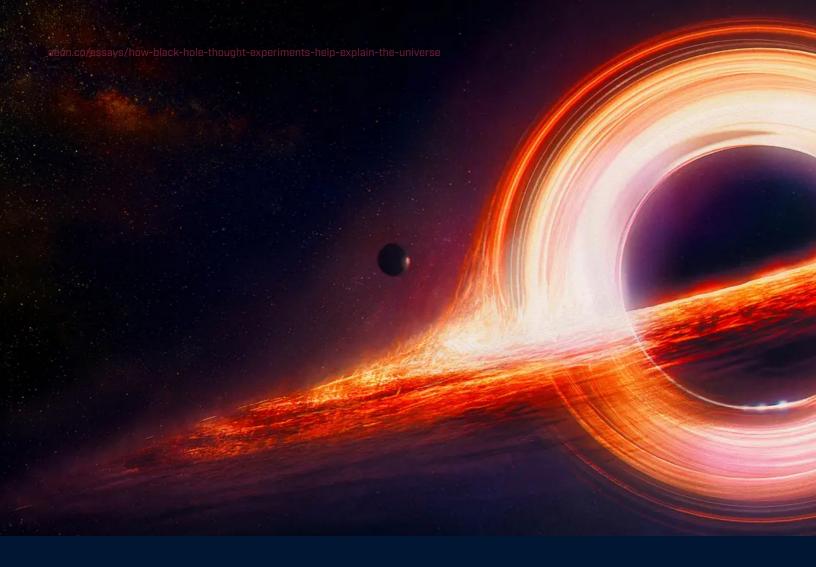
Dr. Simon and NanoGrav are searching for a supermassive pulsar merging event that is still tens of thousands of years away from coalescence. By adding up all the gravitational waves from all of these systems in the universe from black holes merging to supernovas to neutron stars, a gravitational wave background can be formed. Instead of one singular event, pulsar timing arrays are sensitive to the sum of all these events. Using these ancient, celestial remnants (pulsars) that are scattered throughout the galaxy can help turn a specific corner of the Milky Way into a low frequency gravitational wave background. The closest analogy to this is to imagine standing on a beach. You can see each wave as it approaches and crashes onto the shore Now, imagine you are floating in the middle of the ocean where all the waves overlap on top of each other. By combining all the waves together, you see an ocean. This is similar to the gravitational wave background; all of the gravitational waves combined together help draw a picture of the past, present and future universe. They are searching for a background hum of gravitational waves caused by all the celestial objects and bodies in the universe. Pulsar timing

arrays track these waves in real time as an observer, but it can take billions of years for that signal to get to us. We are probing phenomena occurring in the relatively nearby universe, as well as effects resulting from events that took place about 3.5 billion years ago.

The Laser Interferometer Gravitational Wave Observatory (LIGO) is the world's largest facility of its kind and a marvel of engineering. Unlike traditional telescopes that detect electromagnetic radiation, LIGO is specifically designed to detect gravitational waves. Although considered one observatory, LIGO is made up of four facilities: 2 gravitational wave detectors (one interferometer in Washington and the other in Louisiana to eliminate false detections caused by local phenomena like a truck passing by) and two university research centers at CalTech and MIT.

PULSAR TIMING ARRAYS TRACK WAVES IN REAL TIME, BUT THE SIGNAL CAN TAKE BILLIONS OF YEARS TO GET TO US.

For high frequency gravitational wave detection, LIGO looks for these waves on a completely different scale, requiring a completely different detector. I interviewed astrophysicist Dr. Lynn Cominsky of Sonoma State University and member of the LIGO Scientific Collaboration to compare with Dr. Simon's research. Both pulsar timing arrays and LIGO aim to detect ripples in spacetime by observing the effects of massive objects accelerating or merging, further proving Einstein's general theory of relativity. These discoveries enhance our understanding of cosmic



events that are invisible to traditional, lightbased ways of viewing such as those made with telescopes.

While the specific sources of the waves they detect are different, LIGO detects stellarmass mergers and pulsar timing arrays detect the merging of supermassive black holes, both observatories study events that cause distortions in spacetime. These two techniques rely on detecting the effects of gravitational waves rather than directly observing them. Pulsar timing arrays measure timing variations and low-frequency gravitational waves, while LIGO detects high-frequency gravitational waves by observing tiny shifts in the length of its laser arms caused by passing gravitational waves. LIGO consists of two 4 kilometer (2.5 mile) long arms 3000 kilometers (1864 miles) apart. It has two laser interferometers that utilize the properties of light and space to detect gravitational waves. Rather than functioning as an observatory in the traditional sense, LIGO is an interferometer that

splits a laser beam into two, which then travels back and forth through nearly perfect vacuum tubes.

LIGO DETECTS STELLAR-MASS MERGERS AND PULSAR TIMING ARRAYS OF SUPERMASSIVE BLACK HOLES.

The beams are used to monitor the distance between mirrors precisely positioned at the ends of the arms. As the arms of the interferometers change lengths, the laser beams transmitted through them travel different distances, resulting in a change in the "interference" between the waves. Einstein's theory of general relativity predicts that as a gravitational wave passes through the detector, the distance between the

mirrors will shift by an extremely small amount.

LIGO is sensitive enough to detect changes in arm lengths as tiny as one ten-thousandth the diameter of a proton (10^-19 meters). The change in length of an arm divided by the length of that arm is a parameter called a "strain," which represents the infinitesimal fractional amount by which distances are distorted.

THE MERGING OF THESE TWO
BLACK HOLES PRODUCED
A NEW BLACK HOLE WITH A
MASS APPROXIMATELY 60
TIMES OF THAT OF THE SUN.

When observing, each detector collects its own data that is compared in real time with the other detector. Operating together is necessary to verify a gravitational wave detection. The world's first detection of gravitational waves was in September 2015 (known as GW150914) emitted by two merging black holes that occurred 1.3 billion years ago. The merging of these two black holes produced a new black hole with a mass approximately 60 times of that of the sun. The energy radiated during this event was 50 times more than all of the stars shining in the universe, causing ripples in the fabric of the universe to shake like gelatin. This detection occurred in just two-tenths of a second, (100 years after Einstein

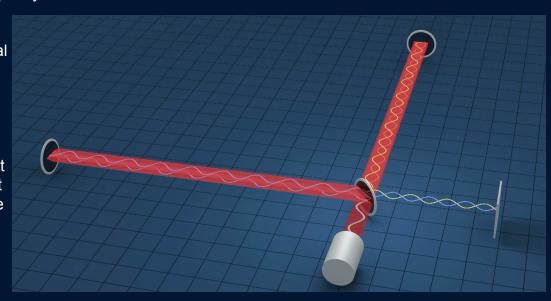
predicted the existence of gravitational waves from his theory of general relativity) demonstrating the immense power and ingenuity of LIGO. Scientists knew black holes existed due to observations of stars that became supernovae, but this was theorized before any direct detection or imaging of black holes occurred. Gravitational waves carry crucial information about their

origins and the nature of gravity that we would not know without these waves.

Pulsar timing arrays and LIGO are contributing to the ultimate goal to create a gravitational wave observatory network across different frequency ranges. Together, they provide a more complete picture of the universe's activity, whether it involves low-frequency gravitational wave activity from large-scale events or high-frequency signals from smaller-scale occurrences. The combined efforts of projects like NanoGrav's Pulsar Timing Arrays and LIGO are transforming our understanding of the universe, particularly in the realm of gravitational waves.

These cutting-edge techniques are allowing us to detect and study some of the most powerful and mysterious cosmic phenomena, from merging black holes to the ripples of spacetime itself. Despite the incredible progress made, these discoveries also remind us of how much remains unknown. Each new advancement in gravitational wave astronomy provides more insight to the vast complexities of the universe. As scientists continue to push the boundaries of what we can observe and comprehend, we are only beginning to grasp the full scope of the universe's history, structure, and future evolution. The collaboration between different observatories and technologies will continue to reveal new insights, showing us that while we have rapidly advanced in our understanding of the universe, there is still so much left to explore.





BRENDAN MCCORD:

BRIDGING PHILOSOPHY AND AI FOR A HUMAN-CENTERED FUTURE

How do we use AI?

n a world where artificial intelligence is advancing at an unprecedented pace, Brendan McCord integrates timeless philosophical principles with cutting-edge technology. As the founder of the Cosmos Institute, a nonprofit that just helped launch the new Human-Centered Al Lab at Oxford, McCord is on a mission to reshape how we think about Al—not just as a tool, but as a catalyst for human flourishing.

In an already complex and probabilistic world AI brings new and risky forms of uncertainty. Amidst this complexity, McCord poses a critical question: What does it mean to have autonomy in the age of AI? For him, it's about more than technological prowess; it's about nurturing both inner freedom—self-mastery and resilience—and external freedom—the protection from external forces, like restrictive governmental controls and media censorship. Human-centered AI emphasizes designing systems that enhance human capabilities and well-being, ensuring that AI aligns with human values and empowers individuals rather than diminishing their autonomy.

A JOURNEY ROOTED IN INQUIRY

McCord's path to becoming a leading voice human-centered AI is anything but conventional. His career began underwater—literally—as he modeled underwater acoustics after studying at MIT. He then served as a submarine officer, spending 610 days in the Arctic. "The experience taught me about the depths of uncertainty and the importance of adaptability," he reflects.

In 2012, as AI was gaining momentum with breakthroughs like ImageNet outperforming humans in image recognition, McCord transitioned to the tech world. While attending Harvard Business School and building a startup, he utilized open-source resources on Coursera to study machine learning. His drive to understand AI's broader implications led him to the government, where he wrote the first AI strategy white paper and managed Project MAVEN. Project MAVEN was a Department of Defense initiative aimed at integrating AI and machine learning to analyze vast amounts of drone surveillance footage. McCord's leadership in this project exposed him to the ethical and practical challenges of deploying AI in critical, real-world situations.

Yet, amidst these achievements, McCord felt a pull toward deeper reflection. "I became very reflective after selling my companies. I wanted to figure out how to model life for my two small kids," he shares. This introspection led him back to the classics, starting with Plato's Republic.

Aaron Schurman



MENTORSHIP & LIFELONG LEARNING

A significant part of McCord's philosophy revolves around education and mentorship. He credits much of his intellectual growth to mentors and structured learning. After his initial struggle with The Republic, he connected with someone who had spent decades reading philosophy. "He helped me think through a broader curriculum," McCord recalls. "It's a great benefit doing it with others."

He encourages others to "get a mentor" and emphasizes the importance of reading slowly and thoughtfully. McCord himself started by dedicating 15 minutes a day to reading, which eventually grew to 3 hours.

THE HEART OF MCCORD'S
VISION IS THE BELIEF THAT AI
SHOULD NOT MERELY PROVIDE
ANSWERS, BUT SHOULD
STIMULATE INQUIRY

FUSION OF PHILOSOPHY & TECHNOLOGY

At the heart of McCord's vision is the belief that AI should not merely provide answers but should stimulate inquiry. He cites Socrates from Plato's Theaetetus, emphasizing that thinking involves the dynamics of questions. "AI systems that support inquiry encourage us to ask 'Am I thirsty?' or 'Do I want caffine?' rather than just

This approach challenges the prevailing trends in AI development, which often prioritize efficiency and utility over depth and understanding. McCord advocates blending Aristotelian ethics with liberalism to foster human autonomy and prevent centralization. "Innovation needs to be balanced with tradition," he asserts. "We must create AI systems centered on human flourishing, not just utilitarian outcomes."

COSMOS INSTITUTE & OXFORD'S HAI LAB

Through the Cosmos Institute and the Human-Centered AI Lab at Oxford, McCord is putting his philosophy into practice. These institutions aim to develop a "philosophy-to-code pipeline," bringing together profound Al expertise and philosophical competence. They are launching a fellowship and grant program to support individuals working at this intersection. These institutions are not just academic think tanks; they are dynamic hubs where interdisciplinary collaboration is the norm. By bringing together philosophers, AI researchers, engineers, and scholars from various fields, McCord seeks to tackle the ethical and existential questions posed by rapid technological advancement. One of the key initiatives is the launch of a fellowship and grant program designed to support individuals passionate about exploring the intersection of AI and philosophy. "We are looking for people who have the potential for profound insights in philosophy and world-class expertise in AI," McCord explains.



"Our goal is to cultivate a new generation of thinkers who can navigate the complexities of technology and ethics." Advocating for Open Source and Security McCord is a strong proponent of open-source Al projects. He argues that such an approach accelerates innovation and allows for collective defense against security threats. "The best system is the most adaptive," he says. "Open-source models can iterate rapidly and preserve feedback loops, which is crucial for both progress and security." McCord emphasizes that open-source models thrive on rapid iteration, allowing for continuous improvements through constant feedback, which ensures they remain agile and responsive to both advancements and new threats. He addresses concerns about security and intellectual property by emphasizing that knowledge sharing is not a zero-sum endeavor. "The spread of knowledge globally lifts people out of poverty and limits

extreme ideologies more than it can be used for war," he notes.

THE DEMAND FOR QUICK ANSWERS VS. THE NEED FOR DEEP INQUIRY

Despite McCord's emphasis on thoughtful inquiry, he acknowledges a significant hurdle: most people simply want quick answers. In an age of information overload, the appeal of instant solutions is undeniable. However, McCord warns that this convenience comes at a cost. "Take the field of medicine, for example," he says. "When doctors decide whether to perform an ACL reconstruction or opt for a less invasive procedure, they're not just making a technical decision.

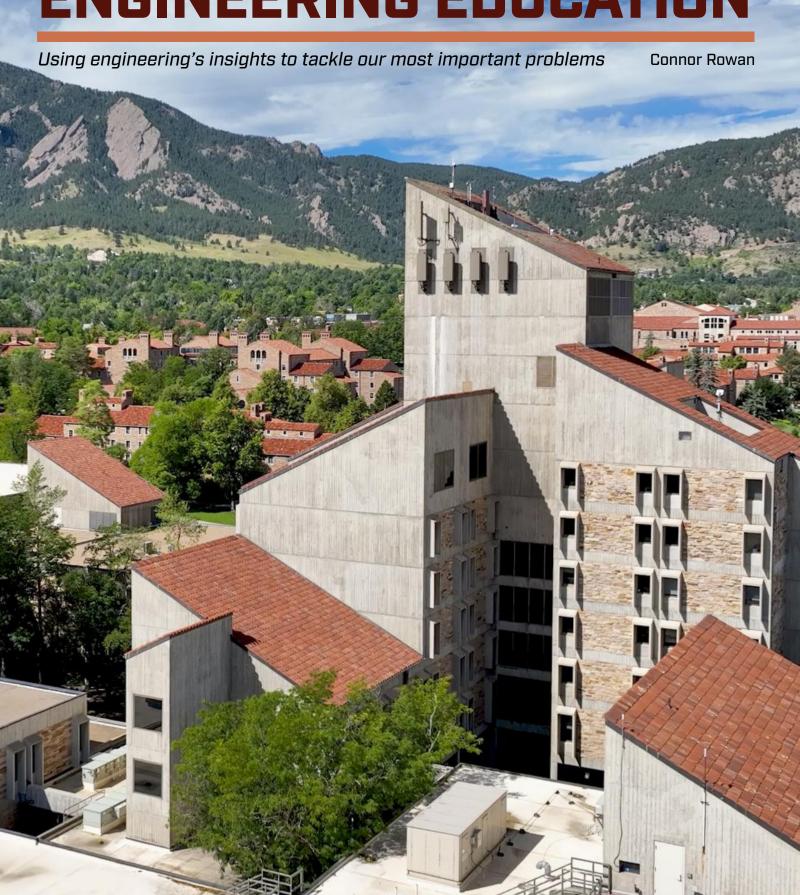
GRAPPLE WITH
PHILOSOPHICAL QUESTIONS
ABOUT QUALITY OF LIFE,
LONG-TERM CONSEQUENCES,
AND PERSONAL VALUES

They're grappling with philosophical questions about quality of life, long-term consequences, and the patient's personal values." These are not decisions that can—or should—be made based on quick answers alone. He argues that while AI can provide data and probabilities, it cannot replace the nuanced judgment that comes from human inquiry. "We need AI systems that encourage us to ask better questions, not just accept the first answer that pops up," he insists. "In doing so, we equip ourselves to make more informed and meaningful decisions."

AI THAT ENHANCES HUMAN INQUIRY

As AI continues to evolve, McCord remains optimistic yet cautious. He envisions AI systems that not only process data but also enhance our capacity for inquiry and understanding. "We need AI to ask the right questions, he says. "Tools can lead to dependence and vulnerability if we're not careful." A human-centered approach has Al fostering a philosophical conversation instead of guessing at what the user wants to hear. His work aims to prevent the centralization of knowledge and power, instead promoting a more democratic and inquiry-driven approach to Al. By integrating philosophical wisdom with technological innovation, McCord hopes to foster a future where AI serves as a partner in human flourishing rather than just a means to any individual end. As we stand at the crossroads of technological advancement and ethical responsibility, Brendan McCord's work becomes not just innovative but imperative. His fusion of philosophy and AI offers an imaginative blueprint for a future where technology amplifies our humanity rather than eclipses it. In championing AI that fosters inquiry and autonomy, McCord is urging us all to engage actively in shaping a world that honors depth over expediency and wisdom over mere information. His vision beckons us to embrace a model of AI development that is as concerned with nurturing the human spirit as it is with advancing technical capabilities.

THE UNTAPPED VALUE OF ENGINEERING EDUCATION



ngineering provides an approach to problem-solving which is practical yet rigorous. Good engineers know that the models they use to describe, predict, and control the behavior of physical systems—from electrical circuits to load-bearing structures—are not true in any strong sense of the word. The long list of simplifying assumptions which precedes deriving governing equations dispels such illusions, suggesting that models, powerful though they are, are but approximations to some inscrutable underlying thing. But as we all know, engineering models are still very useful in spite of their reduction of the world's complexity. Though simplifications can be made on the basis of expedience, engineers learn that they do not have carte blanche.

THE CULMINATION OF A SUCCESSFUL ENGINEERING EDUCATION IS USEFUL WELL BEYOND THE DOMAINS OF TRADITIONAL ENGINEERING DISCIPLINES.

Nature, via physics, imposes clear constraints which must be respected. A model of a mass bobbing on a spring may depart from the real world by excluding air resistance, but it must conserve energy to make any physical sense. Engineering does a nice job of instilling in students a simultaneous humility about models, and a deep respect for fundamental constraints. We can simplify the model of the dynamics of the mass by treating it as a rigid body—as a point, by neglecting friction—but we cannot simplify away energy conservation.

So there are models, which are bespoke simplifications of the world, and there are constraints which any model must respect. Negotiating between customizable models and fundamental laws teaches engineers to be both practical and rigorous. My sense is that this approach to problem-solving—the culmination of a successful engineering education—is useful well beyond the domains of traditional engineering disciplines.

One such domain is critical thought about engineering's contributions to society. For most students and professionals, it is standard to balk at interrogating the problems that engineers are tasked with solving. There is an implicit idea of the division of labor here: society makes demands for products and services, and engineers respond to such demands with solutions of ever-increasing sophistication. For the most part, the problem statements coming from society are not viewed as the engineer's business.

Perhaps engineers become more philosophical when considering work in the defense industry, but the manufacture of private sector goods is usually viewed as a topic for which critical reflection is unnecessary. But life is increasingly technological, which means that technologies control the ways in which we interact with friends (social media), employment (remote work), politics (online news),

and how we spend our time (entertainment). Technology profoundly influences our experience of the world. Could something so ubiquitous honestly be viewed as neutral, as not in need of critical reflection? Engineers are comfortable thinking about the "how?" of technology production, but not the equally-important questions of "why?" or for "whom?" What might it look like to focus the rigorous and practical thought of engineering on these questions, as well?

After all, such questions about the purpose of engineering are just a small step away from the more familiar questions about the practice of engineering. If we doubt the division of labor story, it is clear that engineers should be comfortable with both sets of questions. Engineers must be willing and able to think more philosophically about how technologies shape the world, and why this matters, if they are to utilize their problem solving skills on the big questions of ethics and human flourishing.

Technology is not neutral, and the advent of large language models is an unequivocal recent example of how private sector companies can radically reorient the public's understanding of topics as diverse as education and human consciousness. In spite of their tremendous power, the technologists behind companies like OpenAl are not subject to any democratic electoral process. We might rely on the conviction that all technological development is good, or that market pressures will select for technologies which contribute positively to humanity, but, from the atomic bomb to social media's attention economy, there are many examples showing these hopes are often ill-founded. A third option is to encourage engineers-as bearers of the power to form the world through technology, and as members of society's de facto intellectual elite-to apply a fertile blend of rigor and practicality not just to their work, but also to reflections on the social consequences of their work.

ENGINEERS NEED TO APPLY
A BLEND OF RIGOR AND
PRACTICALITY NOT JUST
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REFLECTIONS ONITS SOCIAL
CONSEQUENCES.

In order to think about the social consequences of a technology, we need to know what "variables" to pay attention to. Though a model of what constitutes a good life—perhaps consisting in things like deep relationships, connection to place, community, enjoyment of beauty, agency—is necessarily an oversimplification, it is an important step in thinking normatively about technology. If one's goal is to steward technological development to promote such a vision of the good life, it is necessary to responsibly reckon with social, political and economic constraints. Capitalism is probably not going anywhere soon. The status quo has inertia, and companies are motivated by the bottom line.

The practicality of the engineering mindset hopefully disavows such utopian thinking. But with a model in hand, however coarse it may be, and an understanding of constraint, engineers are uniquely adept at describing and controlling systems. Given the power that technologists wield in today's world, it is increasingly important that they think as both scientists and humanists, asking simultaneously what is possible? and what is good?

An engineering education is most often seen as a reliable route to financial security, to intellectually stimulating work, or if you are an employer, to hiring an employee comfortable with challenges. But alongside these virtues, through pushing engineering thought into the territory of the humanities, we can view an engineering education as a useful tool for thinking about and acting on important social problems, even when they resist distillation into simple mathematical formulae.

Finding a way to steward technology for the good of society, as opposed to the good of a few corporation's shareholders, is one such problem. But there are obviously many others. I imagine a new kind of engineer, intellectually outfitted for the wickedly interdisciplinary problems of the 21st century. First and foremost, such an individual's loyalties need to be with the wellbeing of the people, whether that is the local community, nation, or the world. Fostering this loyalty is an area where the humanities succeed, and science tends to fail. In order to understand people and their needs, it is necessary to engage with stories and narrative, not just abstract and impersonal theories. It is also necessary to ask ethical, political, and philosophical questions which engineers are often uncomfortable with: What process or group determines the problems that engineers work on? Who gains and who loses from a product? What are the goals of technological innovation? What role does engineering play in actualizing human flourishing? What role should it play? For most, answers to these questions paint the picture of an often imperfect world. The injustice and irrationality such humanistic questions expose is the interdisciplinarilyengaged engineer's call to action-can the insights of engineering be used on these problems as well?

If the engineering thought process of model-building and constraint-identification is to be flexible enough to apply to complex social problems, it is insufficient for education to emphasize memorization and passive absorption of concepts. Engineers need to be educated as participants in the fundamentally creative process which builds up each discipline. The study of fluid mechanics revolves around an imaginative application of Newton's Second Law (F=ma) to each and every particle in a flow. It is frankly amazing that the same principle which describes collisions of billiard balls can be used to model turbulent vortices in the flow around an airplane wing.

This "zoomed-out" perspective—by which students can clearly distinguish between empirical physical laws, creative modeling choices, and self-evidently true consequences of mathematics—is needed if engineering insights are to be mapped onto other types of problems. This perspective helps recognize that science relies on human ingenuity and imagination as much as it does on the empirical

study of nature. Studying engineering models in this way gives insight into the fundamental movements of mind which transform confusion and complexity into clarity and predictability. Without this flexible and more philosophical view of the scientific process, students cannot see that the techniques they are learning could be used to make sense of any problem.

WE MAY START TO
HARNESS SOME OF ENGINEER'S
POWER TO MAKE PROGRESS ON
SOCIAL PROBLEMS, NOT JUST
TECHNICAL.

If engineers can be convinced through deeper study of the humanities to devote their efforts to the wellbeing of people and communities, and if they learn to see engineering fields as particularly clear-cut examples of a universal modeling process, then we may start to harness some of engineer's power to make progress on social problems, even when solutions are not technological. This is because the utility of thinking which is both practical and rigorous need not be limited to the development of technology. In fact, if we accept that basic, universal virtues—things like community, meaning, beauty, political/ religious freedom and personal autonomy-are what really matter, we should be more strict in demanding a clear account of how traditional technological innovation fosters these things. Of course, in a diverse, liberal society there is no reason to expect consensus around core values, and my list may be contested. But spirited, thoughtful, and selfconscious debate about values-and especially technology's role in realizing them-is a far-cry from the widespread political and philosophical illiteracy characteristic of a traditional engineering education.

Whether they know it or not, engineers accrue power as technology continues to infiltrate more areas of life. Perhaps the future may bring a more radical reimagining of technology's place in society, but the first step toward more humane technology is educating engineers to see their power, and to try to use it responsibly.

But what, exactly, does it mean to use this power responsibly? This is an abstract and open-ended question with answers seriously constrained by the realities of the current world. But engineers have extensively trained in balancing the rigors of abstract thought with practical constraints. I trust that we can find an answer to this question, if we go looking for it. But such pursuits may involve deviating from the beaten path of comfortable careers in industry and academia, and thinking about problems which lack the infrastructure of recognition that narrow technical questions enjoy. One can only hope that commitment to goals beyond personal comfort, innovation for its own sake, or corporate profit, are reward in themselves.

AI MADE MY MEDICINE?

AI & the changing healthcare field

or as long as humans have existed on this planet, we have have struggled against disease. Disease of all shapes and sizes, infections, disorders, syndromes; they have been with us since the first humans gathered together. Compounding their burden on our species as civilization grew and advanced. Yet even thousands of years past our first cities were built we still deal with the same diseases, the same ailments that killed our ancestors. Diseases like smallpox have been eradicated thanks to developments made within the past 100 years, others have stumped scientists for even basic treatments, and even more have treatments but no true cure. This is where the race for cures and treatments becomes relevant. For years, scientists have gone through the motions: painstakingly testing hypothesis after hypothesis, often yielding disappointing or dangerous results, only to start over again in the hunt for the cure to the most prolific and life altering diseases.

FOR THE MODERN RESEARCHER, THE OBJECTIVE IS TO UNDERSTAND

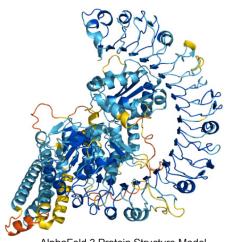
To understand disease, one must understand the underlying cellular mechanisms that truly affect the outcome of the disease. The primary suspects of disease are proteins. The building blocks of our body, the things that make our body run and function, are also the things that can easily tear that body back down. Protein dysfunction has its hand in diseases such as Alzheimer's, ALS, cancer, diabetes, necrotizing enterocolitis, sickle cell anemia, and many more. These diseases are life-altering diseases often with no hope of a cure, quality of life, or survival. Proteins are such an important part of us that even one in thousands not working can cause cascading effects that destroy someone's life.

For the modern researcher, the objective is to understand disease. This objective invariably involves improving our understanding of proteins and their functions on a molecular level. This guest for better understanding lead us to artificial intelligence. Al, while still in its early days, has proven itself to be a useful tool for enhancing research possibilities. Consider AlphaFold, which is an artificial intelligence-driven program that aims to unlock the secrets of unknown protein structures and confirmations that keep us from understanding disease more clearly. Developed by Google DeepMind, AlphaFold provides protein structures by analyzing amino acid sequences and comparing them to the known structures of similar proteins. This process is done through an incredible number of iterations and has been used to predict the structure of thousands of proteins that were formerly shrouded in mystery. In just a few years of development, so much possibility in the world of research and drug development has been unearthed. Proteins that were at one point invisible to the eyes of research have been modeled

Aidan Magruder

and become usable. That is the power of an AI like AlphaFold, and this power has been recognized, the most recent Nobel Prize winners in chemistry were the scientists who helped to develop AlphaFold. AlphaFold is the key to not only understanding proteins but to simulating their interactions.

The structures AlphaFold provides are only the beginning, their modeling power lies beyond structure and extends into the world of molecular dynamics. An oft-overlooked field in chemistry and biology, molecular dynamics is the study of movement of individual molecules in a system and the system as a whole. This field is almost entirely computational: taking classical dynamics and applying them to individual atoms in a system over time frames that would lapse within the bursting of a bubble. While it may seem insignificant given the timeframe, the application of these simulations in biological contexts are wide and significant. Molecular dynamics can be used to model the near-instantaneous refolding of a protein from one confirmation to another. They can help visualize prime mutation sites for protein stabilization or sites for protein cleavage. These simulations prove incredibly useful for streamlining the research process in the wet lab. A molecular dynamics simulation may help a scientist avoid following a research path that ends in no results and high costs. This is also where AlphaFold shows its ingenuity once again. The ability of scientists to simulate structures that were previously unknown or limited gives them a key insight into what kinds of treatments, mutations, or inhibitors make a difference in the protein's function. The structures AlphaFold provides are a key part in the newest generation of drug development. They are key to understanding new disease pathways and how to treat them; to understanding new antibodies and how to optimize them to vaccinate against the most prevalent diseases; to making the world of biological research a more efficient and effective machine. AlphaFold is not just an Al, it is not just a tool, it is a step forward towards a better world with healthier people.



AlphaFold 3 Protein Structure Model

HYDROGEN: STILL THE FUEL OF THE FUTURE?

The huff & puff of new alternative fuels

Peter Job

he debate is never-ending: will hydrogen play a significant role in a shift to low-carbon emitting fuels, or is it too costly and unwieldy to even consider using? Dreamers have labored to develop new methods of production, storage, and transportation for hydrogen gas, but without an entire overhaul of existing infrastructure, hydrogen will never gain any real traction as a fuel source. Yet, despite hydrogen naysayers, research hasn't stopped; progress and breakthroughs are still being made. So, are the dreamers' efforts in vain, or is there still room for hydrogen gas as a fuel of the future?

Advocates for hydrogen highlight the clean burning and energy storage capabilities of hydrogen. Hydrogen gas can be consumed in a fuel cell or burned as an alternative to natural gas, providing electricity or warmth with only water as a byproduct. Unlike wind and solar, hydrogen gas has the advantage of being available on an as-needed basis, since it can be stored or burned as energy demands fluctuate.

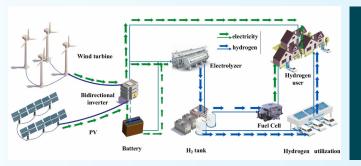
Hydrogen gas is no miracle fuel, however. Aside from a few instances where hydrogen has been found in geologies, hydrogen gas is not naturally occurring. Instead, hydrogen must be produced with chemical processes, which may have energy requirements, such as electrolysis, or may release carbon dioxide, such as steam reforming. Regardless of the method used to produce hydrogen, hydrogen production is costly, both financially and materially.

COUPLED WITH WIND & SOLAR, THE PROCESS TO PRODUCE HYDROGEN GAS WOULD BE CLEAN.

The chemistry of hydrogen presents additional challenges. Since hydrogen is the smallest element, it tends to seep into metals, especially at high temperatures, causing embrittlement and cracking. Still, progress has not halted, and researchers and engineers are still working on innovative ways to produce clean hydrogen, finding solutions to the challenges associated with hydrogen gas.

Methods like electrolysis can separate water into hydrogen and oxygen, but electrolysis requires more

electricity to split water than the resulting hydrogen can provide. Electrolysis is still a promising path forward, however. If coupled with wind and solar power, the entire process to produce hydrogen gas would be clean, with hydrogen acting as a "battery." Electrolysis can produce hydrogen in times of energy surplus to save it for times when there is a need for more power than wind and solar can provide.

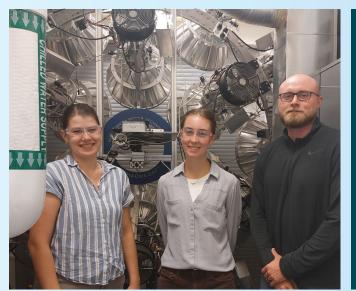


Wind-solar hybrid hydrogen production system: Enhancing wind-solar hybrid hydrogen production through multi-state electrolyzer management and complementary energy optimization

Team Weimer, a CU team of undergraduate and graduate students led by Professor Al Weimer, has done innovative research in hydrogen production methods. The team has introduced a method of splitting water into hydrogen gas and water with Solar Thermal Water Splitting (STWS), which used concentrated sunlight and its resulting high heats to split water into its component parts. This process is more efficient than electrolysis since it uses sunlight directly.

STWS is also more scalable since it can be scaled in three dimensions, unlike electrolysis which requires stacks of modules to produce larger quantities of hydrogen. STWS benefits more from economies of scale than electrolysis since it only requires larger volume, and thus can be manufactured in larger quantities for less of an increase in cost.

Team Weimer has made massive strides to further research in the field of splitting water. Al Weimer has been working on splitting water for the last 20 yea'rs and his team's work has been valuable in improving clean hydrogen production methods. With their continued research using the High Flux Solar Simulator (HFSS) to perform STWS, members of Team Weimer hope to provide hydrogen at a more affordable price point, even developing materials to provide high temperature thermal storage to reduce intermittency by allowing continuous hydrogen production even in cloud cover. Team Weimer is just one of many



Pictured are members of Team Weimer: Linnea Helenius, a second year PhD student with a BS in chemical engineering, Jessica Connell, a Junior in Chemical and Biological engineering, and Kent Warren, a research associate and formerly postdoctoral researcher in front of the HFSS.

Researchers like Team Weimer have made important breakthroughs, but the public has been reluctant to adopt hydrogen due to fears regarding its safety. Many people associate hydrogen with the Hindenburg going up in flames. Experts on hydrogen gas are adamant, however, that hydrogen is safe. Professor Al Weimer explains that "if you have a hydrogen leak, it goes straight up. It's not like gasoline where it sits on the ground heavier than air and we end up with a plume that might ignite." Hydrogen gas is safer than the flammable lithium-ion batteries in electric cars, and hydrogen is not particularly dangerous compared to other fuel sources.

Contributing to public reluctance, California is the only state that has attempted to use vehicles that use hydrogen as their fuel source, or hydrogen fuel-cell electric vehicles (FCEVs). Admittedly, the precedent California has set is not an optimistic one.

As of California's annual assessment of its hydrogen refueling network in December 2023, California had allocated nearly \$257 million for public hydrogen infrastructure, and only had sixty-six hydrogen stations to support fifteen thousand FCEVs on the road. Many stations had closed, including five stations closed by Shell, leaving just one station to serve the entire Sacramento area. The stations that are still running frequently go offline since they can only fuel a few vehicles before needing to repressurize, giving them an availability percentage of just sixty percent. This problem alone has given hydrogen a reputation for being unreliable.

The cost of hydrogen also poses a problem for FCEV drivers, ranging from \$24 to \$36 per kilogram. Even adjusting for the increased efficiency of FCEVs compared to gas powered vehicles, the cost of hydrogen is equivalent to paying as much as \$14.40 per gallon of gas. Filling up the tank can cost upwards of \$180. High costs make FCEVs an unattractive option, even for people living near hydrogen stations and wanting to reduce their carbon footprint.

California's best efforts to promote FCEVs seem to all be in vain. California has provided money to support operations and reduce prices paid by FCEV drivers, but without efforts to reduce the cost of production and improve the technology around dispensing hydrogen, the future of hydrogen fuel may be grim. If FCEVs can't be reliably fueled, the vehicle of the future becomes little more than an expensive lawn ornament.

Based on California's experience with hydrogen, many more people have lost confidence in hydrogen. They see hydrogen as unavailable, unreliable, and expensive. While that may be the case now, researchers, like Team Weimer, are working on methods to reduce the cost of producing hydrogen. Other difficulties that California faced, due to inadequate infrastructure, are preventable by ensuring that infrastructure is built up prior to relying on hydrogen as a fuel source.

EVEN SMALL PERCENTAGES OF HYDROGEN CAN MAKE A BIG DIFFERENCE IN TERMS OF CARBON EMISSIONS.

We can start by using our existing infrastructure. The Hyblend initiative is a project by the US Department of Energy aiming to introduce hydrogen in varying concentrations into existing natural gas pipelines, which would begin reducing emissions that would be produced from burning natural gas alone. There are currently three million miles of natural gas pipeline in the US versus the 1,600 miles of dedicated hydrogen pipeline, so being able to use existing infrastructure will increase the potential use of hydrogen gas exponentially.

Much more research needs to be done before hydrogen can safely be introduced into our gas pipelines, but there is evidence so far that converting natural gas pipelines to carry a blend of natural gas and up to 15% hydrogen may only require modest modifications. Even small percentages of hydrogen can make a big difference in terms of carbon emissions. In the future, even more hydrogen could be integrated into existing pipelines, since new pipelines are often made of fiber reinforced polymer, which can be used for hydrogen distribution.

The future of hydrogen could be very soon, but we can't rush it. The problems that California ran into when trying to push for hydrogen fueled cars are avoidable by ensuring that we have sufficient infrastructure improvements and cost reductions before we jump headfirst into 100% reliance on hydrogen gas. Hydrogen may not be a "quick fix" to energy demands and greenhouse gas emissions, but with sufficient research and preparation, hydrogen can play an important role in a greener future. Hydrogen may be the smallest element, but it has potential to do massive things – if we use it correctly.

THE FEDIVERSE & THE FUTURE OF SOCIAL CONNECTION

Social media, socialising, commercialisation, & connection

Danny Alemayehu

latform decay is the term social media users have used to describe the progression of social platforms over time. Cory Doctorow, the Electronic Frontier Foundation Special Advisor, writes about the degenerating state of the company sponsored platforms like X (formerly Twitter), Instagram, and Snapchat from originally serving as places of online connection to that of a delivery platform for advertisements straight to the consumer. For Doctrow, this degeneration is a given considering these platforms don't follow the two key principles he's identified for running a positive social platform:

- 1. The End to End Principle: Users should be given the content that they request and Creators should be able to give their content to those who want it easily.
- 2. The Right of Exit: Users should not be susceptible to any network effects when leaving a social platform. Specifically, the social platform should be interoperable with other platforms.

If what users see is decided entirely by the platform and they have to choose between remaining possibly connected to their friends or leaving a social platform then Doctorow argues this creates an environment not conducive to social connection but for user exploitation.

It's hard to imagine an alternative platform to these dominant tech giants, many have tried and failed. One prominent example is Vidme's failure to rival Youtube. Yet despite the odds of success in a saturated market, several groups of people have been working on building their own platforms based on the relatively recent ActivityPub standard developed by a web standards committee, the

World Wide Web Consortium, to formulate what users in the space colloquially call "The Fediverse."

What makes the Fediverse unique from traditional social platforms is the prioritization of social community. This is due to the fact that the Fediverse is hosted, developed, and moderated by enthusiastic hobbyists who are passionate about creating safer and better online communities. Practically, this means that any user/group is capable of running their own miniature social space complete with its own set of rules, allowing for not only a wide variety of spaces to suit any user's needs but the ability for the user to satisfy their own need for a social space and the End-to-End Principle themselves. Additionally, Fediverse projects are predominantly open source, allowing anyone to modify, audit, and contribute to these projects such that their ideas influence the growth and development of the Fediverse.

But by far the biggest selling point of the Fediverse is the ActivityPub protocol which allows the different Fediverse platforms to communicate/federate with each other and migrate from platform to platform with relative ease and uphold the Right To Exit. For example, Mastodon, an alternative to X (formerly Twitter) provides the ability to "migrate" between instances (social spaces), allowing users to retain their followers and who they're following in any social space. If an instance goes down due to the volatility of self-hosting, or if some platform is allowing inadequate behavior, users are able to migrate to other platforms instead without losing any of their connections on any previous one.

Of course, this trending space would not go unnoticed by tech companies where now many of them are interested in bringing their dominance to the Fediverse as well. Meta's recent product Threads, another alternative to X (formerly Twitter), integrates the ActivityPub protocol. However, many concerns have been levied about the true intentions of these companies considering their history of embracing new competing technologies, extending them

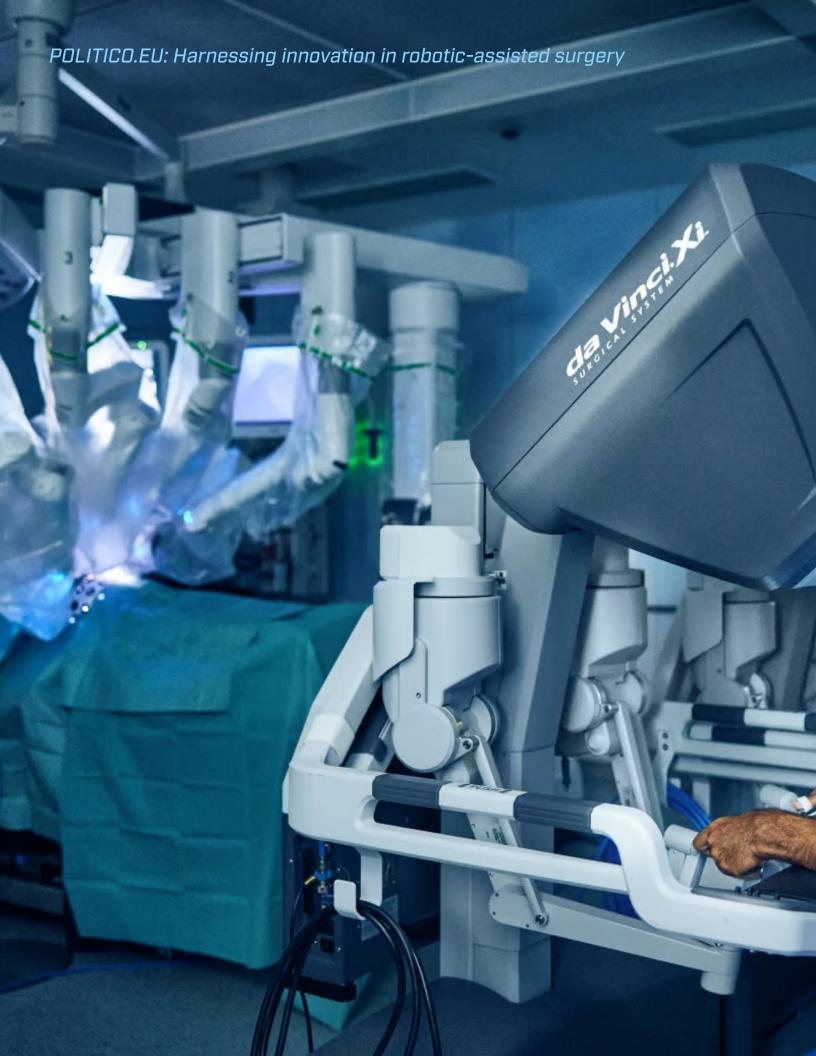




to the point that smaller competitors remain incompatible with the dominant platform, and then extinguishing these protocols such that the competition becomes a nonexistent threat to their market space. But part of what makes the Fediverse resilient is its ability to select with who and who not to interact with, including Big Tech should they prove to possess hostile intentions.

Even if the Fediverse doesn't last, it's worth considering in what ways our platforms and the places we spend so much time on can be better for us. The strength

of network effects on big platforms often make them seem like the only possible option for remaining connected but it's worthwhile to reflect on why these network effects are so prevalent in the first place — a primary method of retaining user attention and driving platform advertising revenue. As a community driven, owned, and developed platform, The Fediverse exemplifies a way for our social platforms to progress that is independent of corporate sponsorship and profit motivations and dependent on community interest, and the people who actually utilize these platforms.



ROBOTS IN THE O.R.

Al & the changing healthcare field

hen we consider causes of surgical

complications, we rarely think about the comfort of the surgeons themselves. However, this is an important issue to consider to improve positive surgical outcomes. Surgeries lasting 3 or more hours generate the risk of surgeon fatigue, leading to increased probability of errors. A study by Cheng et. al (2018) found that "the likelihood of complications increases significantly with prolonged operative duration, approximately doubling with operative time thresholds exceeding 2 or more hours." And this problem isn't rare: over 80% of surgeons have faced difficulties due to their stance during lengthy procedures (Schlussel et. al (2019)). While this may not seem like a major issue, any discomfort faced by surgeons can translate to their patients in the form of detrimental surgical complications. This ergonomical condition is worsened during laparoscopic procedures, which are minimally invasive procedures that allow surgeons to perform surgeries through a small incision. In open surgical procedures, surgeons have a nearly unlimited range of motion. However, laparoscopic procedures

The ergonomic conditions are worsened because of the surgeon's posture. Laparoscopic instruments are passed through a trocar, which is a tube that is inserted in the incision for laparoscopic surgeries. This prevents the surgeon from repositioning themselves at an optimal location leading to dangerous working angles for the doctor. Additionally, surgeons exert large forces when navigating the laparoscopic instruments through patients with thicker abdominal walls.

greatly limit the surgeon's freedom of motion. Therefore, a

during laparoscopic procedures. According to Schlussel et.

al (2019), it is reported that surgeons need to exert 6 times

instruments used in open surgeries. Surgeons grip surgical

instruments more tightly, leading to fatigue in their hands.

as much force to grip a laparoscopic instrument compared to

surgeon has to perform more skillful and intricate maneuvers

Laparoscopic procedures also cause mental fatigue because of how unintuitive they are. The trocars which the laparoscopic instruments are navigated through create a "paradoxical fulcrum effect". If the surgeon moved their hand to the left, the instrument would move to the right due to the fulcrum. The surgeon has to be exceptionally aware of this reversal and work with this constraint. Additionally, in laparoscopic surgeries, the surgeon can only see what

is shown by the laparoscopic camera. Therefore, the operation is performed using 2-D snapshots of the patient's body. The loss of depth perception and spatial awareness also makes the procedure more challenging.

An innovation that is becoming increasingly more widespread promises a solution. Robotic Assisted Surgeries (RAS) are operations performed by a surgeon, but aided by robotic devices. RAS systems consist of robotic arms

Shreeya Roy

with surgical equipment, a console operated by the surgeon, and a vision system that provides a 3D view. Surgeons operate the robotic arms through a console.

R.A.S. SYSTEMS HAVE ROBOTIC ARMS, SURGEON'S CONSOLE, & 3D VISION SYSTEM.

Robotic assisted surgeries come with their own pros and cons. They allow surgeons to perform the operation seated at a console, which resolves ergonomic complications due to lengthy procedures. The robotic arms also have a high degree of precision, which allows surgeons to make complicated maneuvers with ease. The surgeon can also visualize the surgical stage more effectively through a combination of high definition images. The surgeon is able to see the surgical stage in 3-D instead of 2-D, improving depth perception.

However, there are also potential pitfalls to robotic surgeries. Surgeons may require additional training to learn how to use the equipment. The cost of a robotic surgery system is also extensive, with a complete unit costing around 1.5 to 2 million dollars (not including servicing and repair).

Dr. Jeffrey Leftwich and Dr. Dale Varner, general surgeons, had unique insights to share on this issue. While they agree that robotic surgical systems improve range of motion and visualization, one issue is the cost.

While the cost of a system is initially paid for by the hospital, the equipment drives up the cost of surgeries, ultimately affecting patients and insurance payers. Surgeons also lose tactile feedback when working with robotic surgical systems. The pressure surgeons feel in traditional surgeries offers valuable feedback, but this information is lost when introducing a RAS into a surgery. Dr. Leftwich and Dr. Varner expect robot assisted surgeries to become more prevalent in the future since the "horse is already out of the barn". Overall, robotic assisted surgeries have some benefits, but their disadvantages shouldn't be ignored. As we forge ahead with this advanced technology, we have to be mindful about the people who are impacted by this innovation.



Robot Assisted High-Precision Surgery | MIT Technology Review

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