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Machine Learning Techniques, Gas Emission Mitigation, and Environmental Safety

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Abstract

Environmental safety is threatened by gas emissions, among other pollutants and threats to the environment. In exploring machine learning techniques, gas emission mitigation, and environmental safety, this study relied on secondary data. The data were subjected to content and thematic analyses. Analytic description and interpretive devices were employed. The analysis shows that machine learning, a model of artificial intelligence (AI), has the capacity to mitigate gas emissions and foster the attainment of environmental safety. The study concludes that machine learning techniques are efficient mechanisms for mitigating gas emissions and ensuring environmental safety in various regards. In view of the promising opportunities of machine learning techniques, the study recommends that the techniques should be integrated into other systems of managing and combating gas emissions and pursuing the attainment of environmental safety.

Keywords: Machine Learning, Techniques, Gas Emission, Mitigation, Environmental Safety.

Introduction

With Machine Learning (ML) techniques, environmental degradation can be mitigated significantly and environmental safety attained. The techniques can help address issues of poor mitigation of risks to humans and the non-humans in the ecosystem. Studies show that AI technologies can ensure safety and efficient management of risks. Such studies include Kamble and Gaikwad (2024), George et al. (2022), Srivastava (2021), and Jarrahi (2018). As such, Machine Learning (ML) techniques are capable of

reducing gas emissions and ensuring environmental safety. Obiuto et al. (2024) and Regona et al. (2023) prove the major benefits of AI to be efficiency, cost reduction, and optimization of planning and performance. The implication of their proof herein is that ML techniques can foster efficiency in the control of gas emissions and the pursuit of environmental safety; reduce costs and expenses; optimize performance; and aid adequate planning and decision-making.

Also, given Juhrich's (2023) demonstration that AI technologies facilitate detection and prediction of threats to safety, this study is convinced that ML techniques can be result-oriented, problem-solving and efficient in the mitigation of gas emissions for the attainment of environmental safety across the globe. With their detection and prediction capacities, AI technologies help immensely in combating risks to humans and the environment (Okusi, 2024; Akinloye & Shawana, 2023; Bulama & Shirivastata, 2022; George et al., 2022; Shawana, 2022; Thakkar & Lohiya, 2021). Safety risks are both computer-generated and offline or manual. The focus of this paper is on those arising from environmental pollution as a result of poor industrial practices that do not promote environmental safety or the green environment movement.

To reduce the risks, different measures are being employed by various governments and organizations across the globe. However, most of the measures are traditional or analogous and thereby less effective. For effective mitigation of gas emissions for the attainment of environmental safety, this study avers that ML and other AI technologies should be leveraged for lasting solutions. While it is quite true that other AI technologies are also can address gas emissions and pave way for the attainment of environmental safety, this study concerns itself solely with machine learning for the aforementioned purposes. The diagram below offers symbolic insights into ML techniques and those of other AI models in addressing gas emissions and environmental safety concerns:

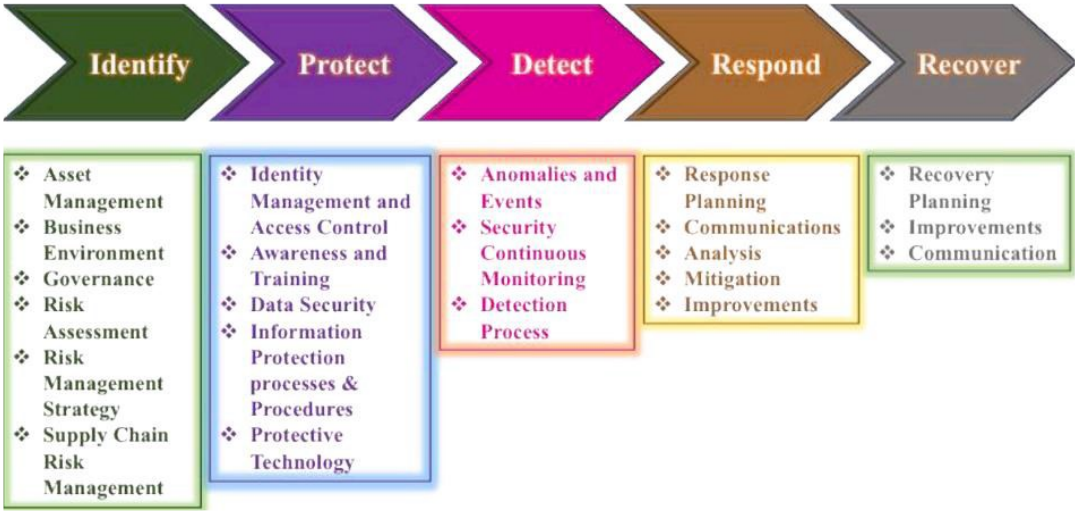


Fig. 1: Cybersecurity Framework
Source: Barrett (2018)

Machine Learning Techniques and Problem-Solving Capability

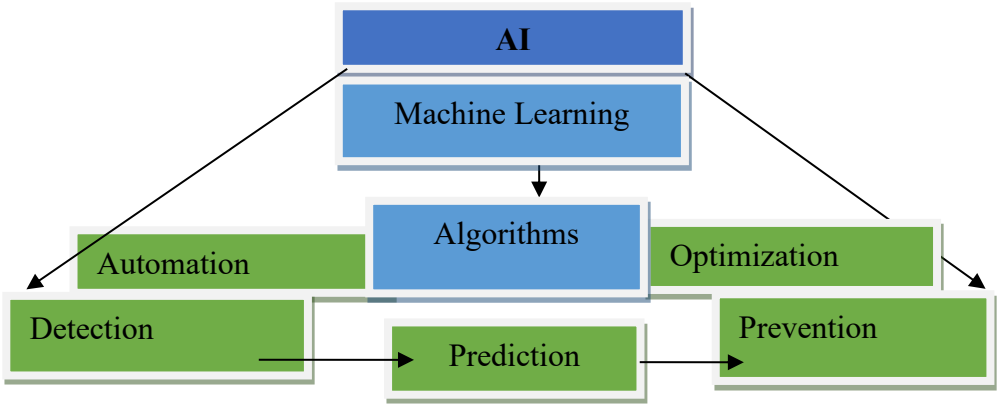


Fig. 2: Machine Learning Capability
Source: Authors, 2024

The Fig. 2 illustrates the roles played machine learning, which make it capable of addressing different issues. Machine Learning (ML) has the following major models or techniques: supervised learning, unsupervised learning and reinforced learning. Each of these has several other techniques. Like other models of AI, ML offers huge innovations to various spheres (Akter, 2024; Onifade & Alola, 2022). The innovations are of great benefit to various endeavors, humans, and the nonhumans alike. This study posits that leveraging ML techniques for gas emission mitigation would bring forth innovations in oil and gas sector, and ensure environmental safety.

Accordingly, ML is proven to be cost-effective (Oyeyemi et al., 2024; George et al., 2022). There is no doubt that its techniques can be leveraged for cost-effectiveness in planning and managing gas emissions and for ensuring environmental safety. Similarly, Digital Image Analysis and Canny Edge Detector smart technologies can maximize the monitoring of safety (Alsakka et al., 2023; Baduge et al., 2022; Seo et al., 2015). It follows that ML techniques can be leveraged alongside smart technologies for effective results in different tasks and activities, including being leveraged for effective mitigation of gas emissions, which guarantees the attainment of environmental safety. As Thuraka et al. (2024a) argue, "all AI technologies and techniques are capable of innovations, multifaceted tasks, solving different problems, and making huge impact on different spheres of life" (p. 51). The quotation is a pointer to the fact that ML has the capacity to proffer innovations and solutions to a range of problems, carry out multifaceted tasks, and impact different endeavours.

With the prediction, detection and safety potentials of AI affirmed by different studies (Juhrich, 2023; Bidhendi & Azizi, 2021), this study avers that ML techniques can be leveraged for solutions to problems or risks posed by gas emissions to the environment. By addressing or reducing environmental challenges caused by reckless gas emissions, ML techniques help ensure environmental safety. As such, advanced technological techniques ought to be deployed

significantly for gas emission control and the pursuit and realization of environmental safety. Kalnawat's et al. (2024) study proves the capacity of machine learning in safeguarding critical infrastructure from cyber threats. Being capable of safeguarding critical infrastructure implies that ML can also foster efficiency in managing gas emissions and industrial facilities in the oil and gas sector. The realization of the aforementioned implies realizing environmental safety.

Okusi's (2024) study proves that machine learning and AI have the capacity to detect, predict, resist and prevent threats to critical infrastructure; optimize the safety of critical infrastructure through automated and effective management of risks; create high level of awareness about how to optimally maintain critical infrastructure; and simulate and train human employees in the industry. The study's findings are confirmation of the stance of the present study that ML techniques have the ability to address the concerns posed by gas emissions and foster the attainment of environmental safety at a significant extent. Thapaliya and Bokani (2024) show that machine learning, deep learning, and natural language processing are AI techniques that can adequately tackle cyber security threats; identify the patterns of malicious activities in comparison with the legitimate ones; empower security systems with large data in real-time; and automate incident response processes that allow for proactive actions and efficient quelling of risks.

The noted findings are pointers to the capability of ML techniques in tackling gas emissions and ensuring environmental safety. The findings also describe how ML techniques play safety role in different settings. Thuraka et al. (2024b) discuss the place of AI and strategic management in the success of various critical projects, proposing the combination of the two sets of strategies for the attainment of successes in project planning, execution, maintenance and sustenance. Leaning on this, the present study posits that ML techniques are technological strategies that can be leveraged alongside conventional strategies to attain organizational and societal safety. With the application of ML techniques, gas emissions and environmental safety concerns can be addressed significantly. This is because the techniques foster reasoned decisions on gas emission control, management and prevention. As proactive, detective and preventive techniques, threats to the environment are detected, predicted and prevented proactively. The automation of gas control processes makes ML techniques suitable alternatives to other measures for controlling gas emissions and attaining environmental safety.

Also, Zhang's et al. (2019) study shows that random forests and support vector machines are ML techniques that enhance efficient and accurate predictions. Their ability to predict effectively and accurately confirms that ML techniques can be leveraged for efficient control, management and maintenance of gas emissions and the attainment of environmental safety. As Carvalho et al. (2019) note, the practice of using real-time data and historical records to predict possible equipment failure and proffer remedy proactively is regarded as predictive maintenance. With predictions, futuristic and momentary issues and faults are identified and solutions proffered. Proactive detection and prediction prevent failures, breakdowns, unnecessary interventions and the attendant effects of failures on safety and service delivery (Ahmad & Kamaruddin, 2012). Preventing the aforementioned can help avert reckless gas emissions, because the equipment for gas control remain in good shape.

Also, ML models have the capacity to process large amounts of data, with which they identify patterns and looming equipment failures (Schwabacher & Goebel, 2007). Neural networks can capture more complex failure modes. Although these are models of deep learning (DL), they are integral parts of ML, because DL is a subfield of ML. The ability to capture complex failures make them more effective in handling large volumes of datasets in construction, as in other sectors (Pasupuleti et al., 2024; Ren et al., 2021). Wiese's (2024) study demonstrates that predictive techniques of artificial intelligence (A) can help in the maintenance of critical infrastructure. This means that ML, a predictive model of AI, can help in the maintenance of construction projects and equipment.

Furthermore, with compliance management, efficient planning and increased performance are obtained (Obiuto et al., 2024; Singh, 2024; George et al., 2022). Thus, ML helps in tackling the risks faced by humans and environment in construction. Besides, ML can foster the attainment of environmental safety (Otasowie et al., 2024). Kamble and Gaikwad (2024), Regona et al. (2023), Regona et al. (2022) and Wang (2019) indicate that decision-making processes, rationality in the human mind and stimulation of learning and teaching are some of the major functions or benefits of AI technologies. These are also the benefits of ML.

ML and Deep Learning (DL) algorithms are proven by Jian-hua Li (2021) to be impacting internet world in a significant magnitude. They also observe that although the high time-consumption of Support Vector Machine (SVM) limits its detective capacity, AVL Tree can be used to reduce time and improve detection, prevention, and performance. The impact obtains in the area of combating gas emissions to attain environmental safety. The study carried out by Kaur et al. (2023) affirms that ML, deep neural networks, decision trees, and web-log-based detection models can detect and predict XSS attacks. Their study also agrees with the stance of the present study that ML can play a critical role in ensuring safety and efficient management of gas emissions. In the same vein, Okusi (2023) shows that deep forest is a technique of the ML that can help detect and prevent XSS attacks and address the issues of class imbalance. The listed techniques are to ML. They can tackle the risks to the environment, especially the cyber-based risks.

It is also quite interesting that Zhang et al. (2019) prove that reinforcement learning and other techniques of the ML algorithms allow systems to learn from data and improve overtime. This would breed efficiency in security, planning and execution of plans and policies on gas emission management and for the attainment of environmental safety. Wusu et al. (2022) demonstrate that various ML algorithms are used for analytic prediction. This means that ML techniques can be used to predict risks to environmental safety, including gas emissions. With the predictive and decision-support algorithms of ML, the following are attained: efficiency, saving of costs, time and resources; fostering better utilization; and preventing many mistakes, errors, faults and risks. In particular, the different techniques of ML, such as data-based method, SVM, NB, KNN, RF, AR algorithms, EL, k-Means clustering and PCA, can be used for various security purposes. Thus, they can be used to ensure safety.

Again, ML alongside other AI technologies and techniques offers efficiency, safety, innovation and enhancement of different activities for optimal performance, productivity and outcomes (Regona et al., 2022). Also, ML offers learning, innovation and career opportunities, including

technology literacy skills. With these skills acquired, different persons involved in the task of quelling cyber security threats are bound to proficiently and significantly tackle the worrisome trends of cyber security threats, which adversely affect the efforts at quelling threats to the environment (Adeniyi & Okusi, 2024; Awofadeju et al., 2023). On the other hand, the key disadvantages include data incompleteness, scalability of models, needing a high volume of time for training, the cumbersome nature of ML and other AI models, and ethical issues like exhibition of bias (Adeniyi, 2024).

Gas Emission and Mitigation Imperative

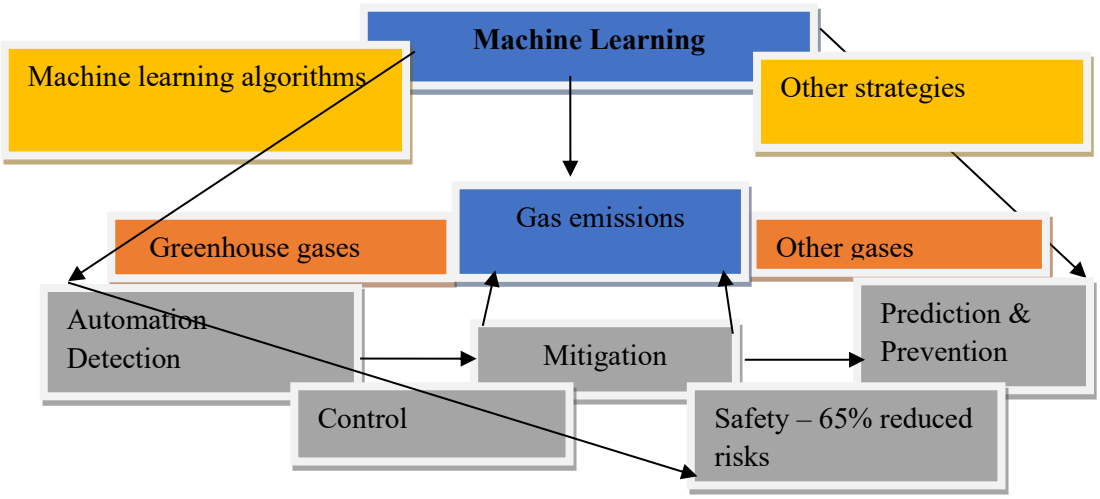


Fig. 3: Machine Learning in Gas Emission Mitigation
Source: Authors, 2024

The Fig. 3 shows how machine learning can be leveraged for the mitigation of gas emissions. Gas emissions, as Ojijiagwo (2017) notes, refers to the systematic channeling of gas to the knockout drum, right from where gas is directed to the flare stack. Carbon emissions into the atmosphere are increased by flared gases like Methane (CH4) and Ethane, posing health hazards to both humans and the non-humans of the ecosystem (McEwen & Johnson, 2012). The non-humans include animals, plants, water bodies, mountains, forests, and other creatures of the ecosystem. Ericsson's (2022) study shows that the emissions of methane and other greenhouse gases threaten environmental safety and economic growth. It is given the threats posed by the emissions of these gases that the present study advocates the adoption of ML techniques for finding lasting solutions.

The emission of gas and other greenhouse gases poses serious threats to the environment. Rodrigues (2022) and Getty Images (2021) share the view that gas flaring causes greenhouse gas emissions and wasted energy. Energy generation through fossil fuel contributes to carbon emissions (Dakwale & Ralegaonkar, 2012). As Shawana (2022) notes, carbon emissions include household energy, residential electricity, space heating, construction and mining

activities, industrial pollutions, transportation, manufacture, meat products, livestock and food production, which all threaten the environment and global warming. Given the situations, it is imperative to use advanced technological techniques for finding solutions to the problems, thereby reducing and preventing the incidences. ML techniques are apt for the purpose.

Shawana (2022) demonstrates that AI-driven techniques can be practically applied to real-world reservoirs in diverse geological settings to detect gas cap and address the associated issues. It follows that ML techniques, which are AI techniques, can undoubtedly mitigate gas emissions. Similarly, Gupta and Sharma (2022) made a review of previous literatures on the advancements in data analytics for gas cap detection. Machine learning and models of artificial intelligence are proven to be data analytics techniques that are capable of improving the reliability and speed of gas cap detection and characterization. Their study agrees with the present study that ML techniques can mitigate gas emissions and other gas related issues like those arising from gas cap.

More so, Bodin's (2021) study attributes environmental degradation and economic hardship/instability in Austria, Portugal and Sweden to gas emissions. Where environmental degradation obtains, the environment is not safe. Thus, to attain environmental safety, ML techniques should be leveraged for addressing gas emissions and the attainment of safety and economic growth. Zimmerman (2004) has observed that experiential, cultural, geopolitical and socio-economic differences among nations and continents account for the variances in the engagement with environmental concerns among American, Australian, New Zealand and French thinkers, researchers, scholars and authorities. In his words, "the experience and the conception of nature, shared by descendants of colonists, differ from the experience and the conception of nature shared by European contemporaries" (p. 4). These words are pointers to why there are more issues of environmental degradation in Europe than Africa and other ex-colonies.

Integrating ML techniques into the processes of controlling and managing gas emissions can yield huge results. The integration of ML techniques into the processes can foster detection and accuracy in managing gas emissions. Also, the utilization of advanced simulation models can help address gas issues. In other words, the combination ML techniques with other advanced simulation models can significantly address gas emissions. The combination can also lead to the attainment of environmental safety.

Nwaezeapu's et al. (2019) study examines hydrocarbon-bearing reserves and sands, using well data in the identification of reservoirs, hydrocarbon, and petrophysical parameters. It proposes the use of integrated petrophysical analysis and seismic interpretation as advanced techniques for addressing the issues associated with hydrocarbon. The present study also proposes the utilization of ML techniques for effective mitigation of gas emissions. It posits that ML techniques can be leveraged for effective identification of gas emissions and for determining the appropriate parameters for mitigating the emissions and other associated issues. ML techniques can help mitigate gas issues. Such issues include gas cap and gas emissions.

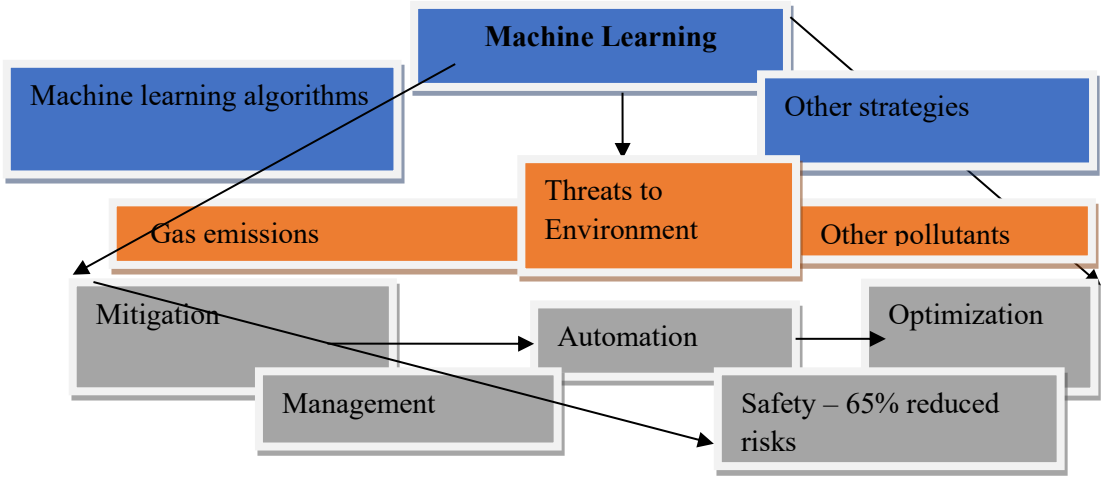


Fig. 4: Machine Learning in Environmental Safety
Source: Authors, 2024

The Fig. 4 represents machine learning alongside its techniques in environmental concerns to mitigate them and ensure safety. Studies confirm that AI techniques can be leveraged for lasting solutions to environmental issues. These include machine learning (ML), deep learning (DL), computer vision (CV), digital image analysis (DIA), internet of things, reinforcement learning (RL), natural language processing (NLP), expert systems (ES), robotics, and AI algorithms & hardware accelerators (Shawana, 2022). Since the focus of this study is on ML, the study will not dwell on the other AI models or subfields. As noted earlier, ML techniques include supervised learning, unsupervised learning, and reinforced learning.

The above mentioned ML techniques, among others, are confirmed to be capable of playing crucial roles in image and speech recognition, generative adversarial networks, content curation, targeted advertising, detection of anomalies and phishing, and automated threat response (Pasupuleti & Inyang, 2022; Pasupuleti, 2022). Regona et al. (2022) and Wang (2019) share the viewpoint that decision-making processes, rationality in the human mind, and stimulation of learning and teaching are some of the major functions and benefits of AI technologies. These noted benefits are of ML too. ML decision-making trees and some of its other techniques are known to be playing a crucial role in decision-making. Nwode et al. (2024) demonstrate that AI techniques can be leveraged for effective decision-making that leads to due implementation of policies.

In the same vein, this study avers that ML techniques can be leveraged for decisions on effective control of gas emissions and industrial and workplace safety. Besides, the techniques can be leveraged for effective implementation of policies on gas emissions and environmental safety. Baduge et al. (2022) and Seo et al. (2015) note that digital image analysis and canny edge detector can maximally monitor safety at a large extent. There are huge benefits of leveraging ML techniques and other AI techniques for the control of gas emissions, which include the attainment of environmental safety. These technologies speed up human efforts at

addressing environmental sustainability risks; conserve and manage environment easily and seamlessly; increase efficiency, environmental sustainability, and advanced monitoring and analysis of environmental impact.

Machine Learning and other AI technologies, such as Deep Learning and Digital Image Analysis, can provide lasting solutions to the challenges of environmental sustainability through cost-effectiveness (George et al., 2022; Wusu et al., 2022; Bidhendi & Azizi, 2021; Xu et al., 2021). Bidhendi and Azizi (2021) indicate that as AI is known for innovations, discoveries, inventions and huge contributory role to growth and development in various spheres. The spheres include safety, oil and gas, environmentalism and environmental sustainability, industrial activities, and the workplace, which all concern the present study. ML, an AI model, is indeed capable of bringing forth innovations, inventions and discoveries in the aforementioned areas of concern. With these, development and growth obtain therein.

The implication of the foregoing assertion is that AI technologies have to be integrated into other measures or systems for better results. The integration of ML techniques into other techniques can yield the desired results in addressing issues of gas emissions and environmental safety. Ojo et al. (2024) agree that AI technologies, ML inclusive, have the capacity to address different problems. According to Koyuncu et al. (2021), AI has the capacity to address the risks of environmental sustainability in the 21st century. Since ML is one of the subfields or models of AI, it is quite true that ML techniques can pave way for the attainment of environmental safety. On their part, Onifade and Alola (2022) and Yigitcanlar et al. (2020) indicate that AI and smart technologies provide massive data sets, with which carbon emissions and those of other gases can be contained and the impact of gas emissions reduced significantly.

Indeed, ML techniques are AI-based technologies capable of providing massive data sets, with which gas emissions and environmental concerns can be addressed. Basically, the application of ML techniques to the processes of attaining environmental safety can bring forth innovations, automation, seamless and efficient operations; effective prediction and detection leading to safety; efficient management of risks leading to appreciable extent of safety; optimization of operations and performance; reduction of costs, expenses, time and resources; influencing decision-making and policies on environment; and fostering regulatory compliance (George et al., 2022; Thuraka, 2022; Bidhendi & Azizi, 2021; Srivastava, 2021; Yigitcanlar et al., 2020; Jarrahi, 2018). The listed benefits and roles of AI technologies in general and ML techniques in particular are captured in the following diagram on AI patterns for detection, prediction and prevention of risks:

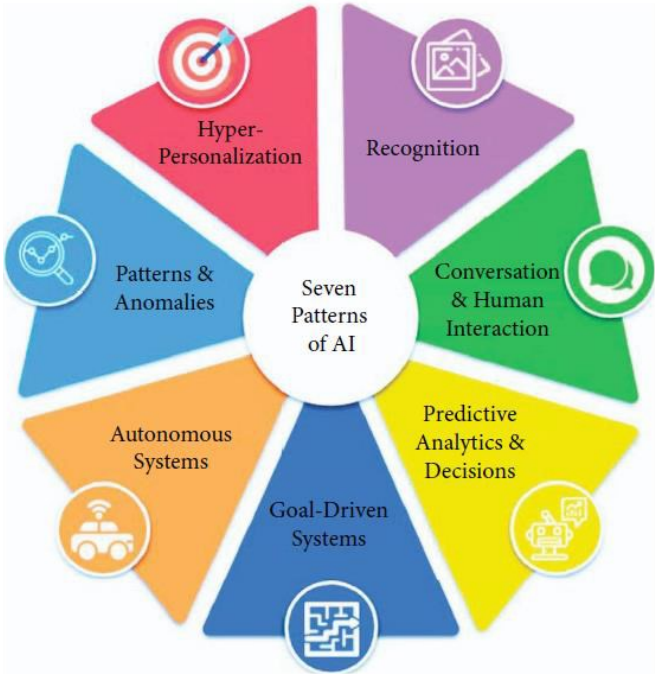


Fig. 5: Seven AI Patterns
Source: Rashid et al. (2023)

Conclusion

The study has shown that gas emission affects environmental safety. It presents machine learning as a variable technology-based means of mitigating gas emissions and other environmental concerns. By addressing gas emissions and environmental concerns using the AI techniques of machine learning, environmental safety can be attained significantly. The study explains how ML techniques can be leveraged for effective management of gas emissions and the attainment of environmental safety. It shows evidence from previous literatures that affirm the ability of ML to solve problems in different spheres. Also, it offers graphic or symbolic illustrations of how ML techniques are capable of mitigating gas emission and environmental safety issues. The roles of ML as well as several other AI models, which constitute the benefits, are highlighted and described. Given the ML capability, roles and benefits, this study recommends its adoption at a significant extent in oil and gas sector and environmental management endeavor for lasting solutions to issues of gas emissions and environmental safety.

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