Artificial Intelligence, Engineering Systems and Sustainable Development

Driving the UN SDGs

Edited by

Tulsi Pawan Fowdur, Satyadev Rosunee, Robert T. F. Ah King, Pratima Jeetah, and Mahendra Gooroochurn

Artificial Intelligence, Engineering Systems and Sustainable Development

This page intentionally left blank

Artificial Intelligence, Engineering Systems and Sustainable Development: Driving the UN SDGs

EDITED BY

TULSI PAWAN FOWDUR
University of Mauritius, Mauritius

SATYADEV ROSUNEE
University of Mauritius, Mauritius

ROBERT T. F. AH KING
University of Mauritius, Mauritius

PRATIMA JEETAH
University of Mauritius, Mauritius

AND

MAHENDRA GOOROOCHURN
University of Mauritius, Mauritius

emerald PUBLISHING

United Kingdom – North America – Japan – India – Malaysia – China

Emerald Publishing Limited
Emerald Publishing, Floor 5, Northspring, 21-23 Wellington Street, Leeds LS1 4DL

First edition 2024

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-83753-541-5 (Print)
ISBN: 978-1-83753-540-8 (Online)
ISBN: 978-1-83753-542-2 (Epub)

INVESTOR IN PEOPLE

Contents

List of Figures and Tables

Chapter 10

Chapter 13

Chapter 14

Chapter 16

Chapter 17

Chapter 18

This page intentionally left blank

About the Editors

Dr Tulsi Pawan Fowdur received his BEng (Hons) degree in Electronic and Communication Engineering with first-class honours from the University of Mauritius in 2004. He was also the recipient of a Gold medal for having produced the best degree project at the Faculty of Engineering in 2004. In 2005, he obtained a full-time PhD scholarship from the Tertiary Education Commission of Mauritius and was awarded his PhD degree in Electrical and Electronic Engineering in 2010 by the University of Mauritius. He is also a Registered Chartered Engineer of the Engineering Council of the UK, Fellow of the Institute of Telecommunications Professionals of the UK and Senior Member of the IEEE. He joined the University of Mauritius as an academic in June 2009 and is presently an Associate Professor at the Department of Electrical and Electronic Engineering of the University of Mauritius. His research interests include mobile and wireless communications, multimedia communications, networking and security, telecommunications applications development, Internet of Things (IoT) and artificial intelligence (AI). He has published several papers in these areas and is actively involved in research supervision, reviewing of papers and also organising international conferences.

Dr Satyadev Rosunee is an Associate Professor of Applied Sustainability in the field of Textiles and Entrepreneurship at the University of Mauritius. Satyadev earned his PhD from the University of Manchester Institute of Science & Technology (UMIST, UK), Masters from Leeds University and a Bachelor of Technology degree in Textile Technology from Maharaja Sayajirao University, Baroda, India. Satyadev was Dean of the Faculty of Engineering from 2015 to 2018 and founding member of two departments namely: Department of Textile Technology (1990–2012) and Department of Applied Sustainability & Enterprise Development (2012–now). Satyadev has supervised nine PhDs, awarded by the University of Mauritius. He has published about 50 papers in peer-reviewed journals and conference proceedings. He is passionate about sustainability and entrepreneurship as drivers of innovation and social good.

Prof Robert T. F. Ah King holds BTech (Hons), MPhil and PhD degrees in Electrical and Electronic Engineering. He is a Professor by way of Personal Chair in Power Systems in the Department of Electrical and Electronic Engineering at the University of Mauritius. He is a Registered Professional Engineer in Mauritius and a Chartered Engineer, UK. His research interests include power systems, computational intelligence and optimisation. He is a member of the Institution of Engineers Mauritius, Institution of Engineering and Technology (IET), UK and Institute of Electrical and Electronics Engineers (IEEE), USA. Prof Ah King is the Chair of the IEEE Mauritius Section. He is a Technical Committee Member on Soft Computing of IEEE Systems, Man, and Cybernetics Society. He was the General Chair for ELECOM 2016, ELECOM 2018, ELECOM 2020 and ELECOM 2022 conferences. He has been on the Technical Programme Committees of several conferences and has served as reviewer for several leading journals.

Dr Pratima Devi Jeetah is an Associate Professor in the Chemical and Environmental Engineering Department of the University of Mauritius. She has a PhD degree in Bioprocess Engineering and a Master degree in Sustainable Energy Engineering from the Sweden University of KTH. She has a first-class Bachelor's degree in Chemical and Environmental Engineering and she is a gold medallist. Her research interest is in waste management/waste valorisation which particularly focuses on lignocellulosic waste conversion to bio-ethanol and on producing sustainable green functional products. She has worked on several EU/ACP/ERASMUS+ funded projects namely Small Developing Island Renewable Energy Knowledge and Technology Transfer Network (DIREKT); Lifelong Learning on Energy Access, Security and Efficiency Project (L3EAP), GEVALOR: ReSources Project, FESTII project (Formation et Enseignment Superieur pour la Transition energetique dans les territoires Insulaires at en Indianoceanie) and the EDU-ABCM project (Capacity Building on Student-Centered Energy Education in Cameroon, Ethiopia, Mauritius and Mozambique). She has also worked on numerous internally funded project namely from the UNDP, Mauritius Research and Innovation Council, Higher Education Commission and University of Mauritius funded research projects. She was the Head of the Department of Chemical and Environmental Engineering from February 2018 to February 2020. She has organised several international conferences on Energy, Environment and Climate change and workshops on eco-friendly bio material. She was also selected as one of the young emerging scientists to present her research works at the 2nd Commonwealth Chemistry Conference event in May 2023. She has published numerous scientific papers in impact factor journals. She has also published several book chapters and research papers in conference proceedings. Her publications can be viewed under the following Google Scholar link https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=pratima+jeetah&oq=pratima.

Dr Mahendra Gooroochurn works as a Senior Lecturer in the Mechanical and Production Engineering Department of the University of Mauritius. He is a Chartered Engineer registered with the Engineering Council of UK, an accredited green building design and construction professional registered with the USGBC, an Edge Expert registered with the International Finance Corporation (IFC) and a WELL accredited professional registered with the International Well Building Institute (IWBI). He holds the following professional engineering memberships: MIET, MIEEE and MASHRAE. He has industry experience as research manager and head of sustainability in the building services engineering sector and has research interests in sustainability in the built environment, circular design, circular economy and climate action, in which he acts as reviewer for several journal publishers and has published book chapters, journals and conference papers. He has been the Ellen McArthur Foundation Circular Economy Pioneer for Mauritius from the British Council Sub-Saharan Arts programme and the COP26/COP27 representative of Mauritius for the Association of Commonwealth Universities (ACU) Futures Climate Research Cohort. He has organised several IEEE conferences in multidisciplinary engineering disciplines and workshops and exhibitions on sustainable development and circular economy.

List of Contributors

Robert T. F. Ah King	University of Mauritius, Mauritius
Noushra Shamreen Amode	University of Mauritius, Mauritius
Lavesh Babooram	University of Mauritius, Mauritius
Khim Hoong Chu	Honeychem Research, New Zealand
Yasser M Chuttur	University of Mauritius, Mauritius
Zaheer Doomah	University of Mauritius, Mauritius
Tulsi Pawan Fowdur	University of Mauritius, Mauritius
Mahendra Gooroochurn	University of Mauritius, Mauritius
Visham Hurbungs	University of Mauritius, Mauritius
Neetish Hurry	International Economics Ltd, Mauritius
Pratima Jeetah	University of Mauritius, Mauritius
Deejaysing Jogee	University of Mauritius, Mauritius
Khalid Adam Joomun	University of Mauritius, Mauritius
Naraindra Kistamah	University of Mauritius, Mauritius
Samiah Mohangee	University of Mauritius, Mauritius
Ackmez Mudhoo	University of Mauritius, Mauritius
Anshu Prakash Murdan	University of Mauritius, Mauritius
Manta Devi Nowbuth	University of Mauritius, Mauritius
Vishwamitra Oree	University of Mauritius, Mauritius
Virendra Proag	University of Mauritius, Mauritius
Jean-Luc Probst	University of Toulouse III Paul Sabatier, France
Arvinda Kumar Ragen	University of Mauritius, Mauritius
Bhimsen Rajkumarsingh	University of Mauritius, Mauritius
Ramful Raviduth	University of Mauritius, Mauritius
Satyadev Rosunee	University of Mauritius, Mauritius

Ashven Sanghan	University of Mauritius, Mauritius
Asish Seeboo	University of Mauritius, Mauritius
Danraz Seebun	University of Mauritius, Mauritius
Yashwantraj Seechurn	University of Mauritius, Mauritius
Gaurav Sharma	Shenzhen University, China; Shoolini University & Glocal University, India
Mika Sillanpää	University of Johannesburg, South Africa; Aarhus University, Denmark; Zhejiang Rongsheng Environmental Protection Paper Co. LTD, China; Chandigarh University, India
Geeta Somaroo	University of Mauritius, Mauritius
Riaan Stopforth	University of KwaZulu-Natal, South Africa
Dinesh Surroop	University of Mauritius, Mauritius
K Tahalooa	Mini Factory Ltd, Mauritius
Roshan Unmar	University of Mauritius, Mauritius

Preface

In 2015, all member states of the United Nations adopted the 2030 Agenda for sustainable development. In view of ensuring peace and prosperity in the present and future, for all people and the planet, the 2030 agenda provides a very comprehensive shared blueprint. The agenda sets forward the creation of a global partnership between all developed and developing countries, having as core objective an urgent call for action to attain the 17 Sustainable Development Goals (SDGs). From climate action to good health and well-being, 17 high level themes and 169 targets have been identified and expected to be delivered by 2030, in the United Nations' Sustainable Development Goals (SDGs). It is important that measures to end poverty and other deprivations are taken along with strategies that lead to reduction in inequalities, enhanced health and education, and the promotion of economic growth, without neglecting actions for preserving our oceans, forests and tackling climate change in general.

Development in any country is impossible if, reliable and affordable energy, safe water and sanitation, as well as telecommunication facilities, are not easily accessible. These elements are indispensable for productive growth, healthy development and allow productive industrial growth through efficient and robust transportation systems. Engineering disciplines have a crucial responsibility of forming engineers who at the most basic level should be able to implement transportation, energy and telecommunications systems, as well undertake projects on safe water and sanitation. Hence, engineers have a major role to play to support the delivery of the SDGs. Integrated and intelligent engineering solutions which can deliver robust infrastructure, sustainable energy and access to the latest communication technology are indispensable to accomplish several of these SDGs. It is also vital to bridge the digital divide, where access to the internet is still a major obstacle in several parts of the world. In order to provide the means for cohesive solutions that can achieve sustainable development, engineers will have to employ state of the art disruptive technologies such as 5G,IoT, AI, cloud computing, blockchain and 3D printing among others.

AI and machine learning techniques are now widely used in all branches of engineering to build and optimise systems, solve intractable problems and also provide AI technology with new data inputs for interpretation. The combination of AI and engineering can indeed act as a real catalyst to achieve the UN SDGs.

The main purpose of this book, therefore, is to analyse different concepts and case studies in engineering disciplines such as Chemical, Civil, Electrical, Telecommunications and Mechanical Engineering with a view to demonstrate how engineering systems and processes can leverage the power of AI to drive the UN SDGs. Such a study is of paramount importance and will be a valuable source of information for researchers, engineers and policymakers to be able to better design and adopt AI-enabled techniques in different engineering areas with a view to catalyze the achievement of the UN SDGs.

Acknowledgements

We would first like to thank all the authors for their invaluable contributions to this edited book. We are thankful to the reviewers of the book proposal for their constructive comments and suggestions to improve the book. We are also extremely grateful to the editors and the book production team of Emerald Publishing, in particular Miss Kirsty Woods, for their excellent advice and guidance throughout this book project. Finally, we would like to thank Professor Boopen Seetanah who helped us in establishing our first contact with the Emerald team.

This page intentionally left blank

Chapter 1

Advances of Artificial Intelligence in Engineering

Tulsi Pawan Fowdur, Satyadev Rosunee, Robert T. F. Ah King, Pratima Jeetah and Mahendra Gooroochurn

University of Mauritius, Mauritius

Abstract

In this chapter, a general introduction on artificial intelligence (AI) is given as well as an overview of the advances of AI in different engineering disciplines, including its effectiveness in driving the United Nations Sustainable Development Goals (UN SDGs). This chapter begins with some fundamental definitions and concepts on AI and machine learning (ML) followed by a classification of the different categories of ML algorithms. After that, a general overview of the impact which different engineering disciplines such as Civil, Chemical, Mechanical, Electrical and Telecommunications Engineering have on the UN SDGs is given. The application of AI and ML to enhance the processes in these different engineering disciplines is also briefly explained. This chapter concludes with a brief description of the UN SDGs and how AI can positively impact the attainment of these goals by the target year of 2030.

Keywords: AI; machine learning (ML); UN SDGs; sustainability; engineering; systems

1.1 Artificial Intelligence (AI)

AI refers to a subfield of computing whose aim is to equip computer systems, robotic systems or any engineering system with the ability to conduct certain tasks and exhibit reasoning faculties normally possessed by intelligent beings (Zicari, 2018). AI enables automation, manages complexity and scalability and leverages data from remote systems in real time. AI methodologies include machine learning (ML), deep learning (DL), optimisation theory, game theory and

Artificial Intelligence, Engineering Systems and Sustainable Development, 1–13

doi:10.1108/978-1-83753-540-820241001

meta-heuristics (Russell & Norvig, 2020). DL and ML are most commonly used in engineering systems (Fowdur et al., 2021).

1.1.1 Definition and Types of AI

The founding father of AI, Alan Turing, defines this discipline as: 'AI is the science and engineering of making intelligent machines, especially intelligent computer programs. It is usually defined as the science of making computers do things that require intelligence when done by humans' (Copeland, 2000; Deloitte, 2018). There are two main classifications of AI, namely AI based on capabilities and AI based on functionalities.

For the classification of AI based on capabilities, there are three main types of AI as follows:

a. *Artificial Narrow Intelligence (ANI)*: ANI is limited to perform only very specific tasks that it has been trained to perform, such as, playing chess, purchasing suggestions on e-commerce site, self-driving cars, speech recognition and image recognition (Rahman, 2020). Consequently, it is often known as weak AI. It is used in most actual systems, for example, IBM's Watson supercomputer and Apple Siriis.
b. *Artificial General Intelligence (AGI)*: AGI exhibits human-like understanding and learning capabilities such as sensory-perception, good motor, natural language, creative, complex problem solving and social skills (Goertzel & Pennachin, 2007). AGI systems are currently still being researched and are yet to be deployed in practice.
c. *Artificial Super Intelligence (ASI) or Strong AI*: AI at this level can surpass human intellect and execute any task with better cognitive qualities. ASI can think, reason, solve puzzles, make judgements, plan, learn and communicate autonomously (Yampolskiy, 2017).

For the classification of AI based on functionalities, there are four main types of AI as follows (Hintze, 2016; Khan, 2021).

Reactive Machines: These forms of AI are the most fundamental, doing a single job with a specified set of rules and without memory. Both the Deep Blue system from IBM and AlphaGo from Google are instances of reactive machines.

Limited Memory: It has a short-term memory capacity and can temporarily store prior events or facts. It acquires knowledge from past events and applies it by analysing events or information. One of the most impressive applications of Limited Memory systems is autonomous vehicles.

Theory of Mind: This AI should recognise human emotions, individuals, beliefs and interact socially. It has not yet been developed and several research are currently being conducted in this field.

Self-Awareness: This AI will have its own consciousness and exhibit extraordinary intelligence, common sense, sentiments and self-awareness. It will also be fully autonomous. This is only a hypothetical concept and a lot of research remains to be done before it is actually developed (Hintze, 2016; Khan, 2021).

1.1.2 Categories of ML Algorithms

ML is the process of learning through the automatic detection of meaningful patterns in data. ML is useful to solve issues having tremendous complexity and adaptability (Shalev-Shwartz & Ben-David, 2014). The mathematical models of ML algorithms are mainly derived from statistical concepts (Alpaydin, 2004).

The main categories of ML algorithms are shown in Table 1.1 and defined as follows (Fowdur et al., 2021; Russell & Norvig, 2020):

a. *Supervised Learning*: It employs labelled data to develop the learning model (training process), which can be used for a classification or regression analysis. The objective of classification analysis is to assign a category label to each sample input. Regression predicts continuous values using statistical characteristics.
b. *Unsupervised Learning*: It consists of clustering and dimensionality reduction to find hidden patterns and relevant features in unlabelled data. Clustering groups samples into distinct clusters based on similarity measures. A high-dimensional data space can be reduced to a lower dimensional one via dimensionality reduction, without sacrificing too much information.
c. *DL*: DL is a subset of ML that is designed to learn autonomously without human intervention. With minimal human input, DL algorithms may readily be applied to situations and deliver extremely accurate results, even beyond human performance (Goodfellow et al., 2016). DL algorithms require the same data collection step as shallow learning but they automate the feature selection process to combine the feature selection and regression steps (Sutton et al., 2018). Algorithms perform the feature extraction independently of human inputs.
d. *Shallow Learning*: Shallow learning algorithms include three main learning steps: data collection, manual feature selection and regression. The data are characterised by pre-defined features. The feature extraction is done manually and necessitates domain knowledge of the data.
e. *Reinforcement Learning* (RL): In RL, the learners are not given instructions on the actions to perform. They train themselves through random independent actions in their training environment and are rewarded for each correctly performed action. Eventually, they are transformed into intelligent systems, capable of identifying the actions leading to the maximum reward (Sutton et al., 2018).
f. *Ensemble Learning*: In ensemble learning, many trained learners collaborate to produce a single output in response to a given input. A mechanism such as averaging is then used to integrate the results from all of the learners to provide a single, more reliable result. The rationale is that a group of decision is better than a standalone decision (Zhang & Ma, 2012).

Table 1.1. Main Categories of Machine Learning (ML) Algorithms (Fowdur et al., 2021).

Machine Learning (ML)	Unsupervised learning	Shallow learning	Clustering: • K-Means (Jordan, 2021) • Hierarchical • Gaussian mixture Dimension Reduction: • Principal component analysis • Isometric Mapping
		Deep learning	• Restricted Boltzmann machine (Fischer & Igel, 2012). • Generalised additive model
	Supervised learning	Shallow learning	Classification: • Naïve Bayes • K-nearest neighbour Regression (Beeharry et al., 2018): • Simple linear • Multiple linear • Polynomial
		Deep learning	• Multi-layered perceptron • Convolutional neural network (Khan et al., 2018)
	Reinforcement learning (Sutton et al., 2018)	• Q-learning • SARSA	
	Ensemble learning (Mienye & Sun, 2022)	• Random forest • Gradient boosting machine	

1.1.3 Advantages of AI and ML

AI and ML provide several advantages as summarised below (Chowdhury & Sadek, 2012; Davenport et al., 2020; Ogigau-Neamtiu, 2021; Phillips-Wren & Jain, 2006; Wuest et al., 2016).

a. *Repetitive and hazardous task automation*
   By employing intelligent process automation, recurrent and dangerous tasks are assigned to automated systems, thus enhancing efficiency, precision and adaptability, and reducing the risks.
b. *Error reduction and continuous enhancement*
   With ML and AI, algorithms are used to take decisions based on pre-collected data. The algorithms' accuracy improves as the amount of data increases, leading to error reduction and continuous improvement.
c. *Automated and faster decision support*
   Augmented decision-making processes based on AI decision models use fuzzy systems and neural networks to assist in decision support tasks such as: organising received data, integrating and visualising data, prioritising and filtering event specific relevant data, designing an optimal response, assessing and quantifying risks.
d. *Complex problem solving*
   AI is allowing complex problems including the processing of multi-dimensional and multi-variety data, and several challenges such as weather forecasting, medical diagnosis and self-driving cars, to be addressed by employing sophisticated DL models.

1.2 Advances of AI in Electrical, Electronic and Telecommunications Engineering

Electrical and electronic engineers design, develop and test new generations of devices and equipment in their quest for innovation. With the advent of AI, the field of electrical and electronic engineering has been empowered with nature-based methodologies to improve our everyday life. AI acts as an enabler for SDG targets by supporting the provision of energy services to the population as well as low-carbon systems. In fact, AI allows technologies like electrical autonomous vehicles and smart appliances to use demand response in the electricity sector with benefits across SDG 7 on affordable and clean energy, SDG 11 on sustainable cities and communities and SDG 13 on climate action.

The progress made in ML and natural language processing has impacted on almost every industry and area of scientific research as well as in engineering. Electrical and electronic engineers use AI to optimise systems as well as provide new insights in the development of AI technology for better interpretation. A recent example is the emergence of fully autonomous vehicles. Moreover, harnessing AI's potential can enhance the performance of a system. AI can automatically detect errors or performance degradation so that engineers can address these issues before these become critical.

AI actually refers to a system that mimics the human mind for decision-making and problem solving. Research within electrical and electronic engineering in AI have evolved over the years and can be categorised into expert systems, fuzzy logic systems, ML, artificial neural networks (ANNs) and DL. For instance, the application of AI has been quite substantial in power systems with implementations in the operation and planning of the infrastructure of the generation, transmission, distribution and utilisation of electrical energy. For example, AI is used to forecast the output of solar and wind power generation based on weather conditions and thus meet the load demand. ML has also flourished in areas of signal processing. It has enabled signal modelling, pattern recognition and inference development. With lesser noise in their inputs, the performance of Internet of Things (IoT) devices and other AI-enabled systems has greatly improved.

Led by the mobile and 5G broadband services in the IoT era, the telecommunication industry has experienced rapid growth due to the adoption of AI. Based on traffic information by region and time zone, AI enables communications service providers to build self-optimising networks. Preventive maintenance is possible for operators by using data-driven insights to monitor the state of equipment and anticipate failure based on patterns. Support requests for installation, set up, troubleshooting and maintenance can be handled by virtual assistants for customer support. A form of business process automation technology based on AI known as Robotic Process Automation can improve efficiency of billing, data entry, workforce management and order fulfilment. AI's powerful analytical capabilities can be harnessed to prevent fraud. Through smart upselling and cross-selling of their services, telecommunication companies can improve their revenue and increase their number of subscribers.

1.3 Advances of AI in Mechanical Engineering

Mechanical Engineering, being one of the oldest engineering disciplines, is at the core of the economic development of every nation, covering a broad range of areas such as structural design and analysis, maintenance engineering, risk management, tribology and materials engineering, thermal and energy engineering among others. With such a breadth of application areas, Mechanical Engineering, and its modern specialisation in the form of Mechatronics to cover the increasingly vital interface with electrical/electronics, software and control engineering, offer valuable tools and techniques to promote the UN SDGs. Ranging from materials innovation to develop more durable and better performance components for the broad infrastructural, biomedical, transport and aerodynamics sectors to allowing the development of material recipes for keeping materials in the loop for a circular economy, Mechanical Engineering has taken prominence in the energy sector where the thermodynamics principles govern several industrial phenomena which can be optimised to achieve energy efficiency, as a direct aid in our combat against the severe challenge of climate change. Of prime bearing for Mechanical Engineering are the following SDGs: SDG 7: Affordable and Clean Energy, SDG 9: Industry, Innovation and Infrastructure, SDG 12: Responsible Consumption and Production and SDG 13: Climate Action.

Mechanical Engineering has been at the forefront of the industrial revolution with advances in robotics and automation paving the way for the different phases of this transformation, including the Fourth Industrial Revolution pertaining to the use of data to optimise processes and resource use through the application of AI techniques. The manufacturing industry has been at the heart of our society's economic and technological growth, with a clear shift over the recent decade from mass production to product customisation to suit customer preferences, where AI algorithms have been instrumental in mapping customer requirements from online survey data into engineering specifications. The increasingly smart dimension of product lines has been made possible through a re-invention of the manufacturing sector, both from the customer end to be able to respond quickly and adequately to their preferences and from the industry's innovation and sustainability perspective to achieve resource efficiency, risk reduction and safety protocols. The use of AI in crash tests is an example of the latter. The availability of sensor data to collect states from industrial processes has enabled the development of automated fault diagnosis and predictive maintenance protocols with significant benefits with higher precision and less downtime.

The techniques provided by AI such as K-means clustering, Support Vector Machines, Principal Component Analysis and DL have been central in the management of this explosion of multidimensional and cross-disciplinary datasets in the broad manufacturing sector. In this respect, Enterprise Resource Planning (ERP) platforms are now essential digital platforms for the manufacturing industry, heavily utilising these AI techniques in trend analysis, pattern recognition and decision-making. In specific mechanical engineering sectors such as robot control, machine vision, fracture mechanics, materials innovation and fluidics to name a few, the power of AI is being harnessed to both complement and overcome the challenges of conventional theoretical and analytical methods, while serving as a basis for continual improvement through reinforcement learning. Like other sectors, Mechanical Engineering is poised to undergo fundamental AI-based changes over the next decade, with further closer linkages to other engineering and non-engineering disciplines.

1.4 Advances of AI in Chemical, Environmental and Energy Engineering (CEEE)

CEEE is a branch of engineering that studies the fundamental principles of energy, material and momentum transformation and reaction in order to use energy and materials more effectively, profitably and safely in industries and in the society and has proven to be a potent instrument for finding thorough solutions to a variety of environmental issues. Along with safeguarding people from harmful environmental effects like pollution, CEEE also aims at improving environmental quality, improving waste management, recycling, public health and the control of air and water pollution. CEEE has been extensively applied to typical and emerging environmental technologies such as wastewater treatment, biofiltration, anaerobic digestion among others and to develop a low carbon economy with strategies that will help society become more resilient to dangers associated with climate change. Hence, the following SDGs are directly relevant to the field of CEEE, SDG 6: Clean Water & Sanitation, SDG 7: Affordable & Clean Energy, SDG 12: Responsible Consumption & Production and SDG 13: Climate Action.

In order to achieve high-performance *t*, accurate control, optimal planning and operation scheme with the aid of ubiquitous sensing, proactive understanding, big data and automated learning, it is crucial to integrate AI technology with the CEEE sector. AI has been extensively utilised in numerous CEEE applications, including modelling, chemical process optimisation, process control, fault detection and diagnostics. AI approaches are increasingly useful nowadays due to their ease of use, generality, resilience and adaptability. Other current advances in AI in the CEEE field are reinforcement learning, statistical ML and evolutionary computation that show promise for solving a variety of problems in the chemical industry related to oil and other chemical product characterisation, decision-making, environmental perception and autonomous intelligent control. AI can be applied in chemical engineering to improve the efficiency of chemical processes such as in the petrochemical production and refining industry. The efficiency and efficacy of chemical processes can be increased by using AI to evaluate data from these processes and find trends. Additionally, chemical manufacturing can be made safer and more effective with AI to forecast the behaviour of chemical systems and make decisions based on information obtained. For instance, DL, a well-liked AI approach, has proven to be successful in identifying operation modes, fault identification and risk assessments in the refining process. As for the application of AI in the field of energy engineering, it has been reported that it is possible to use a variety of IoT components, such as sensors for light, humidity, temperature, speed, passive infrared and proximity. It is also useful for controlling heating, ventilation and air conditioning (HVAC) systems for lower energy consumption. AI can also be used to manage the power grid, predict equipment problems and improve the efficiency of power plants. In the environmental engineering sector, AI may be used to forecast environmental threats and improve the efficiency of environmental systems like in water treatment facilities, to evaluate environmental system data and find patterns that can be exploited to increase the effectiveness and efficiency of these systems. Moreover, AI can be used to forecast the carbon dioxide emissions at the global level, as well as low-cost estimates of soot and NOx emissions from the combustion of solid fuels (Jadidi et al., 2020; Jena et al., 2021).

1.5 Advances of AI in Civil Engineering

Civil Engineering has played an important role in the making of our modern society by offering technical solutions to the design of resilient infrastructures in various contexts, and in recent times in the engineering of sustainable solutions. The built environment is a key sector of Civil Engineering, where humans are known to spend more than 90% of their time, and hence can influence our well-being, welfare and productivity through the design choices made. Indeed, it is no surprise that the building sector has received high emphasis in sustainability