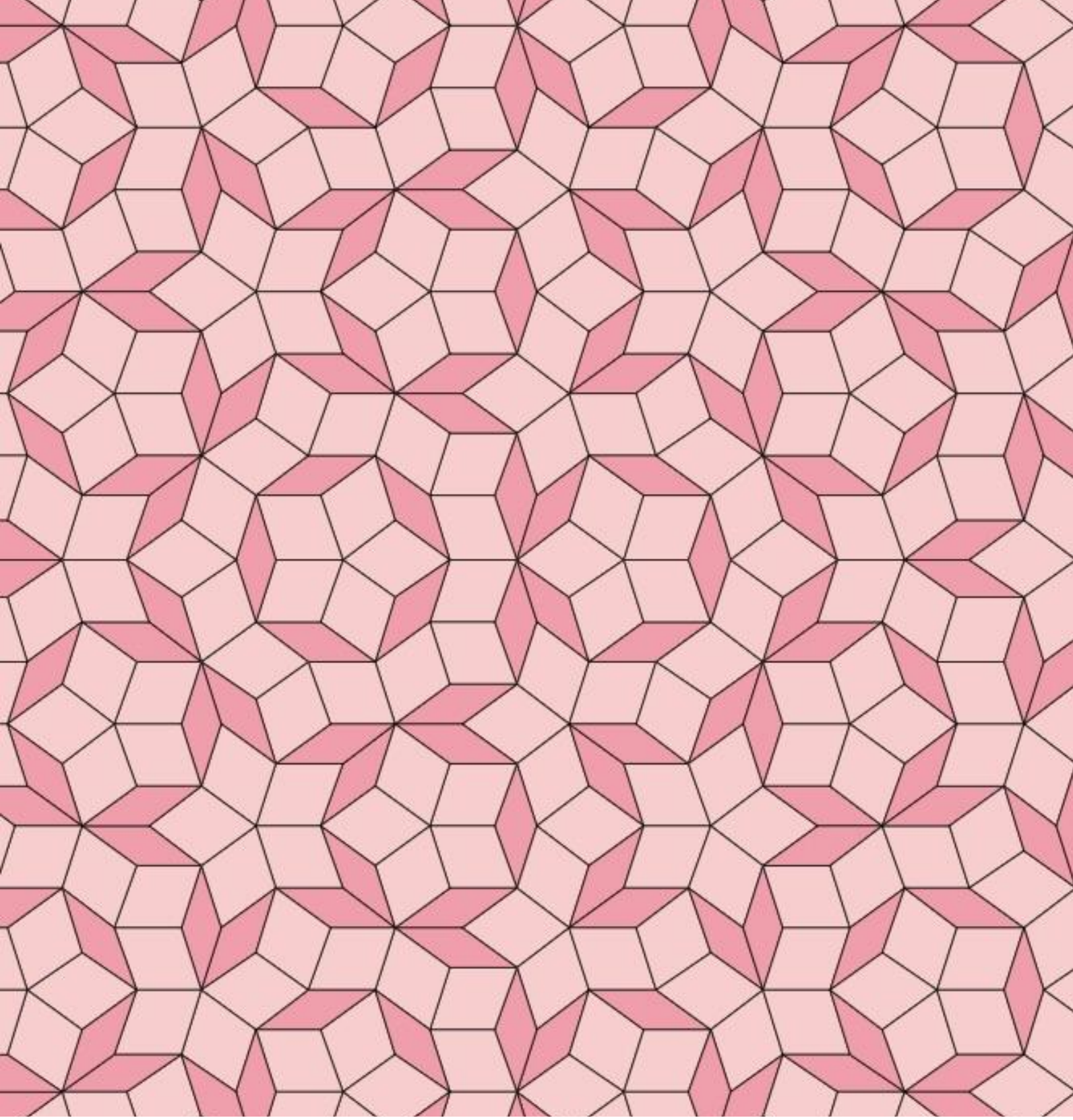

THE PENROSE MAGAZINE

Science, Technology, Engineering, Maths

Issue 3, 14 Mar 2025

Welcome to the Third Issue of the Penrose Magazine!

Penrose is our Computer Science, Engineering and Physics magazine where we hope to establish a community of young people who are passionate about STEM and want to share with their peers and further their knowledge beyond their curriculum. This installment of the magazine centers around the theme 'STEM in Media' Students have researched a variety of topics from the reality of flashbangs in gaming, to the effect of time travel on the universe. We hope to continue fostering an environment where people are encouraged to push themselves to create meaningful work and support each other to grow.

Thank you so much for choosing to read Penrose and we hope you enjoy.

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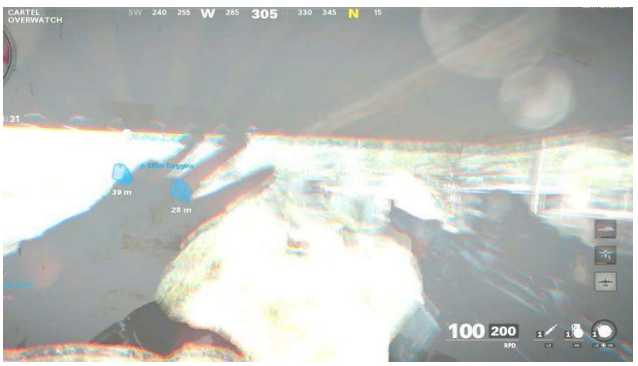
The Reality of Flashbangs in Gaming

Call of Duty: Mobile is a popular first-person shooter game. One of the distinct features of the game is its realistic maps and weapons [1]. Many of the game's maps are inspired by real-world locations. Likewise, many of the game's weapons are based on actual military weapons. A short survey confirmed that one of the most recognised weapons in the game is the "flashbang grenade", otherwise known as a stun grenade [2]. Given its existence in real life, how do the mechanics and effects of flashbangs in *Call of Duty: Mobile* compare with real-world stun grenades?

Flashbang Grenades in Call of Duty: Mobile

Call of Duty: Mobile offers several types of tactical equipment. This equipment does not eliminate the enemy, but will disrupt them and offer the team a tactical advantage [3]. One of the most popular tactical weapons is the "flashbang". This weapon temporarily blinds and slightly deafens the enemy, similar to the effects of a stun grenade in real life.



In the game, flashbang grenades are thrown into the air, and when they hit the ground, a detonation is triggered. This is followed by a loud "bang" and a bright flash. Any player within the radius of the grenade at this point will experience a tinnitus effect for a few seconds, which is a constant ringing sound in the ears. The movement of the players is also restricted. While they can walk and run, they cannot sprint [4].

Precise data on the effects of deploying a flashbang grenade was gathered. Several in-game scenarios were tested and screen-recorded at 60 frames per second (fps). These recordings were imported into Video Star, a mobile application that allows for frame-by-frame video analysis. The videos were analysed one frame at a time, and values such as start and end times were recorded for specific events that occurred. The duration in frames was converted to seconds using a simple formula:

$$Seconds = \frac{Frames}{FPS}$$

The grenade takes 3.117 seconds to hit the ground after being thrown and detonates with a flash and a loud "bang" 2.567 seconds after hitting the ground. This is the delay. The flash appears as a full white screen for 1 second and gradually fades over 2.13 seconds. The loud "bang" lasts 1.93 seconds, and is at its loudest for 1.45 seconds. However, the tinnitus effect lasts 11.617 seconds after the initial detonation. The player's movements are slower and

restricted for 4.483 seconds after the grenade went off. Players facing away from the grenade, or those outside its radius, only experience a slightly softer “bang” for 1.93 seconds.

The Real M84 Stun Grenade

A stun grenade is a non-lethal, explosive device that combines sound, light, and shockwaves to temporarily disorient people [5]. In real life, its effects are more extreme and typically last longer, ranging from a few seconds to several minutes, depending on the circumstances.

After hitting the ground, there is a delay of about 1.5 seconds before the grenade explodes [6]. While the device is non-lethal, it causes great pain and discomfort upon detonation. The loud “bang” produces a sound of over 170 decibels (dB), which exceeds the pain threshold of human hearing, which is only at about 130 dB [7, 8]. This loud disturbance causes pain as well as tinnitus in anyone in range. The flash emitted by the grenade is measured at about 7 million candela (cd) [9]. A standard 40-watt (W) lightbulb is approximately 245 cd [10, 11].

In-Game Flashbangs versus Real World Stun Grenades

There are several notable similarities between the flashbangs in *Call of Duty: Mobile* and the stun grenades in the real world. These include the blinding flash, the loud bang, the tinnitus, and the restricted movement. While these effects are underplayed in the game, the representation is still present. *Call of Duty: Mobile* is a competitive game focused on entertainment rather than realism. In real life, a person exposed to a stun grenade’s detonation would typically have their vision return to normal after about 10 minutes on average[5]. However, in the game, the vision returns to normal after 2.13 seconds. For reasons such as gameplay pacing, several of the effects are simplified, while some effects, such as the psychological effect, are not represented in the game. Despite these changes, players are still gaining a basic understanding of flashbang grenades and their effects on humans.

In conclusion, *Call of Duty: Mobile* effectively represents a stun grenade and its impact on humans. The main components of a stun grenade are portrayed in a manner that allows players to gain knowledge about how they work and how they would affect a human in real life. The science of stun grenades is well integrated into the game and shines light on the potential for games to provide valuable knowledge of STEM topics intuitively.

By Mandisa Jili ‘26

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Pioneering Virtual Reality Technology: The Virtual Director and CAVE

Human knowledge is increasing at a rapid rate, yet the complicated concepts that have emerged because of this are still unintelligible to the average person. Complex ideas within science are challenging to imagine and understand at a deeper level, causing the public to turn away from learning such topics. To counteract this problem, visual storytelling was introduced as a way to entice people to learn theories that seem daunting to approach in an easier manner than they would through traditional learning. This inspired Donna Cox to build the Visual Director to help create visual narratives from data.

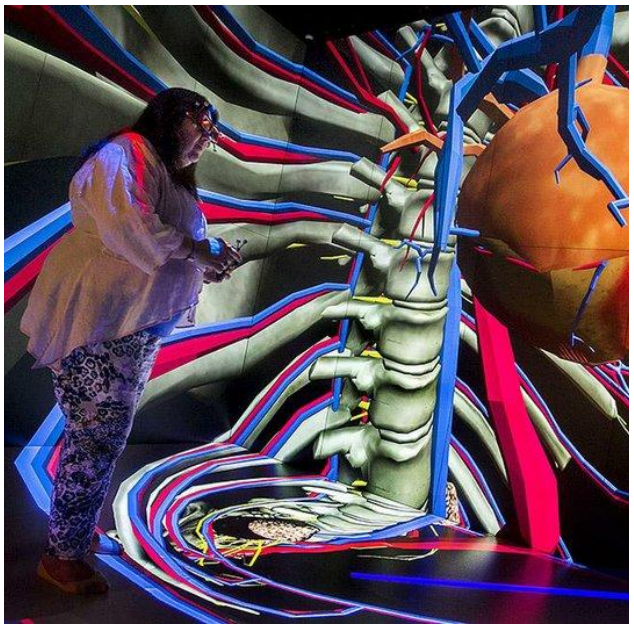
In order to achieve visual storytelling, large datasets need to be presented in a way an audience can understand. This, however, is a challenge in itself; Scientific studies often require vast amounts of research and explanation, leading many of them to be represented by Big Data- large amounts of data from a variety of different data types, with new data being created constantly. In order to understand these extensive amounts of data, they need to be processed and sorted [1]. Traditional systems structure data by its data types and relationships before processing it, using a data processing model known as Schema-on-write. If the data does not meet prerequisites, it cannot be processed [2].

The nature of big data renders traditional data analytics impractical. The solution to this is through using a different type of processing model-Schema-on-read. This model allows data to be processed without having to meet a predetermined set of rules, allowing it to be structured as it is read instead of beforehand [3]. Interpreting data is a necessary step in order to visualize data effectively; however, even when these datasets are processed, they still are unlikely to be understood by the general public. This is the issue that scientist and artist, Donna Cox, was able to overcome.

Originally from Oklahoma City, Donna Cox became passionate about art and sciences from a young age. In 1967 she became the first person in her family to achieve a high school diploma before moving to Denver in pursuit of exploring art further. Soon after, she decided to attend the University of Wisconsin (UW), obtaining a Bachelor of Art and a Master of Fine Arts in 1985. In the same year, Cox joined the National Center for Supercomputing Applications (NCSA) to work with them on early data visualization

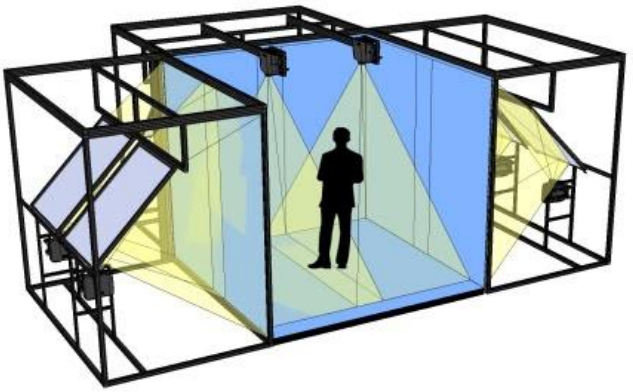
[4]. It was here that the Visual Director was conceptualized and a new era of data driven CGI began.

The Virtual Director is the earliest example of a Virtual Reality (VR) camera-choreographed system, specifically created for scientific visualizations. The visuals produced vary from static images to time-lapse and dynamic visuals. These visuals are generated by mapping processed data (atmospheric readings, particle speeds, etc) to visual elements (points, lines, curves, etc) by converting numerical values into their graphical representations [5]. This allowed a viewer to be guided through scientific discoveries in a manner that was uncommon at the time. Fundamentally, the Virtual Director is a software framework that operates as a choreography and navigation system. However, in order for its visualizations to be fully appreciated, it needs to exist in a VR environment. This led to the use of Carolina Cruz-Neira's work: Cave Automatic Virtual Environment (CAVE) [5].



Carolina Cruz-Neira was originally born in Venezuela and obtained a degree in 1987. She then moved to the U.S where she attended the University of Illinois, obtaining her Master's degree in Engineering and her Ph.D in Engineering in 1991 and 1995 respectively [6]. Whilst studying in the U.S, Cruz-Neira was introduced to computer graphics, inspiring her to get involved with VR. This led to the innovation of CAVE: the groundwork for many technologies within VR including the Virtual Director.

CAVE, created in 1992, is an environment where VR can exist within a confined space. This allows for an immersive VR environment as stereoscopic displays, room-sized computer graphics, and motion-tracking technology all exist within it. This allows for objects to appear suspended in mid-air as the projectors within the CAVE interact with the user's headset, allowing the object to be seen in high-quality from all angles [5].



The utilization of CAVE enables 4 key features in the Virtual Director: Interactive 3D camera choreography, remote virtual collaboration, key-frame animation techniques, real time visualization in immersive environments, and integration of art and science. This allowed scientists to meet in cyberspace, allowing each viewer to have their own perspective as they interact with each other and the space around them in real time [5].

Despite the incredible advancements achieved in virtual reality through the Virtual Director, there are a number of limitations presented by its design. As the Virtual Director is run within a CAVE, it requires highly specialized hardware and technology, making it expensive and inaccessible for regular use. The Cave environment also prevented large scale uses as it required a confined space to be used. Furthermore, this equipment was complicated to maintain and set-up, making it difficult to use for

non-researchers.

Recent technologies have been able to overcome these limitations by utilizing the Virtual Director and CAVE's initial research. Modern headsets, such as the Oculus Quest, create immersive virtual environments without the need for a confined space with specialized equipment. As the internet is now more accessible than when the Virtual Director was originally invented, visualizations can commonly be accessed, viewed, and created online.

The Virtual Director and CAVE allowed for a new age of data visualizations, laying the groundwork for virtual-reality technologies ever since. Work by the Virtual Director and CAVE can be seen in several popular films and documentaries, including 'A Beautiful Planet' narrated by Jennifer Lawrence. Women like Cox and Cruz-Neira were able to bridge the gap between art and science, creating a more accessible way for the public to grasp difficult scientific concepts, leaving a lasting impact on both the art world and science and technology.

By Eleanore Shiner '26

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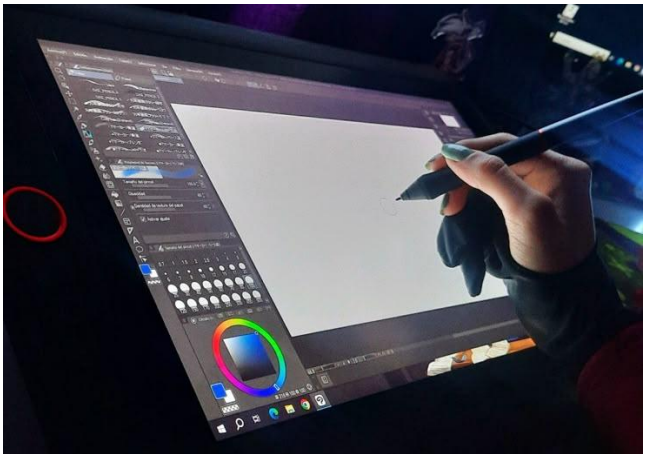
AI in Animation

The animation medium has been heavily impacted by the use of artificial intelligence in the last decade, enabling animators to use their tools more effectively and increase overall production speed. However, it is important to consider the various practical and ethical problems with using generative content in animated film. There are many concerns that come part and parcel with any use of AI in any particular job, and this article aims to evaluate these concerns, and come to a conclusion of whether AI is a helpful tool and companion to animators, or whether the use of partly or fully generated animation impacts employment, and creates lifeless and uninspiring animations.



An in-between animator (or tweening artist)'s job is to animate in between the key frames of any particular scene, making animations flow better and feel smooth. However, a recent technique, interpolation, relies on using AI to generate these in between frames. If effective, the impact of interpolation could be great, lessening production costs and the time taken to complete any given scene. However, interpolating frames comes with its fair set of drawbacks. It has been known to produce blurry frames, especially those with complex detail or containing text, and in addition, due to it being an AI, it often will not understand the animator's intention, and tends to ignore things like clothing physics, movement, and lip syncing, making animation look strange and unnatural. If not used correctly, the end result is a blurry mess that makes the animation feel like it was covered in vaseline. [1]

Another use of artificial intelligence in animation is the use of AI-generated backgrounds. If these backgrounds do not build off of an animator's previous work, it can make most backgrounds generic at best. However, if done with a previous reference, it can look fairly convincing. When done right, AI generated backgrounds can mimic the overall animation style to the point where it can be considered passable, if not good, for use in professional animation. [2]

Finally, one of the huge concerns is from an ethical and moral standpoint. Even without the drawbacks of AI, using artificial frames

and techniques can result in huge employment loss, as well as the possibility of plagiarism from other animators as AI has been known to do. In addition, many people in the animating community openly oppose AI animation due to the AI lacking the consideration and way of thinking that real animators have, to create lifelike and realistic animation, without it feeling off in some way. “The Dog & The Boy” was revealed to have been partially made with generative AI, which started a controversy as people on social media were outraged by this, and claimed that it was simply a way to avoid paying animators for labor, and overall undermined the spirit and hard work that goes into animated film. [3]

In conclusion, AI has been known to have some issues when used for animation, as well as very possibly decreasing employment if it were to become industry standard. However, it is also extremely efficient, as well as being very low cost as opposed to hiring actual animators. If, instead of being a replacement, it was a tool, used by animators to do things more efficiently while not impeding the animation style or creative vision of the animator, AI could make a valuable contribution to the industry of animation.

By Axl Funk ‘28

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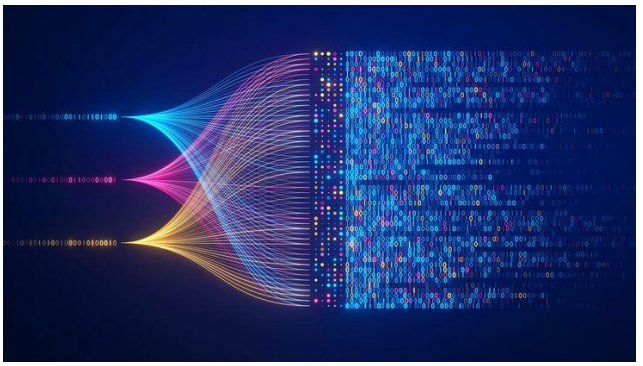
Navigating Ethics in AI-Powered STEM Education

Artificial intelligence and its ethical standing is a field that is constantly evolving and getting more complex. As AI technology continues to advance, we are seeing an increase in the impact it is having on higher education, particularly in the science, technology, engineering, and mathematics (STEM) fields. This shift is raising ethical concerns as AI could radically change how students engage with the material they are learning. The benefits of AI are indisputable, but its ethical implications must be carefully considered. The transformations that are coming with the rise of AI is an area of great interest and growing expertise.

As AI tools are integrated into every part of our lives, several key questions must be asked. First, many generative AI tools are created and owned by corporations. This raises questions about how users can be sure they are protected against inaccurate information or harmful interactions, as corporations often prioritize profit, which can influence the design and deployment of AI. They also may not always ensure diversity in the datasets, leading to AI systems that propagate existing stereotypes, misinformation, or inaccuracies. Generated material that contains incorrect information could mislead students, influencing their learning experiences and understanding of content.

Furthermore, there are concerns about privacy and data security, specifically the people who have access to the information and how users' privacy rights are being protected. The ethical use of this data is not just about protecting an individual's privacy, but also making sure that the users' information is not being used for profit or to benefit harmful practices.



Additionally, as AI systems are trained based on content that is input, they can inadvertently spread biases and/or stereotypes that could be harmful. For example, algorithms used in admissions processes have been proven to replicate existing biases, sometimes to an "alarming extent". [1] Ensuring that AI tools avoid these biases is critical. Because AI systems are trained on data sets, they will only be as unbiased as the data they are given. If the data is skewed, the AI inputs could be biased, leading to unfair treatment of certain groups. This is especially problematic in STEM education where equity is crucial. To prevent this, developers must prioritize the integrity of the data to ensure that it is representative and bias-free.

Another emerging issue is the over-reliance on AI. The use of AI in education may cause students to become too dependent on technology, hindering their critical thinking and problem solving skills. Students who rely too heavily on AI will miss out on

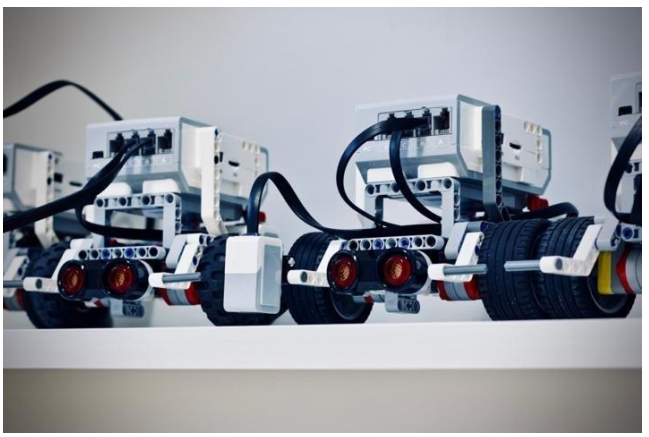
cognitive challenges that only come from independent learning. Students who actively engage in problem solving activities without assistance ultimately develop better critical thinking skills. [1] If AI systems and tools prioritize speed and efficiency over a deeper understanding of concepts, students will only gain a surface-level understanding of topics. By offering instant feedback, AI tools could encourage students to bypass the thought processes required for a deep understanding of concepts, leading to a decline in motivation and curiosity. As AI continues to play a larger role in education, specifically STEM education, it is important to find ways to use these tools to enhance, not replace, traditional teaching and learning methods.

Another ethical dilemma that arises is the impact AI usage has on the environment. Training AI models requires a large amount of computing power which consumes a large amount of energy. A study conducted in 2019 found that training a large AI tool can generate as much harmful carbon emissions as five cars, leading to a concerning impact on the environment, and this has increased over the years. [1] As AI becomes increasingly relevant, we must ask ourselves how much damage we are causing by relying on AI in classrooms, labs, and further.

Nevertheless, AI presents significant opportunities in STEM education. The potential benefits of AI tools in learning environments could reshape how students approach their learning. One of the biggest current applications of AI is to assist with the creation of personalized learning

experiences that target the needs of specific students. These experiences adapt to different learning styles, providing students with feedback that helps them understand challenging concepts. Research has shown that personalized learning can significantly improve performance and student engagement. [1] In addition, AI systems can improve efficiency in administrative tasks such as grading, resource allocation, and the overall streamlining of operations across departments. This frees up time for staff to focus on developing new teaching strategies or creating better learning experiences for the students.

In terms of practical learning, AI-powered robotics and engineering platforms can now be used in education, allowing students to design, build, and program robots using AI-driven tools. This allows students to optimize designs, making the process of building and programming devices more accessible and efficient. This approach enhances students' technical, critical thinking, and problem solving skills. [4]



The ethical considerations around AI in STEM education are complicated but by no

means unconquerable. By working collaboratively, AI developers, educators, policymakers and students can ensure that AI is implemented in classrooms responsibly. Transparency and accountability are crucial in addressing the concerns regarding data security, fairness, and bias. Additionally, educators and support staff must ensure that AI tools are used to enhance traditional learning methods, not replace them. If used effectively, AI definitely has the potential to transform STEM education by providing personalized learning, improving efficiency, and fostering critical thinking skills and creativity. As AI continues to evolve, responsible development and use must be prioritized to ensure that its impact is positive. By addressing the ethical concerns and fostering a collaborative approach between everyone involved, AI's full potential can be harnessed while still maintaining the protection of students' rights, well-being, and academic success.

By Swara Kakaraparthy '26

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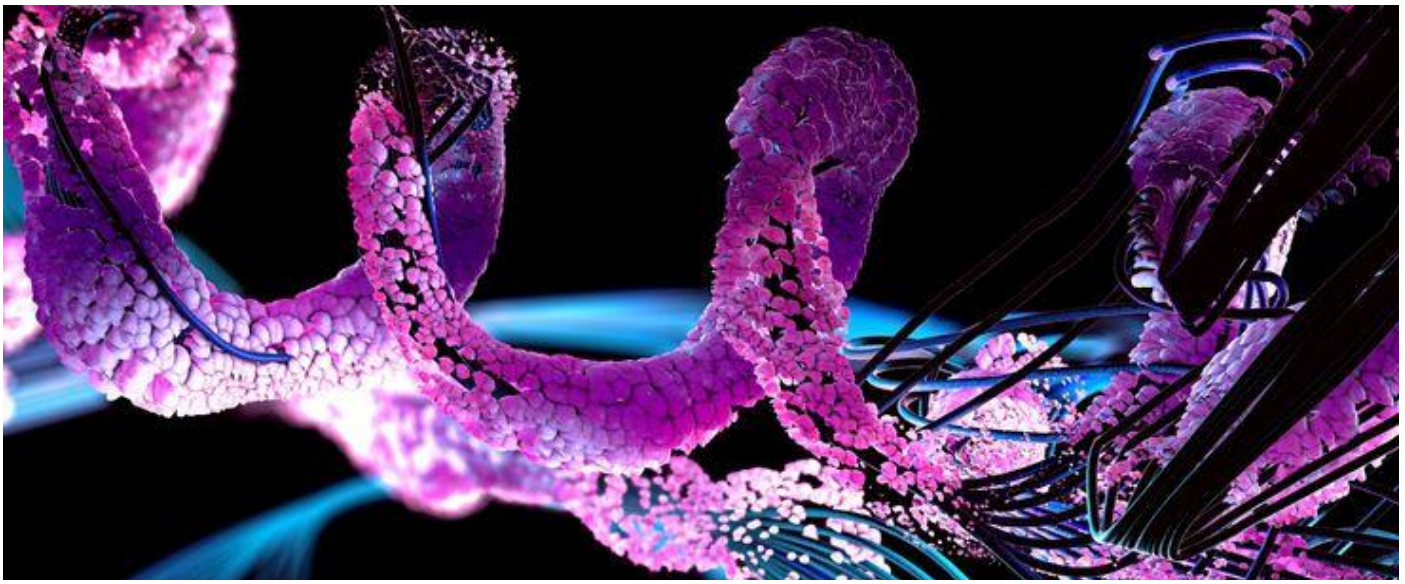
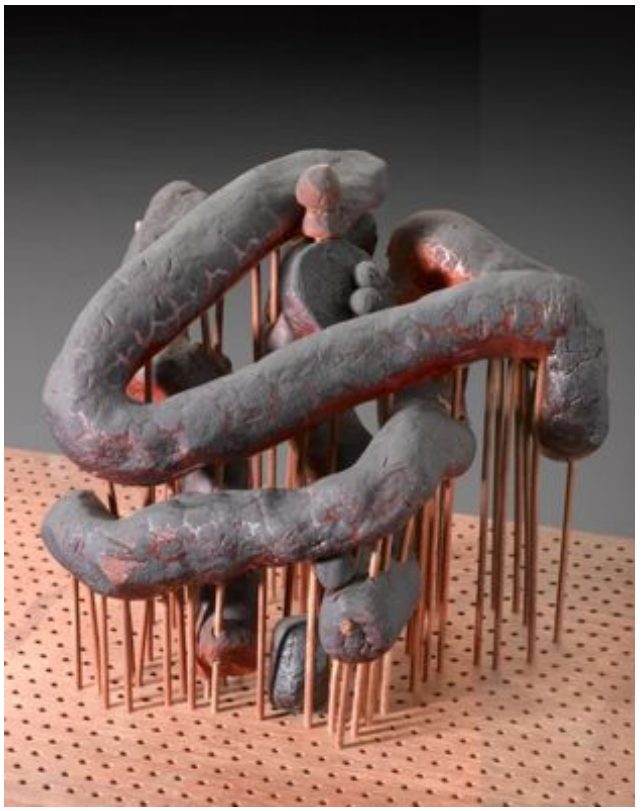


Solving the Protein Folding Problem

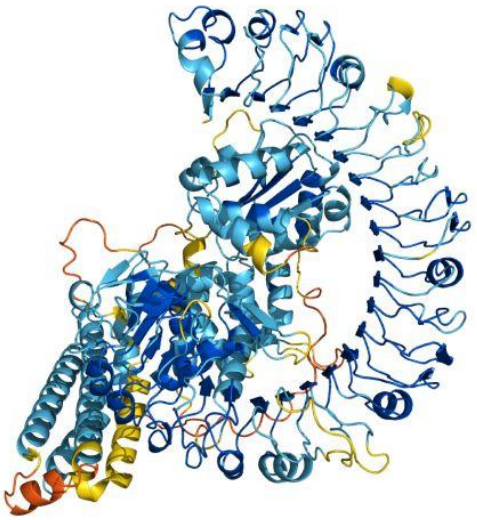
In 1958 John C. Kendrew published a photo of myoglobin, making it the first folded 3D protein structure discovered; since then, we have been trying to map out the folds of every protein. [1] However, due to their unpredictability, the job was deemed more difficult than one may have expected. DeepMind decided that they were up for the job, so they developed the AlphaFold AI which would end up debuting in 2018 and winning a Chemistry Nobel Prize in 2024. [2][3]



In the early 1950s, biologists John Kendrew and Max Perutz suspected that the structure of different proteins would allow them to determine their particular functions. However, the process that they used was X-ray crystallography. This method involved growing crystals out of proteins from tissue samples then using X-rays that were shone at the crystals to be able to calculate the angles at which the atoms were placed. [4] The individual atoms would have to be pieced together to form the molecular structure which was incredibly time-consuming and costly. Around 200,000 proteins were modelled in this way, but, despite this high number, it was relatively small in comparison to all the proteins in the world. [4]

To speed up this process, some scientists decided that the best way to start would be to have estimates for each of the proteins rather than exact models. This idea was something that AlQuraishi talked about molecular biology, referring to it as “probabilistic process” in an interview with SE daily. [5] DeepMind took this into account when they started working on their AI model in the lab. They commenced with a physics-based machine learning approach, where they mapped out each of the atoms in known proteins, and inputted them into the system as a dataset. The AI then used this data to discover any patterns in the way that proteins form and fold to then be able to predict how different amino acid sequences may end up folding. By the end of the development, the team could input a sequence of amino acids that formed a protein and would be able to have the full 3D model returned within a very small

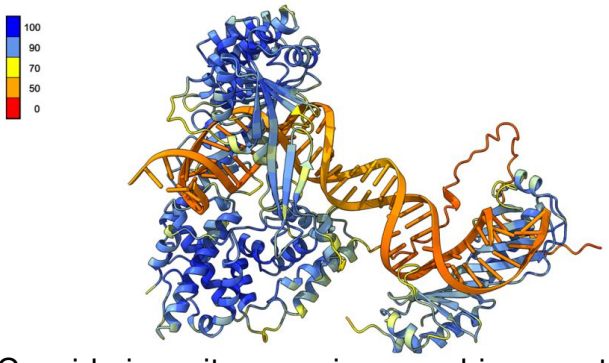
margin of error. This program was named AlphaFold and was entered into the CASP13 (Critical Assessment of Structure Prediction 13) and won. The source code was then released to the public to allow scientists across the globe to access this innovation.



This model, however, was not the end of research for scientists involved in proteomics. So, in 2020 he entered AlphaFold2 into the CASP again. This time he won by a landslide, and from that moment DeepMind was able to claim that they had revolutionized protein mapping. This model was able to predict the proteins to the utmost accuracy. AlphaFold2, being based on the same machine learning that AlphaFold was built with, is also able to compare different proteins directly. It would scan its database and search for any similarities with similar amino acid sequences in nature. Any similarities in sequences would show how the proteins evolved together, allowing the prediction to be that much more accurate. After this evolution of AlphaFold, the number of proteins available to the public shot up to around 200 million, each of which accurate within an atom margin. [6]

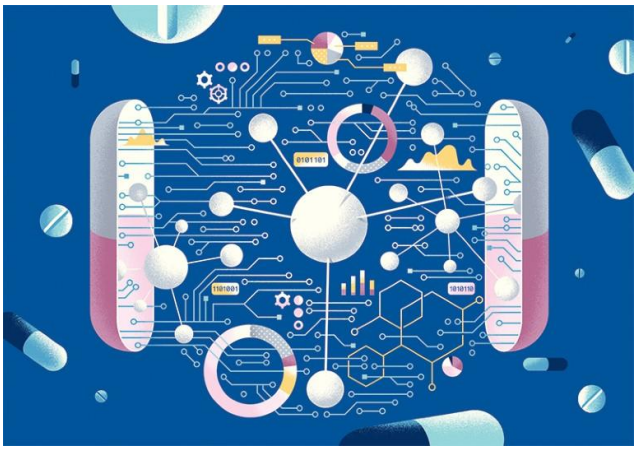
Despite huge wins, the program did not account for any kinds of mutations, and the source code was not entirely available to the public. AlQuraishi knew that this was an issue and so the DeepMind team was adamant on solving it. That is how OpenFold came to be. This project commenced six months later and was led by master's student Gustaf Ahdritz, who is now a PhD student in the AlQuraishi lab at Columbia. [7] This allowed scientists to be able to access more of the data behind the program along with the process behind predicting the proteins. It enabled the public to be able to find ways of improving the codes (as it was and still is open source) as an attempt to improve it; this would also allow others to factor in any other mutations.

These findings allowed the public to be much more involved in scientific discoveries. The program and the hundreds of millions of proteins it mapped out are available on the OpenFold website where the public are able to muse on their findings for their own scientific gains but also as an inspiration to all those in the technology community.



Considering its previous achievements, DeepMind wanted to go even further. They decided to develop AlphaFold3, which they used to depict different proteins interacting with biomolecules such as DNA and RNA. This was a huge innovation for the field and was deemed infinitely more impressive than its predecessors AlphaFold1, 2, and OpenFold, having been reported to be 50% more accurate than them. [8] The program maintains a nuance understanding of how proteins interact and remain to claim potential for future drug discoveries by being able to predict the binding sites and optimal shapes for the potential drug molecules. [8] This would be able to reduce the time and cost of experimental methods when producing these drugs, allowing them to focus on the most promising candidates. However, while these programs were downloadable, AlphaFold3 is only available

through a web server. Furthermore, each user is limited to 20 requests per day (which was only 10 when the website was launched in 2024) and is limited on which molecules it can see the proteins interact with; for example, you cannot find out how proteins interact with naval drugs. This was mainly as an avoidance of an attack regarding competition with the DeepMind spinoff Isomorphic Labs which worked with drug discovery efforts. [10]



Despite the huge additions that the company had made for biology, they decided to favour commercial ambitions; this proves how the media is hindering the community within this field of work. [8] DeepMind set out to have transparency with its users, but, after gaining some recognition in the field, it felt that hiding its information would be more beneficial for them as a company. Although this allows the program to be safer from theft, it still shows the public that they are no longer the focus of this project. AlphaFold1, 2 and 3 are examples of huge developments being cut short due to the fear of competition. That is what the media has done to technology. Now, AlphaFold hides behind the manuscripts that the developers sent out to the critics rather than allowing their works to be viewed by the public. As this becomes the norm for all these companies, the connection to the consumers depletes; their recognition as a scientific company also loses value. Many critics went as far as to say that DeepMind, by not allowing AlphaFold's program to be available to the public, lost its scientific credibility.

AlphaFold has clearly revolutionized biological research, providing evidence for the fact that one can always go beyond in order to dazzle the public. Even if DeepMind believes in hiding its source code, it still remains to be accessible to all; all versions of AlphaFold are available to the public in one form or another and should be looked at in awe. These bodacious curls of brightly coloured protein folds have allowed scientists to engineer faster and more efficient drugs that have saved lives. The work of AlQuraishi will forever be a marvel and will forever be seen as a huge turning point in not only biology, but also technology and the development of AI.

By Rosalia Bialek '27

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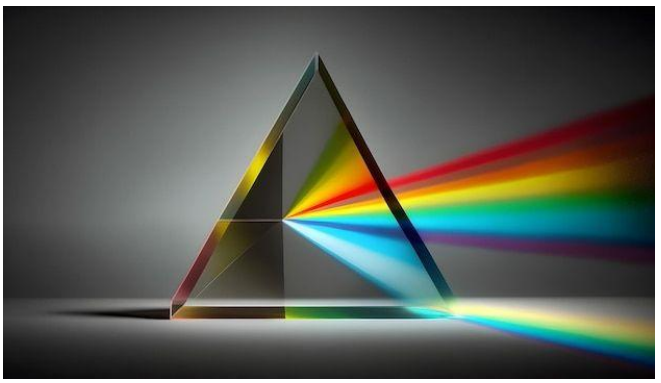
How Movies Are Really Captured: The Photoelectric Effect

Whether your favourite movie includes crazy martial arts, a cliché romance, or a ghost-catching trio; each one can be simplified down to a bunch of moving images. Whilst actors can span from iMovie to Hollywood material, it is the camera magic that preserves their performance forever. The first thing to note is that even though hair and makeup does wonders, movies are not magic and begin on a tiny scale with tiny particles.

Photons, also known as ‘particles’ of light, have a mass of zero and are emitted by atoms. Photons are emitted when an electron moves from a higher (excited state) to lower (ground state) orbit within an atom. A good example of this is fireworks, where energy is absorbed by electrons, and excited electrons return to lower energy levels, releasing light and energy.

The photoelectric effect is a phenomenon where electrons are emitted from a metal surface when light is directly shone onto it. [1] This phenomenon is direct evidence for the particle nature of light, which describes how light behaves as both a wave and a particle. Light interacts with matter as a particle and can exist as tiny packets of energy called photons. In the photoelectric effect, light - as photons - interacts with the metal to emit energy.

However, only certain frequencies of light are able to cause the emission of electrons. Since we can treat light as a wave, if the frequency of light is too low, (e.g. red light) no electrons will be emitted. If the frequency of light is higher, (e.g. green light) electrons will be emitted regardless of the intensity or duration of light shone. The minimum frequency is called the threshold frequency.

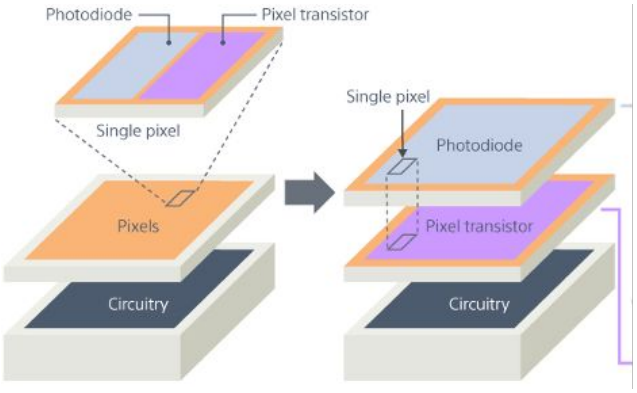


In cameras, the threshold frequency is the minimum frequency of light required to eject electrons from a material’s surface so the camera can detect light and make an image. [2] This is why even if it looks like a romantic starlit movie scene, there are probably tens of lights in the background helping to capture your beloved actors.

The photoelectric effect is the principle of how a digital camera works. Digital cameras are used to shoot the majority of films, due to the cost benefits and visual aesthetics appeal. This effect enables light to convert into electrical signals which create images. Digital cameras contain sensors made up of a single slab of silicon with insulating channel stops to isolate individual pixels. This slab acts as a photoelectric diode, a device that converts light into electric energy. It is then coated with a thin layer of silicon oxide. This is an insulator to improve sensor performance. Thin strips of aluminium are laid perpendicular to the insulating channels, completing the sensor. [3]

When the camera shutter opens, it allows

light onto this sensor. When the photons of light hit the sensor, they interact with the electrons in the silicon atoms (via the photoelectric effect), causing electrons to be emitted. These electrons migrate to the top of the sensor and are trapped by the charged aluminium strips. Once the shutter closes, the sensor holds the charge of the exposure and electrons are stored in the pixel grid. The sensor reads out the charge of each pixel and converts it into a digital signal, then processes it to form the video image. [4,1]



No director or filmmaker can get the perfect shot every time. Sometimes, videos turn too bright or appear washed out. This overexposure occurs when the sensor receives too much light during the exposure period. A slower shutter speed allows the sensor to be exposed to light for a longer period, which can lead to overexposure. To create special visual effects, filmmakers may adjust the shutter speeds for a blurry car chase or a sharp and evocative close-up.

The photoelectric effect is only the very base of cinematography and the future for digital cameras is vast. AI integration looks to enhance autofocus and subject tracking, and an uprising of artificial editing seems to be becoming more and more popular. But regardless of the latest AI trying to generate entire films themselves, nothing can quite beat encapsulating live moments forever.

By Alexa Shaw-Toole ‘28

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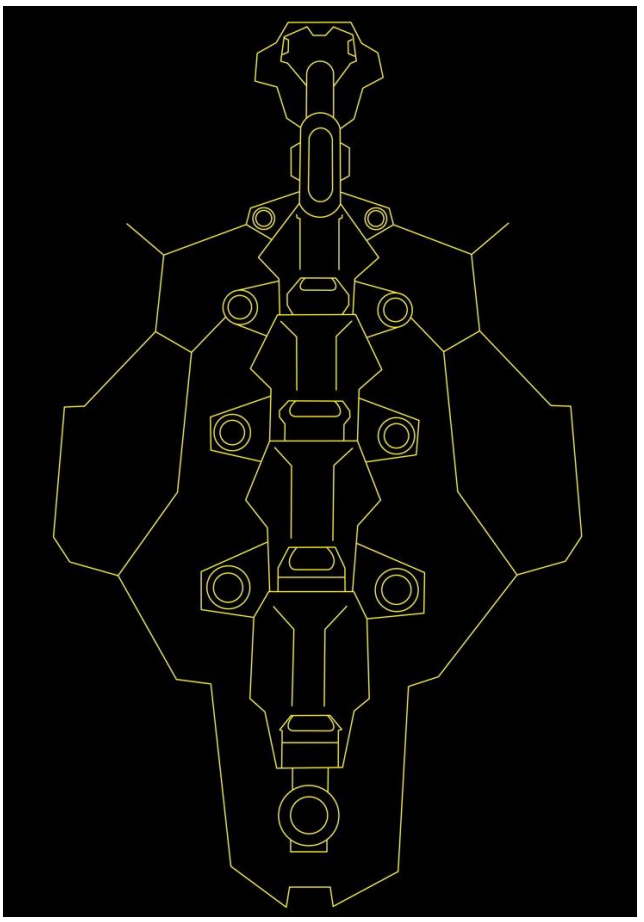
How Close We Are To Cyberpunk 2077 Cyberware

The game Cyberpunk 2077 provides us with a glimpse into the future of our world and it especially brings attention to advancement in technology. In terms of cyberware the game offers a wide variety of prosthetics, eye implants, brain chips etc. All of them improve a specific physical ability of the user's body and sometimes even provide new skills. However, if too many implants are used or if a user abuses their abilities, there is a possibility that the user can undergo mental deterioration, known in the game it is called cyberpsychosis.

Cyberpunk 2077 consists of several types of cyberware with a vital one being Operating System (OS) cyberware. Cyberware in this category meet specific criteria: they are built into the central nervous system, affect multiple body functions, and provide both passive and active effects. OS cyberware is made up of three categories: Berserk, Cyberdeck, and Sandevistan. Berserk is a hormone regulation implant enhancing the flight or fight response on will. Cyberdeck is a brain chip which allows its user to "hack" other technology in-game. Sandevistan gives its user the ability to slow down time in-game.

Of these three technologies, the least realistic is Sandevistan. Sandevistan is implanted into the user's spine. As this is an implant, it does not affect the time itself, but rather it makes the user faster and their reaction time quicker, therefore, everything just appears to be slow. The most fitting method to achieve this would be to increase the blood flow in the user's body by interacting with the nervous system to influence how quickly the body can react. Additionally to the fact that this ability is impossible to achieve with current technology, if it were implemented into our society, it could result in negative consequences.

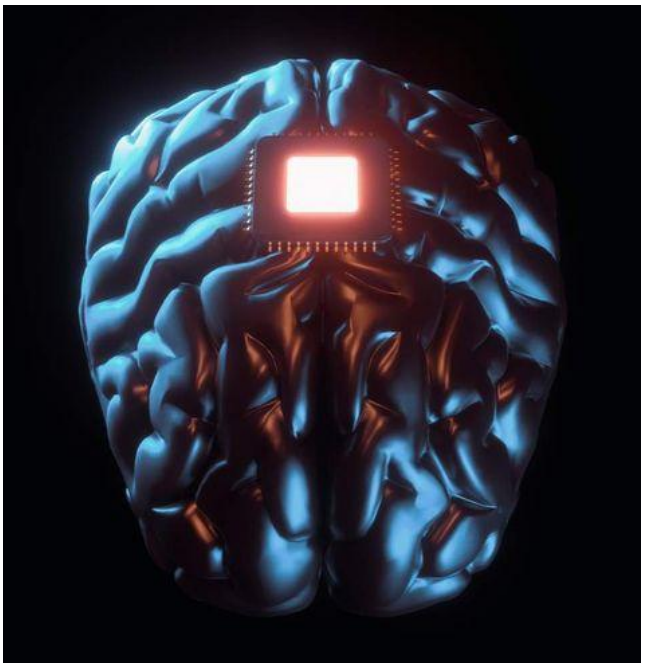


Firstly, when increasing the blood flow in the human body, vessels will experience immense amounts of stress especially compared to its regular pressure. This could lead to the user experiencing anything from extreme fatigue to internal bleeding across the whole body, as their blood vessels pop and tear. Therefore, if this ability were to be implemented in real life, the user's entire circulatory system would have to be replaced with an artificial one. This in itself would be immensely difficult to carry out as most vessels are so small and so deep in the body.

Another implant in the OS section is Berserk. This implant regulates the work of adrenal glands, amplifying the flight or fight response. Therefore, it would be relatively easy to replicate in the real world as a one-off use as hormone regulating medicine (e.g. epi-pens) has already been created. However, providing the user with the constant ability provided by the Berserk could prove to be more difficult as our modern hormone treatment involves taking medicine or injections instead of implants.

The Berserk module controls the natural release of adrenaline in the body. The hypothalamus is the part of the brain responsible for sending signals to the adrenal glands, thus we are able to send artificial electrical signals to the adrenal glands in order to make them release adrenaline when required. The Berserk implant is then complete by giving the user a switch to turn the circuit on or off.

However, similarly to the drawbacks of Sandevistan it will take an enormous toll on the user's body and the surgery to install the electrical device would be incredibly dangerous.



The most realistic OS implant, which has already been partially produced and tested in the real world, is Cyberdecks. In the game, Cyberdecks are small computers embedded in the brain to provide access to cyberspace. Even though we don't have "cyberspace" in our world we do have the Internet and other electronic devices. The company Neurolink has developed a similar purpose chip to the Cyberdecks. Neurolink reads the electrical signals that are carried by neurons in the body and then sends a Bluetooth signal or a radio wave with instructions on the action to a specific device. By recording and decoding neural signals from individual neurons and then transmitting them back to the brain using electrical stimulation, the chip enables users to control devices solely through thought [1]. If Neurolink gets developed further it might be able to reach the full capacity of Cyberdeck, but in real life.

A significant implant in Cyberpunk 2077 outside of the OS section are the arm implants. In the Cyberpunk universe there are 4 different kinds of arm implants available to the player: Gorilla Arms, Mantis Blades, Projectile Launch System and Monowire. The abilities of Gorilla Arms are

to boost the physical potential of the user. In order to recreate this ability, it is required that the user's physical capabilities are enhanced in addition to basic arm functions. This could be achieved by using more durable material for the body of the implant. Mantis Blades are more theoretically possible if we ignore the basic function limitation, the actual blade segment would need to be able to fold to fit inside the user's arm. This would lead to a very weak structure of the blade with very few uses available.

The Projectile Launch System is a cannon in the user's arm. The size of the actual firing mechanism is too small and unrealistic to be implemented in the modern world and therefore currently the closest we can get to replicating it would be by replacing the arm with a small scale cannon. Still, with these adjustments the user would experience an immense amount of recoil which may lead to broken bones and internal bleeding. Finally, Monowire is a whip-like monofilament wire only a molecule wide [2]. With the current state of technological advancements, we are unable to recreate these implants. Therefore, for now we have to focus our attention on improving our current technology before taking on such a big and difficult task. Each of these implants would be difficult to create with our current technological knowledge. Because, to this point there are no functional prosthetics that could replace an arm's flexibility and utility fully. As medicine, AI, and biomechanics continue to advance, it's likely that we will see more progress towards the cybernetic future of the game, though perhaps not as flashy or as effective as in the game.

By Denys Zazuliak '26

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How Water Simulations Work

Water simulations are everywhere in modern computer graphics with results from both real-time systems and pre-recorded systems. Water simulations are useful for creating beautiful visuals as well as many real-world applications such as oil spills management, and modelling weather, ocean currents, and airplane movement. They have also been used in heavy industry for fluids moving through pipes and other objects such as turbines that may be interacting with fluids.

Fluid simulations arise from the computational analysis of fluid dynamics in the 60s mainly for engineering. However, they soon found use in the visual effects in both video games and visual effects.

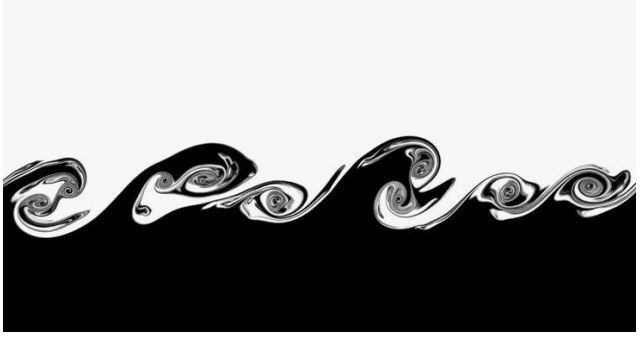
Early visual effects simulations mainly focused on the surface properties of a fluid, these run as finding a displacement map across the surface and stopping there. There are many ways to find this displacement map with the most common being the sum of sines method. It creates great visuals however is not a simulation of the water but instead a model that creates decent-looking results. It is also incapable of modelling scales where surface tension is the dominating force i.e. small scales and very viscous fluids like mud. When modelling entire oceans, it can also struggle as it tends to tile however this limitation can be overcome. This method is still commonly used in modern real-time systems such as video games as it is computationally cheap and therefore perfect for systems that do not need to be physically accurate or need to interact with complex geometry.

On the whole displacement maps are very limited as they cannot model how water moves and interacts, with a major limitation being that a displacement map can only have one displacement value for each point in the 2d plain. This means that a cresting wave can never be shown.

As our computational power increased and our demands for better and more complex models increased, we turned to the Navier-Stokes equations which is a general formula for modelling all fluids. The equations are quite complex however when working to create good models we can make a few assumptions: water has essentially no viscosity - this is only true at large scales, but models are more commonly made for larger scales regardless, and water is incompressible. From these assumptions, we reach the formula:

$$acceleration = \frac{body\ forces - change\ in\ pressure}{density}$$

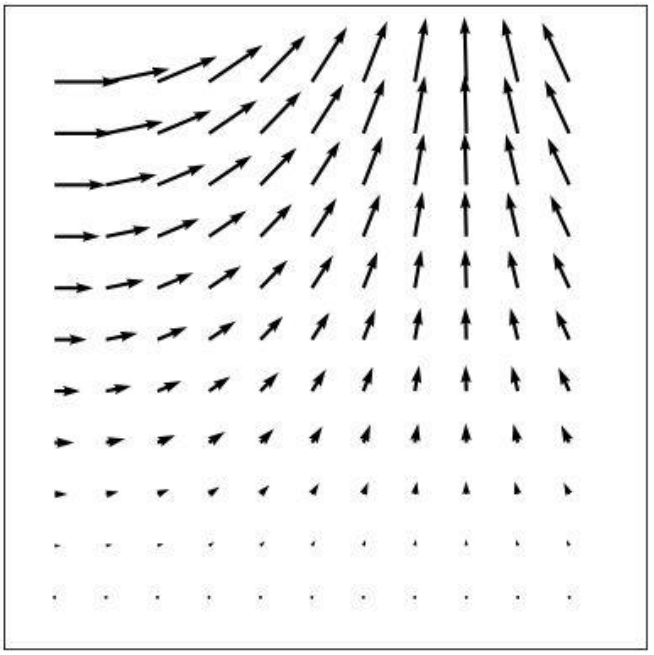
Body forces are forces that act evenly across all particles in the system, such as gravity or electromagnetism.



There are two main methods for actually simulating: particle simulation and a gridded method. With a particle simulation, the computer tracks millions of particles at a time and calculates each collision. This method is initiative and would be the first method that most people would implement

if they were to make a fluid sim. This method has limitations and often results in certain issues, for example, if not enough frames are simulated you can get particles jumping through each other or ending up very close to each other which causes the particles to be thrown apart from each other. This can cause strange behaviour such as the visual that small explosions are constantly happening in the water flinging off little chunks. This leads to many simulations to simulate many more frames that are needed, these are called subframes, which means that each frame has many times more computational effort than is needed.

The second method is called the grid method, and works by splitting the space into thousands of cubes and then modelling the fluid as properties of the cube. Each cube has some properties such as the momentum, velocity and pressure of the water inside it. Then it checks how much of the water moves out and how much moves in. This is then repeated in each frame. This method is better for large oceans where billions of particles may have been potentially needed, which is computationally infeasible. However, it struggles with small



details and it may end up leading to strange interactions. There is also a potential to lose “mass” where water can stop existing if carefully programmed, which simply cannot occur with the particle simulation.

These two methods are both very powerful, in fact, they can be combined and are often used in tandem. Most modern simulations use both methods layered together. These basics let you create nearly any simulation.

By Ethan Benavides Levy ‘26

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Would Time Travel Break The Universe?

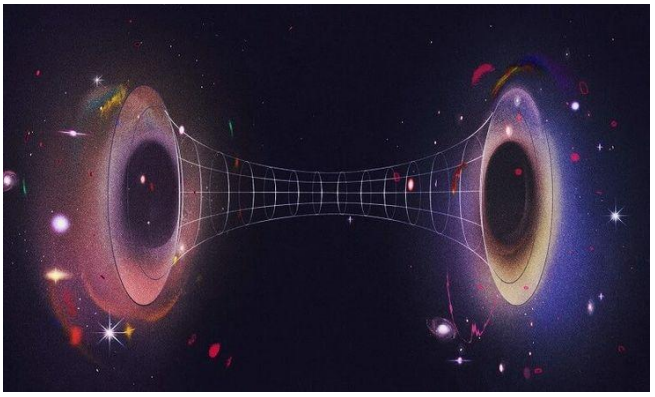
Time travel is something often seen in science fiction novels as an enjoyable fantasy but with the increase in recent technological advancements time travel is becoming more talked about. However, time travel could have the potential to "break" the entire universe. In order to determine whether time travel would have this consequence, we must first consider if it is possible at all. To approach this, we can break it down by seeing if time traveling into the future or into the past is possible individually.

Travelling to the future is much easier to consider as it can be thought of as time going by someone much faster than the rest of the world. This is called time dilation and it is based off of Einstein's theory of relativity. Essentially, the faster someone moves or the stronger the gravitational field is around them, the slower time passes. This has been proven to work from the Hafele-Keating Experiment in 1971 when two atomic clocks were flown on a plane while two others stayed in a laboratory. It was discovered that, due to time dilation, the atomic clocks on the flight ticked slightly slower due to the speed they were travelling. [1] So, if we moved a human at speeds nearing the speed of light and subjected them to immense gravitational fields, time for them would move much more slowly and everything they observe around them would appear to be moving much more quickly. In theory, this means that you could push a human years into the future in mere minutes with a very large gravitational field, as is shown in films such as 'Interstellar'. This is effectively time travelling into the future.

This would likely not break the universe as going into the future without going into the past would not create any paradoxes. Without travelling there, one cannot send any signals into the past to alter the future that they are in. "Travelling to the future" is effectively what we do constantly by living through time. To travel further into the future, we just have to let time move a little faster around us. One example of the effects of time dilation is the twin "paradox". This is a thought experiment where one twin goes through space at

extremely fast speeds while the other stays at home. When the first twin returns from space she will be younger than the twin staying at home, leading to two twins of different ages. [2] However this isn't a "paradox" as there is no law in physics which says twins must always be the same age.

Traveling into the past is a bit more difficult as it is much more theoretical than travelling to the future. One theory suggested is to find a wormhole or rift which goes back through space-time as if it was folded like a piece of paper. [3]. However, there are a number of theoretical ideas that would need to be true for it to exist. For example, the wormhole would collapse on itself due to its own gravity so it would have an energy emitting force in the centre. This is often theorised as a white hole, the opposite of a black hole, that constantly emits energy instead of absorbing it like its counterpart.



Despite these limitations, if a way to time travel into the past was invented then it could be argued that it would come with significant consequences. If someone went back in time to when they were 10 then travelled back to their original time, this could create a time paradox. If you visit yourself in the past you must have a recollection of being visited when you were younger [4]. This means there cannot be a first time where you visit yourself in the past. This is called the boot-strap paradox. There are 2 main theories to get around this. One, the time-traveller suddenly remembers that when they were 10 they visited themselves from the future. History is constantly updated for as long as they are in the past which changes the present. Two, as they travel back, an alternate timeline opens up, completely separate to their initial reality and both timelines play out simultaneously.

In the second theory, when the time-traveller returns to their normal timeline nothing will have changed as they cannot affect their own timeline in any way by going to the past. In theory one where the time-traveller stays in their timeline, a loop is created of their younger self growing up then travelling back to the past. But this poses a question of what would happen if their younger self decided not to travel back in time to complete the loop and if it would break the universe. If we follow the same logic as before and say that history is rewritten when they go back, it makes logical sense that when they die, history is rewritten again and they never actually time travelled.

This is an easy way to get around the paradox of visiting yourself in the past. If the timeline updates itself each time you travel back, there can be a first time that you visit yourself in the past and there can be an endless loop afterwards. An interesting note about the second theory is that you have no obligation to go back in time to "complete the loop" if one is visited by their future self as they would have been visited by someone from another timeline separate from their own future. This means that there will not be a

paradox from visiting yourself in the past if theory 2 is true.

A famous paradox that many people know could cause problems for both theories. The paradox goes, “if you go back in time and kill your grandfather, you will never be born meaning you never killed your grandfather.” This paradox can serve as a problem for our first theory as the history of the universe would constantly update at an infinitely fast speed between four different outcomes. Your grandfather is dead from you killing him and you are alive, your grandfather is dead and you do not exist as you killed him, your grandfather is alive again because you killed him so you never existed to kill him in the first place or both of you are alive. This would likely “break the universe” due to the fact that the world around everyone would be changing at infinitely fast speeds, meaning people would likely be doing different actions at the same time which in the current realms of physics is impossible.

However, there is a theory for this called the inevitability theory [5] where some things are inevitable, even with human intervention. In the context of time travel, some people believe that the universe does not allow actions to happen if they will break the universe. For example, one would simply not be able to kill their grandfather or even time travel at all. Another theory is that the entirety of the past and future have already been “written” and humans have no free will and will not create any paradoxes. Theory two takes a simpler approach. If one travels back into the past and kills their grandpa, they are not killing their grandpa. They are killing their grandpa from an alternate timeline that they do not exist in. Therefore, if the second theory is true, there should be nothing which would “break the universe”.

In conclusion we will likely never know the answer in our lifetimes or even at all as a species. If the small chance of time travel being possible is true, it is unlikely to break the universe. However humans are incredibly destructive and with the powerful weapon of time travel, they would likely destroy everything the universe has to offer, alternate timeline or not.

By Gray O'Donnell ‘28

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Thank You!

That concludes the third installment of the Penrose Magazine. Thank you so much for reading this installment and we hope you enjoyed!

Finally, we would like to thank our authors for taking the time to write the articles, as this magazine would not have been possible without them.

If you would like to write for the next edition of the Penrose magazine, please email Penrosemagazine@gmail.com