Artificial Intelligence, Engineering and the Engineer

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In contrast with our intellect, computers double their performance every eighteen months. So the danger is real that they could develop intelligence and take over the world. Stephen Hawking

Executive summary and Foreword

The Year 2022 was a watershed year for artificial intelligence, with the release of several consuming-facing applications like ChatGPT. Dall.E. and Lensa. [1] The common theme is the use of Generative AI-a paradigm shift in the world of AI. While current generations of AI use pattern detection or rule following to help analyse data and make predictions, the advent of transformer architectures[2] has unlocked a new field. Generative artificial intelligence.[3] Generative AI can mimic the human creative process by creating novel data similar to the kind that it was trained on, elevating AI from enabled to potentially co-passenger.[4]

Although early traction has been through consumer release, which could be era defining, Generative AI has the potential to add contextual awareness and human like decision making to enterprise workflow, and could easily change the way we do business. We may only just be beginning to see the impact of solutions like Google's contact centre which is designed to enable Natural language customer service interactions, and industry specific solutions. In 2022 venture capital forms have invested $2Billion and technology leaders made significant investment, such as Microsoft's $10Billion stake in Open AI and Google's $300 million stake in Anthropic.[5]

Still questions remain about how engineers and engineering enterprises could use generative AI to deliver design and efficiency gains, product improvements or operational change. Similarly we are only beginning to see how Generative AI could be commercialised and how to build a sustainable business models. Even so, Generative AI is in its infancy and not without risk. Ultimately Generative AI could create a more profound relationship between humans and technology, even more than the cloud, the smartphone, and the internet did before.[6] The AGI "market" will likely double every two years for the

[1] https://www2.deloitte.com/content/dam/Deloitte/ie/Documents/Consulting/ie-generative-artificial-intelligence.pdf
[2] https://en.wikipedia.org/wiki/Transformer_(machine_learning_model)
[3] https://link.springer.com/article/10.1007/s10956-023-10039-y
[4] https://hbr.org/2023/07/how-generative-ai-can-augment-human-creativity
[5] https://www.nytimes.com/2023/01/23/business/microsoft-chatgpt-artificial-intelligence.html
[6] https://www.linkedin.com/pulse/generative-ai-destroying-internet-bernard-marr/

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next decade.[7] Numbers aside we believe the economic impact could be far greater.

Artificial general intelligence (AGI) can potentially revolutionise the engineering and design world as we know it and it is imperative that engineering New Zealand understands where AGI fits and when it should be adopted. Ref: Ljarotimi

However, the development and deployment of AGI must be approached with caution and responsibility. We must ensure that these systems are aligned with human values and interests and do not threaten our safety and well-being. Ref: Zhou

The Question

"When it comes to accepting the professional Engineer is the implementor of AI, does the institution to which she belongs have a role or even a duty to "Deep Mind" the subject given that universities are unlikely to for a generation and thus prepare the mid-level professional to the new world of artificial intelligence and all that it entails. Does this mean the Institution must establish its own data lake or negotiate arrangements with other like institutions to put a mega date lake in place for all to use. Does this approach therefore mean that the Institution becomes a hand holding service to the member engineer rather than an educational arm."

Entire Document copied from Ron's Professional Journal

Chief Technical Officer
Dr Ron McDowall ONZM

[7] https://www.mckinsey.com/featured-insights/mckinsey-explainers/whats-the-future-of-generative-ai-an-early-view-in-15-charts

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01 - Foreword

This Foreword is compiled from current research and an interview (via Zoom) with Tamilayo Ijarotimi who is a scientific writer. (much of the material while curated is quoted from the writer's interview). Sharon Zhou [8] was also interviewed and her commentary follows that of Ijarotimi.

CTA "What is your world view of AGI as it relates to the Engineering Profession?"

Ljarotimi "Artificial general intelligence (AGI) is a theoretical form of AI that can learn and reason like humans, potentially solving complex problems and making decisions independently.

Those working on the development of AGI aim to replicate the cognitive abilities of human beings, including perception, understanding, learning, and reasoning, across a broad range of domains and as such will have a profound effect on design and engineering."

ZHOU: Unlike other forms of AI, such as narrow or weak AI, which are designed to perform specific tasks, AGI would perform a wide range of tasks, adapt to new situations, and learn from experience. AGI would reason about the world, form abstract concepts, and generalise knowledge from one domain to another. In essence, AGI would behave like humans without being explicitly programmed to do so. AGI would thus have the capacity and ability to learn from the design experience and pass on such learnings to other projects and continue to improve the principles of engineering in almost an osmosis manner. How far this is off is unknowable!

CTA "What are the anticipated impacts on the nature of engineering Institutions"

Ljarotimi "It is anticipated that the impact on engineering institutions by AGI will be extensive and will exceed the impact of AI by a significant scale. Some of the key characteristics that would make AGI so powerful specifically for engineering and design include:

- Access to vast amounts of background knowledge: AGI would tap into an extensive pool of knowledge on virtually any topic. This information would allow it to learn, adapt quickly, and make informed decisions. For an engineering Institution this should be straightforward requirement.
- Transfer learning: AGI could transfer knowledge and skills learned from one task to other related tasks.
- Abstract thinking: AGI could comprehend and work with abstract ideas, enabling it to tackle complex problems and develop deeply innovative solutions.

[8] https://www.linkedin.com/in/zhousharon/

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- Understanding of cause and effect: AGI would be able to anticipate the outcomes of its decisions and take proactive measures to achieve its goals by understanding and using cause-and-effect relationships. This means that it could predict the consequences of its decisions and take proactive measures to achieve its goals."

CTA "What are the potential benefits and opportunities for engineering."

Ljarotimi "The benefits and opportunities of AGI are endless. With its ability to process large amounts of data and find patterns, it could also

AGI could also improve human life in countless ways. Automating tedious and dangerous tasks could free up our time and resources to focus on more creative and fulfilling pursuits. It could also revolutionise industries such as transportation and logistics by making them more efficient and safer. In short, AGI can change our lives and work in ways we can't imagine."

Ljarotimi "As artificial general intelligence (AGI) continues to make strides, it's becoming increasingly important to consider the ethical implications of this technology. One of the primary concerns is whether or not AGI can learn and understand human ethics. One worry is that AGI is left unchecked, machines may make decisions that conflict with human values, morals, and interests. To avoid such issues, researchers must train the system to prioritise human life, understand and explain moral behaviour, and respect individual rights

help engineering better understand the complexities of climate change and find new ways to mitigate its effects.

Zhou "There are also safety risks associated with AGI, particularly if it becomes more advanced than human intelligence. Such machines could potentially be dangerous if they develop goals incompatible with human values. Therefore, it's essential to approach AGI development cautiously and establish proper regulations and safeguards to mitigate these risks."

CTA "What are the primary Ethical considerations engineering should be mindful

and privacy. Another ethical concern with AGI is the potential for bias in decision-making. If the data sets used to train AGI systems are biased, the resulting decisions and actions may also be biased, leading to unfair treatment or discrimination. We are already seeing this with weak AI. Therefore, ensuring that the data sets used to train AGI are diverse, representative, and free from bias is crucial."

The issue of job displacement is another concern with AGI. As AI becomes more intelligent, it will take over tasks previously done

by humans, leading to job displacement and economic disruption.

This includes creating mechanisms for accountability and transparency in machine decision-making, ensuring that AGI is

developed unbiased and ethically, and establishing safeguards to protect human safety, jobs, and well-being.

CTA Can you both sum up please.

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Both: Artificial general intelligence (AGI) can potentially revolutionise the engineering and design world as we know it and it is imperative that engineering New Zealand understands where AGI fits and when it should be adopted. However, the development and deployment of AGI must be approached with caution and responsibility. We must ensure that these systems are aligned with human values and interests and do not threaten our safety and well-being.

The Engineer

So what does all this mean for the professional Engineer and engineering?, well that's what this study is all about. Given the suggested complex scenarios going forward from the Blackroom study performed in 2022 by Engineering NZ for the planet, it's clear that Engineers will be unable to provide the decisions and answers needed for a safe environment for the inhabitants of this planet without the 'data' and systems that AI will provide. We begin this study by re-examining the Blackroom outcomes from 2022 regarding AI and AGI.[9]

9 https://d2rjvl4n5h2b61.cloudfront.net/media/documents/Foresighting_Report_Short_Version-FINAL.pdf

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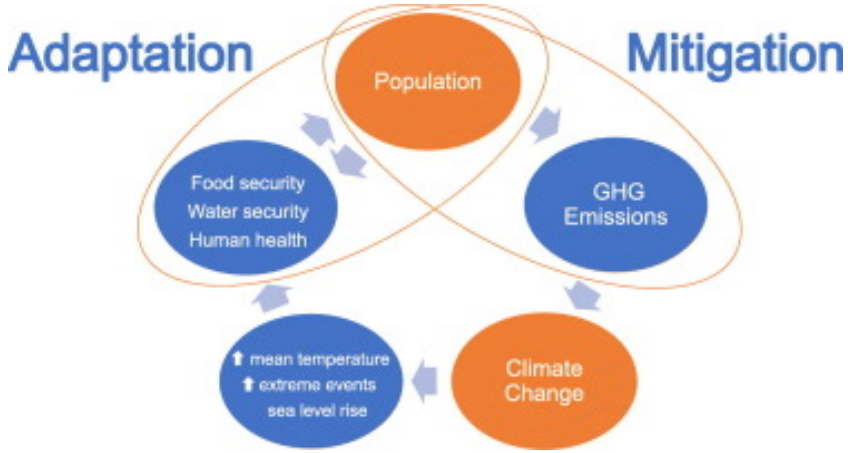
If you think for a moment about the climate issues, decarbonisation, sustainability, zero emissions, zero waste, resilience, declining biodiversity, massive species loss, significant changes to all food and the agriculture industry, loss of petrochemical and plastics industries and the massive changes to the automotive and transportation industry, new fuels, Hydrogen, EVs or ammonia, continued climate heating, flooding, desertification, storms and cyclones the advent of AI, AGI and singularity.

All of it shrouded in massive population increases (3.5 Billion extra by 2048) with housing shortage, increasing inequality and declining food security issues then one can see easily that the global questions for the next several decades to 2050 and beyond is characterized by deep complexity of a degree and level we certainly have not seen since the green revolution in agriculture in the 1960s when the planet required a four-fold increase in food production. The production increases (volume as well rate) researched indicate that we are entering a zone of unknown unknowns and we will have societal divisions on an unprecedented scale.

The question we must ponder within the AI and AGI project meeting is where the engineer fits in this future and what should their membership organization be reshaped to or repurposed to remain relevant to these engineers. Engineers are generally across all sectors of the society from infrastructure, generation, transmission, buildings, hospitals, housing inequality and poverty, biodiversity loss, automation, and autonomy etc. As such their impact going right up to 2050 is highly significant but we believe, substantially different from now in 2021. Engineers are characterized by their problem-solving ability. In the future however as the research tells us they will be still problem solving but in complex unknowable. This reality is the key to what the organization (Eng NZ) will need to pivot. We have done it before.

Because of the interconnectedness of engineers and its institutions, to global engineering the scope of this work is large. For the last 90 days we have been collecting and cataloguing hundreds of papers and articles from around the planet as well as interviewing engineers and owners of major engineering companies to get a handle of where our profession and its membership Institution fits in the future both near and far.



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As the future is fast approaching in terms of technology we will be looking right out until 2070 but focusing the Strategic foresighting statements and backcasting on 2050 as this is still within the working life of the majority of our younger generation engineers. For any foresighting project the secret sauce is research, and this project where the Institution is subject to many sets of mega trends the research scans were widely set. A five-month research program has investigated all the likely trends, disruption and impacts of systems development, the global future system state, climate, decarbonizing etc, and the market's innovations from a futures point of view.

ARUP is an originally Norwegian based engineering consultancy group and it seemed to us to be entirely appropriate that we are mindful of their superb work.

02-2 Blackroom purpose

The purpose of the original research project was to identify and describe global meta-trends, critical uncertainties, market's innovations and their implications that are likely to influence the business and sectors that Engineering New Zealand are currently involved with and to propose, given the meta-trends, new directions for the Organisation in the coming decades. The Organization's executive felt that with the astonishing rate of change in their sector that a view of the future was in order, so that the existing corporate paradigm did not become irrelevant to its members.

The aim of the Blackroom project was to provide a set of recommendations that the organization should pivot to a role that would be relevant to its members in the coming decades.

02-3 Scenarios from Blackroom

Several trends finally emerged from the findings, which highlight the responses from the participants of the study, literature research, STEEP and research interpretations along with the excellent work done by ARUP. Each Basic Theme was treated with the same level of importance, including critical uncertainties and predetermined aspects, and therefore are not differentiated by the number of references. The Basic Themes were formed into Organizing Themes which were then collected together as Key or Mega/Meta Trends. The basic themes will be placed within this report for completeness within the appendices.

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The Basic Themes are presented on a Transitions Map in this section. The Transitions Map follows the World Economic Forum Mapping concept.[10]

The developed "Waves of Change" are taken from the Meta-trends into the Blackroom and the final Strategic Foresighting statement derived during the Blackroom deliberation. The resulting Foresighting statement and the backcasting with road maps is the subject of the final report. For the overall Global Waves of change we have referenced the ARUP four plausible 2050 scenarios and the waves that will affect out businesses, organizations, countries and people are noted below. Jo Da Silva ARUP Fellow and Director puts it like this. "It is now recognized that human systems are putting our planetary systems under significant stress. Thus, we thought it appropriate to consider four worlds in which these two systems would be juxtaposed as the axes. The world today is marked by rapid change. Some trends point towards human progress, others indicate an increasingly perilous outlook for the planet

Each of the resulting scenarios are compelling for different reasons: from a world in which both the societal systems and natural systems move towards collapse, to one where sympathetic symbiosis is the baseline for all activities on our planet. We believe that these four worlds are consistent, coherent and plausible. Indeed, there are indications that each scenario can already be found somewhere on Earth." [11]

Wave One: We live in a world characterized by increasing complexity and uncertainty. Climate change, biodiversity loss and resource scarcity threaten future generations and will require urgent global action and collaboration over the next decade. Meanwhile, digital technology, urbanization and changing demographics will impact communities, businesses and economies, radically affecting every aspect of our lives. The future, 2050 and beyond, will be determined by our ability to address today's environmental challenges and social changes to meet the needs of nearly ten billion people who will be primarily living in urban areas.

Wave two: Both people and planet are on the path to a regenerative world. Society consumes resources at the rate at which they can be replenished, populations are diverse, and societal structures are balanced. Humanity is well on its way towards a shared consciousness and an understanding of Earth's limited resources – that production and consumption are intrinsically linked to the natural environment. There is no 'away 'to throw discarded things. Global ecosystem services are recognized and valued, helping to improve the quality of both planet and society. Circular processing measures are in place and most nations abide by them. Full life cycle and ecological resource assessments are mandatory for all new products. Global biodiversity loss has halted, and protected areas are seeing ecosystem recovery. Everyone has, and knows, their carbon quota and daily spend; AI provides daily updates, and state governments penalize overspend.[12] The multi-stakeholder

[10] https://www.weforum.org/agenda/2017/11/what-is-a-transformation-map/

[11] https://d2rjvl4n5h2b61.cloudfront.net/media/documents/Foresighting_Report_Short_Version-FINAL.pdf

[12] https://www.un.org/en/climatechange/science/climate-issues/biodiversity

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vision for an equitable and thriving future has prevailed. All global leaders are proud to wear the 'thriving planet = thriving people 'symbol showing their support for the drive towards the post-Anthropocene epoch. Cities around the world have transitioned from being in conflict with nature to something approaching symbiosis.[13]

Wave three: Climate action and biodiversity recuperation are the top-line of every national and transnational agenda. The results of the galvanized global efforts have been unprecedented for the environment, but not without significant sacrifice from people who are realizing the trade-offs did not quite work out for them. Humanity now lives in self-imposed servitude to the environment under the mantra of 'happy planet, happy people. 'For most of the last two decades, the Earth and its health have enjoyed the highest priority in the public consciousness.[14] The scale and speed of environmental degradation of the first quarter of the century, with extreme weather events, rising urban air pollution and climate migration, drove governments and major global cities to act swiftly, and strictly, on climate action. Popular unrest and ardent civil demand led to unanimous agreement that everyone must help the planet to heal.[15] Protected lands have expanded worldwide, and significant resources have been allocated to restoring ecosystems. The extinction curve is flat and many species previously on the brink of extinction are regenerating. The effects of climate change can still be felt and sea levels continue to rise, yet the impacts are less severe than expected. Achievement of the targets came at a much greater expense to society than expected. The changes to where people lived, what they ate and how they travelled were sudden and extreme. [16]They permeated every aspect of daily life. A myriad of new job types was created but most were dangerous and undesirable, as workers were tasked with cleaning up environmental pollutants and processing materials for re-use. Extreme urban densification, driven by urban growth boundaries for land-use regeneration, led to a premium on space. Pervasive carbon taxation and individual carbon allowances have severely slowed consumerism for the aspiring global middle-class.[17] To save on their carbon allowance, people regularly repurpose used items and upcycling is at an all-time high, with a thriving 'Do Everything Yourself (DEY) ' culture. In many countries, rubbish collection and prospecting are a reliable income stream.

Wave Four: Climate change and the inexorable consumption of Earth's resources has resulted in fundamental destabilization of natural systems. Resource, energy, water, and food shortages are pervasive across the world. Environmental consciousness is largely non-existent. The established world order has shifted, and the global center of power has moved to the East.[18] China has a strong economic presence and position globally and dominates the research and manufacturing of technologies.

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13 https://www.diplomaticourier.com/posts/2050-y-our-future

14 https://wedocs.unep.org/bitstream/handle/20.500.11822/33991/FECA.pdf?sequence=1&isAllowed=y

15 https://www.coursehero.com/file/p3ueo3ar/established-in-Europe-and-China-as-global-courts-agree-to-hear-its-first-Climate/

16 https://en.wikipedia.org/wiki/Climate_change_in_New_Zealand

17 https://www.brookings.edu/articles/missing-from-cop26-lifestyle-choices-of-middle-class-and-rich-consumers/

18 https://www.jstor.org/stable/42896450

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The incentive to reach and operate in these inaccessible and inhospitable locations is greater than ever; access means the ability to harvest rare materials and resources that are increasingly scarce on Earth. While the USA, China, Russia, and Europe conduct the vast majority of extractions, Japan, India, Indonesia, Iran, Brazil and others are expanding their presence, leading to an increase in resource conflicts. [19] Natural resources that were previously taken for granted and considered basic human rights – such as water, air, ozone, land and the oceans – are now genuine commodities. Water sources are highly regulated with restricted access; corporations now hold a monopoly over most of the global water supply. Those who can't afford to pay for the premium cost of water must rely on localized, often contaminated water sources.[20] Similarly, clean air is accessible only to those who can afford it. Agricultural systems suffer extensively from the transformed climate and regularity of extreme weather. Geo-engineering and GMO crop development are the only way to feed the global population.[21]

Wave Five: For most people, life is as good as it's ever been. The planet, on the other hand, is not as healthy. In many ways, this period reflects a business-as-usual trajectory from 2020: the condition of humanity has continued to improve at the expense of the environment.[22] Climate considerations have come third, subordinate to economic development and societal wellbeing. When coordinated action continued to falter on a global level, the super-economies settled for ambitious adaptation programmes. Future-proofing their own critical infrastructure while protecting their populations is a priority. A sense of urgency for climate action is palpable, but "Why should we go first?" or "Not in My Backyard" dominates the dialogue. Thus, most national governments hesitate or delay the needed large-scale actions. The Netherlands, most of Scandinavia and Germany are a few places that have started trying to mitigate their impacts on the planet by introducing carbon-free transport weeks complete with penalties and fees for those who do not comply. Norway, Finland, Singapore, Costa Rica, and California have implemented Personal Carbon Limits. Many cities are taking an active role in developing urban agriculture to secure their populations 'food supplies and reduce reliance on surrounding areas. Despite these localized efforts, the exploitation of planetary resources continues almost unabated.

Virtually everything on the 2020-2040 Transitions map (Focussed around the Engineer) from the Blackroom study is to do with AI and AGI.

Interdependent Synchronous Innovation

19 https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/2025_Global_Trends_Final_Report.pdf

20 https://www.graygroupintl.com/blog/water-inequality

21 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5790416/

22 https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change/

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At a pace never seen before the market demand for synchronous and interdependent automation development is unprecedented. Funding for Natural Language Processing, Artificial General Intelligence and Cognitive intelligent systems to be developed synchronously is at a level not seen before in automation development.[23] In the next decade massive funding of start-ups in this area will be astonishing. Engineering NZ need to decide at what level they want to participate. Much of the development will be open-source given the speed and synchronicity of it. Most autonomous systems will be open source. [24]

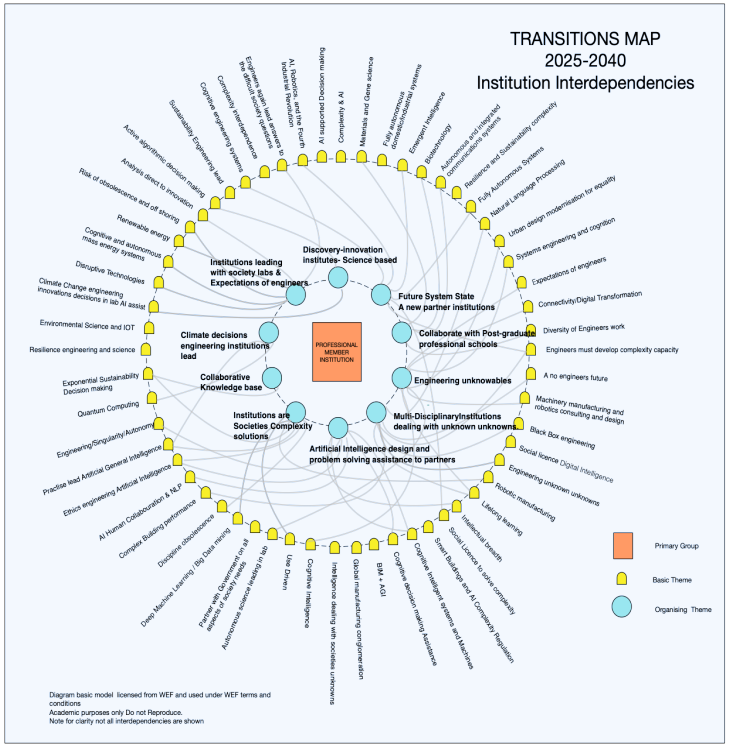
Wave Six : The Perfect Storm

For Engineering NZ all the above 'Waves of Change' are in a state of flux with all the elements happening at the same time. All these elements occur as the world population and food demand goes exponential and the imperative of climate change along with the need for cognitive intelligence, sustainability, resilience in manufacturing 6.0 and big data. and AI.[25]

02-4 AI Foresighted future

Engineering NZ is by 2050 a global-focused international entity that has made a significant positive contribution to the realization of the post Anthropocene environment and a mature and sophisticated research and development facility that is fully engaged with the complex nature of the planet's business with respect to a sustainable, resilient, secure food system, balanced and equitable world, devoid of human division, poverty, famine, war and a stabilized climate.

We got there by establishing Engineering NZ as the 'go to' socio-technical membership organization providing leadership and coordination of technical, ethical, and societal perspectives to enable members to provide solutions to the complex issues facing the planet. To do this we established a new discipline of Post Anthropocene



[23] https://www-file.huawei.com/-/media/corp2020/pdf/giv/intelligent_world_2030_en.pd

[24] https://serokell.io/blog/is-open-source-the-future

[25] https://www.mdpi.com/2071-1050/15/4/3010

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engineering and a new type of engineer focused on achieving the post Anthropocene environment in 2050, and thus we are now the world's leader in this new discipline.[26]

We got there by utilizing the special character of New Zealand that was founded on the principles of Te Triti o Waitangi and Te Ao Maori thus the Institution has broadened its role and assumed the lead in developing more integrated socio-technological approaches to society's problems. Te Ao Māori principles are integral in our cultural and intellectual approach as we embrace members from all genders, cultures and beliefs.

Our membership is truly diverse, reflecting the make-up of the society we serve and welcoming of engineering professionals from all disciplines and backgrounds.

We got there because much of society's critical decision making was enabled by Engineering NZ's Socio-technical member resources/network using AI assisted complexity decision making AGI methodologies which it has developed itself over the previous decades while developing Post Anthropocene engineering discipline.

We got there because the backbone of Engineering NZ's facilitation of this work is through its local and global connectivity, its role as a trusted partner to governments, and its close relationship with communities. Since realized, a critical contribution has been to lead the development of the construction of its socio-technological member resources/network Lab with significant funding from Government in the late 20s after it had employed new technologists and created its own 'big data' systems and AI capability and with the establishment of its own Strategic Intelligence network and the creation and implementation of the Post Anthropocene Engineer as a new engineering discipline. After this we were self-funding by utilizing our knowledge of this new engineering discipline and that of our members on commercial global networks.

The members of the Institution not only comprise traditional engineers, but engineers who perform a valuable role of integrating technical solutions into the social and cultural expectations of society. Members of society who adhere to the principles of Engineering NZ were encouraged to become members.

Our members are now engaged with critical decision making in all sectors within multiple levels of society. We reflect society's diversity and are aligned with other like organizations around the world on the principles of post Anthropocene. The institution has kept to its enduring visionary pillars established in the early 2020s, namely Collaboration, Credibility, Influence, Recognition and Thriving.

02-5 AI Backcasted schedule

Society Expectations

There is an unspoken expectation that engineers and their institutions must deliver for the planet in the same way they did back at the beginning of the industrial revolution in the 1800s and the green

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26 https://d2rjvl4n5h2b61.cloudfront.net/media/documents/Foresighting_Report_Short_Version-FINAL.pdf

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revolution in the 1960s. It is generally accepted that the near and far future have serious questions of complexity where many of the answers are in the realm of unknown unknowns and in fact may border the unknowable. Society expects that engineers will operate in this realm and provide answers to these difficult questions regarding Climate, decarbonization, renewables, engineering transitions, AI, AGI, and singularity. The faith that communities have towards engineers to solve these issues is far greater than for the science fraternity in general. Communities worldwide believe that all ethical considerations involving autonomy will be solved by engineers and their institutions. Autonomy for all systems is the end game and all engineers of all disciplines need to start on this journey now. Cognitive intelligent networks are ubiquitous and fully integrated within and across all sectors.

Decision making leadership for society.

Decision making in the complexity field on 'unknown unknowns' will become the Institution's main future work. This will involve large scale AI assist algorithms initially and then the Institution will develop its own AGI to make these enormous decisions regarding autonomy and surveillance systems etc. If the Institution does not pivot to assume leadership of the complex unknown unknowns' questions at a technical laboratory level, then engineering will dissolve into a mass of specialist guilds and all general engineering membership institutions will vanish by 2030.

Engineering Unknown unknowns' leadership

At a pace never seen before the market demand for synchronous and interdependent automation development is unprecedented. Funding for Natural Language Processing, Artificial General Intelligence and Cognitive intelligent systems to be developed synchronously is at a level not seen before in automation development.[27] If engineers do not pivot to this reality with all design engineering, they will not be participating at any level at all in a few years. By 2030 all engineering design, calculations and analysis will be performed by AGI. It is this reality that the Institution must lead.[28]

Wave Four : Climate and carbon Neutrality leadership

The big complex questions of unknown unknowns is the basis for all engineering beyond 2030. Climate change, carbon neutrality will be fully mandated against all manufacturing and energy companies and organizations worldwide over the next two decades starting immediately.[29] Sustainability Engineering and resilience and transition engineering will be the market entry price for many jurisdictions and will require complexity engineering at all levels. The society expectation of engineers in this regard will peak around 2035 and the demand for

[27] https://www.linkedin.com/pulse/future-work-adapting-automation-ai-sagar-sethi/

[28] https://waitbutwhy.com/2015/01/artificial-intelligence-revolution-1.html

[29] https://www.beehive.govt.nz/release/public-sector-be-carbon-neutral-2025

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engineering institutions to answer the complex climate questions and carbon neutrality will never go away. [30]

02-6 Summary for this Chapter

As Natural Language Processing is fully developed by 2030 the demand for cognitive intelligence collaboration will occur with rapid application for all human-machine interfacing.[31] The Engineering Institution must front this as there are a myriad of ethical questions within the complexity questions. There will be no human operators in call centers, information facilities, banks, insurance, local government, super-markets, etc. Engineers will be deeply involved with job loss design and new job creation. To operate as engineers in this environment will require a new type of engineer and this must be set up, technically managed and supported by the Institution.

The question we must ponder within this AI and AGI study is where does the engineer fits in this future and what should their membership organization be reshaped to or repurposed in order to remain relevant to these engineers, and do we need to integrate AI into the individual engineer's future and when.

As such the engineer's impact going right up to 2050 is highly significant but we believe, substantially different from now in 2023. Engineers are characterized by their problem-solving ability. In the future however as the research tells us they will be still problem solving but in complex unknowables and that may require an in-depth knowledge and expertise in AI and AGI. [32]

This reality is the key to what the organization (Eng NZ) will need to consider pivoting to and what may happen to us if we don't!

[30] https://www.engineeringnz.org/news-insights/its-a-decade-for-engineers/

[31] https://www.callaghaninnovation.govt.nz/assets/documents/ai-whitepaper.pdf

[32] https://www.proquest.com/openview/2a396fdf520843d7b492cd609bd74dd7/1?pq-origsite=gscholar&cbl=18750&diss=y

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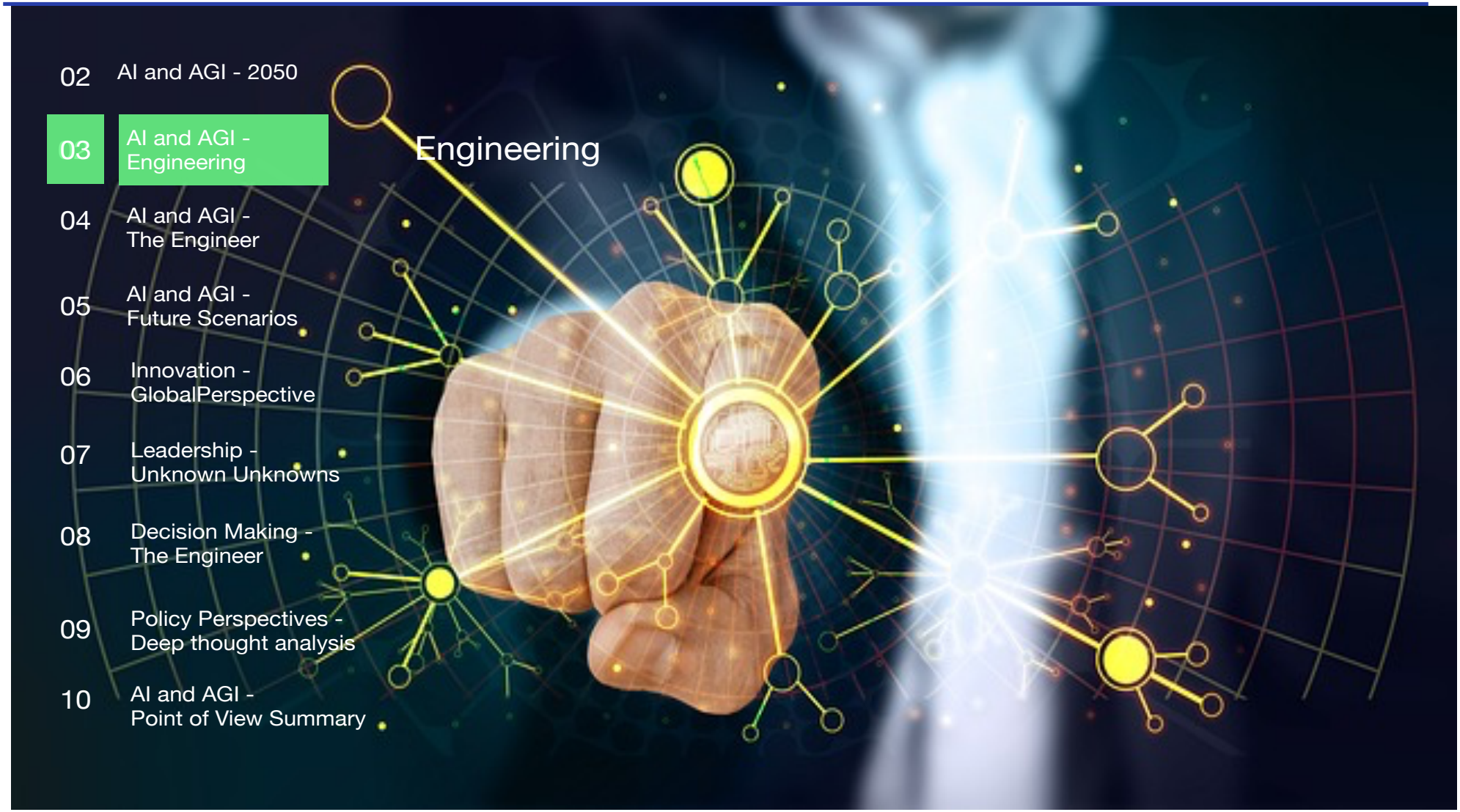

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03-1 Introduction

THE LIGHT SIDE VISION. According to the World Economic Forum Jobs of Tomorrow article, engineering skills are one of the highest-demand skills. Indeed, engineering has always been considered an evolving industry. The rapid advancements of AI technology and related jobs, such as machine learning (ML), enable engineers to complete their work in a more efficient way and solve a wider range of problems, empowering their expertise and making them the main actors of the industry's future development and success, thus creating a growing need for their profession.[33]

THE DARK SIDE VISION. "AI and automation in engineering may cause job losses and economic inequalities. Engineers must be cautious when implementing AI to avoid negative consequences, such as losing insight into what is happening and eventually losing their jobs, despite the overall benefits." [34]

From the standpoint of existential risk, one of the most critical points about Artificial Intelligence is that an Artificial Intelligence might increase in intelligence extremely fast. The obvious reason to suspect this possibility is recursive self-improvement.[35] The AI becomes smarter, including becoming smarter at the task of writing the internal cognitive functions of an AI, so the AI can rewrite its cognitive functions to work even better which makes the AI still smarter, including smarter at the task of rewriting itself, so that it makes yet more improvements.[36] The key implication for our purpose is that an AI might make a huge jump in intelligence after reaching some threshold of criticality.[37]

Eliezer Yudkowsky, Research Fellow Machine Intelligence Research Institute.

03-2 The Planet

Machine learning and the planet

With net zero commitments taking effect across the built environment industry, our industry is going to be increasingly (and rightly) expected to answer tougher questions about the designs we propose and the energy and emissions those solutions might produce. [38] This is another area where machine learning can help us navigate. Given the lifespan of buildings and infrastructure, we will need to develop more and more powerful machine learning tools to answer questions about the world these projects will join: from the effects of rising oceans, more powerful storms and flooding to greater rising temperatures and extremes of cold. [39] Climate modelling tools that can

33 https://www.weforum.org/agenda/2023/05/future-of-jobs-2023-skills/
34 https://www.neuralconcept.com/post/will-ai-replace-engineers
35 https://academic.oup.com/book/40615/chapter-abstract/348239228?redirectedFrom=fulltext
36 https://alife.co.uk/essays/the_intelligence_explosion_is_happening_now/
37 https://intelligence.org/2023/04/07/pausing-ai-developments-isnt-enough-we-need-to-shut-it-all-down/
38 https://bpcc.org.pl/is-artificial-intelligence-going-to-design-your-next-building/
39 https://link.springer.com/article/10.1007/s10311-023-01617-y

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make increasingly accurate predictions will be invaluable as engineers and designers adapt their own decision making in a rapidly warming world. [40]

The Research Questions

Will AI replace engineers? What vision for our future is more probable? Should we believe the Dark Side or the Light Side stories?

We wonder what will happen next, whether jobs will decrease or increase. And will AI automate and destroy jobs, or automate and enhance them?

Should we follow the legendary Ned Ludd in a sort of "Butlerian Jihad", or stick to the point of the World Economic Forum and Prof. Klaus Schwab, talking of a golden age thanks to new approaches like Industry 4.0 and AI? [41]

03-3 Profession of Engineering

Why AI Won't Replace Engineers

The ideal approach here is to balance AI automation and human expertise. By leveraging AI as a powerful tool to complement human skills, engineers can harness the full potential of both worlds.

This symbiotic relationship enables engineers to achieve unparalleled levels of efficiency, innovation, and precision while retaining the invaluable qualities of human intuition and creativity.

Embracing AI as a collaborative partner rather than a replacement empowers the engineering community to address complex global challenges and drive progress towards a brighter future.[42]

In conclusion, AI approaches will not replace simulation software or engineers. AI will rather be used by simulation experts to validate concepts or explore much more complex physical phenomena (such as vehicle acoustics if we talk about a CFD application) while the early development process is done within the design teams.[43]

03-4 The Professional Engineer

Will AI replace engineers – or will it usher in a 'golden age of engineering'?[44]

When Open AI released the Generative Pre-trained Transformer 3 (GPT-3) language generator in June 2020, many were shocked.

The artificial intelligence (AI) program was able to produce pieces of writing indistinguishable from those created by quite skilled human writers.[45] Many asked whether the emergence of such programs spelled the end of journalism as a human profession. There are other disciplines previously reserved for talented humans that today's AI can comfortably tackle. It can write songs that mimic the sound of famous pop stars or

40 https://www.advancedsciencenews.com/climate-modeling-turns-to-clouds-to-unravel-a-long-standing-enigma/
41 https://www.neuralconcept.com/post/will-ai-replace-engineers
42 https://www.neuralconcept.com/post/will-ai-replace-engineers
43 https://www.neuralconcept.com/post/will-ai-replace-engineers
44 https://www.quora.com/When-will-AI-replace-engineers
45 https://www.imeche.org/news/news-article/feature-will-artificial-intelligence-replace-engineers

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create paintings in the style of great masters of the past.[46] In engineering, architecture and design, a new type of AI-based software emerged, capable of creating a multitude of solutions to a problem in a short period based on predefined criteria.[47]

The components that AI designs today are so far of a rather fundamental nature – brackets, housings, forks, support structures and the like. The engineers get a range of options to choose from, but it's still the engineer who is making the decision.[48] Haimes says that, thanks to the speed at which the computer produces the iterations, the resulting product is better optimized. That leads to cost reductions, greater reliability and streamlined manufacturing. "It's not an automated process, it's assisted," says Haimes.[49] "In the future, we will continue to include more and more design goals, but there will always be a role for the engineers. We are not replacing them."

The World Economic Forum has been following the evolution of AI for many years. According to the forum's 2020 Future of Jobs report, new opportunities spawned by the expected growth of the AI industry will eventually outnumber the jobs that will be lost. But the forum's head of AI and machine learning, Kay Firth-Butterfield, agrees that not all technical professions will be spared.[50]

"It's getting much more important to get into more complex roles because the computers will be more and more able to do the basics," says Firth-Butterfield. "There will always be opportunities for people who have PhDs, people who are thinking about new ways of developing tools or starting businesses that will use AI to solve various problems.[51] Those jobs will survive. Jobs that involve basic coding probably not so much." Ultimately, Firth-Butterfield believes, AI will usher in the "golden age" when engineers will be able to focus on "the fun things, and

46 https://www.incadence.org/post/will-ai-replace-humans-in-music#:~:text=Early%20Studies%20Suggest%20AI%20Has,music%20generated%20by%20human%20beings.
47 https://www.imeche.org/news/news-article/feature-will-artificial-intelligence-replace-engineers
48 https://www.imeche.org/news/news-article/feature-will-artificial-intelligence-replace-engineers
49 https://www.goodwin.edu/enews/the-importance-of-computer-aided-manufacturing/
50 https://www.weforum.org/agenda/2020/10/dont-fear-ai-it-will-lead-to-long-term-job-growth/
51 https://www.imeche.org/news/news-article/feature-will-artificial-intelligence-replace-engineers#:~:text=But%20the%20forum's%20head%20of,%2C%E2%80%9D%20says%20Firth%2DButterfield.

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the AI will support them". Mark Girolami, professor of civil engineering at Cambridge University, and the Royal Academy of Engineering research chair in data-centric engineering, shares the excitement. "Some jobs will disappear, but new ones will emerge," says Girolami.[52]

"Forty years ago, we needed draughtsmen to draw technical drawings. That's all automated now. But we now need a lot of software developers and engineers who are freed from drawing and copying and able to consider the more high-level issues. Jobs transform in response to what's going on societally and that's good. It's going to make society safer and jobs more fulfilling."

Girolami, however, cautions that the profession cannot sit around and wait for things to change. It must proactively prepare for the AI-driven future and make training in data-centric sciences a cornerstone of engineering education.

Girolami and Firth-Butterfield agree that, one day, AI will get so good that it will be able to take over the creative design process completely. It will be able to further develop itself, making all data scientists who train and develop it today redundant. But this moment still seems quite far in the future. "Deep learning is incredibly powerful for very specific problems, it's good for simple, very constrained types of designs. But for the more generic, mental-level problems such as creative design, there is still quite a way to go," says Girolami. "When I was at university, everybody was talking about AI doing this and that, but it still hasn't happened. We have moved closer to it. It will happen at some point. But whether that will be in 10 years or 30 years, that's difficult to say."[53]

Firth-Butterfield agrees that the pace of progress doesn't match the expectations. The World Economic Forum predicted only a few years ago that the profession of truck driver would soon become obsolete because of autonomous vehicles.[54] The task to automate driving, however, proved more challenging than expected. "We used to think that lorry drivers would soon be out of work, but it is proving much harder to do even on the sort of roads that we have in America, which are much easier for autonomous vehicles to navigate than, for example, streets of London," says Firth-Butterfield. " The promise of AI is there, but we still have a number of nuts to crack to say this is going to be fully autonomous." The slow progress, says Firth-Butterfield, is largely owing to the shortage of computer scientists capable of developing AI algorithms and training the machines. Ironically, she adds, to become an AI may not be the safest career choice. "Now, we need to educate a lot of people because we need a lot of people to do the work," she

[52] https://eureta.org/is-artificial-intelligence-going-to-replace-engineers/
[53] https://www.linkedin.com/pulse/conversation-yuval-noah-harari-artificial-nicholas-thompson/
[54] https://hbr.org/2019/09/automation-isnt-about-to-make-truckers-obsolete

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says." But come 2030, 2040, those people are all going to be looking for new jobs because AI will be able to do their job itself."

03-5 AI and AGI and the engineer

As architects, designers, engineers and planners, we work in a complex and dynamic context – we are concerned with not just how things are now and have been, but what they will be like in the future. [55] Beyond the impressive creativity of GPT-3, what we as a community really need are insights into the real-world contexts into which our design decisions must succeed and endure.[56] We need to know how strong a region's storm winds might blow or how much rainfall future storms might produce, how will the climate affect ground water or a myriad of other factors that increasingly challenge the built and natural environment. Machine learning's ability to discern patterns and make predictions under incredibly complex sets of conditions might be more what we need.[57]

Another area that shows great promise is the emerging convergence between machine learning and science, leading to new technologies that build on the huge body of knowledge in mathematics, physics and other sciences. [58] Traditional computing methods have become more powerful but even today the level of computing power required can be expensive and slow to use. In the built environment industry

modelling and simulation are areas where we need continuous improvement in speed, scale and complexity of computing tasks. Machine learning tools with GPT-3-like ability to consider billions of factors simultaneously, trained on larger data sets, should enable us to make a quantum leap as we study scientific alternatives, find optimal solutions, and handle more complex models. [59] This would be very valuable on typical fluid flow phenomena such as wind, atmosphere, water flows, structures, materials, chemistry and other hard to compute elements. At Arup, they have already been experimenting with AI accelerated air flow simulations (the interaction of wind with buildings). In the past these have played a limited role in design and

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55 https://www.arup.com/perspectives/is-artificial-intelligence-going-to-design-your-next-building

56 https://medium.com/semi-random-thoughts/why-gpt-3-is-a-good-product-not-just-a-groundbreaking-model-aee82adfaf79

57 https://www.mdpi.com/2073-431X/12/5/91

58 https://www.arup.com/perspectives/is-artificial-intelligence-going-to-design-your-next-building

59 https://www.linkedin.com/posts/tristram-carfrae-rdi-7a4600111_digital-sustainabledesign-wearearup-activity-6907730735672008704-QeEU/?trk=public_profile_like_view&originalSubdomain=be

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typically only one or two cases have been studied (because of their time and computational cost). This new approach (although the technology is not yet fully mature) promises far more freedom to explore options and reach optimal solutions more quickly. [60]
In the case of flood prediction, we see AI models that have learnt from historical data and are informed by physics, being far better able to generalise to, for example, an extreme storm event in a future climate and we are already beginning to test this approach on projects. [61]

As AI tools are expanding, it seems that in the near future, data scientists, computer scientists, and other new jobs and profiles in AI technologies, such as DL (deep learning), will be the knowledge workers. [62] However, in this chapter, we will show the application of AI tools for the product development process and that Artificial Intelligence (AI) is rather a help for critical thinking.

Will AI replace engineers? We feel the answer to this question is "no". The future is bright.

Follow us to understand our arguments on AI technologies and near future benefits. Rather than quoting market research analysts, we will give practical hands-on examples from the world of engineers.

By merging test data, simulation tools data, and technical drawings (CAD) data, data scientists and computer scientists are creating more opportunities and jobs for themselves but also for engineers involved in manufacturing processes and product development. [63]

They do this by providing valuable data-driven AI insights to all engineers in the supply chain from concept to production. Thus, the job market for engineers is going to shift from manual executions to more concept work, creating new jobs for humans in all industries rather than more power for an "evil AI". [64] As the technology progresses, concerns arise about job displacement in the transportation industry, where autonomous vehicles could replace human drivers. [65]

The Rise of Artificial Intelligence in Engineering

The use of artificial intelligence (AI), machine learning (ML), and deep learning (DL) in engineering has sparked a heated debate regarding the benefits of automation versus human expertise. [66] AI technologies have revolutionised the field, offering efficiency, accuracy, and problem-solving capabilities. Extensive manual labour and time-consuming calculations can now be

60 https://www.arup.com/perspectives/is-artificial-intelligence-going-to-design-your-next-building
61 https://www.nature.com/articles/s41612-023-00388-1
62 https://www.pewresearch.org/internet/2018/12/10/improvements-ahead-how-humans-and-ai-might-evolve-together-in-the-next-decade/
63 https://www.neuralconcept.com/post/will-ai-replace-engineers
64 https://news.ycombinator.com/item?id=35177257
65 https://www.sciencedirect.com/science/article/pii/S0264275121001013
66 https://link.springer.com/article/10.1007/s42979-022-01043-x

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accomplished with remarkable speed and precision, all thanks to AI-driven automation. [67]

Semi and Fully Autonomous Driving

As a good example, AI technologies have revolutionised the automotive landscape with autonomous transportation. Engineers and researchers have leveraged AI, particularly ML and DL algorithms, to create sophisticated systems that can perceive the environment, make real-time decisions, and navigate safely without human intervention. [68]

The Challenge of Perception

One of the most critical tasks in autonomous vehicle development is perception, where the vehicle must interpret its surroundings using sensors such as cameras, lidar, and radar systems. [69]

Traditionally, engineers relied heavily on manual labour to develop handcrafted rules and algorithms for object detection, lane recognition, and other perception tasks. This process was not only time-consuming but also prone to errors and inefficiencies.

Positive Impacts of Technology

The impact of autonomous driving on the US workforce presents several positive aspects.

Firstly, it's expected to enhance road safety significantly, reducing accidents caused by human errors. [70]

Secondly, autonomous vehicles handling transportation opens up new opportunities for workers to focus on other value-added tasks during their commutes. Additionally, this technology may lead to increased productivity, as delivery and logistics industries can streamline operations and reduce transit times. Finally, developing and maintaining autonomous vehicles create new job opportunities in engineering, software development, and manufacturing sectors.

The Importance of Engineering Data

With the advent of AI and deep and machine learning techniques, engineers now have the ability to train neural networks to learn directly

67 https://www.sciencedirect.com/science/article/pii/S2666675821001041
68 https://medium.com/@adityamhaske711/case-study-self-driving-cars-1e837ad4c872
69 https://www.mdpi.com/1424-8220/21/16/5397
70 https://www.sciencedirect.com/science/article/abs/pii/S1369847821001649

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from vast amounts of data. [71] For instance, convolutional neural networks (CNNs) have shown exceptional performance in image recognition tasks, enabling autonomous vehicles to detect pedestrians, other vehicles, and road signs with speed and accuracy.

AI Applications in the Engineering Field

Will AI replace engineers? We will now focus on this question, showing how AI models and generative AI systems can positively impact daily lives.

Generative Design (Autodesk) -

An automotive chassis CAD and Design Automation. The standard design process in industrial product development consists of regular iterations between product designers using CAD and the simulation teams using CAE (Computer- Aided Engineering simulations). [72] At different stages of the development process, with evolving requirements, new designs need to be assessed and improved using standard CAD/CAE tools. Professional Journal

This sophisticated turbo-machinery simulation would be impossible to produce with "simple CAE" These are the bottlenecks that Neural Concept Shape (NCS) has solved with a new class of AI-based algorithms based on ML and DL. [73]

Shape models handle raw 3D CAD and CAE data, allowing simulation to be conducted early in the design process. This provides designers with simplified and real-time access to simulation results. [74] These interactions involve consequent waiting times, and the simulation tools are not always compatible with the requirements of fast-paced projects. Furthermore, different file formats and the complexity of simulation teams' tools are often further slowing down the process. Quicker simulation approaches, integrated into design tools, are an attractive alternative. However, most of these so-called "simple CAE" or " upfront solutions" simulation tools have some serious disadvantages. [75] Basically, they lack accuracy, do not correlate well with Neural network architecture behind NCS, with a self-learning model providing a CAE surrogate to solve prediction for engineers NCS' CAD interface enables product designers to quickly and accurately iterate on designs, resulting in better solutions for customers. [76]

Real-time design exploration: from CAD geometry to CFD results in a few seconds using NCS AI model AI Adoption in CAE Teams Engineers remain at the core of the product design process in mechanical engineering and other industries. Using their knowledge and experience, CAE simulation domain experts are now becoming responsible for the quality, update, and deployment of the mentioned AI models. [77]

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[71] https://www.ibm.com/blog/ai-vs-machine-learning-vs-deep-learning-vs-neural-networks/

[72] https://www.linkedin.com/pulse/how-cad-cae-revolutionizing-competitive-landscape-eleation-hnh3f/

[73] https://www.neuralconcept.com/post/will-ai-replace-engineers

[74] https://craft.io/crf_glossary/what-is-cad-cae/

[75] https://www.neuralconcept.com/post/will-ai-replace-engineers#:~:text=However%2C%20most%20of%20these%20so,proposed%20by%20the%20software%20vendors.

[76] https://link.springer.com/book/10.1007/978-3-030-80568-5

[77] https://www.neuralconcept.com/post/applying-machine-learning-in-cfd-to-accelerate-simulation

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The applications of NCS are infinite. Example of deformation and stress levels after lateral pole crashing of car battery For instance, mechanical engineers' expertise empowers designers with additional AI tools, enabling them to tackle complex engineering challenges more efficiently and accurately and with fewer iterations in the design process. [78]

This symbiosis between AI and engineers is a new workflow, ushering in an era of innovation in CAE software applications for mechanical engineers and engineers in many other industries. [79]

CAD representation of a car ready for CAE simulation (Mercedes) Advantages of AI in the CAE Workflow.

One of the most significant advantages of integrating AI into the CAE workflow is a much smarter and more automated usage of CAE tools in the product development process. [80]

AI-powered algorithms can assist engineers in automating time-consuming tasks, such as meshing and simulation setup, allowing them to focus on higher-level design decisions and analysis. This saves time and reduces the likelihood of human errors with more reliable and optimized engineering solutions. [81]

Approaching Problem-Solving With AI Technologies

AI adoption has revolutionized the way CAE teams and consultancy companies approach problem-solving. With access to AI-driven predictive analytics, engineers can now simulate and analyze a broader range of scenarios, enabling them to explore alternative design options rapidly. This iterative process leads to optimized designs and cycles in the product development process, giving adopting companies a competitive edge.[82]

Furthermore, AI has opened up new possibilities simulation-driven design optimization.

By harnessing the power of machine learning and optimization algorithms, CAE teams can efficiently search through vast design spaces to identify the most optimal configurations that meet multiple criteria. This capability not only enhances product performance but also allows for the creation of innovative and cutting-edge designs that were previously challenging to achieve. [83]

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78 https://www.neuralconcept.com/post/digital-thread-deep-learning-applications-in-engineering

79 https://www.gcu.edu/blog/engineering-technology/unlocking-innovation-ai-mechanical-engineering

80 https://rescale.com/blog/how-cae-simulations-in-the-cloud-accelerate-innovation/

81 https://www.linkedin.com/pulse/exploring-impact-artificial-intelligence-software-roles-ayodele-nhg1f/

82 https://www.neuralconcept.com/post/the-future-of-cad-technology-innovations-and-implications

83 https://www.sciencedirect.com/science/article/pii/S2666675821001041

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Why AI won't replace engineers

The ideal approach here is to balance AI automation and human expertise. By leveraging AI as a powerful tool to complement human skills, engineers can harness the full potential of both worlds. This symbiotic relationship enables engineers to achieve unparalleled levels of efficiency, innovation, and precision while retaining the invaluable qualities of human intuition and creativity. [84] Embracing AI as a collaborative partner rather than a replacement empowers the engineering community to address complex global challenges and drive

progress towards a brighter future. In conclusion, AI approaches will not replace simulation software or engineers. AI will rather be used by simulation experts to validate concepts or explore much more complex physical phenomena (such as vehicle acoustics if we talk about a CFD application) while the early development process is done within the design teams. [85]

Reluctant adopters

Haimes doesn't expect AI to overtake the engineering sector any time soon. In fact, he says, despite engineers 'propensity for new technology and assumed geekiness, the profession might be among the last to embrace this innovation. "Engineers are very data-driven people, they want to know whether the technology has been proven to work," says Haimes. [86] "They want to be able to understand what's happening in the background and whether they can trust the system. They are not going to commit to it unless they have a full evaluation of how it works and it's proven that it's successful."

The engineering community is particularly concerned about the fact that current AI applications run in the cloud, adds Haimes. The companies don't have control over the systems and data centres and prefer not to take security risks with their intellectual property.

"Engineering and manufacturing is probably one of the last industries to truly embrace cloud," says Haimes. "That will change over the next five to ten years. "And that's also the timeframe in which I expect generative design to really get into the mainstream adoption phase and become embedded in most CAD applications." When it comes to the future of

[84] https://www.linkedin.com/pulse/significance-ai-hi-symbiotic-relationship-darren-richard-hngue/

[85] https://www.sovtech.com/blog/human-vs-ai-collaboration-in-software-development-harness-the-power-of-ai-generated-code

[86] https://www.imeche.org/news/news-article/feature-will-artificial-intelligence-replace-engineers

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AI, Firth-Butterfield believes that it is in the hands of the humans who are developing it today. AI doesn't need to replace musicians, writers, painters or engineers if humans don't want it to. "Technically, AI will one day reach the point where it can replace engineers, designers and architects," she says. "But it's up to us to decide what we want to use it for. And I suggest we should focus on using it on solving some really painful issues that we face, such as curing diseases, rather than taking away the jobs of engineers, architects or journalists."

03-6 Summary for this Chapter

Firth-Butterfield agrees that the pace of progress doesn't match the expectations. The World Economic Forum predicted only a few years ago that the profession of truck driver would soon become obsolete because of autonomous vehicles. The task to automate driving, however, proved more challenging than expected." We used to think that lorry drivers would soon be out of work, but it is proving much harder to do even on the sort of roads that we have in America, which are much easier for autonomous vehicles to navigate than, for example, streets of London," says Firth-Butterfield. "The promise of AI is there, but we still have a number of nuts to crack to say this is going to be fully autonomous. "The slow progress, says Firth-Butterfield, is largely owing to the shortage of computer scientists capable of developing AI algorithms and training the machines. Ironically, she adds, to become an AI developer may not be the safest career choice. "Now, we need to educate a lot of people because we need a lot of people to do the work," she says. "But come 2030, 2040, those people are all going to be looking for new jobs because AI will be able to do their job itself."

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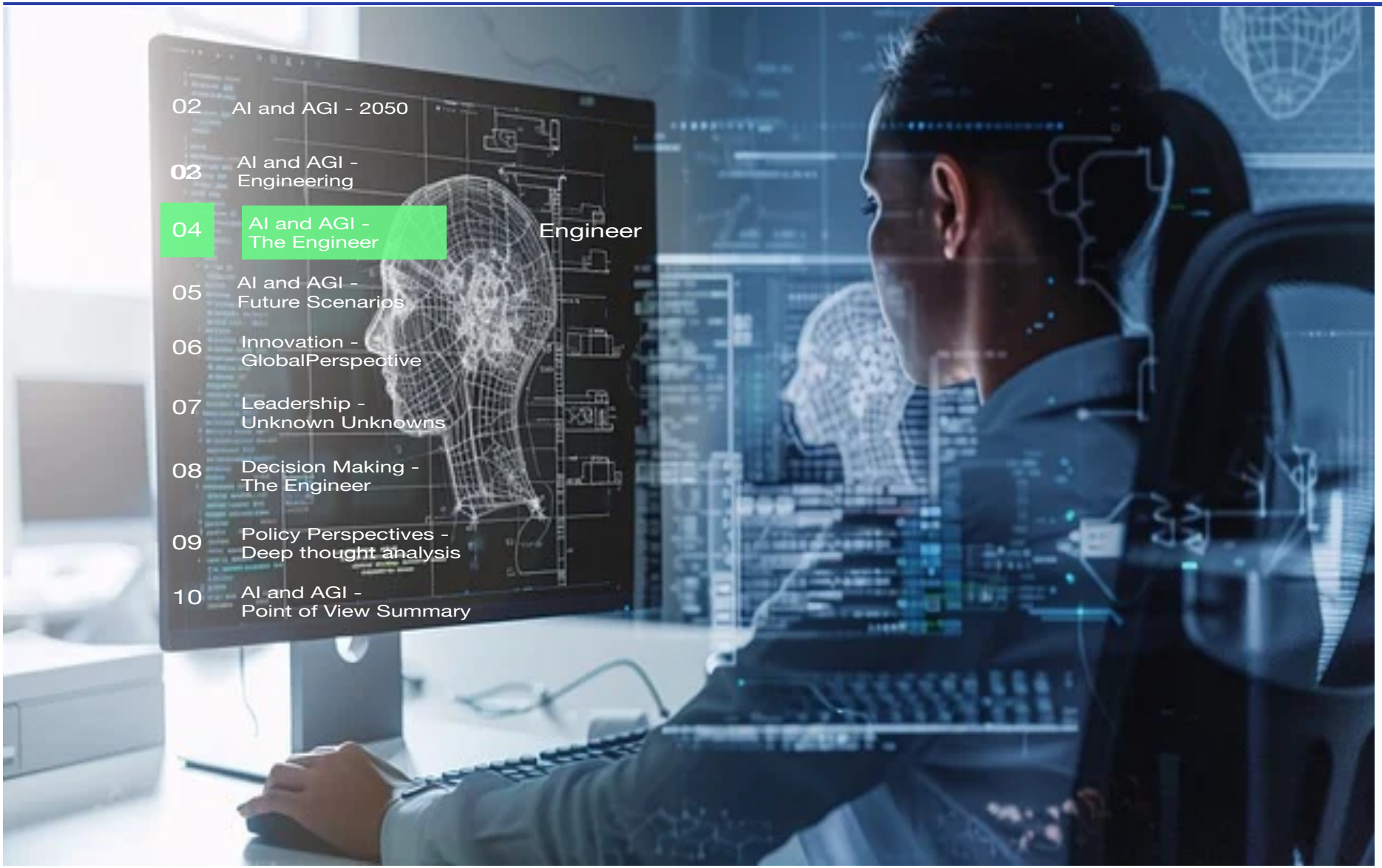

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We won't really be able to understand why a super intelligent machine is making the decisions it is making. How can you reason, how can you bargain, how can you understand how that machine is thinking when its thinking, when it is thinking in dimensions you can't conceive of?

Kevin Warwick, Professor of Cybernetics University of Reading.

04-1 Introduction

Like most engineers, I like Single Line Diagrams (SLD) that clearly show the process in a set of easy to follow icons. So in that spirit I set about drawing up a SLD that depicts what I think the Engineer of the near future gets out of AI and how he or she might use it in the manner of a slide rule. On the assumption that all engineers will ultimately be using AI or AGI in some form, it matters that we understand how the AI and AGI need vast databases of information in order to be able to make the decisions and recommendations engineers need.

One thing that we have as practising engineers that other professionals do not have, and it would be nigh impossible to form synthetic versions of, is experiential learning. By capturing all the experiential learning of the practising engineer means we have the initial formation of a huge data source of real time performance and decision making systems that will lend itself to self generated AI. [87]

The rest of this chapter is oriented to understanding the data sources required and how that all fits together to allow the engineer to visualise a SLD and where he or she fits into it and can use it just like when the slide rule first arrived on the engineers desk

4-2 Experiential Learning

In terms of education, all professions require key balances of emphasis: between university preparation and experiential learning, between early preprofessional education and continuing education, and between theoretical knowledge e.g., conservation of energy and experiential knowledge e.g., design, the latter coming from "the field" of practice. [88] The concerns span the developmental spectrum: What is to be known? How is it to be conveyed? Who is to teach and learn? Engineering is no exception; and in a period of rapid technosocial change, many items of professional importance are being recognised and distilled first in practice, and only thereafter in more scholarly terms in the academy. In such a practical setting, a strategy that relies on infusing new knowledge solely via university preparation of entry-level recruits, cannot keep pace with professional demands. [89]

Hence, the role of experience is of special concern in engineering. In the broadest sense, experience includes internship or cooperative education, pre-registration professional development, post-registration

[87] https://www.sciencedirect.com/science/article/pii/S2666675821001041

[88] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8711830/

[89] https://www.researchgate.net/publication/306020931_Learning_strategies_a_synthesis_and_conceptual_model

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continuing education, and probono activity; all in addition to customary "billable" professional work. [90]

It is clear that the professional leadership is focusing on the future; and on developing a more complete articulation of professional service around future opportunities and challenges. The leading words "entrusted by society" indicate a willingness to earn an enhanced social role. Implied is the engagement of emergent challenges and opportunities, and the delivery of results.

Clearly, this is a vision of professional service, beyond the simpler occupational model described earlier. Equally clearly, this is not a "dream vision" or a hope; it is a vision of what the profession aspires to be. This vision for the profession and the role of civil engineers requires a new set of knowledge, skills, and attitudes that are consistent with it. These are the subject of the Body of Knowledge activity. Daniel R. Lynch [91]

4-3 Data Sources

It is the Body of Knowledge and the experiences that form the biggest database of engineering on the planet. All institutions and most large engineering consultancy practices have vast storage of reports, evaluations, assessments, failure reports, proven methods and engineering practise notes and this will ultimately form the best database system for AI and AGI within engineering. Engineering world wide will share this enormous Data base and will ultimately form the data lake that the AI systems require.

4-4 Data Lake

A data lake is a repository that can store your organisation's structured and unstructured data in a single storage pool. It can handle large volumes of raw data without the need for it to be structured on entry. [92]The key benefits of data lake solutions

- Capable of handling raw, unstructured data
- Can be broken down into simple components for quick set-up
- Easier to manage with scalability in the cloud
- More flexible as it can store a range of file formats
- Data can be analysed to gain new insights
- Typically low storage costs
- Artificial intelligence (AI) and machine learning (ML) tools can be applied to unstructured data types, such as image recognition or natural language processing.

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90 https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=289a6d19337d8e6af9985e5d110140b6b48fb7a5

91 https://www.researchgate.net/publication/358739177_Civil_Engineering_Body_of_Knowledge_for_the_21st_Century

92 https://www.linkedin.com/pulse/data-lake-vs-warehouse-understanding-differences-use-wwjne/

Artificial Intelligence, Engineering and the Engineer

Data lake use cases

Data lakes provide data consistency and can be used to power big data analytics, ML and predictive analytics to unlock valuable insights that inform business decisions. Some examples of data lake use cases include:

- Financial organisations such as investment firms may use data lake solutions to collect and store real-time market data to help manage portfolio risks
- Subscription-based media streamers can use a data lake to gather insights on customer behaviour to improve their recommendation algorithms
- Healthcare organisations may use a data lake to help them improve patient care to enhance outcomes and reduce costs
- Data scientists and sales engineers can use a data lake to help them build predictive models to identify consumer behaviours.

In conclusion, it is crucial to remember that this is not an either-or situation. Rather than focusing on the industry, the conversation should focus on the right tool for the job. For example, within healthcare, a data lake is better at handling complex data such as medical records. However, a data warehouse is ideal for standard engineer record data, so a combination of both is needed to fully optimise the available data. [93] Where data may be inputted in inconsistent formats, a data lake can be used to land and standardise data for ingestion into a data warehouse. Data lakes can also make for cost-effective archives, providing low cost storage to house infrequently accessed data. Utilising data lakes in this manner opens up the possibility for streamlined warehouses, reduced costs and increased performance.

Adopting a hybrid approach that includes both solutions working together to perform different tasks may be the most productive and cost-effective solution for engineering.

The evolution from modules to agents in software engineering reflects the industry's ongoing quest for more dynamic, adaptable, and efficient systems. As AI continues to evolve, the integration of agents in platforms like LangChain and AutoGPT, along with developments like Microsoft's Autogen and OpenAI's Assistants, will likely redefine how we interact with and leverage AI and move towards building AGI systems using multi-agent software engineering (MASE). [94]

[93] https://www.linkedin.com/pulse/data-lake-vs-warehouse-understanding-differences-use-wwjne/

[94] https://blog.finxter.com/langchain-vs-autogen-comparing-the-latest-in-ai-language-processing-tools/

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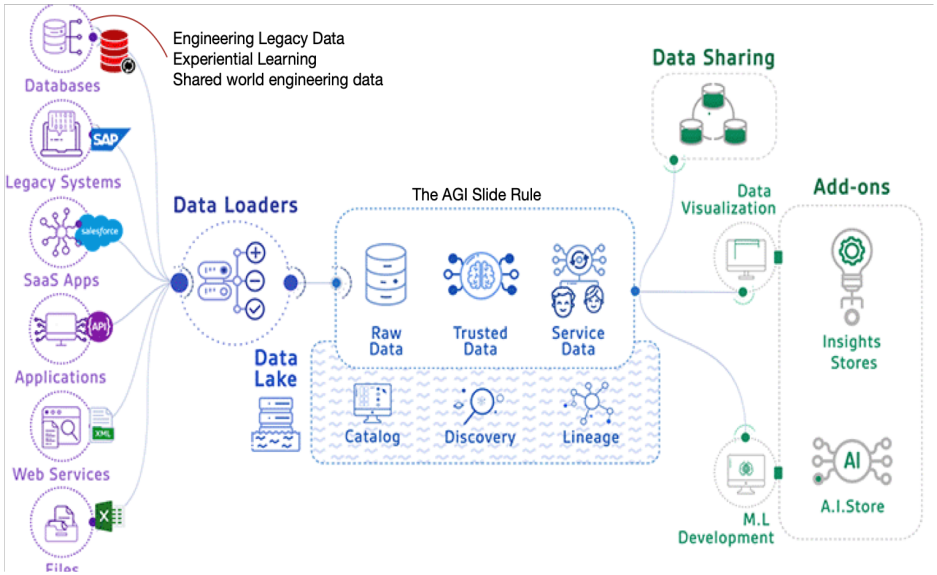
4-5 Final SLD Flow Chart for AI



First, let's define what an Agent is and what it consists of.
1) A custom knowledge base and memory (this is in addition to the LLM's knowledge it may interact with and a way to store and access memory,
2) Skills and tools — ability to do specialised tasks based on custom instructions provided to it and tools it can use, and finally
3) Effectors and Receptors— Ability to talk to other services and Agents to achieve a certain goal using Natural Language and APIs. A conceptual diagram of an independent, specialised agent.

4-6 Summary for this Chapter

The AI Architecture Evolution

In the realm of Gen AI when the LLMs became popular we saw the emergence of two open source frameworks LangChain and Llamaindex that allows developers to ferry information back and forth from LLMs in the early days. As the use cases evolved that required semantic search of data that LLMs were not aware of, we saw encapsulations of objects to talk to vector databases in a pattern called Retrieval Augmented Generation (RAG). To be fair, LangChain always had the notion of an Agent and you could use a combination of Tools and vector stores to build a custom use case. More recently, LangChain added a few things to the stack that made this architecture more useful and production ready. This includes LangSmith, a way to debug your LLM applications, LangServe — a way to deploy your application and finally — Templates — a way to create independent and specialised AI services that are then automatically also exposed as API endpoints, making them able to communicate easily with other Templates and agents.

The Rise of Auto-agents

When you combine multiple specialised entities (agents), you now have some interesting use cases that start to become a reality, for example, researching, writing, self-critiquing, rewriting, and publishing similar

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marketing function. If this sounds very similar to Artificial General Currently, there are a few popular frameworks that allow users to create agents and have them work together towards a common goal.

- AutoGPT — One of the original GenAI Auto-agents framework, you can use it to build your own agent and once you define a goal, AutoGPT works with multiple agents, do self-prompting, have a chain of thoughts and complete tasks.
- SuperAGI — Very similar to AutoGPT, this allows users to also build their own agents.
- Microsoft's Autogen: Microsoft's recent announcement of Autogen marks another significant milestone. In Autogen, agents can be defined in a configuration file and managed through a proxy agent, incorporating a human-in-the-loop approach. This allows for more dynamic and responsive AI systems.
- OpenAI's Assistants: A Parallel Development

OpenAI's Assistants feature a few concepts that are very similar to the agents. Every assistant has threads (multiple messages in one conversation), the ability to use tools (custom functions and API call outs), and store and retrieve context and memory (retrieval tool). However, at the time of writing this article, they currently lack API support and the capability for inter-agent communication, which might be on the horizon. This is not to discount the fact that you can call these agents and execute them through your code if you use their SDKs.

What is impressive about this framework though is the fact that you can use this framework to generate images, and also send audio, text and video files as input. This means, we can build an Assistant that can see and hear and respond either in text, image, video, sound or can go and perform an action. In my opinion, (CTA) we are now witnessing the very beginning blocks of building AGI applications for engineering.

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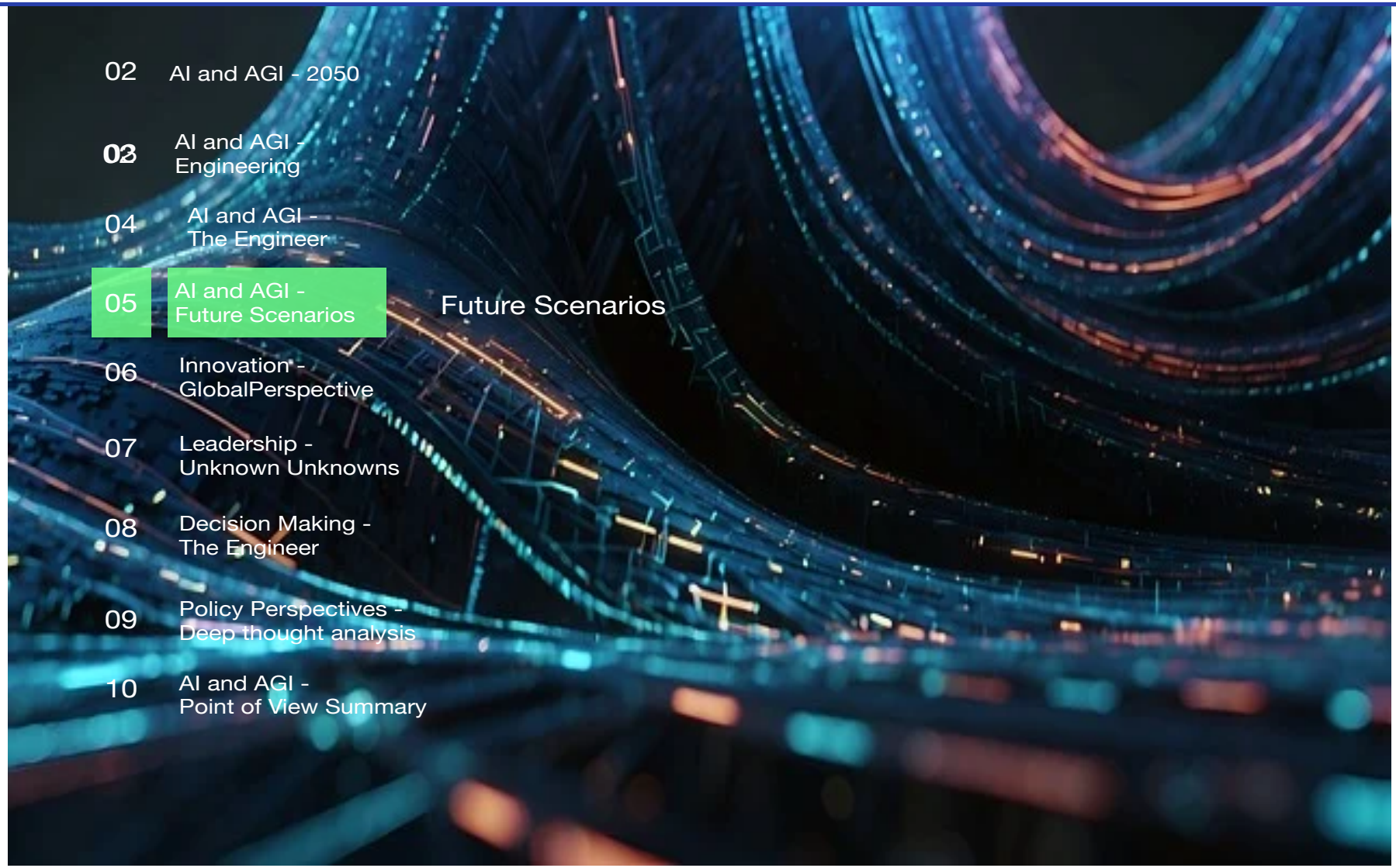

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But if the Technological Singularity can happen, it will. Even if all the governments of the world were to understand the 'threat" and be in deadly fear of it, progress towards the goal would continue. In the fact the competitive advantage - economic, military, even artistic - of every advance in automation is so compelling that passing laws, or having customs, that forbid such things merely assures someone else will.

Vernor Vinge. THE COMING TECHNOLOGICAL SINGULARITY 1993

5-1 Introduction

The greatest fear about AI is singularity (also called Artificial General Intelligence), a system capable of human-level thinking. According to some experts, singularity also implies machine consciousness. [95] Regardless of whether it is conscious or not, such a machine could continuously improve itself and reach far beyond our capabilities. Even before artificial intelligence was a computer science research topic, science fiction writers like Asimov were concerned about this and were devising mechanisms (i.e. Asimov's Laws of Robotics) to ensure the benevolence of intelligent machines. [96]

5-2 Climate Change

The recent IPCC report released in Apr 2022 reiterated the need to take collective action and more importantly to accelerate actions — "It's now or never, if we want to limit global warming to 1.5°C (2.7°F)," said IPCC working group III co-chair Jim Skea. It will take all tools and innovations at our disposal to support the acceleration, including AI, which will offer a sizeable and promising opportunity. Accordingly, AI is a 'game changer 'for climate change and environmental issues. [97]

- Predicting Climate change. The world's climate scientists have the most difficult task: to predict with some accuracy that the future will be hotter than today. This requires several models that divide the planet's atmosphere, ocean, forest, and land surface into a grid of cells, which is a complicated process. [98] For example, calculating the state of the climate system for every minute of an entire century would require over 50m calculations for every grid cell.

The Intergovernmental Panel on Climate Change (IPCC) reports are based on many climate models to show a range of predictions, which are then averaged out. AI is helping to determine which models are

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95 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/

96 https://dalealbertsgarage.com/a-velocity-connected-with-scientific-advance

97 https://medium.com/60-leaders/can-ai-help-us-solve-humanitys-burning-problems-like-climate-change-71dfc00cd9ed#:~:text=The%20recent%20IPCC%20report%20released,III%20co%2Dchair%20Jim%20Skea.

98 https://climate.nasa.gov/news/2943/study-confirms-climate-models-are-getting-future-warming-projections-right/

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more reliable and thereby improving the accuracy of climate change projections. [99]

5-3 Resources and Energy

Circular economy principles are meant to design out waste and pollution, keep products and materials in perpetual use, and regenerate natural systems. The advantages are substantial, for example, in Europe alone we could create a net benefit of Euro 1.8 trillion by 2030 AI can play an important role in accelerating circular economy development by a) reducing time required to prototype b) supporting product as a service, at the operational stage, with better asset utilisation, demand prediction, preventive maintenance, and smart inventory management, and c) optimising circular infrastructure in closing the loop by improving the processes to sort and disassemble products, remanufacture components and recycle materials, components, and materials. [100]

A report by the Ellen MacArthur Foundation highlights that the potential value unlocked by applying AI in some or all the principles (Design, Operation, and Infrastructure) in the food industry is up to USD 127 billion a year in 2030. Equivalent AI opportunity in the consumer electronics is up to USD 90 billion a year in 2030. [101]

-AI for Energy. The electric grid is one of the most complex machines on Earth. However, it is evolving rapidly with the addition of variable renewable energy sources. Due to the inherent variability of wind and solar, the current grid faces many challenges in accommodating the diversity of renewable energy. [102] The utility industry needs smart systems that can help improve the integration of renewables into the existing grid and make renewable energy an equal player in the energy supply. AI and IoT technologies can fill this gap by improving the reliability of renewable energy and modernising the overall grid.

Firstly, when coupled with AI, smart & centralised control centres offer flexibility to energy suppliers to cleverly adjust the supply with demand. [103] Secondly, AI enables improved integration of micro-grids. Thirdly, it improves safety and reliability with AI to manage intermittency. Fourthly, the integration of AI can help renewable energy suppliers expand the marketplace by introducing new service models and encouraging higher participation. A couple of big players like Xcel Energy and General Electric in the energy field are already harnessing the power of AI in the renewable energy space. [104]

Artificial Intelligence has a huge potential for sustainability and climate change that is yet untapped. Organisations, while designing the

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[99] https://news.climate.columbia.edu/2018/06/05/artificial-intelligence-climate-environment/

[100] https://www.nokia.com/thought-leadership/articles/hidden-value-in-your-waste/?did=D00000006821&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kThT9zpppEF-dwBRB60QGgORidtd8Ad0Ll2Sr-_jKeajgHGIgdhdA60aAv6bEALw_wcB

[101] https://www.ellenmacarthurfoundation.org/explore?search=AI&sortBy=rel

[102] https://towardsdatascience.com/ai-and-ml-to-save-the-clean-transition-acceleration-or-just-to-keep-the-light-on-during-the-storms-9219b52a8fba

[103] https://www.researchgate.net/publication/357541102_Application_of_AIIoT_for_Smart_Renewable_Energy_Management_in_Smart_Cities

[104] https://www.iea.org/commentaries/why-ai-and-energy-are-the-new-power-couple

Artificial Intelligence, Engineering and the Engineer

architecture and capability for AI, should explore AI-enabled use cases from a climate action perspective. [105]

More importantly:

- Mitigating the carbon emissions generated from AI by adopting renewable energy and optimisation techniques in their algorithms.

- Building a strong foundation for AI with the various use cases in mind including climate change.

- Collaborating and sharing, as this is critical in avoiding wasted efforts in duplicating models and helping to accelerate scale-ups. This should be done across industries, and across organisation sizes including small and medium-sized organisations. This will minimise the overall cost and reduce the time required to bring AI into the market.

- Promoting innovation within and outside the organisation. There has been an increased focus on ESG reporting as it is becoming mandatory. However, innovation is what will help organisations to really bring the emissions to the required level. We need to educate and promote AI technologies to employees and encourage experimentation, learning, failing to eventually succeed and accelerate the climate change reduction ambitions. [106]

5-4 Complexity and criticality

The engineering profession is not immune to the influence of AI. In fact, AI is revolutionising the field, opening up new possibilities and transforming traditional practices. Here are some key ways in which AI is impacting the engineering profession: [107]

Design and Optimisation

AI is increasingly being used in the design and optimisation of engineering systems. By analysing vast amounts of data on performance, efficiency, and other factors, AI algorithms can identify optimal designs for complex systems such as aircraft, automobiles, and manufacturing processes. This not only leads to more efficient and effective engineering designs but also enhances industries like transportation and manufacturing. [108]

Automation of Engineering Tasks

AI is playing a crucial role in automating various engineering tasks. By analysing data from sensors and other sources, AI algorithms can identify potential issues with engineering systems and provide recommendations for resolution. [109] This reduces the need for human intervention in maintenance and operation, improving efficiency and

105 https://www.gpai.ai/projects/climate-change-and-ai.pdf
106 https://www.linkedin.com/pulse/esg-drives-innovations-across-its-three-pillars-alusch-h-amoghli/
107 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/
108 https://chell.co.uk/what-impact-is-ai-having-on-engineering/
109 https://www.snowflake.com/data-cloud-academy-generative-ai-llm/?utm_source=google&utm_medium=paidsearch&utm_campaign=ap-nz-en-nb-genaigeneral-phrase&utm_content=go-rsa-evg-ac-data-cloud-academy-generative-ai-llm&utm_term=c-g-ai%20automation-p-684264283872&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTi42xWJgaHB71WwHQUK6b-PjiqHjw7PKc3HmBVNlN57GOM3mF2-wPwaAriXEALw_wcB

Artificial Intelligence, Engineering and the Engineer

minimising errors. Engineers can focus on value-adding activities while AI handles repetitive and mundane tasks. [110]

Simulation and Analysis

AI is also enhancing the accuracy and speed of engineering simulations and analyses. Machine learning algorithms can analyse simulation data and identify patterns or trends that might be difficult for humans to detect. This enables engineers to make more informed decisions and optimise designs more effectively. AI-driven simulations can provide valuable insights into system behaviour, helping engineers develop robust and efficient solutions. [111]

Expertise Augmentation

AI is augmenting the expertise of engineers by providing them with powerful tools and resources. AI algorithms can assist engineers in complex problem-solving, providing insights and suggestions based on extensive data analysis. This collaboration between humans and AI systems amplifies engineering capabilities, leading to innovative solutions and improved efficiency. [112]

Predictive Maintenance and Fault Detection

AI is transforming maintenance practices in engineering. By analysing sensor data and historical performance data, AI algorithms can predict when equipment is likely to fail and recommend maintenance actions to prevent costly breakdowns. [113] This proactive approach to maintenance reduces downtime, increases equipment lifespan, and improves overall operational efficiency

Robotics and Automation

AI-driven robotics and automation are revolutionising the manufacturing and industrial sectors. Robots equipped with AI capabilities can perform intricate tasks with precision and efficiency. They can handle complex assembly processes, optimise production flow, and improve overall productivity. The integration of AI and robotics is reshaping how engineers approach manufacturing and is leading to the development of more advanced and flexible production systems. [114]

Energy Optimisation

AI is also being used to optimise energy consumption in engineering systems. By analysing data on energy usage patterns, AI algorithms can identify opportunities for energy efficiency improvements, reducing costs and environmental impact. This is particularly relevant in sectors such as building management, where AI-driven systems can optimise heating, cooling, and lighting to achieve maximum energy efficiency. [115]

Safety and Risk Management

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110 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

111 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

112 https://hbr.org/2018/07/collaborative-intelligence-humans-and-ai-are-joining-forces

113 https://www.leewayhertz.com/ai-in-predictive-maintenance/

114 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

115 https://discover.aveva.com/paid-search-op-pi-gro-power/whitepaper-the-three-step-approach-how-power-companies-can-maximize-the-value-of-industrial-data?utm_term=energy%20data%20management&utm_campaign=G_S_A_APAC_All_Campaign_Solution_Operations_Operate-PI-Growth-Industries&utm_source=adwords&utm_medium=ppc&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kThxwqWcs5PaBXIUr_y0QSBGz-LBaGMYjtlYrrFyfOTVTwS4pGvb3JUaAnjSEALw_wcB

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AI has the potential to enhance safety and risk management in engineering operations. By analysing historical data and real-time sensor data, AI algorithms can identify potential safety hazards and predict risks. [116] This enables engineers to take proactive measures to mitigate risks and maintain a safe working environment. AI-driven systems can also help in emergency response planning by simulating different scenarios and providing insights into the best course of action.

Enhanced Collaboration and Communication

AI technologies are improving collaboration and communication among engineering teams. AI-powered tools enable engineers to share and access information more efficiently, facilitating collaboration across geographically dispersed teams. Natural language processing capabilities make it easier to extract relevant information from vast amounts of data, enabling engineers to make informed decisions quickly. [117]

Ethical Considerations

While AI brings numerous benefits to the engineering profession, it also raises ethical considerations. As AI becomes more prevalent, engineers need to ensure that AI systems are designed and used responsibly. This includes addressing issues such as bias in AI algorithms, ensuring transparency and accountability, and considering the potential social and economic impacts of AI implementation. [118]

The Future of AI in Engineering

The impact of AI on the engineering profession will continue to grow in the coming years. As AI technologies advance and become more sophisticated, engineers will need to adapt and acquire new skills to leverage the full potential of AI. The ability to understand, develop, and integrate AI systems will be a valuable asset for engineers. [119]

Moreover, the collaboration between humans and AI systems will become increasingly important. Engineers will need to work alongside AI technologies and leverage their capabilities to drive innovation and solve complex engineering challenges. This partnership between human expertise and AI capabilities will lead to groundbreaking advancements in various fields of engineering.

Artificial Intelligence is reshaping the engineering profession, unlocking new possibilities, and transforming traditional practices. From design optimisation to automation, AI is revolutionising how engineers approach their work. [120] Embracing AI technologies and developing the necessary skills will be crucial for engineers to thrive in the rapidly evolving engineering landscape.

5-5 AI and Post Anthropocene design

Classic computing has taken us quite far. AI algorithms on classical computers can exceed human performance in specific tasks like playing chess or Go. For example, AlphaGo Zero beat AlphaGo by 100-0.

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116 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

117 https://www.solentive.com/solutions/inrule-business-automation-and-decisioning?gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTgc6M88MEfP-zZZOQLyc5mqbOEjsvSyEw6WFtc9Jme7gOrN9Wujc7waAuydEALw_wcB

118 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

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AlphaGo had beaten the best players on earth. [121] However, we are approaching the limits of how fast classical computers can be.

Moore's law, which is based on the observation that the number of transistors in a dense integrated circuit double about every two years, implies that the cost of computing halves approximately every 2 years. However, most experts believe that Moore's law is coming to an end during this decade. Though there are efforts to keep improving application performance, it will be challenging to keep the same rates of growth. [122]

Quantum Computing, which is still an emerging technology, can contribute to reducing computing costs after Moore's law comes to an end. Quantum Computing is based on the evaluation of different states at the same time whereas classical computers can calculate one state at one time. The unique nature of quantum computing can be used to efficiently train neural networks, currently the most popular AI architecture in commercial applications. [123] AI algorithms running on stable quantum computers have a chance to unlock singularity.

Understand why some believe that we will not reach AGI

There are 3 major arguments against the importance or existence of AGI. We examined them along with their common rebuttals:

1- Intelligence is multi-dimensional

Therefore, AGI will be different, not superior to human intelligence. [124]

- Yann LeCun, one of the pioneers of deep learning, believes that we should retire the word AGI and focus on achieving "human level AI". [125]
- He argues human mind is specialised and intelligence is a collection of skills and the ability to learn new skills. Each human can only accomplish a subset of human intelligence tasks.
- It is also hard to understand the specialisation level of human mind as humans since we don't know and can't experience the entire spectrum of intelligence.
- In areas where machines exhibited super-human intelligence, humans were able to beat them by leveraging machine-specific weaknesses. For example, in 2023 an amateur was able to beat a go program that is on par with go programs that beat world champions by studying and leveraging the program's weaknesses. [126]

However, these differences do not stop humans from achieving far more than other species in terms of many typical measures of success for a species. [127]

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121 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/#:~:text=Classic%20computing%20has%20taken%20us,the%20best%20players%20on%20earth.

122 https://www.universitywafer.com/moores-law.html

123 https://www.linkedin.com/pulse/quantum-computing-next-revolution-finance-paul-netherwood/

124 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/#:~:text=1%2D%20Intelligence%20is%20multi%2Ddimensional,hundreds%20of%20nuts%20for%20months.

125 https://www.linkedin.com/posts/yann-lecun_i-think-the-phrase-agi-should-be-retired-activity-6889610518529613824-gl2F/

126 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/

127 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/

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Intelligence is not the solution to all problems

For example, even the best machine analysing existing data will probably not be able to find a cure for cancer. It will need to run experiments and analyse results to discover new knowledge in most areas. [128]

This is true with some caveats. More intelligence can lead to better designed and managed experiments, enabling more discovery per experiment. History of research productivity should probably demonstrate this but data is quite noisy and there are diminishing returns on research. We encounter harder problems like quantum physics as we solve simpler problems like Newtonian motion. [129]

AGI is not possible because it is not possible to model the human brain

Theoretically, it is possible to model any computational machine including the human brain with a relatively simple machine that can perform basic computations and has access to infinite memory and time. This is the Church-Turing hypothesis laid out in 1950. It is universally accepted. However as stated, it requires certain difficult conditions: infinite time and memory. [130]

Most computer scientists believe that it will take less than infinite time and memory to model the human brain. However, there is not a mathematically sound way to prove this belief as we do not understand the brain enough to exactly understand its computational power. We will just have to build such a machine!. [131]

And we haven't been successful, yet. For example, the ChatGPT large language model launched in November/2022 caused significant excitement with its fluency and quickly reached a million users. [132] However, its lack of logical understanding makes its output error prone. Achieving the singularity from where we are now is relatively a simple jump, it is just time and advancements combined with a team somewhere who is dedicated to it and has the money to pull it off.

The missing part of the equation would be asking the question "what is consciousness?" and understanding that. [133] Then, understanding how to model that with non-biological machinery even at small levels, like modelling the consciousness of an amoeba or more advanced things like snakes and squirrels. Then if we know for certain what it is and how to model it, just run an adaptive evolution algorithm on itself, modelling out all of the processes in human cognition until it can beat them everywhere. Then, allow it to simply rebuild itself to continuously improve. [134]

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128 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9846804/
129 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/
130 https://plato.stanford.edu/entries/church-turing/
131 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/
132 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/
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134 https://research.aimultiple.com/artificial-general-intelligence-singularity-timing/

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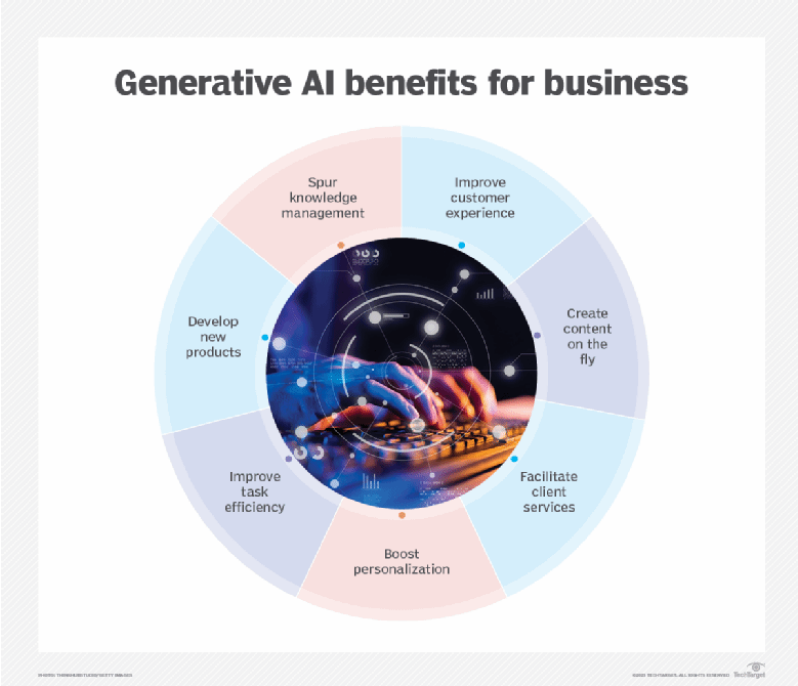

Navigating the New Risks and Regulatory Challenges of GenAI

The use of generative AI promises to continue to grow rapidly. Consequently, leaders must understand the risks and challenges of this new technology and develop policies and practices to guide its usage.

The rapid rise of generative AI, including large language models (LLMs) such as, is creating new risks and regulatory challenges for business. Although it is still early days, companies cannot afford to delay developing policies and practices regarding the use of these technologies. [135]

What new risks do these technologies pose, particularly as their users may rely on them for health, legal, or other professional services as well as business decisions? And how can both the developers building these tools and the companies using them assess and mitigate the risks? In this article, we provide some guidance.

Proprietary information leaks Earlier this year,

Samsung that its employees had accidentally shared confidential data with ChatGPT — meaning that the company's proprietary information could be used to further train OpenAI's model and potentially be revealed to other users. Similarly, with some clever prompt engineering, users convinced Microsoft's AI powered chatbot to share information. Despite current safeguards in place, it's clear that LLMs have the potential to pose substantial risk with respect to confidential or sensitive information that passes through these systems. [136]

Addressing this risk requires joint efforts by both users and developers of generative AI tools. For example, guidelines for the prompts employees use as inputs to generative AI tools residing outside the company boundaries must be considered, and tools that alert employees when they are about to send a prompt that may include sensitive company information to a third-party generative AI system may need to be deployed.

Moreover, when a company fine-tunes existing that is, core AI models currently mostly available from big tech companies that can be adapted for multiple downstream applications — with their own data, it should double down on data governance and prioritise visibility into the quality

[135] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

[136] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

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and clarity of the provenance of any data used, especially if the company works with external providers to do that fine-tuning. [137]

Companies may also want to consider creating a so-called "sandbox" to allow employees to explore the capabilities of generative AI tools without sharing their prompts or the data with the developers. [138] For example, set up such an environment where users can easily switch between different LLMs through a single interface without having prompts or any data inputs being shared with the LLM vendors. Such approaches are not without trade-offs: For example, not sharing such information with the developers could potentially limit how well the generative AI can be fine-tuned for the specific needs of the company.

Developers of these technologies also need to undertake careful due diligence with respect to both the data and the data providers used to train these AI models. In some cases, this may mean training models only on well-defined data sources and always carefully reviewing the provenance of the data that underlies a given tool or that passes through a tool during its usage. [139]

For example, Getty recently to develop generative AI tools that would be trained on fully licensed content, enabling the company to ensure that the content creators who own the rights to the images used to train these models are able to get royalties from artificially generated images. [140] Perhaps more importantly, the Getty approach promises those using the system protection from lawsuits claiming copyright infringement on the output of the generative AI system due to the provenance of its training data.

5-6 Inaccurate or Harmful outputs

Generative AI is trained on a given data set, and there's no easy way to trace back the source of an output to a specific input or to instruct the model to "forget" any problematic, sensitive, or illegal data on which it may have been trained (although exciting new research on how to control their behaviour is ongoing). As a result, these tools run the risk of creating outputs that are inaccurate or otherwise harmful, potentially at a substantial cost: When Google's AI chatbot made a in its first demo, the company's valuation dropped by more than $100 billion. [141] Hallucinations, misleading content, and other factual errors that make their way into LLM outputs range from amusing mistakes to costly and downright costly or even dangerous misinformation.

In response, developers and users alike need to implement monitoring and feedback processes to ensure the quality of the outputs generated by these technologies and to continuously improve them. In addition, companies also need to monitor the quality of the final work produced when employees use these technologies. While use of, say, LLMs can significantly improve the quality of the work — as by a team of people from Harvard, MIT, the University of Pennsylvania, and the Boston Consulting Group shows — quality may actually deteriorate for some tasks. What if, for example, ChatGPT leads to worse employee performance or hurts the quality of decisions and services? [142]

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137 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

138 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

139 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

140 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

141 https://www.reuters.com/technology/google-ai-chatbot-bard-offers-inaccurate-information-company-ad-2023-02-08/

142 https://sloanreview.mit.edu/article/the-working-limitations-of-large-language-models/

Artificial Intelligence, Engineering and the Engineer

To ensure proper governance, including rigorous monitoring and continuous improvement processes, companies will also have to decide what level of internal transparency is best — or necessary — when using these technologies. There is a spectrum of approaches business leaders can take: from explicitly not constraining (and even encouraging) their employees to use generative AI to defining guidelines for usage (which may be suggestive and unenforceable) to setting up more-heavy-handed processes to detect and regulate usage. [143]

As a side note, a hands-off approach isn't necessarily a bad idea. In some applications, it may make sense to focus on the quality of the output rather than on exactly how that output was produced. We do not regulate the use of calculators, slide rules, treatises, and other tools; instead, we monitor the quality of the work accomplished with those tools. [144]

Similarly, if it proves possible to put fact-checking or other systems in place to ensure that outputs are accurate, free from hallucinations, and avoid other pitfalls of AI-generated content, then there may not be as strong a need for employees to disclose that an AI tool was used in the course of their work. There are also contextual factors at play: In some applications, occasional errors may be acceptable, whereas in others, there may be limited or no margin for error. The level of risk can

determine whether generative AI can be used in specific business cases.

Another consideration that will inform what approach to take is technical limitations. For example, many education leaders have that it will be very difficult to detect cheating by students using ChatGPT to write essays or complete assignments.[145] While and training programs are emerging to help people detect AI-generated content, there are many applications in which enforcement of restrictions on the use of generative AI remains a challenge.

In fields like these, it may be especially important to either intentionally take a more hands-off approach (when the risk of harmful outputs is minimal) or to complement technical solutions with other forms of trust signalling and quality control such as certification or audits by reputable third parties (in situations where it's more important to avoid certain types of harmful content). [146]

Potential New Liabilities

The potential for harmful or inaccurate content in turn drives a whole host of new liability risks when using generative AI tools in business. As tools like GPT-4 demonstrate the ability to pass professional exams and perform certain tasks on par with humans in fields such as and , they're increasingly likely to be incorporated into real-world applications. [147] And while this certainly creates new opportunities, it also creates new risk as companies may be held liable for any harmful content or unsafe decisions these tools help them make.

For example, ChatGPT has been shown to be effective at producing first drafts of such as contracts, wills, and complaints. But risks of errors can increase when, say, a lawyer uses ChatGPT to draft a will for a client but does not notice that ChatGPT's output includes provisions that are

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143 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

144 https://www.linkedin.com/posts/quantum-gears_navigating-the-new-risks-and-regulatory-challenges-activity-7133084211413950464-1AwF/

145 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

146 https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

147 https://www.techtarget.com/searchenterpriseai/tip/Generative-AI-ethics-8-biggest-concerns#:~:text=Like%20other%20forms%20of%20AI,copyright%20infringements%20and%20harmful%20content.

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barred in the client's state — meaning that the will won't be enforceable. Or, say, if a lawyer uses ChatGPT to draft a complaint for a contract dispute and it hallucinates details about the case that are not true. In situations like these, lawyers can be subject to , including disbarment, and their firm may be subject to legal action.

Similarly, LLMs can be used to help physicians diagnose patients or to help patients learn about medical issues. Patient-facing mental health related chatbots are also hitting the market. But what happens if the chatbot gets it wrong and a patient suffers as a result? Normally, if doctors make mistakes, they can be sued for medical malpractice. But it's less clear today whether the technology or health care provider would be held legally liable in a case of AI-driven malpractice (such as due to the use of a chatbot) or, for that matter, whether medical malpractice insurers would pay out in the case of such a lawsuit. This is particularly challenging with generative AI as its outputs are not easily traced back to specific data or data providers. [148]

Liability in the medical context is further complicated by the notion of a "standard of care." In medicine, malpractice is defined as deviation from what a reasonably skilled, competent, and educated medical provider would have done under the same treatment circumstances. Today, that definition would deem excessive reliance on an LLM as a problematic deviation from the standard of care. But there may come a time when the standard of care changes to incorporate some amount of (responsible) generative AI usage, potentially creating legal risk associated with choosing not to use these tools alongside the risks that come with using them.

Professionals and companies will need to consider a number of difficult questions that may arise due to reliance on the output generated by these technologies. [149] What happens if potential licensure issues arise when non-professionals use LLMs to generate professional documents? Some uses of generative AI in law might be of law, leading to sanctions. What role do the users versus makers of generative AI have in policing the boundaries of how these models are used? What about intermediate users such as legal aid services, who make such tools available to clients and/or train those clients on how to best use the software? [150]

To be sure, as there are no cut-and-dry answers, professionals and organisations would be wise to consult legal experts and carefully determine the best way to mitigate liability risk in their unique business environment. Laws are also likely to evolve as these technologies become more widely used, and as new risks — and new legal cases are identified. But no matter what, providers and users of these technologies need to consider all of these new complex liability issues

[148] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7332220/

[149] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

[150] https://www.linkedin.com/posts/claudiazeisberger_iswintercoming-activity-7132707865022140418-wP8V/

and either avoid them entirely or take proper insurance and/or risk mitigation measures.

Regulatory Risks

The speed of innovation is so fast that generative AI applications can violate digital regulations as soon as those come into effect. For example, LLMs and foundation models are already exposing and testing the limits of regulations including the EU's , which was recently adopted to ensure trust and safety online, as well as the EU . [151]

Clearly, regulations governing the use of AI are still evolving. But as these laws expand to encompass new generative AI tools, companies relying on the large-scale generation and sharing of AI outputs may face new regulatory hurdles. For example, on the IP front, many litigations are already pending related to copyright concerns from artists and creators whose content has been used to train these models. [152] Firms using tools built on questionably sourced data may find themselves unwittingly in violation of copyright and other regulations as these legal structures mature.

In light of this complex and rapidly changing regulatory landscape, companies should be vigilant about adopting the appropriate protocols and safeguards to ensure that these technologies are used effectively, responsibly, and legally. Any decisions about the use of such technologies — including when, by whom, how, and for what purpose they can be used — need to be made dynamically and at a meaningful level of granularity. [153]

5-7 Summary for this Chapter

Competitive Pressure to Get on the Bandwagon

Despite these many risks, as generative AI becomes increasingly commonplace in a wide range of industries, opting not to use it may become increasingly untenable. If using an LLM can save lawyers several billable hours of work, their clients are likely to pressure them to do so — even if the systems in place to monitor these tools 'outputs are still fairly limited.

Indeed, are already advocating that law schools should teach students how to use LLMs, arguing that these tools are likely to become an unavoidable component of the legal profession. In many industries, pressure to cut costs and stay competitive may push professionals to adopt these tools before they truly are ready, with insufficient structures to mitigate any substantial risks they may create. As such, companies will increasingly need to consider how to balance trade-offs between the potentially questionable quality of AI tools 'decisions or outputs and the competitive advantages associated with the speed, efficiency, and scale they enable. [154]

The tradeoffs involved in using AI — such as those between explainability and accuracy, or privacy and security — are not new. One of the key tradeoffs of powerful tools like generative AI is between quality and speed. For example, these technologies have the potential

[151] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai
[152] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai
[153] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai
[154] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

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to help meaningfully address the public's enormous unmet civil legal needs. A significant number of middle-income Americans receive no meaningful assistance when facing important civil legal issues such as child custody, debt collection, eviction, and foreclosure. Providing individuals with access to LLMs — for instance to help them draft contracts or wills — could give them a head start before they make use of a limited-time legal aid provider through the "lawyer for a day" programs some courthouses offer. But what is gained in terms of speed and scale may be lost in terms of quality. It may also create externalities: For example, judges may now face seemingly plausible but actually "hallucinatory" legal documents.

Balancing tradeoffs is never easy. Users and developers of these technologies need to decide on minimum quality standards that need to be ensured when generative AI tools are in the hands of people with less training, without excessively sacrificing speed and efficiency. Companies may also need to include proper quality controls and management of breaches of quality standards, possibly in a gradual manner (i.e., potentially being less strict for early proposals and designs and stricter for final products). At the minimum, executives need to determine the relative importance of speed and scale versus quality for each use of generative AI.

Currently, generative AI is still mostly used when visiting a particular website and offering a prompt in the case of a chat-based LLM or providing a seed image or prompt or both in the case of image-based generative AI. [155] But as major generative AI companies are rapidly pushing towards much more full-scale integration into existing familiar products, we may not be far off from a moment where generative AI will be ubiquitous as, say, how predictive text has become in sending a text message from a mobile phone.

While we are still in the early stages, it is the essential moment to develop an organisational strategy for dealing with generative AI. Executives need to understand both the potential applications of these innovations as well as the new risks they can introduce and adopt tools, processes, and practices that can give their organisations a head start in managing these risks.

[155] https://hbr.org/2023/11/navigating-the-new-risks-and-regulatory-challenges-of-genai

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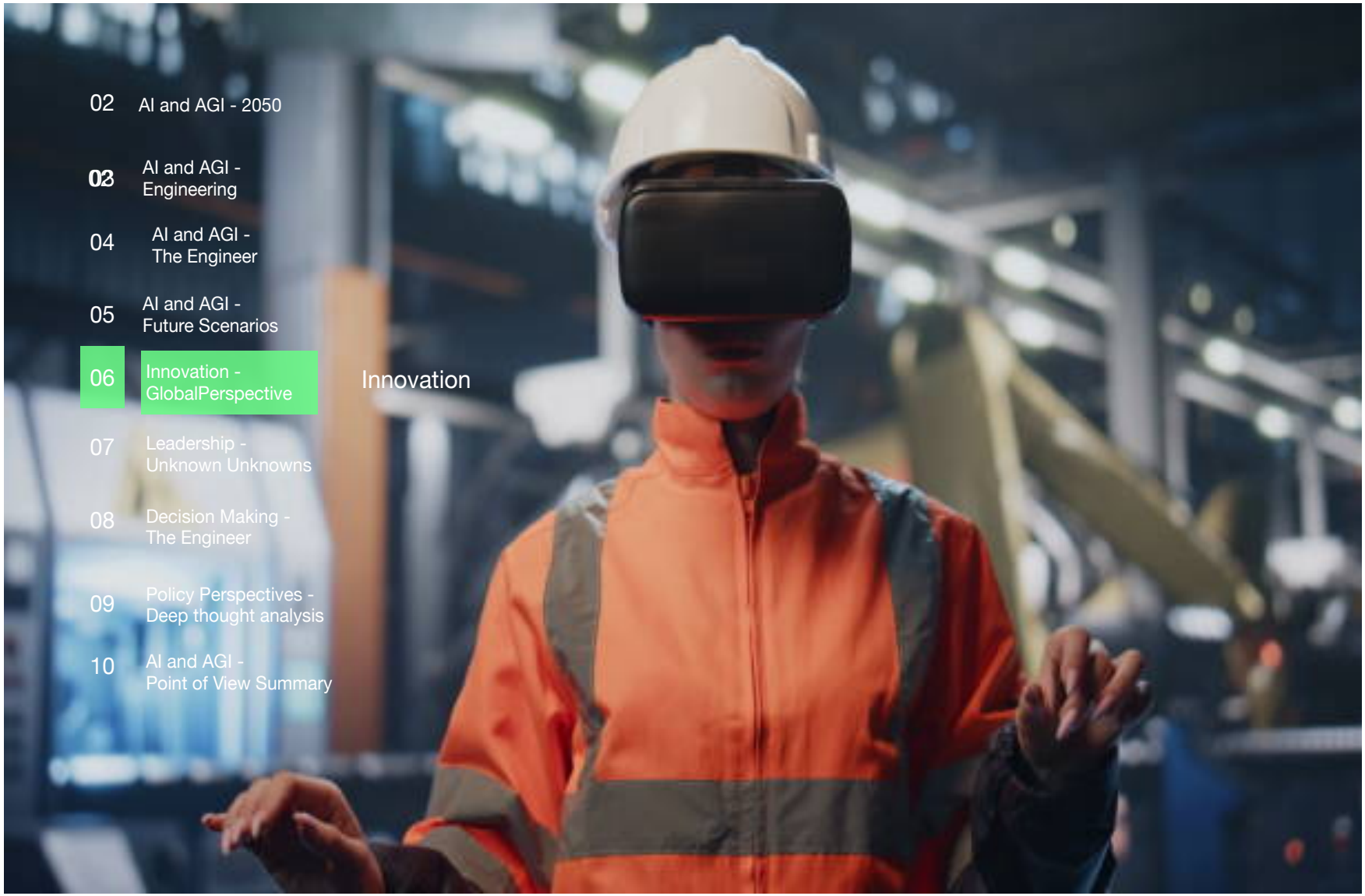

Artificial Intelligence, Engineering and the Engineer

I'm going to predict that we are just a few years way from a major catastrophe being caused by an autonomous computer system making a decision.

Wendall Wallach, ethicist, Yale university.

6-1 Introduction

"When Will AI Exceed Human Performance? Evidence from AI Experts," elite researchers in artificial intelligence predicted that "human level machine intelligence," or HLMI, has a 50 percent chance of occurring within 45 years and a 10 percent chance of occurring within 9 years. [156] But anyone who has ever had a conversation with Siri or Cortana, (some of the virtual assistants on the market today), might argue that HLMI is already here. Eliza Kosoy, a researcher in MIT's Center for Brains, Minds, and Machines, points out that machines are already surpassing humans in some domains. They can beat us at many strategy games like chess, the board game Go, and some Atari video games.

Machines can even perform surgery and fly airplanes. Recently, machines have started driving cars and trucks—though some of them might have issues passing driver's ed. Despite this, Kosoy believes, "with enough data and the correct machine learning algorithms, machines can make life more enjoyable for humans." [157]

Kosoy's objective is to better understand the way in which humans learn so that it can be applied to machines. She does this by studying intuitive physics and one-shot learning.

Intuitive physics refers to the way in which humans are able to predict certain, dynamic changes in their physical environment, and then react in kind to these changes. For example, being able to sense the trajectory of a falling tree and therefore knowing the direction to move in to avoid being hit.

One-shot learning is the ability to learn object categories from only a few examples. This seems to be a capability that the machines are lacking…at least for the time being. Kosoy explains that the best algorithms today need to be exposed to thousands of data sets in order to learn the difference between, say, an apple and an orange. Children, however, can tell the difference after only a few introductions. Kosoy says she is "personally very curious about how children are able to learn so quickly and how we can extract that process in order to build faster machine learning that doesn't require as much data." [158]

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156 https://www.quora.com/What-are-the-chances-of-artificial-intelligence-becoming-sentient-and-surpassing-human-intelligence#:~:text=In%20a%20paper%20published%20last,of%20occurring%20within%209%20years.

157 https://engineering.mit.edu/engage/ask-an-engineer/when-will-ai-be-smart-enough-to-outsmart-people/#:~:text=Eliza%20Kosoy%2C%20a%20researcher%20in,perform%20surgery%20and%20fly%20airplanes.

158 https://engineering.mit.edu/engage/ask-an-engineer/when-will-ai-be-smart-enough-to-outsmart-people/#:~:text=Eliza%20Kosoy%2C%20a%20researcher%20in,perform%20surgery%20and%20fly%20airplanes.

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Another caveat to the machine-versus-human intelligence race is the incorporation of emotion. In 1997, when the IBM computer Deep Blue beat the Russian world champion chess player, Garry Kasparov, Kasparov was so distraught that he never played quite the same again. Sure, Deep Blue was able to "outsmart" Kasparov, but did its programming have the emotional intelligence to graciously show good sportsmanship so as not to crush Kasparov's sprit? To put it another way: when you have a bad day at work, can you really count on Siri to empathise? " Human empathy and kindness are an important part of intelligence," Kosoy notes. "In this domain, I doubt AI will ever outsmart us."

6-2 *High Velocity Automation*

There are two big takeaways from these forecasts on AI timelines:

1. There is no consensus, and the uncertainty is high. There is huge disagreement between experts about when human-level AI will be developed. Some believe that it is decades away, while others think it is probable that such systems will be developed within the next few years or months. [159]
2. There is not just disagreement between experts; individual experts also emphasise the large uncertainty around their own individual estimate. As always when the uncertainty is high, it is important to stress that it cuts both ways. It might be very long until we see human-level AI, but it also means that we might have little time to prepare. [160]
3. At the same time, there is large agreement in the overall picture. The timelines of many experts are shorter than a century, and many have timelines that are substantially shorter than that. The majority of those who study this question believe that there is a 50% chance that transformative AI systems will be developed within the next 50 years. In this case it would plausibly be the biggest transformation in the lifetime of our children, or even in our own lifetime. [161]

   The public discourse and the decision-making at major institutions have not caught up with these prospects. In discussions on the future of our world – from the future of our climate, to the future of our economies, to the future of our political institutions – the prospect of transformative AI is rarely central to the conversation. Often it is not mentioned at all, not even in a footnote. [162] We seem to be in a situation where most people hardly think about the future of artificial intelligence, while the few who dedicate their attention to it find it plausible that one of the biggest transformations in humanity's history is likely to happen within our lifetimes. [163]

6-3 Role of AI & ML in Engineering

159 https://ourworldindata.org/ai-timelines
160 https://ourworldindata.org/ai-timelines
161 https://forum.effectivealtruism.org/posts/BsAmChNX9cvwEccny/our-world-in-data-ai-timelines-what-do-experts-in-artificial
162 https://ourworldindata.org/ai-timelines
163 https://ourworldindata.org/ai-timelines

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Like many other sectors, engineering is being transformed by artificial intelligence and machine learning. However, even though these technologies appear to be everywhere, we must not lose sight of how magnificent they are and the incredible things they enable us to achieve today and in the future. [164]

Engineers' responsibilities may change due to artificial intelligence and machine learning, but it may also allow them to achieve things they couldn't previously.

Artificial intelligence in the engineering sector employs both software and hardware components. As a result, machines will be able to support not just intelligent production lines and challenging manufacturing activities as they get more sophisticated but also create and enhance tasks over time with little or no human intervention via machine learning. [165] For example, automobile manufacturers have been using robots on the manufacturing line for quite some time, and they have progressed from doing simple technical duties to executing numerous precise motions necessary for some of the most complicated elements of the process.

6-4 Interdependent Synchronous Innovation

AI & ML - How It Will Affect Engineering's Future Artificial Intelligence and Machine Learning are two branches of computer science that are closely connected. These two technologies are among the most popular for developing intelligent systems. [166]

Although these are two related technologies that are frequently used interchangeably, they are still distinct names in many situations. On a broad level, we may distinguish Artificial Intelligence and Machine Learning as:

- Artificial Intelligence (AI) is a larger idea that aims to produce intelligent machines that can replicate human thinking capabilities and behaviour
- Machine learning is an application or subset of AI that allows computers to learn from data without being explicitly programmed.

ML and AI have a bright future because they give machines the power to learn, making them more human-like. ML and AI are presently used in a variety of fields, particularly those related to engineering. [167]

Future of AI and ML - What Will It Look Like

Machine Learning is beginning to migrate to the cloud as a massive quantity of data becomes more readily available. Data Scientists will no

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164 https://www.linkedin.com/pulse/how-artificial-intelligence-machine-learning-used-engineering-marr/

165 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php

166 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php#:~:text=ML%20and%20AI%20have%20a,particularly%20those%20related%20to%20engineering.&text=Machine%20Learning%20is%20beginning%20to,data%20becomes%20more%20readily%20available.

167 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php

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longer write bespoke programmes or maintain infrastructure explicitly. Instead, AI and machine learning will assist systems in scaling, generating new models on the fly, and delivering faster and more accurate results.

Machine Learning and Artificial Intelligence are widely employed in the following industries:

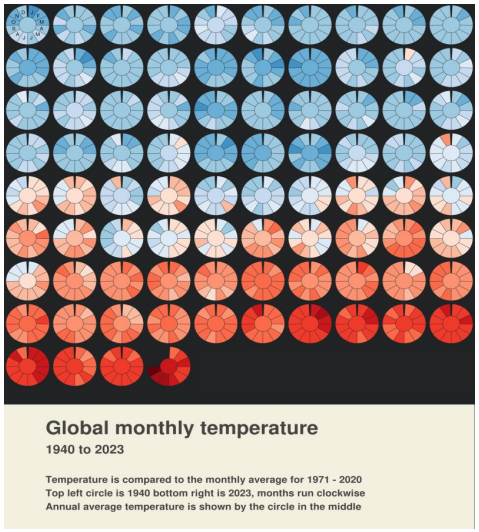
- Financial Trading
- Personal Security
- Online Search
- Healthcare & Fitness
- Sales and Marketing
- Transportation & Conveyance

Artificial Intelligence and Machine Learning have reached a vital tipping point, augmenting and extending practically any technology-enabled service, product, or application including engineering.. People have worked hard in the post-industrialisation age to construct a machine that behaves like a person. [168]

The thinking machine is AI's greatest gift to humanity; its magnificent entrance has abruptly modified the operating laws of commerce. Self driving cars, digital assistants, robotic manufacturing workers, and smart cities have all demonstrated that intelligent machines are conceivable. [169]

AI has altered most industrial areas, including retail, manufacturing, finance, healthcare, and media, and it continues to expand.

Since the pandemic, the use of Artificial Intelligence (AI) has skyrocketed as the entire globe has pushed toward digitalisation. According to research conducted by Oxford University and Yale University, AI will surpass humans in many aspects and will automate all human employment over the next 120 years. [170]



Most of us recognise that climate change is an issue that needs to be tackled quickly for the future of our planet. Even recently at the U.N. Climate Change Conference (COP26), governments across the globe were pledging to tackle the climate crisis and setting targets for carbon neutrality. [171] However, relying on the legal system and governments is Carbon emissions measurement is notoriously cumbersome. Our

168 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php

169 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php

170 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php#:~:text=Since%20the%20pandemic%2C%20the%20use,over%20the%20next%20120%20years.

171 https://www.un.org/en/climatechange/cop26

analysis suggests 40% of a sustainability professional's time is spent collecting and cleaning data. Only 1 in 20 of those asked were even 70% confident in the accuracy of their emissions calculations.[172]

Weforum use artificial intelligence (AI) to lighten these loads. Knowledge graphs define relationships between business activities and datasets, and natural language models speed up text processing and interrogation, enabling accurate analysis at granularity that would not be feasible through human effort alone. [173] As emissions reduction strategies turn into operational plans and interventions compete with each other for priority, granular analysis combined with business context become important.

But using intelligent, self-learning systems to tackle these challenges brings risks, especially with 'black box 'modelling approaches where underlying sources and biases are unclear. Can we trust these systems to make environmental trade-offs for us, weighing climate change against other complex challenges such as ocean plastic? [174]

Mitigating these risks will require leaning into issues that already make us uncomfortable. More transparency. More unbundling of catch-all goals such as those presented by ESG ratings. For AI to help us make the world more sustainable, we need to start with a much better understanding of what we're solving. [175]

6-5 Summary for this Chapter

The increasing expansion of AI can enhance the world's ability to mitigate and adapt to the impacts of climate change. Its power lies in its ability to process large amounts of data, identify patterns and make predictions, which can optimise resource efficiency and support decision-making for emissions reduction strategies in pursuit of net zero.[176] But equally important to mitigating emissions is adapting to the impacts of climate change that are already here, which AI can also help with.

AI can enhance climate modelling capabilities that predict future climate conditions and help businesses, communities and policymakers take proactive measures to address climate-related risks and build resilience. AI algorithms can also assess risks associated with climate-related events such as floods, hurricanes and droughts by integrating data from multiple sources, including weather data, historical records and geographical information systems. As the world warms, AI is a critical

[172] https://www.weforum.org/agenda/2023/06/these-new-technologies-will-accelerate-the-transition-to-net-zero/

[173] https://www.weforum.org/agenda/2023/06/these-new-technologies-will-accelerate-the-transition-to-net-zero/#:~:text=We%20use%20artificial%20intelligence%20(AI,feasible%20through%20human%20effort%20alone.

[174] https://www.weforum.org/agenda/2023/06/these-new-technologies-will-accelerate-the-transition-to-net-zero/

[175] https://www.weforum.org/agenda/2023/06/these-new-technologies-will-accelerate-the-transition-to-net-zero/#:~:text=Mitigating%20these%20risks%20will%20require,of%20what%20we're%20solving.

[176] https://link.springer.com/article/10.1007/s43762-023-00100-2

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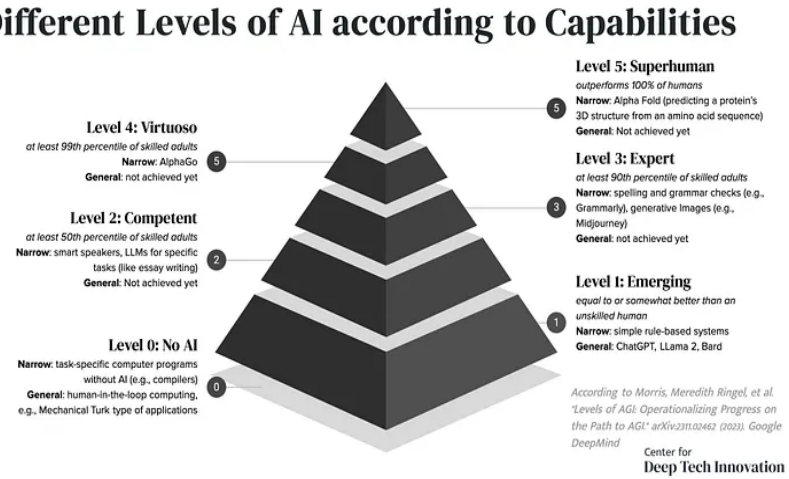
tool to adapt to the climate volatility and extreme weather we are locked into, while also helping reduce emissions to keep the planet liveable. The role of engineers in this near future with their augmented expertise and understanding is critical. [177]



[177] https://edition.cnn.com/2023/11/26/tech/ai-climate-solutions/index.html

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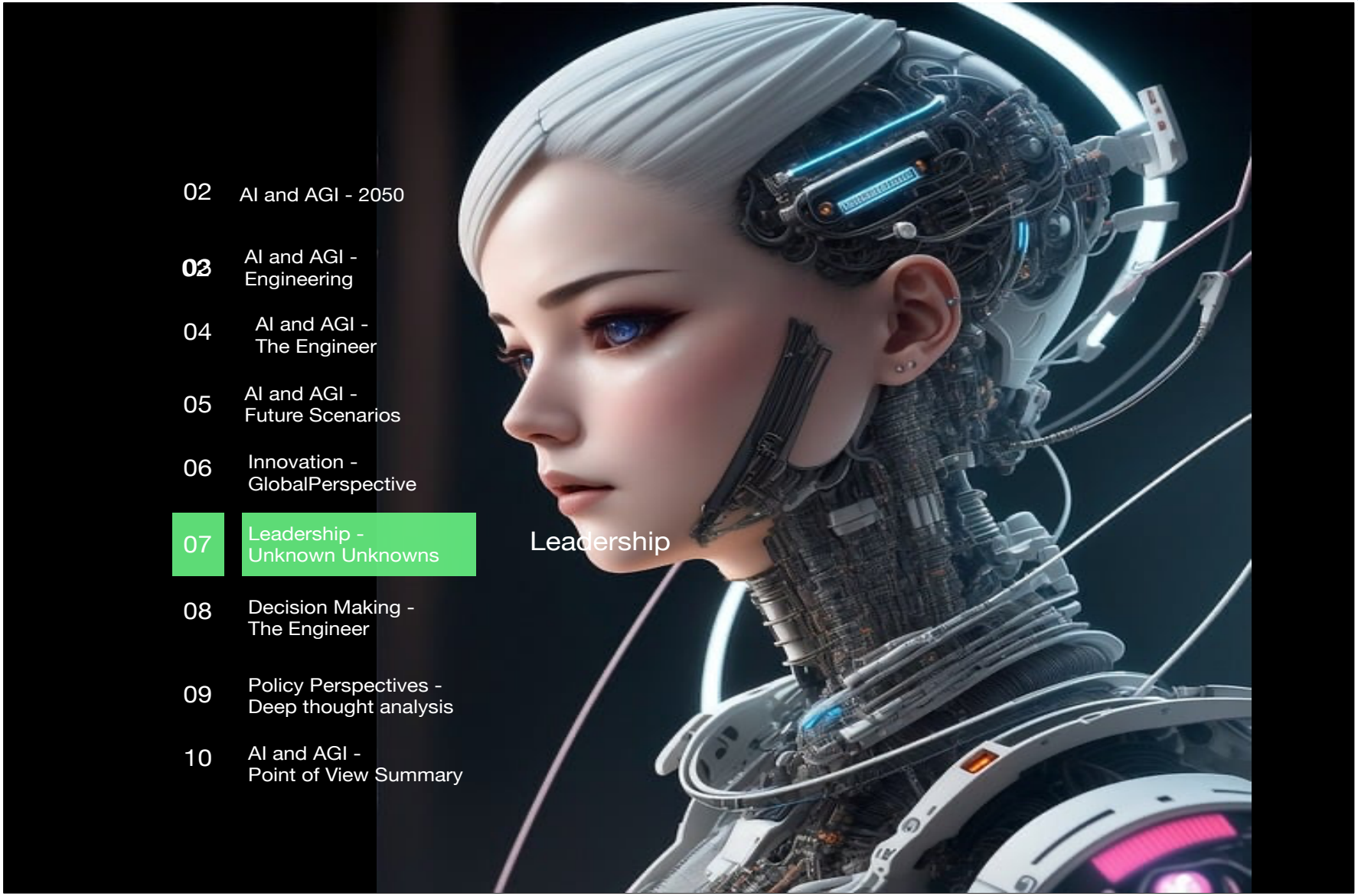

Artificial Intelligence, Engineering and the Engineer

7-1 Introduction

Many of the activities that engineers are responsible for, such as design and simulation, may be aided by artificial intelligence systems. Consider how, once upon a time, Computer-Aided Design (CAD) was only a supplement to engineering but is now an essential element of the everyday workflow. [178]

These technologies will assist engineers in enhancing their capabilities and allow them to explore design and weight-saving solutions previously unthinkable. Another way AI may help engineers is by automating low-value jobs, allowing engineers to focus on higher-value ones. Machines will be beneficial in assisting with engineering judgement by utilising machine learning to detect patterns in data. While there are several advantages to using artificial intelligence and machine learning in engineering, some engineers are afraid that robots may usurp their employment.

Automation has and will continue to take over work that people have historically done; nevertheless, this can liberate humans to accomplish higher-level activities and take over positions that require human-specific abilities that do not yet exist.

According to a University of Oxford assessment, scientific and engineering occupations are the least threatened and will profit the most from artificial intelligence capabilities. As AI and machine learning revolutionise the way engineers work, they must be ready to adapt to the latest technologies. [179]

In addition, engineers must optimise the job so that interactions between people and robots are as unobtrusive as possible.

Universities can play a crucial role in educating engineering students on the benefits of AI and ML early on to ensure their preparation for the technology. As it is easy to mould their brains during the learning process, the operation of these technologies can become second nature to them and allow for faster progress in the developing industry.

The reality is it will be engineers that save the planet providing AI and AGI Data Pools are available and properly utilised. Running in parallel with the technical side of AGI software are the intrinsic management planning tools. [180]

7-2 Design Post Anthropocene for carbon

The final answers for dealing with Carbon are complex and cannot be solved without AI and AGI. The data lake pools will require to be established before major inroads into the carbon solution sets can be delivered. The same argument exists for all manufacturers systems and products. Most products used by society today are manufactured from vast volumes of carbon, require carbon and Co2 during use, additional chemicals and copious amounts of water and in most cases an effluent is produced. Obviously for the planet this regime cannot be allowed to

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178 https://www.linkedin.com/pulse/how-artificial-intelligence-machine-learning-used-engineering-marr/

179 https://blogs.nitte.edu.in/AI_&_ML_How_It_Will_Affect_Engineerings_Future.php

180 https://aiindex.stanford.edu/wp-content/uploads/2023/04/HAI_AI-Index-Report_2023.pdf

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continue. Engineers have been unable to do the engineering at a level that is suitable to underlying solution sets to be excised because of the lack of data and information.

7-3 Climate and carbon neutrality leadership

Many cities, industry organisations, and companies have set out strict carbon neutrality standards for their operations in the years ahead. But when Architecture 2030 took a hard look at the data, they realised embodied carbon — the energy and emissions from materials and construction — was a significant and largely ignored gap in the industry. [181]

Globally, building-sector operational energy produces 30% of greenhouse gas emissions, while materials and material production add another 20%. In total, the building industry produces 50% of the globe's greenhouse gas emissions. To meet zero carbon emissions goals by 2050, we have to look at embodied carbon more seriously.

Since a building's structure accounts for 50% of its embodied carbon, structural engineers are essential players in the struggle toward carbon neutrality. The Carbon Leadership Forum's Structural Engineers 2050 Challenge (SE 2050) is inspiring engineers to work toward embodied carbon benchmarks while contributing essential data along the way.

Arup's senior structural engineer Lauren Wingo and sustainability associate Frances Yang are part of the SE 2050 working group designing and managing a commitment initiative to help structural engineers meet this challenge. The CTA recovered interview data from their interviews with ARUP. We spoke to Lauren and Frances about the pitfalls of and progress made toward embodied-carbon neutrality — and how structural engineers can help achieve this industry-wide change.

How would you characterise the building industry's response to carbon neutrality targets so far?

Frances Yang: We've seen reports from the Intergovernmental Panel on Climate Change and other organisations pointing out the urgency and repercussions of reaching specific amounts of carbon dioxide in the atmosphere. Plus, with better projections about the sources of emissions, we're seeing sector-specific reduction requirements at milestones leading up to 2050.

That has created more awareness for the building sector and our clients. The motivation is there for the building industry to look at carbon as a critical metric and to reduce not only operational carbon emissions, but the embodied carbon in our building and infrastructure materials.

Lauren Wingo: Now that our buildings are becoming more and more operationally efficient due to better mechanical and electrical design, the focus is shifting towards embodied carbon, where structural engineers play a larger role.

To reduce embodied carbon, the most essential step for structural engineers is to mindfully choose the right materials and use them as efficiently as possible. For instance, Frances has done a lot of work around how we can use higher-performing concrete, which has a lower environmental impact. The impetus is on structural engineers to be

[181] https://www.arup.com/perspectives/structural-engineers-hold-the-keys-to-carbon-neutrality

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thoughtful about the materials they're specifying and have an awareness of the environmental effects of those different material types.

Finally, we need to collect embodied carbon data from our own projects, actually look at that data, and have metrics against which we can gauge our performance.

What are the biggest challenges you find in trying to reduce embodied carbon on projects?

Frances: Noting what Lauren just said, there's currently not much data available. Well-resourced organisations like the Department of Energy have helped with years of operational energy data collection. We don't have anything like that for the carbon embodied in buildings. There's a big difference in methodologies, and it's hard to measure. There's no meter on the building for embodied carbon, so there aren't those reliable numbers to compare performance.

Right now, there are several efforts underway to standardise that measurement and capture data in a way that will be meaningful and comparable. But we're still at an early stage, and I don't think we can wait for that standardisation. We need to start tracking data and building fluency and awareness now. We already know how energy intensive it is to make steel and cement, we know there are enormous benefits to reusing buildings and salvaging materials. There are things structural engineers could do now.

That said, the construction industry is averse to change. There's risk aversion to using salvage materials, when something has had a previous life or when you don't know the exact material properties unless you test every single piece. I t quickly becomes cost prohibitive, and it's not the way an owner or contractor is used to doing things.

Lauren: It also varies widely by region in terms of what technology is being adopted by the local market. In some markets, there may not be low embodied carbon options available. The rate of adoption for these technologies is also dependent on market incentives. At the moment, there isn't a certification program like ENERGY STAR for the embodied energy of buildings, and when local jurisdictions pass green building codes, they're still focused on operational efficiency. Without the incentives in place, people aren't willing to invest in embodied carbon mitigation.

What do you think needs to happen before we see industry-wide change?

Frances: There's a chicken and egg thing that happens among owners, policymakers, and investors. Policymakers want a project or a win to point to that says, "Hey, if we make this policy, it's feasible, it'll work, there's a benefit." Owners are very hesitant unless they have a financial incentive, while the financiers aren't going to fund something unless the policies or programs are in place to help them see a return on the investment.

Each one is almost waiting for the other. That's why there's a real need to make even incremental movement. If one group starts making even a little bit of headway, the other entities will respond. But we have to do this on a hundred different fronts.

One case study is the Marin County Low Carbon Concrete Code, where the Bay Area Air Quality Management District funded a grant for Marin County to test a green building code amendment that limits carbon emissions on concrete. They learned that cement producers in the Bay Area emit as many greenhouse gas emissions as all the area's bus traffic. Since the air district had reached their limit technology-wise

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in working with the cement manufacturers to lower emissions, Arup helped Marin and partner jurisdictions develop a green building code provision that puts a cap on how much cement will be used on projects, thereby reducing demand for cement and regional emissions from the plants overall.

Hopefully ideas like this can spread. We are seeing interest from cities like Los Angeles, Portland, New York, and Boston to replicate something similar. Eventually initiatives like this could grow statewide, then nationwide.

Lauren: Bringing an awareness of and education around embodied carbon to the public realm will help motivate the industry to change on a larger scale. That's what I hope the SE 2050 program will accomplish. There's a need for structural engineers to take on this responsibility despite the lack of obvious financial or regulatory incentives. And we're happy and ready to take that on in alignment with our firm's values and those of our clients. It's time for our profession to act and take the lead in a process moving much too slowly.

7-4 Engineering Unknown unknowns Leadership

"Unknown unknowns" is a concept coined by former U.S. Secretary of Defence Donald Rumsfeld to describe things that we don't know we don't know. In other words, these are the information, knowledge, or factors that are outside our awareness and understanding, making them difficult to anticipate or plan for. [182]

The concept of unknown unknowns highlights the inherent limitations of human knowledge and perception. It reminds us that there are always gaps in our understanding and that unexpected events or circumstances can arise. While we can strive to gather information, conduct research, and make informed decisions, there will always be unknowns that we cannot account for.

Unknown unknowns can manifest in various areas of life, including business, science, personal relationships, and global events. In business, for example, an organisation may launch a new product or service with careful market research and analysis, only to encounter unforeseen

challenges or unexpected customer preferences that were previously unknown.

Organisational leadership has long been associated with knowledge, expertise, and making informed decisions. Embracing the concept of

[182] https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

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unknown unknowns requires a fundamental shift in leadership mindset. It entails accepting that despite our best efforts to gather data and conduct thorough analysis, there will always be uncertainties that escape our awareness. [183] This reinforces that a very different leadership approach is required to be effective in today's rapidly changing environment. Leaders are encouraged to approach situations with curiosity, openness, a willingness to learn and pivot, while leaving the need to be seen as an 'expert authority figure who has everything under control 'at the door.

The Power of Adaptability and Learning

To effectively lead in the face of unknown unknowns, adaptability becomes a critical leadership trait. Leaders must cultivate a growth mindset that embraces change, encourages experimentation, and fosters continuous learning. Instead of being paralysed by uncertainty, leaders must reframe it as an opportunity for growth, innovation, and the discovery of new possibilities.

What this looks like: Adaptive leaders remain agile and flexible in their decision-making processes. They understand that as new information emerges and circumstances evolve, adjustments and course corrections may be necessary. These leaders actively seek diverse perspectives, encourage dissenting opinions, and promote an environment where experimentation and calculated risk-taking are genuine values. [184]

Leading Authentically by Example

Leadership in the face of unknown unknowns requires authenticity. Leaders must demonstrate vulnerability by openly acknowledging their own limitations and uncertainties. This authenticity creates a safe space for open dialogue and encourages others to embrace the unknown with courage and resilience.

What this looks like: Authentic Engineering leaders build trust and inspire their teams through transparent communication, empathy, and genuine connection. They lead by example, modelling the adaptability and learning mindset they wish to cultivate within the organisation. They make it a priority to foster a culture of psychological safety by empowering employees to take calculated risks, learn from failures, and innovate. [185]

Capabilities for Navigating Unchartered Territory

Here are some essential focus areas for leaders who have a desire to be effective and impactful in navigating unknown unknowns.

Heighten Self-Awareness: Don't underestimate the power of self-reflection and introspection to gain a deeper understanding of your strengths, weaknesses, values, and blind spots. This well tested habit will equip you with the insights needed to adapt certain behaviours and make informed decisions in unpredictable situations. Importantly, don't be afraid to seek feedback from others on your ability to deal with ambiguity, if you genuinely want to grow. [186]

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183 https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

184 https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

185 https://www.graygroupintl.com/blog/authentic-leadership

186 https://hbr.org/2022/03/dont-underestimate-the-power-of-self-reflection

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Develop Adaptability and Resilience: Uncertainty demands adaptability, and you need time and space to explore new perspectives, challenge assumptions, and adopt a more agile approach. At a time when workplace burnout is on the rise, proactive rest serves as a strategic leadership tool for developing resilience, facing the unknown and embracing change. Unlike reactive rest, which is typically taken in response to feeling fatigued or overwhelmed, proactive rest focuses on recognising the importance of rest as an integral part of maintaining optimal performance, preparing us for responding to uncertainty.

Enhance Strategic Decision-Making: While strategy typically involves analysing known information and making informed decisions, it is equally important to address the presence of unknown factors. This requires time to consider various scenarios, anticipate potential risks, and evaluate the potential outcomes of different choices. This will enable you to be more adept at making informed decisions even in the absence of incomplete information. [187]

Building Strong Relationships: Leadership relies on strong relationships and collaboration. Prioritise enhancing your interpersonal skills, communication abilities, and emotional intelligence. This will make you much more effective at stakeholder engagement, conflict resolution, and fostering a culture of trust and psychological safety within your teams. Strong relationships will also help you to tap into the collective intelligence of your teams, fostering a collaborative environment that is better equipped to handle uncertainties.

Strategic Vision and Innovation: Engineers need to consider potential disruptions and market shifts. It's necessary to explore emerging trends and identify opportunities for innovation. It's also the leader's role to model creative thinking and foster a culture of experimentation to be able to respond to unknown unknowns. Talking innovation is not equivalent to engaging in experimentation, avoid this trap. [188]

Accountability and Goal Setting: To achieve a genuine shift in your approach, putting in place a structure that holds you to account will keep you on track towards your desired development goals. Consider who and what practices will support your leadership goals.

Executive coaching plays a pivotal role in supporting leaders to navigate the challenges posed by unknown unknowns and cultivate the qualities necessary for effective leadership in an uncertain world and changing organisational context. When making a shift in one's leadership approach, this can be a challenging personal journey filled with uncertainty and having expert support is crucial at such stages in leadership development. [189]

7-5 Trusting AI

Generative artificial intelligence (AI) is proving to be a powerful tool for a broad range of engineering disciplines, offering highly streamlined processes and work products, and providing invaluable insights for industry leaders. [190]

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[187] https://link.springer.com/article/10.1007/s40685-020-00129-7

[188] https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

[189] https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

[190] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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But while the term 'generative AI' is the tech industry's favourite buzzword, what exactly is it? At its core, generative AI is a subset of artificial intelligence that can generate new data, designs, or models based on existing data by using machine learning (ML) components and algorithms. Generative AI's power lies in its ability to optimise and accelerate processes, making it an ideal technology for engineering disciplines that require high precision, efficiency, and innovation.

Also: 4 ways generative AI can stimulate the creator economy

The Intersection of Generative AI and Engineering

The surge of generative AI can harness tremendous potential for the engineering realm. It can also come with its challenges, as enterprises and engineers alike figure out the impact of AI on their roles, business strategies, data, solutions, and product development. What does the future roadmap look like for bringing generative AI into the software fold? [191]

Each of the major engineering disciplines can apply generative AI toolsets in a similar manner, but also in their own unique ways -- and each field also has unique commercial and open-source solutions they can use to leverage generative AI and ML to their best advantage.

Let's look at nine major engineering disciplines and think about how they might approach using generative AI, including examples of specific solutions, both commercial and open source. Many of these tools have been used for years, but are now incorporating generative AI features, or have capabilities that continue to be refined by improving their data models or codebases, which their developers train or optimise with commercial and open-source generative AI and ML toolsets and methodologies. [192]

How can generative AI and ML be used in software engineering?

Software engineering is about more than just writing code; it's the art and science of designing, developing, and maintaining software systems that power our societies. It's the discipline that provides the foundational technology for the modern digital world, from mobile applications to the complex algorithms that drive AI.

Software engineering encompasses many activities, including requirements analysis, system design, programming, testing, and maintenance. Generative AI and ML offer transformative solutions that can automate and optimise various aspects of software development, making it faster, more efficient, and more robust. [193]

Enabling digital transformation:

• Automated code generation: Commercial tools, such as OpenAI's Codex (also used in GitHub Copilot in Microsoft Visual Studio) and open-source platforms like Sourcery, can generate code snippets, reducing development time and errors.

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[191] https://www.zdnet.com/topic/the-intersection-of-generative-ai-and-engineering/

[192] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

[193] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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• Automated testing: Solutions such as Testim.io and open-source frameworks like JUnit can automate testing and ensure robust software quality.

• DevOps automation: GitLab's Auto DevOps and open-source tools like Jenkins can automate deployment and monitoring, enhancing operational efficiency.

How can generative AI engineering? and ML be used in data

Data engineering is a specialised field that enables data-driven decision-making in organisations. It involves designing, constructing, and maintaining architectures, databases, and large-scale processing systems that transform raw data into actionable insights. [194]

Also: Why generative AI so popular: Everything you need to know Data engineers ensure data is available, reliable, and in a format that data scientists and business analysts can use for their analyses. As data volume, velocity, and variety grow exponentially, data engineering becomes increasingly complex and vital, requiring disruptive tools that use generative AI and ML to provide velocity and insights on demand. [195]

Creating actionable insights:

• Synthetic data creation: NVIDIA's DataSynth and open-source platforms like Synthea (for creating test patient health Professional Journal data) can generate synthetic datasets for robust machine-learning training. [196]

• Automated schema design : Open-source tools like Apache Avro can automate database schema design, streamlining data storage and retrieval.

• Real-time data handling: Open-source tools, such as Apache Flink and Apache Kafka, can optimise real-time data processing, which enables efficient data-stream management.

How can generative AI and ML be used in mechanical engineering?

Mechanical engineering shapes everything from the vehicles we drive to the appliances we use at home. It encompasses designing, analysing, and manufacturing various mechanical systems, from simple mechanisms, such as levers and pulleys, to complex machinery like aircraft engines and robotic arms. [197]

Mechanical engineers work to solve some of the most challenging problems, including how to make machines more efficient, sustainable, and safe. Generative AI is becoming a key optimising technology within the mechanical engineering discipline, offering powerful tools for

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194 https://www.altexsoft.com/blog/what-is-data-engineering-explaining-data-pipeline-data-warehouse-and-data-engineer-role/

195 https://www.linkedin.com/pulse/understanding-data-engineering-depth-comprehensive-guide/

196 https://www.upwork.com/hire/nvidia-ai-platform-specialists/landing/?utm_campaign=SEMNonBrand_Google_INTL_Marketplace_L1_AI-Srvcs_Tier1&utm_medium=PaidSearch&utm_content=157285057860&utm_term=nvidia%20ai%20platform&campaignid=20266139401&matchtype=b&device=c&partnerId=Cj0KCQiAwvKtBhDrARIsAJj-kTi6FnEHPso9blsI9-WsVaGhc00QXCyYIXn-7KfjwDIHt1KBy8kAEfwaAkVVEALw_wcB&utm_source=google&cq_cmp=20266139401&cq_plac&cq_net=g&ad_id=683694157390&gad_source=1

197 https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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producing more efficient designs, improving material utilisation, and predicting maintenance needs.
The mechanics of everyday life:
• Design optimisation: Autodesk's Generative Design and open-source solutions like FreeCAD can optimise mechanical designs for various constraints.
• Material utilisation: Commercial platforms, including Altair Inspire (for structural analysis), Materialise (3D printing for the healthcare industry), and open-source tools like Opencascade SALOME, can optimise material usage, reducing waste and costs.
• Predictive maintenance: IBM's Watson and open-source platforms, such as Python's scikit-learn machine-learning tool, can forecast mechanical failures, enabling proactive maintenance.

How can generative engineering? AI and ML be used in civil
Civil engineering, a field with ancient roots, is essential for designing and maintaining bridges, roads, and buildings. Civil engineers ensure our communities are functional, safe, and sustainable, tackling complex challenges such as urban development, traffic congestion, and disaster resilience. [198]
Also: The ethics of generative AI: How we can harness this powerful technology.

As we face the modern challenges of rapid urbanisation and climate change, the role of civil engineering becomes even more critical. Generative AI is emerging as a transformative technology in this field, offering innovative solutions for optimising infrastructure design, predicting natural disasters, and efficiently allocating resources. [199]
Building infrastructure:
• Infrastructure design: Bentley's Generative Components and open source 3D-modeling solutions like Blender can assist in infrastructure planning and optimising designs based on various constraints.
• Disaster prediction: Platforms like One Concern and open-source tools such as OpenQuake can predict potential disasters, enabling preventive measures.
• Resource allocation: Oracle's Primavera P6 and open-source platforms, such as GanttProject and ProjectLibre, can optimise the allocation of resources, including labor, materials, and time, ensuring efficient project execution.

How can generative AI and ML be used in electrical engineering?
Electrical engineering is the driving force behind the technologies that power our modern world, from the electricity that lights up our homes to the electronic devices that keep us connected. It is a broad field encompassing a range of sub-disciplines, including power generation and distribution, electronics, telecommunications, and control systems. [200]

[198] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/
[199] https://www.researchgate.net/publication/377365448_Transforming_the_Civil_Engineering_Sector_with_Generative_Artificial_Intelligence_such_as_ChatGPT_or_Bard
[200] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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Also: The best AI chatbots As society becomes more interconnected and energy-conscious, the role of electrical engineering is increasingly vital, and key challenges, such as renewable energy integration, data security, and automation, require innovative solutions. Generative AI and ML offer groundbreaking approaches for automating circuit design, optimising energy management, and enhancing signal-processing techniques. These approaches will enable electrical engineers to create more efficient, reliable, and sustainable systems, which can shape a brighter future for us all. [201]

Powering everything:

• Circuit design: Platforms like Cadence and open-source tools like KiCad can automate and optimise electrical circuit design, saving time and effort.

• Energy management: Solutions such as Verdigris for smart-building design and open-source platforms like OpenEnergyMonitor, and the various projects for energy providers hosted at LF Energy, can optimise energy generation and consumption, contributing to sustainability. [202]

• Signal processing: Commercial software such as MATLAB and open-source alternatives like GNU Radio can enhance signal-processing techniques, improving communication systems. Professional Journal

How can generative AI and ML be used in chemical engineering?

Chemical engineering plays a pivotal role in many industries, from pharmaceuticals and petrochemicals to food processing and materials science, involving the application of chemical, physical, and biological processes to convert raw materials into valuable products. Chemical engineers optimise manufacturing processes, develop sustainable energy solutions, and ensure product quality and safety. [203]

Also: These are my 5 favourite AI tools for work [204]

As industries strive for greater efficiency, reduced environmental impact, and enhanced innovation, chemical engineering becomes increasingly crucial, demanding constant innovation to meet evolving consumer needs and regulatory standards. Generative AI offers chemical engineers unparalleled process optimisation, material synthesis, and quality control capabilities, allowing them to achieve unprecedented efficiency and precision, driving the industry into a new era of sustainable and high-quality production.

Transforming raw materials:

• Process optimisation: Commercial technologies like AspenTech and open-source platforms like COCO Simulator can optimise chemical manufacturing processes.

• Material synthesis: Commercial SaaS solutions such as Citrine Informatics and open-source tools like Avogadro can assist in discovering new materials. [205]

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201 https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

202 https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

203 https://www.hajim.rochester.edu/che/about/what-do-chemical-engineers-do.html

204 This is the author's engineering specialty

205 https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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• Quality control: Companies such as Lighthouse, tools like Advantive InfinityQS, and open-source data science solutions like KNIME can be used to predict product quality in real time.

How can generative AI and ML be used in biomedical engineering?

Biomedical engineering is a unique interdisciplinary field that merges engineering principles with the complexities of biology and medicine, aiming to enhance health care by developing technologies that improve medical diagnosis, treatment, and patient care. From designing state-of-the-art medical devices like MRI machines and prosthetic limbs to developing cutting-edge techniques for tissue engineering and drug delivery, biomedical engineers are at the forefront of medical innovation.

As the health care sector faces contemporary challenges, such as an aging global population, escalating healthcare expenses, and the growing demand for personalised medical treatments, Generative AI can be a highly transformative technology for pharmaceutical development and healthcare, offering unparalleled opportunities for accelerating drug discovery, customising prosthetic designs, and enhancing medical imaging. [206]

Bridging medicine and technology:

• Drug discovery: Commercial technologies like Atomwise and open-source platforms like RDKit for Cheminformatics can accelerate drug discovery by predicting molecular properties. Microsoft's recently open sourced EvoDiff can be used to discover protein sequences for new drugs and therapeutics.

• Prosthetics design: Commercial tools like 3D Systems' Medical Modelling and open-source solutions such as Open Bionics can design customised prosthetics and implants.

• Medical imaging: Commercial platforms such as Nanox AI and open-source tools like ITK Insight Toolkit can enhance medical image quality, aiding more accurate diagnoses.

How can generative AI and ML be used in aerospace engineering?

Aerospace engineering is a specialised field that focuses on developing and designing aircraft, spacecraft, and related systems and equipment. Aerospace engineers design commercial airliners, drones, satellites, launch vehicles, space capsules, and space habitats, working on complex challenges, including aerodynamics, propulsion systems, structural design, and navigation. They aim to push the boundaries of what is possible in air and space travel. [207]

Also: ChatGPT and the new AI are wreaking havoc on cybersecurity in exciting and frightening ways

As humankind sets its sights on achieving lofty goals, such as space tourism and interplanetary colonisation, the role of aerospace engineering becomes increasingly pivotal. The field, once only the domain for government agencies with mega-budgets, is ripe for innovation, especially as it grapples with fuel efficiency, safety, and environmental sustainability issues. Generative AI offers novel solutions for optimising aircraft designs, enhancing navigation systems, and improving fuel consumption.

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[206] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8285156/

[207] https://www.crimsoneducation.org/nz/blog/what-do-aerospace-engineers-do/

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Reaching for the skies:

• Aircraft design: Siemens' NX and open-source platforms like OpenVSP can optimise aircraft component designs for weight, strength, and aerodynamics. [208]

• Navigation systems: Defence industry solutions from Northrop Grumman and open-source tools, such as ArduPilot and Dronecode, can enhance navigation and control systems.

• Fuel efficiency: Honeywell's Forge and solutions like JSBSim can optimise fuel contributing to sustainability.

open-source consumption,

How can generative AI and ML be used in environmental engineering?

Environmental engineering is a critical discipline that focuses on protecting and improving the natural environment for human health and ecological well-being. Environmental engineering encompasses a wide range of activities, from water treatment and waste management to air-quality control and renewable energy solutions. [209]

Also: Train AI models with your own data to mitigate risks

With pressing challenges, such as climate change, pollution, and resource depletion, the role of environmental engineering becomes increasingly vital, requiring innovative solutions to complex problems, and often involving interdisciplinary collaboration between scientists, policymakers, and community stakeholders. Generative AI is emerging as a powerful tool in this arena, offering cutting-edge solutions for optimising waste management, modelling climate impacts, and efficiently utilising natural resources, so engineers can develop more effective and sustainable strategies to safeguard our planet for future generations. [210]

Saving the planet:

• Waste management: Commercial platforms like Rubicon can optimise waste collection and recycling processes.

• Climate modelling: The Community Earth System Model and open-source platforms like OSClimate and OpenFOAM can model climate impacts.

• Resource optimisation: Open source map-data solutions, such as Overture Maps Foundation and OpenStreetMap, can be used to optimise natural resources.

7-6 Summary for this Chapter

Generative AI and machine learning are more than just technological advancements -- they are driving changes in tooling, processes, and methodologies that are revolutionising the engineering landscape. The unique ability of these technologies to optimise and accelerate processes across various engineering disciplines makes them indispensable for modern engineering disciplines. As such, the message for businesses and engineering leaders is clear: embrace generative AI to stay competitive and enhance leadership with greatly evolved expertise.

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[208] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

[209] https://www.liebertpub.com/doi/full/10.1089/ees.2015.0334

[210] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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8-1 Introduction

Expertise Augmentation

AI is augmenting the expertise of engineers by providing them with powerful tools and resources. AI algorithms can assist engineers in complex problem-solving, providing insights and suggestions based on extensive data analysis. This collaboration between humans and AI systems amplifies engineering capabilities, leading to innovative solutions and improved efficiency. [211]

From 3D printed smart homes to music composed by Artificial Intelligence, emerging technologies are undoubtedly going to disrupt the future world of work.

Will the robots take our jobs? Or will we have more time for leisure? Who will be the winners and losers? And how can we be prepared? Too often, conversations about the new digital economy are characterised by 'technological determinism – 'a sense that technology will autonomously and necessarily deliver progressive social change. However, technology trajectories are rarely neutral – they tend to reflect and serve specific interests. Left to market forces alone, they are likely to exacerbate existing inequities in the world of work.

Technology trajectories can and should be steered by societal choices and public policies. Speculating or building scenarios for a range of plausible and preferable futures allows us to identify the choices we need to make today to secure a better tomorrow. Let's imagine four different scenarios – hypothetical, yet not implausible – for what the future of work might look like for countries and people in the global south.

Technocracy Rules

Large-scale adoption of advanced robotics and artificial intelligence results in the loss of jobs across numerous industries – from janitors and factory workers to flight attendants and animation artists. Some people are able to adapt by re-skilling, but for most, particularly those towards the middle or end of their careers, the pace of change is too fast. [212] Women are particularly susceptible to technological unemployment – many occupy entry-level positions, which are the most vulnerable to intelligent automation. Tremendous financial gains accrue to large technology companies and a highly educated elite; inequality is at its highest. The growing mismatch between the availability of work and those looking for jobs leads to the widespread use of AI based systems for hiring and performance review, and workplace surveillance becomes commonplace.

Many workers turn to digital platforms to look for gig-work, but fierce competition drives down wages, and poor regulation leaves workers vulnerable to harsh customer-rating systems. Most young people are engaged in invisible and menial tasks such as image recognition and data categorisation for AI startups in industrialised economies. The availability of cheap digital labour has meant that the pace of innovation and invention is faster than ever before; as a result, a cure for most

[211] https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

[212] https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

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major lifestyle diseases has been found and space exploration has become easily accessible to the elite. [213]

Equity First

The threat of large-scale technological unemployment leads governments to restrict foreign investment by large technology companies and levy high taxes on domestic businesses employing robotics and AI. [214] Growth and innovation suffers, but anxiety about large-scale job displacement is alleviated. State investments in rural infrastructure, including basic digital infrastructure and quality education and healthcare, increase significantly. This not only reduces the stress on already saturated urban areas, but also creates new employment opportunities in these sectors.

Perhaps the biggest game changer is the focus on women – care work is finally recognised and remunerated and this allows women to have financial independence as well as seek new education and employment opportunities. [215] Widespread internet connectivity enables hyper-local sharing economies to grow in urban and rural areas, and profits are shared equitably across workers. A four-day work week is introduced to distribute available jobs more evenly and enable greater time for leisure. Growing pressure from consumer groups also pushes business to commit to meet sustainability targets. Many startups and entrepreneurs emigrate to foreign countries, and concerns about brain-drain are on the rise.

8.2 AI for All Decisions

Governments and citizens have collectively articulated national innovation policies that are linked to societal goals, and the development and deployment of advanced technologies is made to align with these goals. [216] Professions considered dangerous, demeaning and dirty are

the first to be automated – manual scavenging and mining are the first to go. Much new innovation is directed toward augmenting existing initiatives for education, healthcare, and environmental management; the growth in these sectors creates multiple new employment opportunities for youth entering the workforce. Businesses are

213 https://www.linkedin.com/pulse/gig-economy-growing-workforce-trend-metapax-7jsif/

214 https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

215 https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

216 https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

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mandated to adopt circular economy principles i.e. to design out waste by creating products optimised for reuse. [217]

To compensate for jobs that have been lost to automation, a four-day work week is introduced, alongside limits on the hours worked per worker. Large-scale manufacturing shrinks, but dispersed manufacturing, made possible by 3D printing, has revived many rural and artisan economies. The platform economy continues to grow, and is regulated to facilitate new forms of employee ownership and social protection. Heavy taxation of data-driven technology companies is used to deliver minimum welfare benefits to citizens, creating an enabling environment for entrepreneurship and experimentation. [218] To compensate, and fuel further social innovation, privacy requirements are relaxed and citizen data is traded on a data marketplace.

Fracture

Below is a discussion about four scenarios which present hypothetical and exaggerated futures for countries in the global south. An acute water crisis cripples the global economy. Traditional manufacturing businesses come to a stand-still, unable to access steady power supply; many jobs are lost, but numerous new ones are created as persistent power shortages result in machines for basic automation being replaced by cheap manual labour. Business in the new digital economy also suffers, as data centres around the world start over-heating and many go into disuse; manufacturing of electronic components and digital devices slows down drastically, as many natural resource pools have been steadily depleted. The digital economy is further crippled by attacks on cyber-infrastructure – government and financial databases are the first targets, affecting the already vulnerable parts of the population the most. [219]

For most, gig-work becomes a necessity, but poor regulation of platforms puts workers at further risk, particularly with a collapse in government funding for social security schemes and quality education and healthcare. Informal and illegal employment is rampant, and women retreat further into various forms of unpaid care work. With the threat of large-scale social upheaval looming, governments readily adopt mass surveillance technologies. Internal policing and cyber-security budgets increase substantially, and the defence and security industries become the largest employers. Employment numbers are high, rule of law is efficiently maintained, and the constant monitoring of citizen behaviour has enabled more efficient rationing of limited natural resources.

These four scenarios present hypothetical and exaggerated futures for countries in the global south. The future of work we want is probably some patchwork of these scenarios. None are perfect and all involve trade-offs, yet some choices are certainly more desirable than others.

A 'business as usual 'approach may lead us closest to a 'technocracy rules 'scenario, characterized by both high growth and high inequality, in which the needs of labour become secondary to the needs of capital. Many jobs will be lost, and the new opportunities created will be available to only a small elite. The pace of innovation and invention

217 https://www.undp.org/sites/g/files/zskgke326/files/migration/acceleratorlabs/NEW_The-Changing-Nature-of-Work_15-June-2021_FINAL.pdf

218 https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

219 https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

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rapidly accelerates but only the highly educated and elite can leverage new opportunities; the expected trickle-down effects are slow and uneven. For most others, gig-work, contractual work and informal work are likely to become the norm, characterized by increasingly precarious employment conditions.

Alternatively, the growth of a surveillance state, attacks on critical cyber-security infrastructure, breakdown of social cohesion and natural resource scarcity could all be triggers for steering toward a 'fracture ' scenario; one in which poverty and social instability are at their highest, and employment opportunities are plentiful but restricted to furthering the national security objectives of the state. The 'equity first 'scenario suggests that decent work is possible even without technological innovation, though at significant cost to entrepreneurship and invention.

The 'AI for all 'scenario paints a picture of high growth, productivity, social cohesion and leisure, but one in which individual needs risk being subsumed under broader national goal. What is the future we want and how do we get there? [220] How do we ensure an equitable distribution of technology gains in the future world of work? What kind of choices are available to us and what are the coping strategies we need to adopt? Innovation trajectories must be made to align with broader societal needs. Automating dirty, demeaning or dangerous jobs, such as manual scavenging or coal mining for example, might be more socially appropriate than replacing human resource managers with automated systems or introducing driver-less cars, particularly in economies with an abundance of labour. With gig-work likely to increase, regulation must play a role in steering digital platforms – the Ubers and Amazon Mechanical Turks of the world – toward safeguarding worker rights and enabling access to social protection mechanisms. New social safety needs will need to be introduced through public policy – from the redistribution of income and working hours to investments in quality and affordable education and healthcare.

The future world of work is unlikely to be the same across social contexts and social groups – some economies and peoples will be better poised to leverage new opportunities, while others risk being further left behind. For many people in the global south, it is the present of work that is an urgent concern. Millions still lack access to basic services – from electricity to education – and finding meaningful work remains aspirational for most. Techno-imaginations of the future must not distract from securing the present. [221]

REF: Urvashi Aneja

8-3 Decision making leadership

AGI's adaptability and reasoning, combined with Generative AI's scenario generation, support decision-making. AGI analyses data, providing comprehensive insights, while Generative AI generates simulations exploring different outcomes. This aids informed decisions in engineering, policy, and research. [222] Just as Slide Rules, Calculators

[220] https://www.linkedin.com/pulse/how-do-you-confidently-use-ai-create-exponential-value-sanz-saiz-h1fyf/?trk=public_post_main-feed-card_feed-article-content

[221] https://artsandculture.google.com/story/how-will-technology-change-our-worklife-barbican-centre/tQVRhKFkyKgtKQ?hl=en

[222] https://medium.com/@Prosesmuses/exploring-agi-and-generative-ai-the-ai-prodigies-4b7010e0248

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like HP and CAD have provided precision to engineering design so too will AGI. But as previously mentioned the design and engineering work of the future is so complex that it cannot be performed by engineers without AI and AGI assistance.

Scientific Discovery and Research

AGI assists scientific research by analysing data and identifying hidden patterns. Collaborating with Generative AI, they generate hypotheses, simulate experiments, and create visual representations. This accelerates discovery in fields like engineering, medicine, physics, and climate science. [223]

Creative Tools and Design Assistance

AGI acts as a versatile creative assistant, supporting artists and designers. It understands objectives and provides insights, suggestions, and alternative design options. Generative AI generates visuals and prototypes based on AGI's guidance, streamlining the creative process.

Deep learning is like a brain within a brain — it's a type of machine learning that uses advanced neural networks with multiple layers to analyse complex data. These complex networks can find patterns and relationships that would be impossible for a human to detect on their own. This is what makes deep learning so powerful and useful in a wide range of applications, from detecting fraud to improving healthcare. It's like having a supercharged AI brain on your team!

Deep learning is still like a curious child that loves to explore and discover new things. Even though we've made great progress in this field, there's always more to learn and new techniques to develop. Researchers are constantly working to make deep learning models even better and more powerful, like adding new superpowers to a superhero! So, we can expect more exciting breakthroughs in the future! [224]

At its core, AI is simply about teaching computers to learn and make decisions on their own. As we continue to develop this technology, it has the potential to improve our lives in countless ways, from helping us stay healthy to making our daily routines more efficient.

But as exciting as these advancements are, it's also important to remember that AI is ultimately a tool that we control, not the other way around. As we explore the possibilities of this technology, we must also consider the ethical implications and ensure that it is being used in ways that benefit society as a whole.

At the end of the day, AI is not just about machines and algorithms it's about using technology to make a positive impact on the world around us. And as long as we keep that in mind, there's no telling what we can achieve. [225]

Adopting AI will make engineering knowledgeable, efficient and capable

With an impressive surge in advancement over the past 18 months, the artificial intelligence (AI) market is on track to reach a staggering

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[223] https://medium.com/@Prosesmuses/exploring-agi-and-generative-ai-the-ai-prodigies-4b7010e0248

[224] https://medium.com/@Prosesmuses/the-abcs-of-ai-a-beginners-guide-to-the-fundamentals-machine-learning-neural-networks-and-41641b0afb10

[225] https://www.pewresearch.org/internet/2018/12/10/improvements-ahead-how-humans-and-ai-might-evolve-together-in-the-next-decade/

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£9.87bn by the end of this year, with an expected growth rate of 15.17% between 2023 and 2030. [226]

Ref: Bret Tushaus is VP of Product Management at Deltek

Given the speed at which AI is progressing, it's not surprising that this technology is leaving its mark on the world of architecture and engineering (A&E). The introduction of AI in A&E is equipping firms with the tools they need to become more knowledgeable, efficient and, ultimately, more profitable.

However, for all the promise and excitement around AI, widespread adoption remains a significant challenge. Deltek's Clarity: Trends and Insights for Architecture, Engineering and Consulting Firms research finds that more than half (53%) of A&E firms report adopting AI is a top challenge for their business. This is a result of businesses grappling with many issues associated with navigating this new, fast-moving technology, such as data accessibility, limited employee awareness, and the complexities of implementation. [227]

Nonetheless, overcoming these AI adoption challenges should be a top priority. Leveraging AI to streamline the project management lifecycle early on and integrating it into business operations could give firms a significant jump on their competitors. [228]

At Deltek, discovering new ways businesses can benefit from leveraging AI technology is key to keeping our solutions relevant and adding value to our customers.

How AI is transforming Deltek project nation

41% of architecture and engineering firms recognise AI as being very important to their business, holding the potential to streamline content creation, facilitate decision-making, and even prescribe and automate action. Following 2023's economic and workforce challenges, the rise of AI couldn't have come at a better time for the project landscape. [229]

AI has the capability to increase project efficiencies by empowering strategic decision-making through analysing historical performance and data inputs. For example, if an A&E firm consolidates all its data within one platform, AI has the capability to predict the probability of winning a potential project, run a report on a project's progress in seconds and make predictions about the future of the project. These insights, which traditionally take hours to collate, empower organisations to distribute resources, understand where investments are best made and focus efforts with greater precision and effectiveness.

Using AI to tackle A&E challenges

The same Deltek research found that admin workload is a top challenge for more than a third (37%) of A&E companies, with managing project-related emails a hurdle for over one in three (36%). On a day-to-day basis, admin-related challenges are almost always more time consuming than predicted. It is these moments that hit productivity most. What can be perceived as a simple task – for example, responding to client

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226 https://www.newcivilengineer.com/opinion/adopting-ai-will-make-engineering-firms-more-knowledgeable-efficient-and-profitable-03-11-2023/

227 https://www.newcivilengineer.com/opinion/adopting-ai-will-make-engineering-firms-more-knowledgeable-efficient-and-profitable-03-11-2023/

228 https://www.sciencedirect.com/science/article/pii/S219985312201054X

229 https://www.newcivilengineer.com/opinion/adopting-ai-will-make-engineering-firms-more-knowledgeable-efficient-and-profitable-03-11-2023/

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emails – in reality takes up 25% of our day. For project-based business, this time waste has a huge impact on the business 'bottom line.

The integration of AI can ease these pressures through automation, allowing project managers to dedicate more time to the human aspect of their projects. While the human-touch is always going to be needed with clients, AI holds the potential to streamline and automate admin workload. Rather than spending hours collating a report for a client each week, AI has the capability to instantly collate all the required insights in moments whenever needed. For example, rather than spending hours bringing another member of the team up to speed on a project, AI can instantly pull together an introduction – including all the vital information. [230] Taking responsibility for admin-heavy tasks, AI enables project managers to focus on the areas of business where humans add the most value. For example, building relationships, exploring new business opportunities, and handling critical situations.

Through these simple efficiencies, AI possesses the potential to elevate project performance metrics by forecasting project outcomes based on current trajectory and historical data. [231]

AI's power being embraced by A&E firms

When integrating AI into A&E firms, it's worth remembering this technology is still relatively new, which means it comes with some challenges. Successful adoption will come from A&E companies embracing adaptability and resilience in the face of the unknown, or yet-to-be-tested. By strategically investing in state-of-the-art technology – through partner integrations or seamless integration within the business – organisations can demonstrate their commitment to enhancing efficiency and productivity. [232]

The rapid advancement of AI has introduced a learning curve for all businesses. Ensuring decision makers stay at the forefront of industry trends is essential to determining which technologies will and won't be useful to their organisation.

For many organisations, the question comes down to what next and how to begin. The key is being on the journey and pinpointing the most significant benefits. This comprehensive approach fosters success, resilience, and competitiveness in a business landscape that is evolving at a rapid pace.

The A&E industry stands at the brink of an extraordinary era driven by AI. Companies that embrace its transformative potential will thrive in an increasingly competitive environment. The path forward is crystal clear: seize the opportunities around AI, embrace streamlined business processes and empower project managers with essential business information in moments, rather than hours. By doing so, project-based businesses will continue to progress, adapt, and flourish in the era of artificial intelligence. [233]

The concept of AI was first introduced in 1956 at a meeting held at Dartmouth College. Since then, AI has evolved significantly, with

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[230] https://www.newcivilengineer.com/opinion/adopting-ai-will-make-engineering-firms-more-knowledgeable-efficient-and-profitable-03-11-2023/

[231] https://hbr.org/2023/02/how-ai-will-transform-project-management

[232] https://www.newcivilengineer.com/opinion/adopting-ai-will-make-engineering-firms-more-knowledgeable-efficient-and-profitable-03-11-2023/

[233] https://www.linkedin.com/pulse/unlocking-potential-ai-transforming-industries-beyond-macartoai/?trk=public_post

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advancements in computing power, algorithms, and data availability driving its growth. Today, AI is used in numerous applications, from voice assistants on smartphones to complex industrial processes. [234]

The Growing Presence of AI in Engineering

The engineering profession is not immune to the influence of AI. In fact, AI is revolutionizing the field, opening up new possibilities and transforming traditional practices. Here are some key ways in which AI is impacting the engineering profession: [235]

Design and Optimization

AI is increasingly being used in the design and optimization of engineering systems. By analyzing vast amounts of data on performance, efficiency, and other factors, AI algorithms can identify optimal designs for complex systems such as aircraft, automobiles, and manufacturing processes. This not only leads to more efficient and effective engineering designs but also enhances industries like transportation and manufacturing.

Automation of Engineering Tasks

AI is playing a crucial role in automating various engineering tasks. By analysing data from sensors and other sources, AI algorithms can identify potential issues with engineering systems and provide recommendations for resolution. This reduces the need for human intervention in maintenance and operation, improving efficiency and minimizing errors. Engineers can focus on value-adding activities while AI handles repetitive and mundane tasks. [236]

Simulation and Analysis

AI is also enhancing the accuracy and speed of engineering simulations and analyses. Machine learning algorithms can analyze simulation data and identify patterns or trends that might be difficult for humans to detect. [237] This enables engineers to make more informed decisions and optimize designs more effectively. AI-driven simulations can provide valuable insights into system behaviour, helping engineers develop robust and efficient solutions.

Predictive Maintenance and Fault Detection

AI is transforming maintenance practices in engineering. By analysing sensor data and historical performance data, AI algorithms can predict when equipment is likely to fail and recommend maintenance actions to prevent costly breakdowns. This proactive approach to maintenance reduces downtime, increases equipment lifespan, and improves overall operational efficiency. [238]

Robotics and Automation

AI-driven robotics and automation are revolutionising the manufacturing and industrial sectors. Robots equipped with AI capabilities can perform intricate tasks with precision and efficiency. They can handle complex assembly processes, optimise production

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234 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

235 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

236 https://www.sciencedirect.com/science/article/pii/S2666675821001041

237 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

238 https://www.leewayhertz.com/ai-in-predictive-maintenance/

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flow, and improve overall productivity. [239] The integration of AI and robotics is reshaping how engineers approach manufacturing and is leading to the development of more advanced and flexible production systems.

Energy Optimisation

AI is also being used to optimise energy consumption in engineering systems. By analysing data on energy usage patterns, AI algorithms can identify opportunities for energy efficiency improvements, reducing costs and environmental impact. This is particularly relevant in sectors such as building management, where AI-driven systems can optimise heating, cooling, and lighting to achieve maximum energy efficiency. [240]

8-5 Social Licence to operate

Safety and Risk Management

AI has the potential to enhance safety and risk management in engineering operations. By analysing historical data and real-time sensor data, AI algorithms can identify potential safety hazards and predict risks. This enables engineers to take proactive measures to mitigate risks and maintain a safe working environment. AI-driven systems can also help in emergency response planning by simulating different scenarios and providing insights into the best course of action.

Enhanced Collaboration and Communication

AI technologies are improving collaboration and communication among engineering teams. AI-powered tools enable engineers to share and access information more efficiently, facilitating collaboration across geographically dispersed teams. Natural language processing capabilities make it easier to extract relevant information from vast amounts of data, enabling engineers to make informed decisions quickly. [241]

Artificial Intelligence is reshaping the engineering profession, unlocking new possibilities, and transforming traditional practices. From design optimisation to automation, AI is revolutionising how engineers approach their work. Embracing AI technologies and developing the necessary skills will be crucial for engineers to thrive in the rapidly evolving engineering landscape. [242]

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239 https://www.aveva.com/en/solutions/digital-transformation/artificial-intelligence/?utm_term=industrial%20artificial%20intelligence&utm_campaign=G_S_A_APAC_ANZ_Always%20On_Solution_Digital%20Transformation_Digital%20Transformation&utm_source=adwords&utm_medium=ppc&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTjxIXNY6l5o1pK9Cht_dBEcL5pyHSl6na8_SWsulKVwZcuW2ZsKN7waAiySEALw_wcB

240 https://utilitiesone.com/the-role-of-artificial-intelligence-in-energy-optimization-for-large-scale-construction

241 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

242 https://www.linkedin.com/pulse/impact-artificial-intelligence-engineering-profession-balino/

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8-6 Summary for this Chapter

The impact of AI on the engineering profession will continue to grow in the coming years. As AI technologies advance and become more sophisticated, engineers will need to adapt and acquire new skills to leverage the full potential of AI. The ability to understand, develop, and integrate AI systems will be a valuable asset for engineers.

Moreover, the collaboration between humans and AI systems will become increasingly important. Engineers will need to work alongside AI technologies and leverage their capabilities to drive innovation and solve complex engineering challenges. This partnership between human expertise and AI capabilities will lead to groundbreaking advancements in various fields of engineering.

Ethical Considerations

While AI brings numerous benefits to the engineering profession, it also raises ethical considerations. As AI becomes more prevalent, engineers need to ensure that AI systems are designed and used responsibly. This includes addressing issues such as bias in AI algorithms, ensuring transparency and accountability, and considering the potential social and economic impacts of AI implementation.

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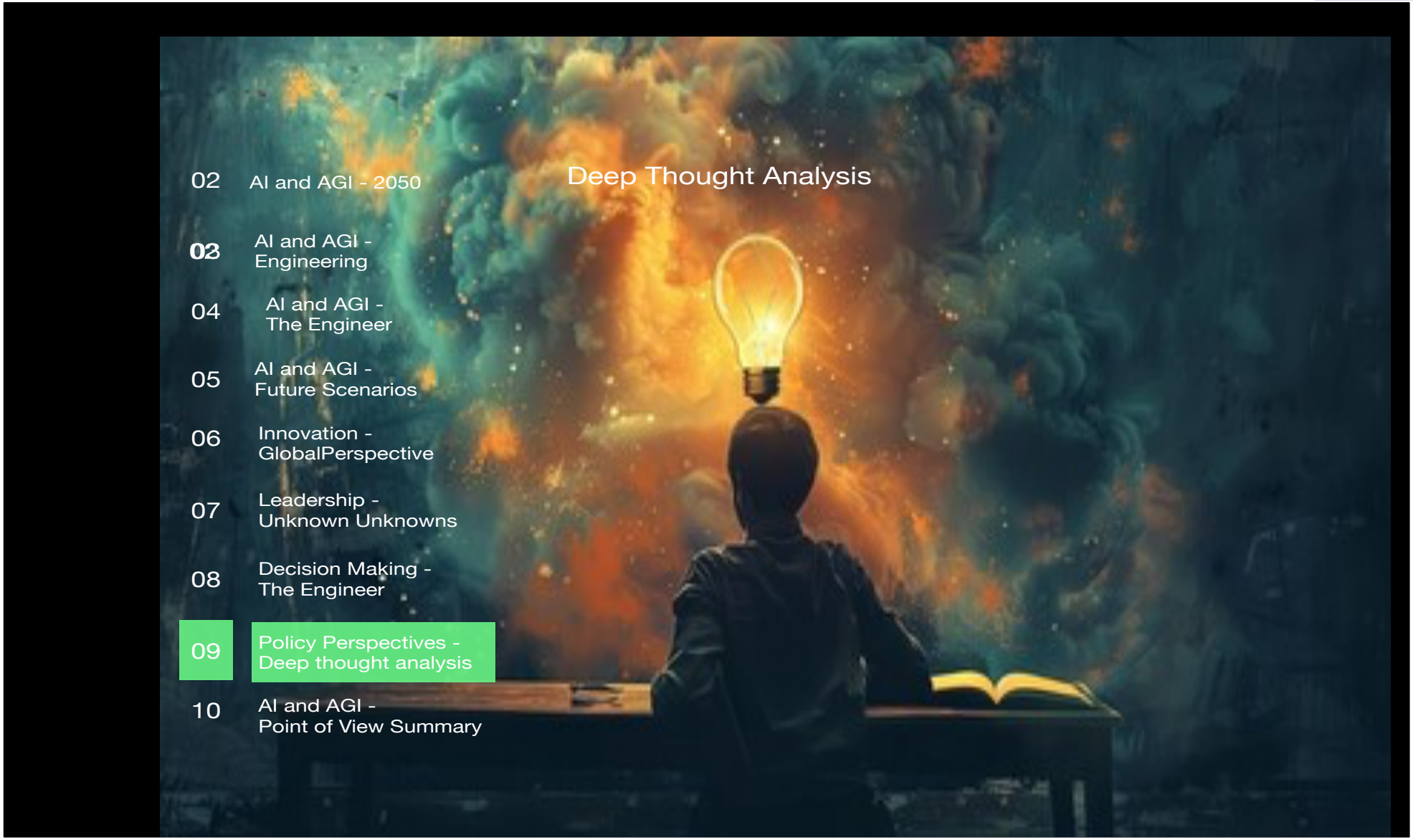

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9-1 Introduction

There is no consensus on why all the related technological and scientific progress has not yet yielded AI software systems with human like general intelligence. [243]

The reason considers the following:

1. Intelligence depends on the emergence of certain high level structures and dynamics across the system whole knowledge base;

2 We have not discovered any one algorithm or approach capable of yielding the emergence of these structures;

3 Achieving the emergence of these structures within a system formed by integrating a number of different AL algorithms and structures require careful attention to the manner in which these algorithms and structures are integrated; and so far the integration has not been done in the correct way.

The AI Revolution represents a fundamental shift in the way we interact with technology and the world around us. AI technologies have the potential to revolutionise everything from healthcare to transportation, and they are already beginning to transform the way we work and live - and increasingly AI is moving closer to a point where human involvement will be considered optional, not essential. [244]

9-2 Culture/Risks/Mitigations

The ethics of advanced AGI is a complex issue with multiple aspects. Among the many issues there are :

1. Risks posed by the possibility of human beings using AGI systems for evil ends.
2. Risks posed by AGI systems created without well designed ethical systems
3. Risks posed by AGI systems with initially well-defined ethical systems eventually going rouge - an especially big risk is these systems are more inherently intelligent than humans, and posses a capability to modify their own source code.
4. The ethics of experimenting on AGI systems when one doesn't understand the nature of the experiment. [245]

9-3 Government/Politics

The Growing Presence of AI in Engineering

By this point, nearly everyone is familiar with the AI tools that started trickling out late last year and seem to gain new capabilities each week. ChatGPT, which launched on 30 November, is the best known. "I don't even think the most hardened tech journalists were quite expecting something as profoundly different as ChatGPT," says King. "It really is like stepping five or 10 years into the future almost overnight, and its

243 https://link.springer.com/chapter/10.1007/978-3-031-21448-6_2

244 https://www.linkedin.com/pulse/new-book-explores-impact-ai-agi-revolution-humanity-future-st-john/

245 https://www.europarl.europa.eu/RegData/etudes/STUD/2020/634452/EPRS_STU(2020)634452_EN.pdf

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capability – without being too hyperbolic – will drive an absolute explosion in terms of what we're going to see." Applications of such chatbots, based on large language models (LLM), can seem practically unlimited. From the relatively mundane – writing shopping lists and travel itineraries – to the more radical – formulating entire business plans and executing them, writing scripts in the style of specific authors, even instructing other AIs on complex tasks ChatGPT and equivalents such as Microsoft's Bing and Google's Bard are revolutionising the production of text, and other types of content.

Chatbots can produce software code, for example, while text-to-image and text-to-video programs are capable of producing photorealistic images of imagined situations. 'Balenciaga Pope', published online last month, showed how unprepared society is for the approaching tsunami of AI-generated social media content. [246]

In short, we seem to be standing on a precipice. Before us lies a very different future to the one that might have been forecast less than a year ago, and countless ways of life and industries will be forced to adapt. From data entry to creative artistic expression, it seems that most activities will be threatened, streamlined, or otherwise changed in one way or another.

Engineering is no different. For many years, the industry has been one of the foremost developers and adaptors of AI-related technology, from machine vision systems to generative design. Now, however, it is one of many sectors facing disruption and transformation from chatbots and their next-generation descendants.

'A futuristic robot factory', generated by DeepAI 'It sounds like me ' Since his teenage years in the '80s, King has always wanted to work at the cutting edge. Describing himself as a technologist, he started work at the IMechE 17 years ago, first as a regional manager, then in business development. Now, he is pivoting towards AI, and is already using the available tools to accelerate his work and explore the boundaries of their capabilities.

He used ChatGPT to write a presentation, for example, the chatbot providing the initial 50-60% of work that he then improved on and added to. King then fed that document into an AI Google Slides extension, which generated a computer presentation within 30 seconds.

The next step was even more radical – King uploaded a 10-minute recording of his voice into the online Synthesia tool, which analysed his speech and 'cloned 'it, letting him input text for it to read out in his own voice. That AI-generated voice introduced the presentation, while a virtual, AI-generated female avatar with a different artificial voice read out the end of the presentation, which King refined with ChatGPT to make it more conversational.

"This version of AI at the moment, let's call it generation one. It's a copilot, and it's going to help us do things better, faster, quicker," he says. "We become the editors of the content, and refine and build on what the AI provides us with." King even used ChatGPT to write a bedtime story for his son, including different characters, before using Synthesia to read it out in his voice. The software gave each character different intonation, just like a human narrator might do. "It's very, very

[246] https://www.imeche.org/news/news-article/feature-how-ai-is-already-changing-engineering-and-the-role-of-the-engineer

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clever," King says. "But it still sounds like me" Plausible sounding nonsense The power of these first-generation tools is clear, and they can already be very useful for individual engineers.

The most obvious application for many will be asking chatbots to write memos, emails or pitches, a process that will be streamlined further as companies such as Microsoft and Google integrate AI tools into their suites of programs. Others might be tempted to use chatbots for calculations or to provide research data, but anyone doing so should exercise extreme caution. Although LLMs are trained on vast libraries of text from websites, books and scientific journals, the way in which they formulate answers means they can provide "plausible sounding but incorrect or nonsensical answers," according to ChatGPT creators OpenAI – shaky foundations for any project. [247]

This partly stems from the fact that answers are probabilistic, rather than deterministic. Roughly speaking, the program selects the most likely word to follow the previous word, not necessarily the most correct or truthful. The mistakes that can happen as a result – saying the peregrine falcon is the fastest marine mammal, for example – mean most tools are not yet suited for creative engineering work.

They could be well-suited for analysis, however, according to King. "If you're inputting a set of information to it, and saying 'I want you to review this, against these criteria, 'as an engineer that could be really powerful," he says. "It can create faster design cycles, increased automation, it can potentially improve accuracy if done in a controlled way." Text-to-design From giddy excitement to existential terror, the rapid rise of new AI tools provoked a wide range of reactions – but regardless of how people feel about it, the cat is out of the bag. The uncoordinated and unregulated release of new tools with ever greater capabilities has kickstarted an AI arms race, and every organisation has to assess their future relationship with it. "If they don't, they'll get left behind by the organisations that do," says King.

One of the most attractive potential applications for engineering companies could be 'text-to-design', a variation on text-to-image programs that generate pictures based on prompts. Could engineers use similar tools to generate engine designs, for example, meeting a set of criteria defined in the prompt?

"I don't think it's that far away," says King, although some barriers will need to be overcome first. Generative design already provides feasible options for components, but it is not used for entire devices. The 'plausible sounding but nonsensical 'output issue would also likely plague attempts at building new text-to-design tools.

How an 'engineering design' is imagined by DeepAI. Current text-to image programs are not suitable for engineering work Even if probabilistic AI tools provide sensible-looking outputs, they do not understand the 'why 'of why something works. Can a program that does not understand why a design might work or not work be trusted to consider the potential harm of an issue down the line?

Engineering companies will also be understandably hesitant about uploading the necessary internal data for specific models to work with and extrapolate from.

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[247] https://www.imeche.org/news/news-article/feature-how-ai-is-already-changing-engineering-and-the-role-of-the-engineer

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If firms could train models on their own securely stored data, they might start to see some huge benefits. [248] The Foundry, by OpenAI, could reportedly enable that. Big engineering firms could rent 'space 'on the platform and ask it to build a model specifically for engineering, safe in the knowledge that all the initial data is accurate, or at least based on their own work.

"Then you get into the realms of real, hugely powerful possibilities," says King. "You could start to create models, designs, drawings whatever. And it could be instantly rendered into video as well." Big data IMechE member Ali Parandeh is busy turning some of those possibilities into reality. "Construction, manufacturing and various other engineering sectors like automotive, these are sectors that are really primed for using AI," he says. "They have all the datasets, and they have all the money to put into it, but they just don't have the capability or don't know where to start." Parandeh hopes to provide a couple of different starting points. Along similar lines to the Foundry, he is working on an idea that would allow companies to train models in their own servers without having to share data with other people, optimizing the benefits of the large inhouse datasets, other specialist knowledge and intellectual property (IP). [249]

He was unable to go into specifics due to commercial sensitivities, but he stressed that "there is still a long way to go" before AI models are used for safety-critical applications in engineering. Areas with a bit more margin for error – such as demand forecasting or quality assurance – are much better suited, he said.

'A giant robot creates an aeroplane', as imagined by DeepAI With a background in mechanical engineering, Parandeh started shifting towards AI while working at Atkins. He started his own meet-up group, with sponsorship from Microsoft, offering a beginner's guide to machine learning. He recently received funding from InnovateUK for Build Your AI, an online educational platform designed to make learning practical skills "as quick and easy as possible".

Covering everything from the back end to the front end, and all the necessary data layers in-between, the programme has two parts. One is focused on business, teaching non-developers the commercial side of AI to maximize its benefit and the contribution to new IP. The other side is focused on individuals and consumers, teaching practical application of AI at the user's own pace.

"A lot of people want to do their own mini-projects in the engineering side, and they have ideas that they want to implement but they don't know where to start," says Parandeh. He hopes that Build Your AI will tackle that with its structured learning, teaching the 'full stack 'of required knowledge to enable engineers to build usable applications. One of AI's biggest effects will inevitably be on the job market. Automation has been linked with job losses since before the First Industrial Revolution, but the rise of AI tools poses perhaps the biggest ever threat. Companies planning to adopt AI must think very carefully about the impact it will have on their human workforce.

"I think they're all very real concerns, and people would probably be right to be asking those questions. I would be – and I am," says King.

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[248] https://www.engineeringnz.org/news-insights/a-massive-paradigm-change/

[249] https://www.imeche.org/news/news-article/feature-how-ai-is-already-changing-engineering-and-the-role-of-the-engineer

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"I think about my own son. I think 'What job is he going to be doing in 20 years from now? 'At the moment, that's maybe a little bit unclear to me, because I'm not completely sure how this all plays out." This is not the first seismic shift in the world of work and communication, however. The last 50 years or so have seen plenty from desktop computers to the web, the rise of email and Google, then the iPhone, and the explosion of social media that followed.

"This might be the biggest one," says King, about AI. "But I think it's OK. I think what happens is we change and we adapt, and roles change, and what we do changes. And where jobs perhaps do change, new ones are created as well, and new opportunities and For engineers, that could mean a shift towards more editor-like roles in future. First, King suggests, the engineer will have a vision of what they want, and what the product should do. They tell the AI, look at the results when they are available, then tweak the prompts (a process already known as 'prompt engineering') until the output is perfect. Such a system with text-to-design applications are not far off, says Parandeh. "You ask it to produce you an engineering design of an engine, and then it gives you that engine design. It's not going to be perfect; it's going to have flaws. And then as an engineer who's chartered, you would then go in and spend the next five hours perfecting that design, instead of having to start from scratch."

Ageing populations in Europe and elsewhere will mean that engineering workforces will need that assistance, Parandeh adds. "The workforce is declining," he says. "In 50 years 'time there's going to be critical workforce shortage, and I think AI is the answer to it because it can actually increase productivity quite significantly, by automating optimizing and forecasting capabilities."

Unlike previous technological revolutions, King predicts the rise of AI could be much swifter and more transformative because developers can use AI tools to improve and develop new programs, creating a kind of feedback loop and driving exponential growth.

"This is an inflection point," he says. "Until now… it's been a sort of steady incline. It's about to go almost vertical, because this technology itself will speed up innovation, and it becomes like a virtuous circle then, you have this human intellect working with machine intellect, and together the ability to think faster and achieve things quicker exponentially – we may be about to enter a period of rapid change.

9-4 Capability and Training

Advancements in the Artificial Intelligence space are happening so fast in 2023 that it's hard to keep up, even for a technology company! In the fascinating landscape of technological evolution, the future of AI and AGI (Artificial General Intelligence) is one of the most exciting prospects.

In this Chapter, we'll explore AGI, ASI (Artificial Super Intelligence), ANI (Artificial Narrow Intelligence), the prospects of human augmentation, and how far away are we from a truly self-sufficient Artificial General Intelligence.

We'll delve into intriguing questions such as "What is true AI?" and "What does the future of AI hold", while exploring the progressive steps from GPT-4 to GPT-5 AGI, and challenging debates like AGI vs AI. Could we witness ChatGPT AGI in the near future? Is AGI possible right

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now? We'll also examine the concept of ASI or Artificial Super Intelligence, further fueling the quest for true AI. [250]

So, let's jump in and navigate the exciting realm of AI, its future potential, and the unprecedented changes that lie ahead.

AI is a broad term that can be used to describe a set of automated tasks that can be carried out by computer software. These tasks are created and designed by humans, and then completed by the software that has also been coded and designed by humans.

With popular tools such as ChatGPT, we are beginning to see the very start of systems that can adapt and 'learn 'in order to increase efficiency and accuracy. This is sometimes referred to as Machine Learning.

However, even though we use the word 'learn 'here, it should be thought of as a different type of learning than what a human is capable of. Learning within this context entails a set of software systems analyzing patterns in datasets, and performing changes based on the system's findings.

There are multiple terms that can be used to describe most of what we have in use today (such as weak AI or ANI). This is what voice assistants fall under in terms of AI categorization.

Essentially, Artificial Narrow Intelligence (ANI), or weak AI, refers to the majority of "AI" systems we use today.

This form of AI operates under a limited set of constraints, excelling in single tasks within a pre-defined, narrow area, such as voice recognition, recommendation systems, image recognition, or driving a car. ANI works according to specifically programmed algorithms or learned behaviour from data, but it does not possess consciousness, real understanding, or any kind of autonomous decision-making capability.

ANI systems are capable of "learning" to improve their performance over time, but only within the specific task they've been trained on. For example, a chess-playing AI can become increasingly proficient at the game but can't leverage that knowledge to play a different game like poker.

Despite its limitations, ANI is currently the most widely deployed type of AI, making significant impacts in various industries, including healthcare, finance, and automotive.

Examples include personal voice assistants like Siri or Alexa, spam filters in your email system, customer support chatbots, self-driving cars, and of course ChatGPT, which we will come on to shortly.

Artificial General Intelligence, also known as strong AI, is something that you will likely start to hear about more in the coming months and years.

AGI is the 'holy grail 'of artificial intelligence and is considered by most to be 'true AI', as this is more in line with what sci-fi movies and novels envision complex AI to become. In fact, it's a very popular misconception that the AI systems we have in use today are actually AGI.

However, unlike ANI, which is designed and excels at a specific task, AGI systems will be able to learn, think and adapt, and implement knowledge across a broad range of tasks at the same level as a human. They will be able to process incredible amounts of data instantly and display a kind of cognitive flexibility that is the hallmark of human

[250] https://www.opace.co.uk/blog/future-of-ai-agi-gpt-5-true-ai

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intelligence. There is no doubt that there will eventually be ethical questions raised in regards to AGI machines in the future, and what rights (if any) they should have.

For example, if AGI machines and systems are able to process information in the same way humans can, does that give these systems the ability to reason and feel emotion? It's an interesting question to think about in addition to considering the intellectual capability and raw processing potential of such systems. [251]

9-5 Collabouration

What is Artificial Super Intelligence?

If things weren't confusing enough with terms like ANI and AGI being used to describe AI, we thought we would throw another one out there – ASI (Artificial Super Intelligence).

ASI refers to a level of artificial intelligence that surpasses human intelligence in virtually all economically valuable work. This not only includes intellectual capabilities, but also the potential to exceed human ability in areas of emotional intelligence, decision-making, and creativity. [252]Essentially, ASI would outperform the best human brains in practically every field, including scientific creativity, general wisdom, and social skills.

In contrast with AGI, which is comparable to human intelligence and can carry out human-level tasks, ASI goes a step further. An ASI system wouldn't just replicate human decision-making; it would be capable of making decisions that humans haven't even considered.

Right now, ASI is purely hypothetical and highly speculative. However with the rate of innovation and change taking place currently within the field of AI, we can easily see a future where ASI is possible possibly even not more than 10 years away.

9-6 Summary for this Chapter

AI remains a complex subject, with terms like ANI, AGI, ASI, GPT-4, and GPT-5 often causing confusion. Adding to the intrigue, the question of "what is AGI?" becomes even more pertinent. Regardless of how complex this subject is, the future of AI is certainly very exciting and we can expect change to happen at an unparalleled level over the coming years. Whilst it feels like we have true AI right now with claims being made that ChatGPT, GPT-4 and tools like AutoGPT and BabyAGI are AGI, this sadly isn't the case. True AI can only be defined as a system that possesses human-like intelligence and can operate autonomously and across a broad range of tasks, at the same level as a human (AGI) or better than a human (ASI). [253]

From our perspective, it seems very likely that GPT-5 will be capable of AGI. Initially predicted that it probably already is behind the scenes, but when or even whether an AGI version gets released is up for debate. In light of recent speculations, notably from the enigmatic figure Jimmy Apples, the debate around the future of AI and the existence of AGI has intensified. Given these developments, it seems increasingly plausible

[251] https://www.opace.co.uk/blog/future-of-ai-agi-gpt-5-true-ai

[252] https://www.linkedin.com/pulse/artificial-super-intelligence-next-frontier-ai-evolution-adav-qarlf/

[253] https://www.opace.co.uk/blog/future-of-ai-agi-gpt-5-true-ai

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that GPT-5 may already include AGI capabilities internally, although its public release remains uncertain.

The topic of true AI and whether we'll see AGI unveiled in the coming year(s) (or 2025 as predicted by Jimmy Apples) is a question that policymakers, industry leaders, and governments will likely decide. If it's not here already, it will be very soon.

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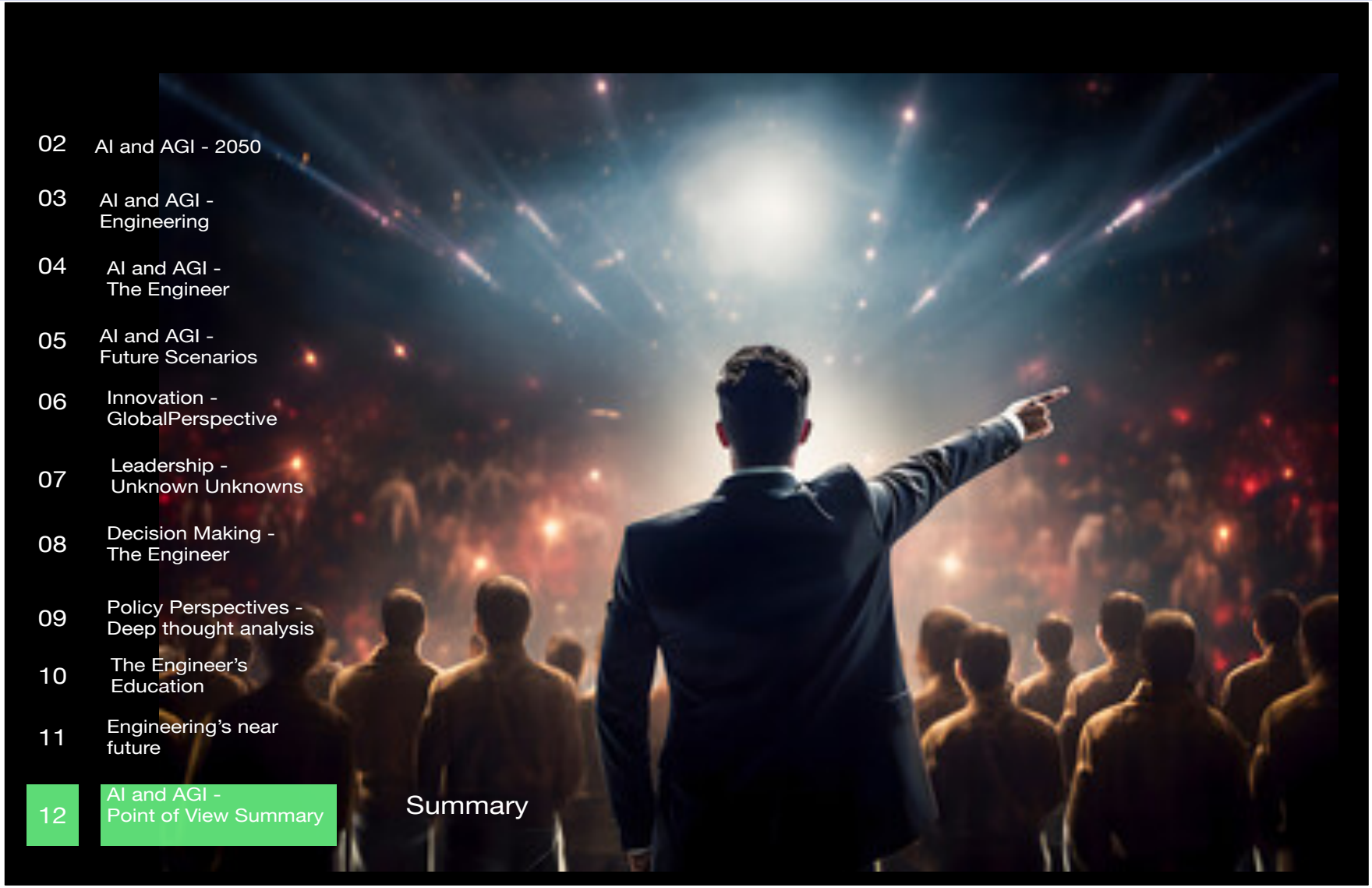

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THE ENGINEER'S EDUCATION

10-1 Introduction

When it comes to accepting the professional Engineer is the implementor of AI, does the institution to which she belongs have a role or even a duty to "Deep Mind" the subject given that universities are unlikely to for a generation and thus prepare the mid-level professional to the new world of artificial intelligence and all that it entails. Does this mean the Institution must establish its own data lake or negotiate arrangements with other like institutions to put a mega date lake in place for all to use. Does this approach therefore mean that the Institution becomes a hand holding service to the member engineer rather than an educational arm.

10.2 The Intersection of Generative AI and Engineering

Generative AI refers to AI models that generate new data based on existing data. Data engineering, on the other hand, refers to the process of collecting, transforming, and storing large amounts of data. When these two fields come together, they can create powerful tools that can help businesses make better decisions, automate processes, and improve customer experiences. [254]

One practical use of generative AI and data engineering is in the field of natural language processing (NLP). NLP is the ability of a computer to understand and analyze human language. With generative AI, NLP can be taken to the next level. For example, a business can use generative AI to create a chatbot that can answer customer questions in a more

human-like way. This can improve the customer experience and reduce the workload of customer support teams.

Another practical use of generative AI and data engineering is in the field of predictive analytics. Predictive analytics uses data, statistical algorithms, and machine learning techniques to identify the likelihood of future outcomes based on historical data. With generative AI, predictive analytics can become even more accurate. For example, a business can use generative AI to create a predictive model that can forecast future sales based on historical sales data. This can help

[254] https://www.linkedin.com/pulse/rise-generative-ai-its-impact-enterprise-business-data-obembe/

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businesses make better decisions about inventory management, marketing, and sales strategies. [255]

The impact of generative AI and data engineering on enterprise business can be significant. Businesses that adopt these technologies can benefit from improved efficiency, better decision-making, and enhanced customer experiences.

10-3 AGI and ML algorithms

How can Generative AI help Data Engineers?

There are several practical ways in which generative AI can help data engineers to preprocess data by automatically identifying and correcting errors:

For example, generative AI can use normalisation techniques, such as min-max scaling or z-score normalisation, to standardise the data and make it easier to compare between different features.

1. Dimensionality reduction: Dimensionality reduction is the process of reducing the number of features in a dataset. This can be useful for machine learning models because it can reduce the complexity of the model and improve its performance. Generative AI can help data engineers to perform dimensionality reduction by generating new data points that are representative of the original data. For example, generative AI can use principal component analysis (PCA) to identify the most important features in the dataset and reduce the dimensionality of the data. [256]

2. Missing value imputation: Missing values are a common problem in datasets, and they can be difficult to handle. Generative AI can help data engineers to impute missing values by generating new data points that are 2. Outlier detection: Outliers are data points that are significantly different from other data points in the dataset. They can be problematic for machine learning models because they can skew the results. Generative AI can help data engineers to detect outliers by generating new data points that are consistent with existing data. For example, generative AI can use clustering algorithms, such as k-means, to identify outliers.

3. Inconsistent data: Inconsistent data occurs when data points are recorded in different formats or units, making it difficult to compare them. Generative AI can help data engineers to identify and correct inconsistent data by generating new data points that are consistent with

Any Ho-Ho in this Wild West?

1. Bias: Another potential risk is the introduction of bias into the generative AI models. If the training data is biased, the generated content will also be biased. This could lead to unintended consequences, such as perpetuating harmful stereotypes or discriminating against certain groups.

2. Intellectual Property: There may be legal issues around the ownership and use of the content generated by generative AI. This includes

[255] https://www.solentive.com/solutions/inrule-business-automation-and-decisioning?gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTg_NjTdfjvZfAq29dFM92-moAO6SPJIN3zJts29SoktwXhIRrDjmdgaAnoHEALw_wcB

[256] https://www.analyticsvidhya.com/blog/2018/08/dimensionality-reduction-techniques-python/

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questions around who owns the intellectual property rights to the generated content, and how it can be used. [257]

3. Complexity: Generative AI models can be complex and difficult to interpret. This can make it challenging for data engineers to identify errors

4. Ethics: There are also ethical considerations to take into account when using generative AI. For example, there may be concerns around the use of generative AI for deep-fakes or other malicious purposes, or the impact of generative AI on the job market.

Machine Learning is a significant subset of Artificial Intelligence (AI) that enables machines to learn automatically without being explicitly programmed. The importance of Machine Learning cannot be overstated in the world of advanced data analysis. In today's world, Machine Learning is applied in various fields such as healthcare, finance, e-commerce, and many more. Machine Learning has revolutionised the way we use data by enabling us to make predictions, recognise patterns, and make decisions based on data. [258]

9-4 Engineer as Institutional Member

In-depth information about Introduction to Machine Learning:

1. Definition: Machine Learning is a subset of AI that enables machines to learn automatically without being explicitly programmed. It involves the use of algorithms that enable machines to learn from data and improve their accuracy over time.

2. Types of Machine Learning: There are three main types of Machine Learning: Supervised Learning, Unsupervised Learning, and Reinforcement Learning. Supervised Learning involves the use of labeled data to train a machine learning model. Unsupervised Learning involves the use of unlabelled data to train a machine learning model. Reinforcement Learning involves the use of rewards and punishments to train a machine learning model.

3. Applications of machine learning: Machine Learning has various applications in various fields such as healthcare, finance, e-commerce, and many more. For example, in healthcare, Machine Learning is used to predict diseases such as cancer and diabetes. In finance, Machine Learning is used to detect fraud and predict the stock market.

4. Machine Learning Process: The Machine Learning process involves the following steps: Data Collection, Data Preparation, Model Training, Model Evaluation, and Model Deployment. Data Collection involves gathering data that will be used to train the machine learning model. Data Preparation involves cleaning and transforming the data so that it can be used to train the machine learning model. Model Training involves using algorithms to train the machine learning model. Model Evaluation involves testing the machine learning model to determine its

[257] https://www.linkedin.com/pulse/addressing-bias-potential-risks-while-using-ai-jon-nordmark-hltbc/

[258] https://mitsloan.mit.edu/ideas-made-to-matter/machine-learning-explained

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accuracy. Model Deployment involves deploying the machine learning model in a production environment. [259]

5. Machine Learning Tools: There are various Machine Learning tools that can be used to develop machine learning models such as Python, R, TensorFlow, and many more. These tools provide libraries and frameworks that enable developers to develop machine learning models quickly and efficiently.

9-5 The Institution and the lake

Machine learning has been rapidly advancing in recent years, and with it, the development of artificial general intelligence (AGI) has been gaining momentum. The potential of AGI to revolutionise the way we interact with machines, and the world around us, is immense. The ability of AGI to learn from experience, reason, and make decisions based on that learning is a significant step towards creating machines that can think and reason like humans. There are many different perspectives on the development of AGI, with some seeing it as a significant threat to human existence while others see it as a way to create a better world. [260]

Here are some key insights on the advancement of AGI:

1. AGI has the potential to transform the way we interact with machines, making them more intuitive and natural to use. For example, an AGI-powered virtual assistant could learn and adapt to the user's habits and preferences, making it easier for them to accomplish tasks and manage their daily routine.

2. The development of AGI has led to concerns about the impact it could have on jobs, with some fearing that it could lead to widespread unemployment. However, others argue that AGI could create new jobs as it opens up new possibilities for innovation and creativity.

3. One of the biggest challenges in developing AGI is ensuring that it is safe and ethical. The ability of AGI to learn and adapt means that it could potentially develop behaviours that are harmful to humans. Ensuring that AGI is designed with safety and ethics in mind is crucial to its development and adoption.

4. The development of AGI also raises important questions about the nature of consciousness and intelligence. Some argue that AGI could lead to a better understanding of human intelligence and consciousness,

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259 https://au.mathworks.com/campaigns/offers/machine-learning-with-matlab.html?gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTgmkF9svB99eRlcfxuKx3xq1UOsIgSURyThKnXN6KUL8mUTVKX2yyAaAgaoEALw_wcB&ef_id=Cj0KCQiAwvKtBhDrARIsAJj-kTgmkF9svB99eRlcfxuKx3xq1UOsIgSURyThKnXN6KUL8mUTVKX2yyAaAgaoEALw_wcB:G:s&s_kwcid=AL!8664!3!623607773656!p!!g!!machine%20learning%20models&s_eid=psn_40621482952&q=machine+learning+models&gad_source=1

260 https://fastercapital.com/content/Machine-Learning--Harnessing-AGI-for-Advanced-Data-Analysis.html?__cf_chl_tk=1RSwSJNVFTuNC3XSrcEYkzcGDehEol6SyDBMBhDE1QU-1706920172-0-gaNycGzNEVA

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while others see it as a threat to the uniqueness of human consciousness.

The development of AGI is a complex and multifaceted topic that requires careful consideration of its potential benefits and risks. As we continue to advance in the field of machine learning, it is important to keep in mind that the development of AGI should be guided by a commitment to safety, ethics, and responsible innovation.

10-6 Summary for this section

The intersection of generative AI and data engineering has the potential to revolutionise the way we do business in the enterprise space. With practical uses in natural language processing and predictive analytics, businesses can benefit from improved efficiency, better decision-making, and enhanced customer experiences. However, there are also potential risks and challenges that need to be addressed. Businesses that adopt these technologies should carefully consider these risks and challenges and take steps to mitigate them.

Generative AI and machine learning are more than just technological advancements -- they are driving changes in tooling, processes, and methodologies that are revolutionising the engineering landscape. The unique ability of these technologies to optimise and accelerate processes across various engineering disciplines makes them indispensable for modern engineering disciplines. As such, the message for businesses and engineering leaders is clear: embrace generative AI to stay competitive and future-ready. [261]

[261] https://www.zdnet.com/article/generative-ai-and-machine-learning-are-engineering-the-future-in-these-9-disciplines/

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THE ENGINEER"S FUTURE SLIDE RULE

10-7 Introduction

Artificial intelligence is a field in data science that blends computer technology with hefty amounts of data to enable problem-solving. You may have experienced AI in a voice search with Amazon's Alexa or Apple's Siri. Search engines also power results with AI to collect and retrieve relevant information based on user inquiries. Videos suggested to you by YouTube or Netflix are AI-driven results that recommend titles based on learning your preferences and viewing habits.

You may hear machine learning mentioned in the same breath as artificial intelligence, but the terms are not entirely interchangeable. Machine learning is a subset of artificial intelligence that learns from experience, adapts, and improves performance without being explicitly programmed.

A third part of artificial intelligence getting a lot of exposure today is deep learning. All AI aims to mimic human thinking, and deep learning is designed to extract maximum value from our way of processing information. [262]

10-8 The AI "Slide Rule"

Our brains use what scientists call neural networks, which are the collection of brain cells that help us process information by connecting signals. Deep learning uses artificial neural networks to process large amounts of data and solve problems with limited human help. These artificial intelligence networks are valued for their ability to handle lots of data, continue to improve as it trains and learns, and solve complex issues. to this end I like to visualise AI or AGI as a assistive tool for engineers much like a Slide Rule was when it arrived on the engineering scene around 1620-1630 shortly after John Napier's publication of the concept of the logarithm. In 1620 Edmund Gunter of Oxford developed a calculating device with a single logarithmic scale; with additional measuring tools it could be used to multiply and divide. It was superseded by the Scientific calculator in around 1972 and was Hewlett-Packard's first pocket calculator and the world's first handheld scientific calculator. (Note the CTA still uses a slide rule and a HP Reverse Polish Notation HP calculator.)

<u>Artificial Intelligence in Preconstruction (On site use of the AGI Slide Rule.)</u>

Before building starts on a commercial construction project, a variety of people and teams from different disciplines and expertise must collaborate and plan how the project will proceed. Preconstruction, as it's called, refers to the phases of construction that take place before the actual construction work begins. Building owners, architects and engineers, trade contractors, general contractors, building product manufacturers, and many others take part in preconstruction.

The preconstruction process in commercial construction helps to ensure that the project is completed on time, within budget, and to the client's satisfaction by identifying and addressing the sequence of people and events that will get the project completed. Just like the projects

[262] https://www.constructconnect.com/blog/ai-in-construction-has-landed

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being built, solid foundational work in preconstruction carries over greatly into the strength of the project. Variations in preconstruction stages occur depending on variables such as the type of structure or project (e.g., hotel, school, road, or bridge), project delivery methods, the scope of work involved, or if it is a public or private construction project.

AI In Preconstruction Project Stages

The following preconstruction project stages provide a framework for the steps before construction starts and how artificial intelligence is changing how this planning is performed.

Pre-Design: This phase includes the conceptual design, initial project planning, project development, and feasibility studies. The project team typically begins with the concept of the structure, performs a site analysis to identify potential obstacles, and develops a plan to address them. This phase also includes the development of a rough or working project scope and budget.

AI in the pre-design or initial project planning and development phase is helpful for feasibility studies to determine if a project is viable. Risks can be identified and analysed with various data, including financial data, market data, and data on the project's potential impact on the environment. Risk analysis can assist in deciding whether to proceed with the project. AI is a powerful tool at this stage because it offers thoroughness and accuracy, along with a general lack of bias. [263]

Design Development: This phase includes the development of detailed design documents that steer the project. Documents included in this stage include architectural, structural, mechanical, electrical, and plumbing plans.

Design development is a critical phase in the project development process. It involves taking the conceptual design and turning it into a more detailed and buildable design, moving from general ideas to more specific ones. The design development phase is where many important decisions are made that will shape the final project, including cost, energy efficiency, and overall functionality. Artificial Intelligence can play a significant role in this phase by providing new tools and techniques to improve the efficiency and quality of the design development process.

Construction Documents: This phase includes the development of final construction documents, including detailed construction plans, building product specifications, and contract documents. The finalisation of the construction schedule is prepared, which outlines the sequence and expected duration of all activities required to complete the project.

AI-based tools can be used to automate the process of extracting, analysing, and processing data from construction documents. For example, natural language processing (NLP) can be used to analyse project requirements and create a detailed project scope document based on two-dimensional construction plans like PDF files. NLP has been around for over a half-century and is the component of AI that understands and interprets human language, written and spoken. This can save time and resources compared to the tedium of traditional methods, such as manual data entry or spreadsheet calculations.

[263] https://www.constructconnect.com/blog/ai-in-construction-has-landed

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Bidding and Negotiation: This phase includes distributing the plans to trades, contractors, and manufacturers for bidding. The project team will review the bids, negotiate with contractors, and select winning bids. For general contractors and trade contractors, this is the essential phase that includes producing and delivering detailed takeoffs and estimates to submit a competitive bid.

Trade contractors, general contractors, and building supply manufacturers assess the project scope, identify opportunities to pursue, analyse bidding strategies, and decide which projects clear the hurdle for success. Trade contractors can use the power of AI to streamline processes, automate repetitive tasks like takeoffs, and improve the speed at which decisions like vetting profitable projects are made.

Permitting and Approvals: This phase includes the submission of the construction documents to the appropriate governmental agencies, where appropriate, for review and approval. Artificial intelligence is used in this phase to validate building code compliance and manage the building permit process. [264]

Finalise Preconstruction: This phase includes finalising contracts, mobilisation of the contractors, and the start of construction activities. Effective preconstruction planning and strategic decision-making are key components of profitability for trades, general contractors, and building product manufacturers.

The finalisation of the construction schedule is prepared, which outlines the sequence and expected duration of all activities required to complete the project.

The preconstruction stages can become more complex due to the nature of the project, the inherent need for effective communication and collaboration among teams, and local and national regulations, among others. Time and budget issues are consistently make-or-break drivers of a profitable construction project. Technology like AI offers an opportunity to improve performance throughout the preconstruction lifecycle.

Where Else AI and Construction Are Teaming Up

Aside from preconstruction, AI is a technology continuing to emerge in other areas of construction, enabling improvements in performance and safety. Some examples include:

Predictive maintenance: AI can be used to analyze data from building systems, such as HVAC and electrical systems, to predict when maintenance will be needed and prevent equipment failure

Site safety: AI-powered cameras and sensors (even some worn by workers) can monitor construction sites for potential safety hazards and alert workers and managers to potential dangers.

Robotics: The efficiency of AI and machine learning have found their way into robotic bricklaying, welding, and even building entire structures with 3D printing.

Project management: AI can optimise the allocation of labor and materials, making the scheduling of construction tasks more efficient and cost-effective.

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[264] https://www.constructconnect.com/blog/ai-in-construction-has-landed

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Quality control: AI-powered cameras and sensors can monitor the quality of construction work, identify defects, and alert workers and managers to issues that need to be addressed.

Building performance: AI could be used to analyse data from building systems to optimise energy efficiency, indoor air quality, and other performance metrics. Simulating building efficiency with AI, for instance, allows the identification of potential energy-depriving areas for better design and construction.

The Knowledge and Insight Enhancer

It is common to hear that computers trained to think like humans are a threat to stealing jobs from people. But construction is inherently reliant on the vast institutional and individual knowledge, something that AI cannot replace. Where human judgment is involved, and we know that's everywhere throughout the construction project lifecycle, AI does not have the capability we humans do.

It's more likely that certain roles and responsibilities will change as AI is implemented. AI combined with a company's organisational knowledge will offer much greater strategic opportunities than those not adopting the technologies to streamline performance and make better data-driven decisions.

Bright Future for AI in Construction

The present and future of AI in the construction industry are promising as more AI-based tools and techniques become integrated into workflows. As technology advances, AI is expected to become an even more integral part of the construction process, helping to improve efficiency, reduce costs, and enhance construction performance outcomes. AI in the construction industry has landed. Get ready for it.

How Generative AI Can Improve Discrete Manufacturing Profitability

As generative AI continues to rise in popularity, we are seeing an exciting shift in the overall artificial intelligence paradigm. For the first time in history, powerful AI tools are now directly available to a much wider audience than ever before.

We have already seen a variety of AI applications introduced into a broad range of industries. Some of these solutions have been straightforward, while others are pretty sophisticated. However, as we turn our attention to the industrial space, the question arises: Can generative AI also help solve problems faced by manufacturing companies?

Research shows that 88% of manufacturers are still facing long lead times from suppliers, most of which are rooted in the challenges brought on by the Covid-19 pandemic. Because of this prolonged struggle, 71% of companies around the world cite raw material costs as their top supply chain issue for 2023.

When this is added to the fact that material costs account for an average of 42% of the entire manufacturing industry cost structure, it is clear that the sector as a whole desperately needs a way to increase efficiency and tool handling to boost outputs and reduce lead times.

In light of this, I believe it is time to turn to generative AI for potential solutions.

Levelling The Playing Field For Small And Medium Manufacturers

The first way that generative AI is improving discrete manufacturing profitability is through the democratisation of artificial intelligence and data science tools. Some of the most recent developments, such as

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OpenAI's ChatGPT code interpreter plug-in, offer smaller industrial companies access to valuable data insights. [265]

Before, this type of data analysis and value extraction would require a team of expert data scientists and months or years of fleshing out an entire, complex data infrastructure before anything useful could be done. This is not only an unfeasible upfront cost but a massive bet on the strategy's long-term usefulness and profitability. For smaller enterprises without the financial cushion to support this, most manufacturers choose to stick with older, tested business models because it is all they can afford.

With the advent of widely available generative AI tools, affordability is suddenly a much less pressing issue. Now, advanced data collection, collation and analysis can be completed by a single, relatively inexpensive tool and reviewed by a single expert or small team of experts. This drastically lowers the barriers to entry and allows for a more innovative, competitive and agile manufacturing market.

The important takeaway is that to benefit from this AI-powered profitability strategy, small and medium manufacturers must take the initial leap of faith by implementing the right technologies to at least begin collecting data from their factory floors. Without this data set, even the best AI tools will be useless. [266]

Three Simple Ways AI Profitability Can Boost Manufacturing

Improving And Streamlining Existing Processes

According to current research, less than a quarter of companies have taken significant strides toward digitalising their manufacturing processes. The few that have incorporated data collection or analytics are generally not leveraging this technology to their advantage. [267]

This leaves the door wide open for manufacturers to implement AI tools on the factory floor that can provide invaluable data and insights regarding ways to trim down the high costs of traditional production and labor methods. Generative AI can collect and analyse machining data or existing instructions for parts production and propose changes that boost efficiency, reduce waste and substantially lower rejection rates, all of which are common manufacturing bottlenecks.

Monitoring Machining Tool Quality

The average manufacturer's bottom line includes 800 hours of downtime, causing millions in lost revenues, higher labor costs, missed deadlines and damaged business relationships. Even planned downtime

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265 https://neo4j.com/generativeai/?utm_source=google&utm_medium=PaidSearch&utm_campaign=GDB&utm_content=APAC-X-SEM-Category-Expansion-Evergreen-Search&utm_term=ai%20and%20data%20science&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTi9wGV0npCpMPRRuSSx62BB1hh-X_cSJ_zheE7Jc1ZFzmLkq1KBKjwaAjMlEALw_wcB

266 https://www.forbes.com/sites/forbestechcouncil/2023/11/22/how-generative-ai-can-improve-discrete-manufacturing-profitability/?sh=66aa2c9561f3

267 https://www.forbes.com/sites/forbestechcouncil/2023/11/22/how-generative-ai-can-improve-discrete-manufacturing-profitability/?sh=1bdadbb361f3

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affects overall outputs, so streamlining planned stops and minimising unplanned incidents is AI's goal. [268]

Generative AI's greatest strength is interpreting data and finding improvements faster than humans. In manufacturing, this means lowering spending on emergency tool repairs and improving a machine's life span through predictive maintenance. With these advantages, unexpected failures are drastically reduced, throughput quality stays consistent and companies can more accurately budget for replacements and maintenance.

Optimising Forecasts With Advanced Data Analysis

The ongoing raw materials shortage and general supply chain issues mean manufacturers must use every available tool to reduce delays and interruptions. Implementing generative AI can help industrial businesses optimise raw materials spending and boost supply chain efficiency through advanced data analysis. [269]

Beyond this, AI can potentially provide more detailed supply and demand forecasting by parsing external market data and past and present forecasts, helping manufacturers optimise inventory levels and smooth their supply chains.

Potential Challenges Of GenAI In The Manufacturing Sector

While generative AI has enormous potential to change the manufacturing landscape, it's important to acknowledge its limitations.

First, there are still plenty of unknowns because the technology is new. We know it works well with text and information, but there isn't as much real-world evidence yet to support it working as seamlessly with industrial equipment data. There will inevitably be challenges as this process is implemented and refined over time. [270]

In addition, there is still a serious lack of user trust within the sector. Factories are already operating with razor-thin margins for errors and problems, so they are wary of adding anything new that might cause problems during the initial implementation. Seasoned professionals will require some convincing to make such a big technological leap because they are used to the way things currently are, even though these processes are quite outdated. [271]

Harnessing The Power Of Generative AI With Data Collection Integrations

Before any manufacturer can take advantage of these robust AI use cases, the first step is upgrading the factory floor with the ability to collect machine data. Without this foundation, generative AI will pass your company by, and competitors will have the advantage.

By taking a small leap of faith into the digital future, the industrial manufacturing sphere can overcome the challenges of supply chain

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268 https://www.forbes.com/sites/forbestechcouncil/2023/11/22/how-generative-ai-can-improve-discrete-manufacturing-profitability/?sh=380bb97361f3

269 https://www.ey.com/en_nz/supply-chain/how-generative-ai-in-supply-chain-can-drive-value

270 https://news.ycombinator.com/item?id=35813322

271 https://www.forbes.com/sites/forbestechcouncil/2023/11/22/how-generative-ai-can-improve-discrete-manufacturing-profitability/?sh=ffe40f961f30

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disruptions, downtime and the inefficiencies of outdated production processes with the help of generative AI. [272]

10-9 How will the engineer use the rule

The professional engineer can be seen as an implementer of AGI in order to increase his or her expertise and knowledge of an engineering situation or technique. AI is used in several allied civil engineering fields, involving applications related to modelling complex tasks as well as determining the design parameters. Technologies including pattern recognition, machine learning and deep learning are used in structural engineering . In construction management, AI is being used to monitor the health of building structures by utilising the data collected from the sensors embedded within buildings. Solid waste management is a process influenced by many nonlinear parameters. AI-based tools could be used for predicting waste generation, operational management of waste collection systems, as well as for monitoring waste containers and disposal sites.

AI is used in project management to assess the risk, task duration and to identify unforeseen labour shortages. Oceanographic data are dynamic in nature, large in quantity and are often non-linear. In this case, AI can improve the analysis and simulation in ocean engineering for forecast and review applications. [273] AI techniques can be used in control engineering to improve control strategies and to have plant-wide control.

The use of AI for plant-wide control is becoming a trend in the number of patents and publications related to AI from 1981 to 2017. AI is also used for optimisation in many domains of electrical engineering. Engineering problems related to power systems, which are otherwise not solvable by conventional techniques, are being solved using AI techniques. Another AI application in electrical engineering is for fault diagnosis and condition monitoring of electrical equipment and machines.

AI is also used for image processing and computer vision applications with a broad range of applications. As such, AI tools are widely applied in many domains related to electrical and electronic engineering.

AI in Manufacturing Workflow.

With the manufacturing sector undergoing a significant shift towards Industry 4.0, manufacturers needed to become competitive in the global market by reducing the product-to-market timelines. Manufacturing reinforced with AI based tools has the potential to learn from simulated examples and be more resistant to failure. [274] Several AI-based manufacturing methods and technologies have been deployed to create adjusted manufacturing algorithms. This is achieved by sifting through structured or unstructured data that is generated throughout a product lifecycle to make manufacturing more intelligent.

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[272] https://www.forbes.com/sites/forbestechcouncil/2023/11/22/how-generative-ai-can-improve-discrete-manufacturing-profitability/?sh=461efccc61f3

[273] https://www.linkedin.com/pulse/role-ai-project-management-chris-chiancone/

[274] https://pdf.sciencedirectassets.com/282173/1-s2.0-S2212827121X0011X/1-s2.0-S2212827121011896/main.pdf

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AI is also being used to improve the security across process workflow by defending against cyber-attacks on engineering and manufacturing organisations. AI has made it possible to build analytical models and provide feedback by utilizing big volumes of data generated during sensor-driven manufacturing workflows. [275] Additive Manufacturing (AM), due to its intrinsic digital nature, is capable of realising a fully digital design production workflow. AI technologies may be integrated into AM, for optimizing resource utilization, facilitating real-time process control, supporting tool path planning algorithms, ensuring protection against side-channel attacks, optimising process parameters for build control and many more. [276] The process of data mining is another potential area for the application of AI-based tools in AM, as it can be a very labour-intensive task without the use of AI algorithms. Moreover, with AI and ML algorithms, it is possible to sift through this data efficiently with fewer errors.

10-10 Education within the Institutions

AGI has the potential to revolutionise education by providing personalised instruction, adaptive learning pathways, and instant feedback, contributing to more effective learning outcomes. [277] AGI can also enhance teachers 'pedagogical content knowledge, allowing for differentiated instruction and support for diverse student needs. By utilising potential AGI-like chatbots, teachers can access a wealth of information and activities catering to various learning styles, leading to more targeted lesson plans and teaching strategies.

Additionally, AGI algorithms can support Human-Computer Interaction (HCI), transforming education by enhancing the design and usability of digital tools, improving the accessibility of learning resources, and creating engaging and interactive learning experiences for students. However, implementing AGI in education also brings new challenges, such as resolving ethical issues, minimising algorithmic biases, and ensuring responsible use in educational contexts. Therefore, educators, researchers, and learners must collaborate as AGI develops to maximise its potential for improving education while addressing the accompanying risks and uncertainties.

10-11 Societies' trust in the Slide Rule

There are two modes of engineering to consider here with respect to Trust. The first are engineers who write the AI and AGI algorithms and this professional engineers who implement them. The only way to engage the trust of society in AI from and engineering point of view is to engage in authenticity as a leader.

"Unknown unknowns" is a concept coined by former U.S. Secretary of Defence Donald Rumsfeld to describe things that we don't know we don't know. In other words, these are the information, knowledge, or factors that are outside our awareness and understanding, making them difficult to anticipate or plan for. This situation clearly defines the advent of AGI in professional engineering.

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[275] https://www.sciencedirect.com/science/article/pii/S1566253523001136

[276] https://www.thermofisher.com/nz/en/home/materials-science.html?cid=msd_xbu_xbu_xmkt_sem_123456_gl_pso_gaw_143pyv&utm_source=paid_search&utm_medium=digital-paid&utm_campaign=cmp-05585-w7h0&gad_source=1&gclid=Cj0KCQiAwvKtBhDrARIsAJj-kTiXqLGNsCNA_YNnwsbRSfACxGDWMfIsEMzRfuUR4NmqmZQU1sXyK2saAppoEALw_wcB

[277] https://www.mdpi.com/2071-1050/15/16/12451

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The concept of unknown unknowns highlights the inherent limitations of human knowledge and perception. It reminds us that there are always gaps in our understanding and that unexpected events or circumstances can arise. While we can strive to gather information, conduct research, and make informed decisions, there will always be unknowns that we cannot account for.

Unknown unknowns can manifest in various areas of life, including engineering, business, science, personal relationships, and global events. In business, for example, an organisation may launch a new product or service with careful market research and analysis, only to encounter unforeseen challenges or unexpected customer preferences that were previously unknown.

Organisational leadership has long been associated with knowledge, expertise, and making informed decisions. Embracing the concept of unknown unknowns requires a fundamental shift in leadership mindset. It entails accepting that despite our best efforts to gather data and conduct thorough analysis, there will always be uncertainties that escape our awareness.[278] This reinforces that a very different leadership approach is required to be effective in today's rapidly changing environment. Engineering leaders are encouraged to approach situations with curiosity, openness, a willingness to learn and pivot, while leaving the need to be seen as an 'expert authority figure who has everything under control 'at the door.

The Power of Adaptability and Learning

To effectively lead in the face of unknown unknowns, adaptability becomes a critical leadership trait. Leaders must cultivate a growth mindset that embraces change, encourages experimentation, and fosters continuous learning. Instead of being paralysed by uncertainty, leaders must reframe it as an opportunity for growth, innovation, and the discovery of new possibilities.

What this looks like: Adaptive leaders remain agile and flexible in their decision-making processes. They understand that as new information emerges and circumstances evolve, adjustments and course corrections may be necessary. These leaders actively seek diverse perspectives, encourage dissenting opinions, and promote an environment where experimentation and calculated risk-taking are genuine values.[279]

Leading Authentically by Example

Engineering leadership in the face of unknown unknowns requires authenticity. Leaders must demonstrate vulnerability by openly acknowledging their own limitations and uncertainties. This authenticity creates a safe space for open dialogue and encourages others to embrace the unknown with courage and resilience.
What this looks like: Authentic leaders build trust and inspire their teams through transparent communication, empathy, and genuine connection. They lead by example, modelling the adaptability and

[278] https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

[279] https://www.designative.info/2023/11/04/managing-and-adapting-to-change-in-thought-leadership-essential-skills-designers-strategists/

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learning mindset they wish to cultivate within the organisation. They make it a priority to foster a culture of psychological safety by empowering employees to take calculated risks, learn from failures, and innovate.

Capabilities for Navigating Unchartered Territory

Here are some essential focus areas for leaders who have a desire to be effective and impactful in navigating unknown unknowns. Don't underestimate the power of self-reflection and introspection to gain a deeper understanding of your strengths, weaknesses, values, and blind spots. This well tested habit will equip you with the insights needed to adapt certain behaviours and make informed decisions in unpredictable situations. Importantly, don't be afraid to seek feedback from others on your ability to deal with ambiguity, if you genuinely want to grow.

Uncertainty demands adaptability, and you need time and space to explore new perspectives, challenge assumptions, and adopt a more agile approach. At a time when workplace burnout is on the rise, proactive rest serves as a strategic leadership tool for developing resilience, facing the unknown and embracing change. Unlike reactive rest, which is typically taken in response to feeling fatigued or overwhelmed, proactive rest focuses on recognising the importance of rest as an integral part of maintaining optimal performance, preparing us for responding to uncertainty. [280]

Enhance Strategic Decision-Making:

While strategy typically involves analysing known information and making informed decisions, it is equally important to address the presence of unknown factors. This requires time to consider various scenarios, anticipate potential risks, and evaluate the potential outcomes of different choices. This will enable you to be more adept at making informed decisions even in the absence of incomplete information.

Building Strong Relationships:

Leadership relies on strong relationships and collaboration. Prioritise enhancing your interpersonal skills, communication abilities, and emotional intelligence. This will make you much more effective at stakeholder engagement, conflict resolution, and fostering a culture of trust and psychological safety within your teams. Strong relationships will also help you to tap into the collective intelligence of your teams, fostering a collaborative environment that is better equipped to handle uncertainties.

Strategic Vision and Innovation:

You need to consider potential disruptions and market shifts. It's necessary to explore emerging trends and identify opportunities for innovation. It's also the leader's role to model creative thinking and foster a culture of experimentation to be able to respond to unknown

[280] https://www.linkedin.com/pulse/embracing-unknown-unknowns-leadership-uncertain-world-wyganowska/

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unknowns. Talking innovation is not equivalent to engaging in experimentation, avoid this trap.

Accountability and Goal Setting:

To achieve a genuine shift in your approach, putting in place a structure that holds you to account will keep you on track towards your desired development goals. Consider who and what practices will support your leadership goals.

10-12 Summary for this section

As future system designers and decision-makers in the AGI era, engineering students should be trained to anticipate and navigate the unknown. These days, engineers often operate in professional, social and societal environments characterised by volatility, uncertainty, complexity and ambiguity (VUCA). Therefore, besides traditional engineering skills, educational programs must also provide students with future skills that are needed to address VUCA situations. This requires the competence and vision to design and manage systems that are resilient to unexpected, unstable and drastic events. Key lessons include the need to integrate VUCA and resilience training in a progressive manner, from graduates level to that of professional engineers. Elements to extend an educational framework are suggested above with curriculum integration based on examples of authentic experiences.

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THE FINAL POINT OF VIEW SUMMARY

10-13 Introduction

In the decades ahead, waves of exponential technological advancements are stacking atop one another, eclipsing decades of breakthroughs in scale and impact. Emerging from these waves are a number of "Metatrends," likely to revolutionise entire industries (old and new), redefine tomorrow's generation of businesses and contemporary challenges. [281] Among these meta-trends are augmented human longevity, the surging smart economy, AI-human collaboration, urbanised cellular agriculture, and high-bandwidth brain-computer interfaces, massive food demands just to name a few. The intervening decades to 2050 will be turbulent, destabilised both by technology disruptions that upend the foundations of the global economy and by system shocks from pandemics, geopolitical conflict, natural disasters, financial crises, and social unrest that could lead to dramatic tipping points for humanity including mass migrations and even war.[282] In the face of each new crisis we will be tempted to look backward rather than forward, to mistake ideology and dogma for reason and wisdom, to turn on each other instead of trusting one another. If we hold strong, we can emerge together to create the wealthiest, healthiest, most extraordinary civilisation in history. If we do not, we will join the ranks of every other failed civilisation for future historians to puzzle over.

10-14 Summary of the Purpose of the Research

From the BlackRoom study performed in 2022, Engineering NZ Foresighted future is that by 2050 it is a global-focused international entity that has made a significant positive contribution to the realisation of the post anthropocene environment and a mature and sophisticated research and development facility that is fully engaged with the complex nature of the planet's business with respect to a sustainable, resilient, secure food system, balanced and equitable world, devoid of human division, poverty, famine, war and a stabilised climate.

We got there by establishing Engineering NZ as the 'go to' socio-technical membership organisation providing leadership and coordination of technical, ethical, and societal perspectives to enable members to provide solutions to the complex issues facing the planet. To do this we established a new discipline of Post Anthropocene engineering and a new type of engineer focused on achieving the post anthropocene environment in 2050, and thus we are now the world's leader in this new discipline.[283]

We got there by utilising the special character of New Zealand that was founded on the principles of Te Triti o Waitangi and Te Ao Maori thus the Institution has broadened its role and assumed the lead in developing more integrated socio-technological approaches to society's

281 https://www.diamandis.com/blog/metatrends-shaping-decade

282 https://tonyseba.com/wp-content/uploads/2020/09/RethinkXHumanityReport.pdf

283 https://d2rjvl4n5h2b61.cloudfront.net/media/documents/Foresighting_Report_Short_Version-FINAL.pdf

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problems. Te Ao Māori principles are integral in our cultural and intellectual approach as we embrace members from all genders, cultures and beliefs.

We got there because much of society's critical decision making was enabled by Engineering NZ's Socio-technical member resources/network using AI assisted complexity decision making AGI methodologies which it has developed itself over the previous decades while developing Post Anthropocene engineering discipline.

We got there because the backbone of Engineering NZ's facilitation of this work is through its local and global connectivity, its role as a trusted partner to governments, and its close relationship with communities.

Our members are now engaged with critical decision making in all sectors within multiple levels of society. We reflect society's diversity and are aligned with other like organisations around the world on the principles of post anthropocene. The institution has kept to its enduring visionary pillars established in the early 2020s, namely Collaboration, Credibility, Influence, Recognition and Thriving.

Decision making leadership for society

Decision making in the complexity field on 'unknown unknowns' will become the Institution's main future work. This will involve large scale AI assist algorithms initially and then the Institution will develop its own AGI to make these enormous decisions regarding autonomy and surveillance systems etc.

10-15 Scale of the Study

Cleary the scale of this study is planetary in dimension. This is why we have communicated with institutions worldwide and consulted journals and articles from hundreds of sources.

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10-16 Principal implications for Engineering

On a day-to-day basis, admin-related challenges are almost always more time consuming than predicted. It is these moments that hit productivity most. What can be perceived as a simple task – for example, responding to client emails – in reality takes up 25% of our day. For project-based business, this time waste has a huge impact on the business' bottom line. The integration of AI can ease these pressures through automation, allowing project managers to dedicate more time to the human aspect of their projects. While the human-touch is always going to be needed with clients, AI holds the potential to streamline and automate admin workload. Rather than spending hours collating a report for a client each week, AI has the capability to instantly collate all the required insights in moments whenever needed. For example, rather than spending hours bringing another member of the team up to speed on a project, AI can instantly pull together an introduction – including all the vital information.

Taking responsibility for admin-heavy tasks, AI enables project managers to focus on the areas of business where humans add the most value. For example, building relationships, exploring new business opportunities, and handling critical situations. Through these simple efficiencies, AI possesses the potential to elevate project performance metrics by forecasting project outcomes based on current trajectory and historical data. When integrating AI into Engineering firms, it's worth remembering this technology is still relatively new, which means it comes with some challenges. Successful adoption will come from companies embracing adaptability and resilience in the face of the unknown, or yet-to-be-tested. By strategically investing in state-of-the-art technology – through partner integrations or seamless integration within the business – organisations can demonstrate their commitment to enhancing efficiency and productivity.

Engineering firms are continually evolving their use of technology to gain a competitive edge. While digital maturity is on the rise in companies of all sizes, technology costs can be a significant barrier. Firms are encouraged to focus on upskilling staff and leveraging existing technology capabilities, as this strategic approach can not only drive operational excellence but also empower firms to navigate the challenges posed by the fast-paced technology landscape effectively. By investing in their workforce and maximizing the potential of their current technology solutions, companies can position themselves as industry leaders ready to embrace the future of technology. Rising technology costs are a significant concern for firms, underscoring the need for strategic evaluation of existing technology to align with overarching objectives. Prioritizing solutions that offer both immediate and long-term ROI is essential for cost-effective technology adoption. Internal champions play a pivotal role by facilitating seamless integration and inspiring colleagues, contributing to heightened employee engagement and retention rates.

10-17 Principal Implications for Engineers

To overcome the paramount challenges presented by technology, engineers must extend their focus beyond merely recognizing emerging trends. An essential component of success involves equipping their staff with the requisite knowledge and skills to harness these AI and AGI technologies effectively. Establishing a culture of comprehensive education throughout the professional engineering staff is pivotal for

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the deployment of these solutions. Furthermore, engineering firms can greatly enhance their technology adoption by fostering collaboration with external experts. These experts bring a wealth of experience and specialized knowledge, which can be instrumental in seamlessly and cost-effectively integrating technology solutions into the firm's existing workflows.

Engineers will need to prioritize strategic technology plans to navigate challenges related to rising costs and talent management. Notwithstanding this needed activity, professional engineers worldwide are advancing digitally, bringing more operations in-house and empowering staff as technology champions.

Research shows that professional engineers are increasingly confident about achieving digital maturity, with 32% now self-classifying as advanced or mature, up from 18% in 2021. Looking ahead, 82% envision advanced or mature stages in five years. However, realizing this vision requires a solid plan and actionable tactics to turn optimism into reality. Cultivating a culture of technology champions ensures that firms maximize their technology investments while enhancing overall workforce effectiveness.

Engineering disciplines and AI

Civil engineering is the backbone of our modern infrastructure, has always been about designing, building, and maintaining the physical and natural environment. In today's fast-paced world, the field is undergoing a transformative evolution, thanks to the infusion of artificial intelligence (AI). AI is changing how civil engineers plan, construct, and manage projects, offering unprecedented opportunities for innovation, efficiency, and sustainability. In this section, we will explore the critical role of artificial intelligence in modern civil engineering.

One of the most significant impacts of AI in civil engineering is its ability to enhance the design and simulation process.[284] AI algorithms can process vast amounts of data to optimize designs, taking into account factors like materials, cost, and environmental impact. This leads to more cost-effective and sustainable solutions. AI-driven simulations can also predict structural behaviour and analyse various "what-if" scenarios, ensuring safer and more reliable structures.

AI streamlines the construction process in numerous ways. Autonomous construction vehicles equipped with AI can perform tasks with precision, reduce labour costs, and improve safety. Drones with AI capabilities are used for site inspections, progress monitoring, and surveying, providing real-time data to project managers. This data is invaluable in decision-making, quality control, and detecting potential issues before they become critical.

Project Management, Scheduling and AI

AI is revolutionizing project management by optimizing schedules, resource allocation, and risk assessment. AI algorithms can adapt schedules in real time, accounting for unexpected delays or changes.

[284] https://emiratesscholar.medium.com/the-role-of-artificial-intelligence-in-modern-civil-engineering-80fdb5eaf7df#:~:text=One%20of%20the%20most%20significant,%2C%20cost%2C%20and%20environmental%20impact.

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These systems also analyse historical project data, helping teams identify potential bottlenecks and resource allocation issues before they occur.

Predictive Maintenance and AI

In the realm of infrastructure maintenance, AI shines by enabling predictive maintenance. Sensors embedded in critical structures continuously monitor their health, collecting data on structural integrity, wear and tear, and environmental conditions. AI algorithms can analyse this data and predict when maintenance is needed, preventing costly failures and extending the life of infrastructure.

Sustainability and Environmental Impact and AI

AI plays a pivotal role in creating more sustainable solutions. It aids in optimizing energy consumption in buildings, traffic management for reduced emissions, and even in water resource management. By analysing data, AI can help engineers make more informed decisions that minimize environmental impact while meeting the demands of a growing population.[285]

Safety and Risk mitigation and AI

AI contributes to safety in construction by assessing site conditions, identifying potential hazards, and alerting workers to safety concerns. Additionally, AI-driven analytics can evaluate the potential risks associated with different project aspects, helping engineers implement mitigation strategies.

Project Cost control

AI helps control costs through data-driven decision-making. It can predict cost overruns, analyse historical data to set more accurate project budgets and identify cost-saving opportunities. This ensures that projects are delivered within budget, avoiding financial surprises.

Artificial intelligence has become an indispensable tool in modern civil engineering. Its ability to process vast amounts of data, improve design, optimize construction processes, enhance project management, and contribute to sustainability is revolutionizing the field. In a world where efficiency, sustainability, and safety are paramount, AI offers civil engineers the tools they need to meet these challenges head-on. The future of civil engineering is an exciting one, driven by the powerful synergy of human expertise and artificial intelligence. Together, they are creating a world of safer, more efficient, and more sustainable infrastructure.

Electrical Engineering and AI (As at 2023)

In the rapidly evolving landscape of electrical systems technology, one innovation stands out — artificial intelligence (AI). Its influence extends across various domains, and one of the most exciting areas witnessing a profound transformation is electrical engineering. As we find ourselves

[285] https://go.daon.com/2024-emerging-tech-impact-radar-ai?utm_term=artificial%20intelligence&utm_campaign=FY24_Gartner14_ANZ_Emerging-tech-impact-radar

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in 2023, AI-powered electrical systems have not only become a reality but are also at the forefront of revolutionizing how we interact with electricity. This article aims to provide an in-depth exploration of these advancements, elucidating how AI is reshaping the field of electrical engineering.[286] Artificial Intelligence (AI) in electrical engineering can be likened to a highly skilled assistant, tirelessly working to optimize the way we manage and harness electricity. While it may sound like science fiction, it is very much a part of our present reality. In 2023, AI-powered electrical systems have made significant strides, ushering in a new era of efficiency, safety, and sustainability.

AI-Enhanced Design and Simulation

Imagine having an expert collaborator by your side as you design complex electrical systems. AI, with its ability to analyse vast datasets and identify design flaws, plays this role seamlessly. It optimizes the layout of electrical grids, ensuring they are not only reliable but also cost-effective._AI is like having a crystal ball for electrical equipment. It can predict when a component might fail and schedule maintenance before any issues arise. This proactive approach not only saves time and money but also enhances the overall reliability of electrical systems.

Smart Grids and Energy Optimization

Picture an intelligent traffic controller for electricity — that's what AI-powered smart grids essentially are. They constantly analyse real-time data to efficiently route power where it's needed most. This dynamic management minimizes waste and maintains a steady power supply, much like a traffic cop ensures smooth traffic flow.

Demand Forecasting

AI goes beyond just reacting to changes in electricity usage; it predicts them. It's akin to having a weather forecast for power demand. By analysing historical data and real-time consumption patterns, AI can forecast when we'll need more or less electricity. This valuable information empowers power companies to optimize production and pricing.

Integration with Renewable Sources

AI seamlessly integrates with clean energy sources such as solar and wind power. It predicts when these sources are most productive and adjusts

[286] https://engineersschool.medium.com/future-of-artificial-intelligence-in-electrical-engineering-how-ai-is-transforming-electrical-

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energy distribution accordingly. In 2023, AI-powered electrical systems are no longer confined to the realm of possibilities; they are a tangible reality that is reshaping the world of electricity. These systems optimize design, enhance safety, and improve energy efficiency.

Mechanical Engineering and AI (As at 2023)

Mechanical engineering has always been at the forefront of technological advancements, driving innovation across various industries. In recent months, the integration of Artificial Intelligence (AI) in mechanical engineering has become a game-changer, providing engineers with unprecedented opportunities to enhance efficiency, optimize designs and revolutionize traditional processes. [287]

The rapid evolution of technology means that tomorrow's mechanical engineers need to be well-versed in AI. Those who acquire AI skills alongside traditional engineering knowledge may be better equipped to navigate the evolving job market and contribute to innovative projects. AI proficiency is becoming a valuable asset and learning to harness its power can be an investment in a successful and fulfilling engineering career.

AI doesn't replace human creativity, it amplifies it. Instead of replacing mechanical engineers entirely, AI can be a powerful tool augmenting their expertise. By automating routine tasks and providing insights based on data analysis, AI frees engineers to focus on more creative aspects of their work. This fosters a culture of innovation, where engineers can explore unconventional ideas, push boundaries, and develop ground-breaking solutions to complex problems.

While AI is advancing rapidly and transforming various industries, the role of mechanical engineers remains vital and adaptive. Read on to discover how AI's integration can further benefit and empower mechanical engineers in their roles and advancements within the industry.

Using Design Optimization and Simulations in Mechanical Engineering

One of the key areas where AI shines in mechanical engineering is design optimization and simulation. Traditionally, engineers relied on manual iterations to refine designs, a process that could be time-consuming and costly. AI algorithms, however, can quickly analyse numerous design parameters, identify optimal configurations and simulate performance under various conditions. This can accelerate the design process and possibly lead to more robust and efficient solutions.

Maintenance is a critical aspect that can directly influence performance and longevity in the realm of machinery and equipment. AI-powered predictive maintenance systems use sensors and data analytics to predict when equipment will likely fail, allowing engineers to schedule maintenance proactively. This reduces downtime and extends the machinery's lifespan, resulting in significant cost savings.

[287] https://www.gcu.edu/blog/engineering-technology/unlocking-innovation-ai-mechanical-engineering

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The marriage of mechanical engineering and AI has given rise to a new era of automation and robotics. Intelligent robots equipped with AI algorithms can perform intricate tasks with precision and adapt to dynamic environments. In manufacturing, this translates to increased efficiency, reduced errors and improved safety as robots perform repetitive or hazardous tasks.

AI's Impact on Material Design – Machine Learning in Mechanical Engineering

Materials play a crucial role in mechanical engineering, and AI is transforming the way engineers approach material design and selection. Machine learning in mechanical engineering algorithms can analyze vast databases of material properties, helping engineers identify novel materials with specific characteristics. This not only expedites the material selection process but also opens the door to the development of advanced materials tailored for specific applications.

Why Mechanical Engineers Should Embrace AI

As we navigate the fourth industrial revolution, the integration of AI is no longer a choice but a necessity for mechanical engineers. Embracing AI technologies can offer several advantages, including increased efficiency, cost savings and the ability to tackle complex engineering challenges with innovative solutions.[288] The adaptability and scalability of AI can make it a powerful tool for addressing the evolving demands of the engineering landscape._While the benefits of AI in mechanical engineering are evident, it's crucial to address the challenges and ethical considerations that come with this integration. As AI becomes more prevalent, engineers must grapple with issues such as data privacy, algorithmic bias and the potential for job displacement. Addressing these challenges requires a holistic approach, involving technological solutions and ethical frameworks that prioritize fairness, transparency and accountability.

Looking ahead, the landscape of mechanical engineering intertwined with AI can present a canvas of endless possibilities. Emerging trends, such as explainable AI and AI-driven innovation, reshape how engineers approach problem-solving. The integration of AI is fostering interdisciplinary collaborations with mechanical engineers, working

[288] https://www.linkedin.com/pulse/upskilling-ai-era-what-mechanical-engineers-need-juxof/

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alongside data scientists and software developers to create holistic solutions that transcend traditional boundaries.

Beyond technological advancements, AI is playing a pivotal role in fostering sustainability in mechanical engineering practices. From optimizing energy consumption in manufacturing processes to developing eco-friendly materials, AI can contribute to a more sustainable and environmentally conscious approach. This global impact showcases the potential of AI to address pressing challenges and create a positive footprint in the world of mechanical engineering.[289]

Mechanical Engineers Can Harness AI for Technological Advancement

The integration of artificial intelligence in mechanical engineering is not just a technological advancement; it's a paradigm shift that is reshaping how engineers approach challenges and innovate. As the field continues to evolve, mechanical engineers who embrace AI may find themselves at the forefront of transformative developments, driving progress across industries. The synergy between mechanical engineering and AI is a testament to the endless possibilities that arise when human ingenuity meets the power of intelligent machines.[290]

[289] https://www.gcu.edu/blog/engineering-technology/unlocking-innovation-ai-mechanical-engineering

[290] https://www.sciencedirect.com/science/article/pii/S0926580522003132

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10-18 Final Report Summary

The adoption of emerging technologies presents several challenges, including concerns regarding their relevance, the absence of internal expertise, and potential knowledge gaps among employees. To effectively address these hurdles, engineers need to proactively invest in upskilling their existing staff. This investment not only equips employees with the necessary skills but also fosters a culture of continuous learning and adaptability, crucial in today's dynamic technological landscape. Additionally, leveraging tech-savvy champions within the organization can be transformative. These champions serve as enthusiastic advocates for technology initiatives, bridging the gap between vision and implementation.

To flourish in this technology-driven era, professional engineers must go beyond acknowledging emerging trends; they must empower their own staff with the skills and knowledge needed to harness these technologies effectively. Cultivating a culture of comprehensive education across operational staff is pivotal for the successful deployment of these solutions, and collaboration with external experts can significantly amplify technology adoption.

The rapid advancement of AI has introduced a learning curve for all businesses. Ensuring decision makers stay at the forefront of industry trends is essential to determining which technologies will and won't be useful to their organisation. For many organisations, the question comes down to what next and how to begin. The key is being on the journey and pinpointing the most significant benefits. This comprehensive approach fosters success, resilience, and competitiveness in a business landscape that is evolving at a rapid pace.

The Engineering industry stands at the brink of an extraordinary era driven by AI. Companies that embrace its transformative potential will thrive in an increasingly competitive environment. The path forward is crystal clear: seize the opportunities around AI, embrace streamlined business processes and empower project managers with essential business information in moments, rather than hours. By doing so, project-based businesses will continue to progress, adapt, and flourish in the era of artificial intelligence. Data and cybersecurity are paramount in the Engineering industry, with 68% of firms citing it as a top IT operations challenge. Cybersecurity threats impact businesses, making robust security policies and procedures crucial. Ensuring the protection of sensitive information and maintaining clients' trust are central to the industry's continued success.

As Engineering firms strive for digital maturity and navigate the challenges of rising technology costs, they must continue investing in their workforce and maximizing the potential of their current technology solutions. This strategic approach not only drives operational excellence but also positions companies as industry leaders prepared to embrace the future of technology.

There is an unspoken expectation that engineers and their institutions must deliver for the planet in the same way they did back at the beginning of the industrial revolution in the 1800s and the green revolution in the 1960s. It is generally accepted that the near and far future have serious questions of complexity where many of the answers are in the realm of unknown unknowns and in fact may border the unknowable.

Society expects that engineers will operate in this realm and provide answers to these difficult questions regarding Climate, decarbonization,

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renewables, engineering transitions, AI, AGI and singularity. The faith that communities have towards engineers to solve these issues is far greater than for the science fraternity in general. Communities worldwide also believe that all ethical considerations involving autonomy will be solved by engineers and their institutions.

In the decades ahead, waves of exponential technological advancements are stacking atop one another, eclipsing decades of breakthroughs in scale and impact. Emerging from these waves are a number of "Megatrends," likely to revolutionize entire industries (old and new), redefine tomorrow's generation of businesses and contemporary challenges. [291] Among these meta-trends are augmented human longevity, the surging smart economy, AI-human collaboration, urbanised cellular agriculture, and high-bandwidth brain-computer interfaces, massive food demands just to name a few.

The intervening decades to 2050 will be turbulent, destabilised both by technology disruptions that upend the foundations of the global economy and by system shocks from pandemics, geopolitical conflict, natural disasters, financial crises, and social unrest that could lead to dramatic tipping points for humanity including mass migrations and even war. [292] In the face of each new crisis we will be tempted to look backward rather than forward, to mistake ideology and dogma for reason and wisdom, to turn on each other instead of trusting one another. If we hold strong, we can emerge together to create the wealthiest, healthiest, most extraordinary civilisation in history. If we do not, we will join the ranks of every other failed civilisation for future historians to puzzle over.

Our children will either thank us for bringing them an Age of Freedom or curse us for condemning them to another dark age. The choice is ours.

This is Engineering NZ's Kodak moment.

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Dr. Ir. Ron McDowall ONZM
BBS/BSc, MPhil, PhD
Distinguished Fellow Engineering NZ, F.NZIM, MInstD, MRSNZ
CPEng, Int PE. APEC Engineer
International Civil Servant UNEP-FAO Rome

[291] https://www.diamandis.com/blog/metatrends-shaping-decade

[292] https://tonyseba.com/wp-content/uploads/2020/09/RethinkXHumanityReport.pdf