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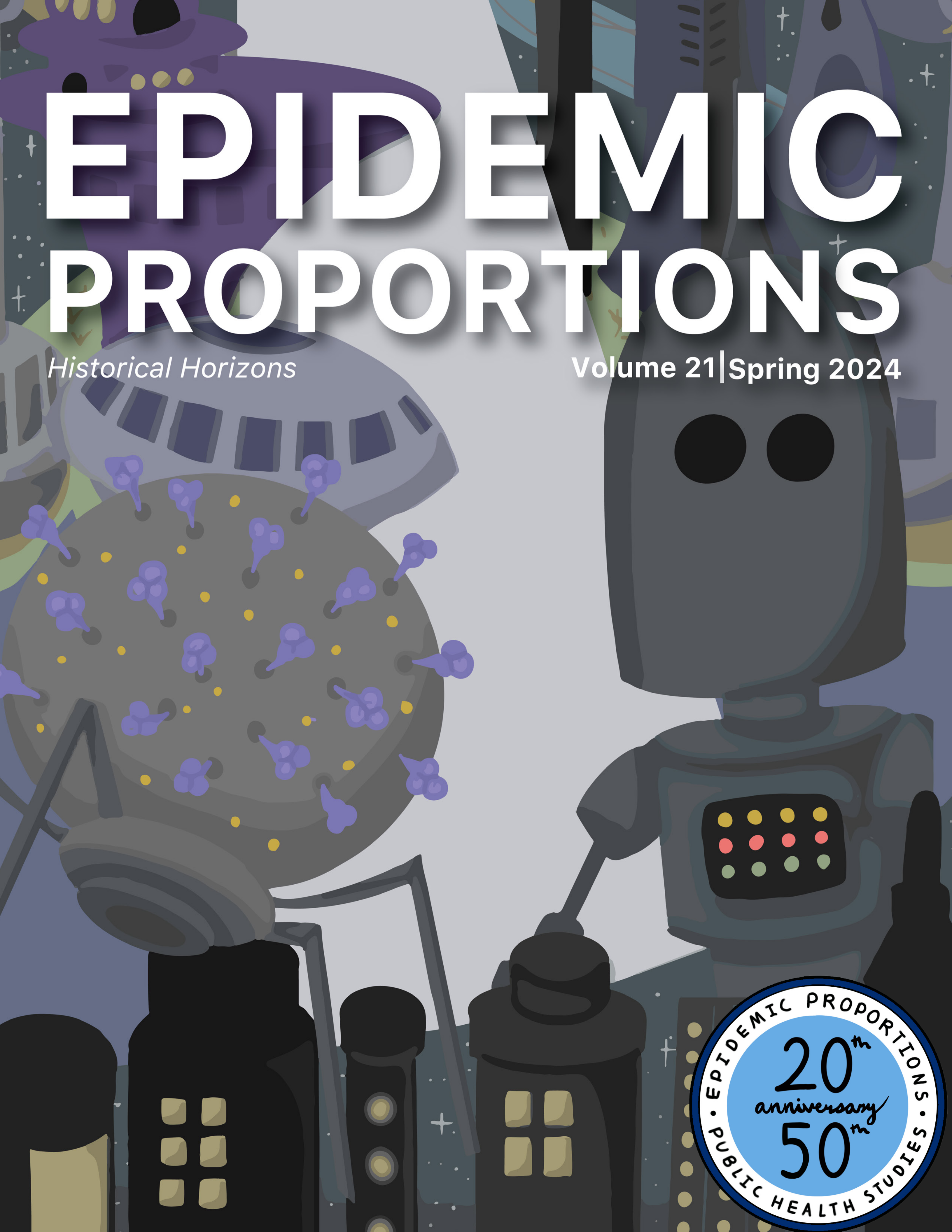

A Gift of Fire: Guiding the AI-driven Healthcare Revolution for a More Equitable Future

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Summary

This editorial examines the role of artificial intelligence (AI) in healthcare, a field where it has become a significant driving force. It establishes AI as a "gift of fire" with the potential to create a safer, more equitable future for healthcare but also become a source of danger. The editorial argues for a balanced understanding of AI's role in healthcare and emphasizes the need for informed public discourse and responsible technology use.

A Gift of Fire: Guiding the AI-driven Healthcare Revolution for a More Equitable Future

As a staff editor for the SciTech section of The News-Letter, I have had the good fortune of attending a series of guest lectures and interviewing graduate students and professors from various labs. Although I anticipated hearing distinct perspectives from various engineering disciplines, I was struck by a recurring theme across every lecture and interview – the pervasive influence of Artificial Intelligence (AI). Contrary to the common perception of AI as an immature technology primarily focused on text generation and mimicking human interactions, I discovered that AI has already revolutionized the landscape of research. It was particularly intriguing to discover its extensive role in state-of-the-art healthcare technology.

This realization marked a pivotal moment where my interests in computer science and healthcare intersected. Having always been drawn to both fields, this was the first time that I truly pondered the implication of such a convergence. As I dived deeper, I gained a profound understanding of AI's role in the healthcare revolution and now present the following insights:

The Dual Nature of AI in Healthcare

The intersection of public health and technology witnessed a pivotal moment during the COVID-19 pandemic when AI played a transformative role in healthcare. With platforms such as COVID-Net for chest X-ray analysis and PathAI for pathology analysis, the impact of AI in enhancing healthcare capabilities during critical periods became clear.[1,2,3] Yet, the healthcare community is divided over its implications. In an interview with the Sydney Morning Herald and The Age, Dr. Anthony Fauci discussed the perceived "dangers of artificial intelligence," believing that if people "look at it under a controlled situation, there are many advantages for artificial intelligence in every aspect of medicine and health".[4] Others, however, remain skeptical, believing that while AI can provide general insights and recommendations, it can never replace the nuanced judgment and empathy that experienced doctors bring to patient care.[5]

I see AI as a "gift of fire"– a powerful tool with the potential to bring a safer and more equitable future, yet a hazard if used irresponsibly. Its applications range from preventative healthcare to disease prediction, medical diagnosis, and robot-assisted surgeries. However, this advancement is not without its challenges, which include concerns about data security and accessibility. To minimize consequences, the public should be informed of both the advantages and disadvantages of medical AI and should approach this technology with responsible guidance and conscience.

AI in Preventive Healthcare

During my first bioinformatics course in high school, I was introduced to sequencing techniques such as Needleman-Wunsch and Smith-Waterman algorithms, which are classical dynamic programming algorithms that compare and identify similarities and differences between genetic sequences. By comparing the patient's DNA with standard human genomes, doctors can pinpoint genetic variations that could be associated with genomic-based diseases. This understanding is crucial in developing tailored treatments and preventive healthcare strategies, potentially revolutionizing how we manage and prevent illnesses at the genetic core.[6]

> **"Deep learning grapples with the complexity and "noise" inherent in real-world data."**

When I arrived at the Johns Hopkins Homewood campus and interacted with computational biology labs, I discovered an increase in alternative use of AI, particularly deep learning, in bioinformatics. Unlike traditional methods that strip away the contexts of problems and simplify them into clear-cut models, deep learning grapples with the complexity and "noise" inherent in real-world data, offering a more nuanced approach to problem-solving.

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Splice site recognition, one of the key research areas in bioinformatics, has brought this approach to light. The purpose of splice site recognition is to identify junctions of alternative RNA splicing, which is a mechanism that splices exons and introns in different combinations for gene regulation and expression. Traditionally, scientists found these splice sites by aligning sequences directly onto a reference genome. However, these predictions can be inaccurate due to misalignments and "noises" in data. To enhance precision, researchers have turned to machine-learning-based methods that are trained with data from known splice sites in specific species. It has been shown that these newer methods significantly reduce the false positive rate and can achieve an accuracy as high as 96%.[7] This enhanced precision has great implications for the detection and prevention of genetic diseases, as a more accurate understanding of genetic variations and mutations could provide methods of intervention for individuals at risk of specific genetic disorders.

Still, this advancement is predominantly driven by large medical companies, making this software often expensive and close-source. In response, academic research communities, like those at Hopkins, are pioneering open-source alternatives, democratizing access to these cutting-edge AI analysis tools. This movement improves accessibility and drives advancement in cost-effective solutions that make healthcare more affordable.

Genomic-based analysis has not been widely adopted as the current diagnostic framework focuses more on therapeutic interventions rather than preventative care. There is a pressing need to shift this paradigm by directing more research and resources toward preventative measures and inclusive medical practices. By training AI models that cater to individual patient profiles, we can advance personalized healthcare and ultimately move toward a more equitable and effective healthcare system that benefits all.

However, an increased reliance on AI in medical diagnostics and prevention also poses several challenges. In recent years, security regarding health records and personal data has emerged as a major concern. As more and more hospitals and clinics transition from physical paperwork to electronic records, even well-guarded systems, like those of major healthcare providers, are not immune to data breaches. Elevance Health Inc., one of the largest health insurance providers, experienced a data breach back in February 2023, which affected over 3 million patients.[8] As research in genomics expands rapidly and the amount of genomic data collected exponentiates, safeguarding sensitive personal healthcare information will become even more important. Although regulatory bodies and governments are beginning to address this issue, the measures in place are still inadequate given the pace and scale of current technological advancements.[9]

AI in Patient Monitoring and Clinical Decision-Making

The integration of patient-reported outcomes (PROs) into healthcare routines, powered by AI, offers a new avenue for predicting disease progression. PROs are data provided directly by patients throughout their healthcare journey that offer insights into their internal experiences.[10] By analyzing self-reported data, AI models are adept at detecting changes in a patient's condition, such as cancer progression, by comparing with a predefined criteria. When anomalies are detected, AI systems can promptly send an alert email to physicians and patients.

PRO's effectiveness in monitoring patient conditions has already been demonstrated in clinical studies.[11] Compared to using traditional checkups such as periodic scans, like CT and PET, and blood tests to monitor patient health and adjust treatment plans, AI's real-time data analysis based on PROs has been shown to alert physicians to changes in a patient's condition much sooner. This can potentially improve patient outcomes by enabling more timely adjustments to treatment strategies and extend the median overall survival of cancer patients beyond that of traditional surveillance.

In 2012, the American Society of Clinical Oncology implemented an AI-integrated platform called CancerLinQ that collects and analyzes cancer patient data, including PROs.[12] By leveraging AI and machine learning, CancerLinQ identifies patterns across datasets so that oncologists can make more informed decisions on treatment options based on real-world evidence and further develop personalized treatment plans.

Another project initiated by the Memorial Sloan Kettering Cancer Center is a remote monitoring app based on AI and PROs. In a 2020 article published in the Journal of Clinical Oncology, they found that this approach allowed earlier detection of complications and disease progression in cancer patients compared to traditional follow-up methods.[13] Ultimately, this AI-remote monitoring method significantly improved survival rates and reduced hospitalizations by enabling timely interventions based on real-time patient-reported data.

There are, however, several challenges in the full adoption of PROs. The primary concern is the accuracy and reliability of self-reported data, which may hinder accuracy in the predictive model trained on those data. A lack of standardized PRO measures and interoperability standards also hinders data sharing and integration across different healthcare systems. To promote their use, standardized PRO measures, education of healthcare professionals on the benefits of PROs, and the development of user-friendly and secure interfaces for data sharing should be implemented in the future. The efforts will undoubtedly require the coordinated action of medical professionals, policymakers, and patients.

AI in Medical Diagnosis

AI's role in medical diagnosis is increasingly evident. AI's data-driven decision-making process currently allows for accurate and real-time medical image analysis and provides healthcare professionals with valuable insights beyond basic statistical analyses.

> **“AI in medical imaging is evolving to replicate the concept of “collective insights”.”**

Medtronic, a billion-dollar biotech company, has pioneered the use of AI for early cancer screening with its GI Genius intelligent endoscopy module.[14] With greater accuracy in identifying seizures, a major symptom of colon cancer, the technology scans every frame in real time and locates up to 50% more cases of colon cancer.

Beyond individual diagnoses, AI in medical imaging is evolving to replicate the concept of "collective insights" for different medical image modalities, such as CT scans, ultrasounds, and MRI.[15] Collaborative analysis, typically consisting of expert panels, yields more diverse accurate diagnoses than the judgment of a single expert. AI can now emulate this decision-making process by generating alternative explanations to a single set of imaging data or consolidating earlier findings of doctors.

Besides mimicking the holistic evaluation of human expertise, this method has the potential to democratize healthcare provision, particularly benefiting remote or underserved areas where medical resources are limited. By granting access to the expertise contained within large datasets, patients in areas where on-site medical professionals are scarce can now access the same level of medical guidance as those in more developed regions. Through AI-driven diagnosis platforms, patients could receive advice, diagnoses, and treatment plans from anywhere and be directed to appropriate healthcare resources if needed. These platforms, once widely adopted, could also optimize resource allocation. By analyzing data patterns, healthcare providers could efficiently allocate medical staff and resources in areas most in need and manage drug inventory, thereby improving overall healthcare accessibility.

Still, due to a lack of available data to train machine learning models due to patient confidentiality,[15] the deployment of AI in medical applications is slower when compared to other healthcare fields. Collaborations focusing on collecting and sharing data ethically and securely and between healthcare institutions and researchers should be incentivized to fuel the development of AI models.

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AI in Robot-Assisted Surgery (RAS)

Robot-assisted surgery (RAS) is undergoing significant transformations with the integration of AI, a field where my previous research at Hopkins's medical robotics lab provided first-hand insights into this evolution. RAS offers numerous advantages over traditional surgery, such as accuracy, reduced risk of complications, and shorter recovery times.[16] However, the lack of haptic feedback when controlling a robotic instrument, which is inherent in traditional surgery, could be disorienting for surgeons and limit their abilities to perform delicate tasks. To resolve this issue, deep learning models are being developed to simulate tactile sensations, providing a more intuitive and responsive surgical experience.[17]

Currently, full teleoperation is employed in RAS due to FDA regulations that ensure every aspect of the surgery depends on the surgeon's control. Recent research in medical robotics has focused on enabling systems to perform basic surgical tasks autonomously. This could significantly enhance the efficiency of RAS, reduce the cognitive load on surgeons and allow for more complex surgical procedures to be performed with robotic assistance.[18] AI could provide the platform to assist in complex tasks like reconstructing the shape of blood clots, planning optimal surgical paths, and providing real-time guidance to the medical team, thereby improving the quality of care and surgical experience for patients.

Concerns arise about the accountability of software failures when using AI in life-critical equipment. Having conducted research in the field of RAS, I believe that stakeholders will need to grapple with the tradeoffs between innovation and safety, especially as many novel concepts are still at a stage of experimentation. The current FDA approval process, often taking months to years, is intended to keep unsafe products off the market to protect the public, who may have insufficient understanding of potential risks. However, this arduous process can also disincentivize companies from inventing new technologies that are life-enriching and even lifesaving.

Accessibility remains a pressing issue. In a cross-sectional study that analyzed the proportion of outpatient procedures with robotic assistance across facility types and patient populations, it was found that the proportion of visits with robotic assistance was higher for patients with private insurance and visiting private for-profit hospitals than the rest.[19] As RAS remains relatively uncommon in ambulatory surgery settings as well, the integration of AI into RAS will likely alleviate this phenomenon by reducing the anticipated increase in expense that will leave underserved communities with less access. To further bridge this gap, existing insurance coverage should be expanded to include RAS to benefit patients beyond those who can afford private insurance and visit for-profit hospitals.

Challenges and Caveats

The rise of AI in healthcare brings several challenges. One study has shown that intraoperative video monitoring may potentially undermine a surgeon's undertaking when doctors who disagree with AI recommendations could face legal consequences if proven wrong in retrospect.[5] Additionally, concerns surround the accuracy of medical advice from AI, which remains largely unverified due to the "black box" nature of neural networks that lack a transparent understanding of how AI systems arrive at their decisions.[20] To address this challenge, researchers are working on developing "explainable AI" to enhance the interpretability of AI models.

Personally, the implication of medical AI has evoked mixed feelings. I experienced an underlying apprehension about a future where doctors, overshadowed by AI, are no longer needed. Yet my computer science background ignites enthusiasm with each advancement in AI technology. This complex interplay between technological and traditional healthcare is also prevalent in society.

It's becoming clear that a future dominated solely by AI in healthcare is unlikely, and that total reliance on AI is often disastrous. Baidu, China's largest search engine, was accused of misleading a college student into following the wrong cancer treatment, ultimately causing his death.[21] As it turned out, the guidance that the student followed appeared first in his Internet search not because it was the best medical option; rather, it was because the sponsor had paid for it. This poses similar questions as to whether AI should be accepted in lieu of human judgment. Protecting public interests as well as ensuring the credibility of information retrieved to obtain legitimate results in life-critical situations is paramount. Indeed, when it comes to medical applications, AI works best alongside humans, not in place of humans.

Conclusion

The dual nature of AI in healthcare presents both opportunities and challenges. It has the potential to revolutionize patient care, improve accessibility, and bridge public health disparities. Nonetheless, responsible guidance is essential to realize its full potential. Collaboration between policymakers, healthcare professionals, and technology experts is crucial to drive ongoing research and to develop dedicated policy support.

As technology continues to evolve, the pressing question becomes not, “can we do it?” but rather, “should we do it?” The answer to this “gift of fire” of AI lies in discovering the delicate balance between technology and human expertise to ensure the best possible care for patients.

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Author Biography

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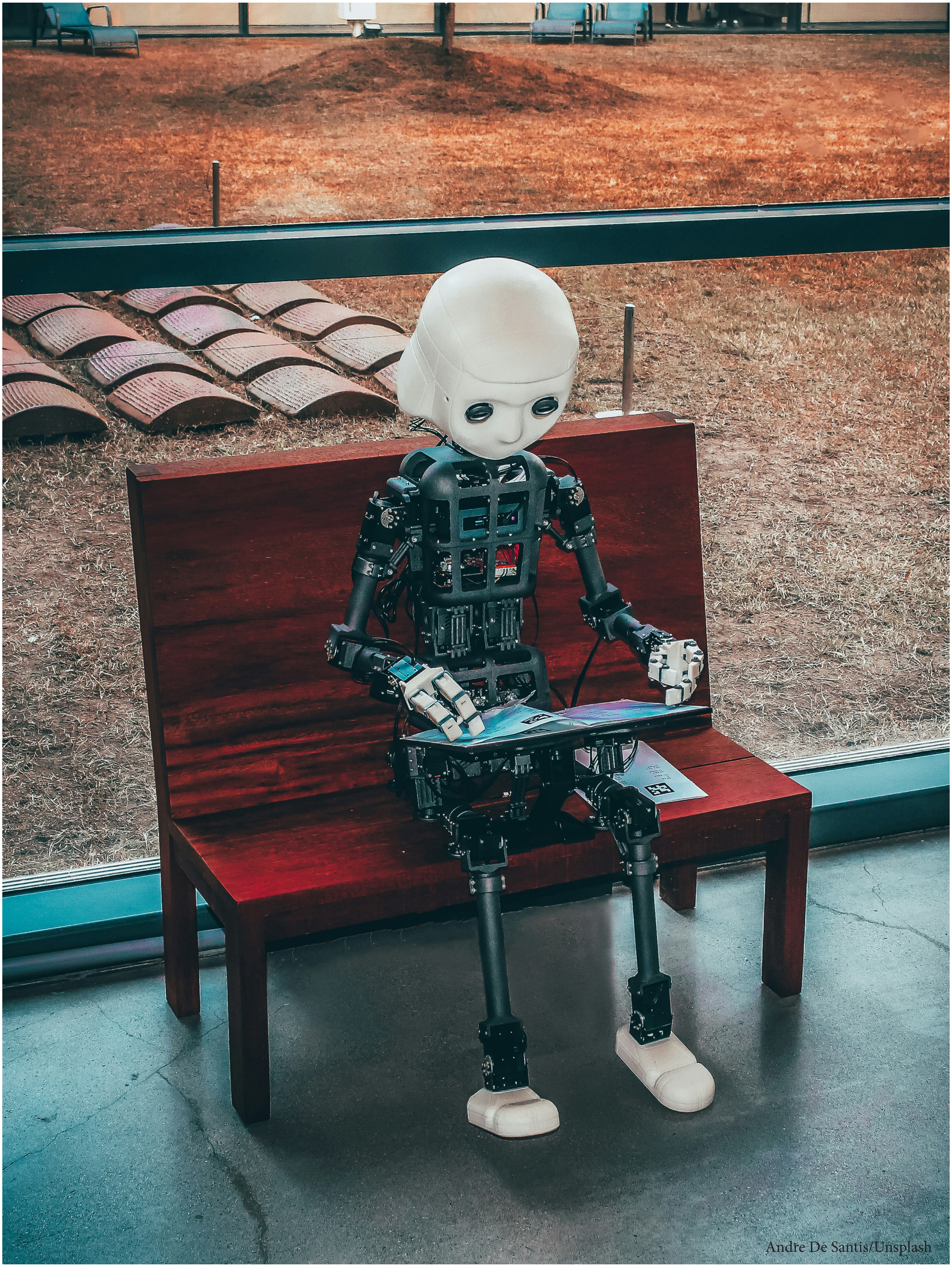
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