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Environmental Surveillance with Artificial Intelligence: A Double-Edged Sword

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Abstract

Environmental monitoring is concept of closely observing the changes taking place in our environment which affects living as well as non-living things. As technology is emerging, there has been a lot of focus on protecting our environment too, many different strategies and many technological tools have been deployed for conservation of natural resources and protecting our environment for sustainable development. This paper focuses on the uses and challenges of artificial intelligence (AI) for monitoring environment. In this paper we use previously published papers for qualitative analysis purpose. We would be discussing about different AI models required for different aspects of environmental monitoring such as air quality monitoring, water quality monitoring, soil quality monitoring, forest cover monitoring, etc., where AI could be implemented for monitoring and providing probable solutions for upcoming threats. On one hand AI proves to be useful in analysing data and predicting probable upcoming changes in air quality, carbon emission, forest cover, etc., on the other hand AI itself is posing threat to environment as its training models emits carbon in large amount.

Keywords: Environmental monitoring, Artificial Intelligence, AI models, air quality monitoring, water quality monitoring, soil quality monitoring, natural disaster monitoring.

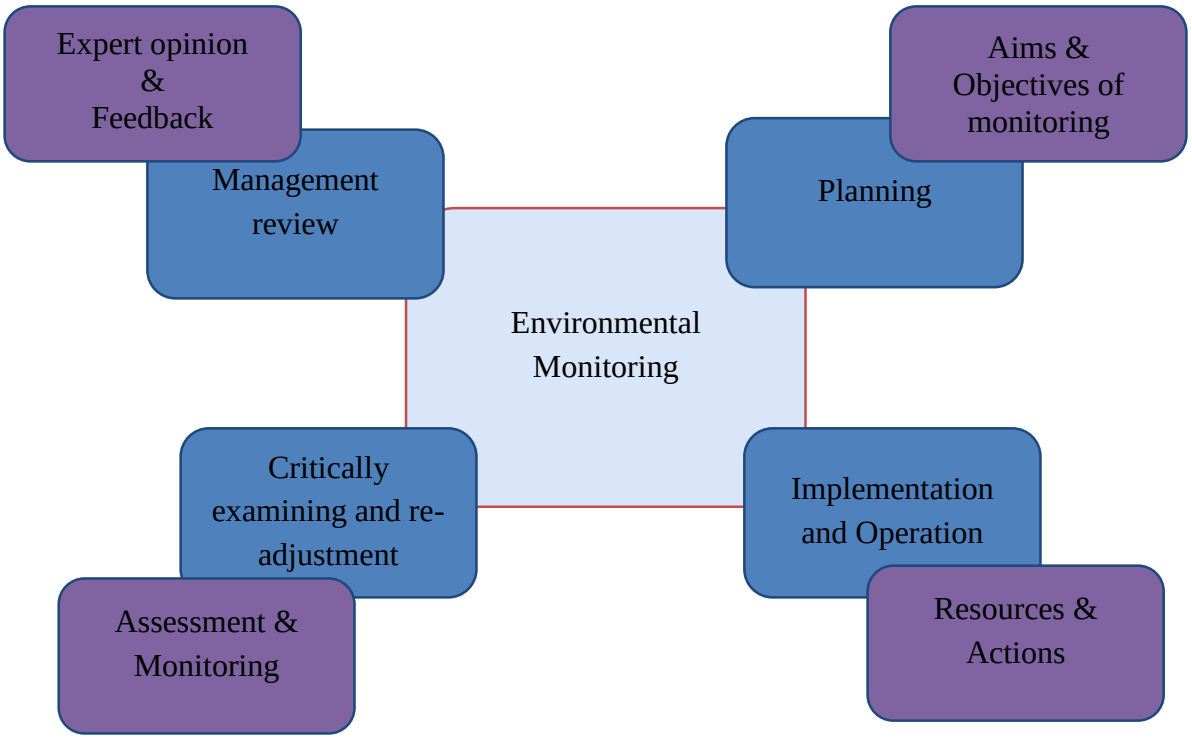
Introduction

According to WHO, “In 2016, 13.7 million of deaths, representing 24% of global fatalities, were attributed to modifiable environmental risks. This means nearly one in four global deaths are linked to environmental conditions”. Environmental conditions can be referred to the external factors that may contribute positively or negatively in development, survival and behaviour of living organism. Environment is dynamic in nature it is continuously changing, these changes always affect the living organism, thus it become necessary to record these changes, therefore, need of environmental monitoring arises. In general, we can say monitoring is a process of repeated measurement of a specific variable over longer period of time and space. Environmental monitoring plays an important role in assessing health and safety problems for public or environmental health purposes. Monitoring helps us to keep their wellbeing updated and informs of potential future issues (Zhang et al, 2020). Traditional environmental monitoring techniques include statistical analysis, laboratory analysis,

and manual sampling (Zhang, 2024; Olawade et al., 2024). Traditional methods of environmental monitoring have its own limitations in the form of manpower, cost and time. As manual sample collection requires more manpower which eventually increases the cost of monitoring and also limited to small sample. To overcome these issues the incorporation of technology has become unavoidable in environmental monitoring. Among these technologies, Artificial Intelligence (AI) has emerged as a transformative force, offering innovative solutions to monitor, predict, and mitigate environmental risks while enhancing the overall safety and well-being of communities (Rane, 2023, Kunduru, 2023, Ukoba and Jen, 2022, Bahroun et al., 2023; Adefemi 2023).

Figure1, depicts the general model of environmental monitoring, which shows the main elements of model.

Figure 1: Environmental monitoring system



This model consists of four basic stages which are as, planning, implementation and operation, critically examining and re-adjustment, and management review. First stage is planning, we should well define our aims and objective of environmental monitoring, and we also fix the target for monitoring as air quality, water quality, soil monitoring, etc., after planning stage, at second stage we identify the resources required for implementation of AI model for real time monitoring like sensors, cameras, internet, storage of data, etc. Third stage, critically examining and readjustment in this the examination of procured data is analysed and corelated with the existing results for authenticity of AI working and system is re-adjusted as per the need. At final stage, we get an expert advice and feedback for the entire process of monitoring.

Artificial intelligence (AI) has emerged as a crucial integration in environmental monitoring endeavours, seeking to enhance the objectivity of results and improve accessibility to regions suffering from limited resources. AI, a subfield of computer science, focuses on creating algorithms and computer programs that can perform activities like sensing, reasoning, earning, and decision-making that would ordinarily require human intellect (Rodgers, 2020; Sarker, 2021a, b; Olawade et al., 2024).

AI can be used for monitoring following aspects of environment:

- Air quality monitoring.
- Water quality monitoring.
- Soil monitoring.
- Early detection of natural disaster.

Air quality monitoring: Now a days maintaining air quality has become a challenge for developing nations like India. In developing nations industries are not in compliance with environment safety standards, which cause air pollution, contamination water, soil degradation, etc. Air pollution is one of the major cause of diseases like tuberculosis, asthma, lung cancers, etc, so it become very important keep regular checking of air index for ppm 2.5, co, etc. also, to reduce greenhouse gas affects it is necessary to take care of carbon emission. In this regard AI promises a lot in monitoring air quality in real time, which enables quick response in managing the air quality.

Water quality monitoring: The earth is covered by around 75% water, but water available for human consumption is around 1% of total water. This fresh water too is in various forms as glaciers, lake, rivers, ground water, etc so it become more important to conserve and monitor the quality of water. There are many factors responsible for degradation of water quality, as such industrial waste, agricultural waste, eutrophication, sewage water dumping into rivers and lakes, etc. ai can boost the entire process of monitoring.

Soil quality monitoring: All living organism need some kind of foods for their survival. Good quality of soil is most important for the production of agricultural products like grains, vegetables, pulses, etc., to fulfil the hunger need of our population we need to maintain the quality of soil. Therefore, the monitoring of soil for good quality is mandatory. The application of AI in soil monitoring represents a significant advancement in agricultural management, environmental conservation, and land-use planning (Abdulraheem et al., 2023; Odawale, 2024).

Early detection of natural disaster: AI models can be trained with historical data for analysing the patterns of natural disasters and comparing the patterns with real time data monitored by system for making accurate predictions in advance of upcoming natural disasters.

As AI is evolving with time and based on data provided it predicts for upcoming events, so AI is learning new things every day. It can real-time monitor the weather conditions as precipitation, wind speed, humidity, temperature, etc.

Related Literature Review

Alotaibi E., and Nassif N. (2024), they have conducted the bibliometric analysis, in this study they have analysed about 4762 publications from 1991 to 2024 which provided a deeper understanding of the research orientation of the application of machine learning (ML) and artificial intelligence (AI) techniques for monitoring environment and analysing the data. They emphasized that application of AI and ML methods in all types of environmental monitoring activities, such as air quality monitoring, water quality assessment, climate change modelling, biodiversity monitoring, and disaster management, has been widely studied. They

found in their study that machine learning algorithms like support vector machines (SVM), decision trees, and random forests have also been employed for environmental monitoring data analysis. Also, in their study they highlighted on the AI/ML-based environmental monitoring techniques using emerging technologies (Internet of Things (IoT), unmanned aerial vehicles (UAVs), passive acoustic monitoring, etc.) have enabled new applications of environmental monitoring. Moreover, these methodologies have been extended to cross-domain, such as biosensors, disease identification, and public health surveillance. Get started in GEE Google Earth Engine weekly quick starts You are new to GEE.

Chisom et al, (2024), in their research paper they have explored the transformative potentials of artificial intelligence (AI) in the field of environmental monitoring and its conservation. Where they have focused on natural disaster prediction, habitat assessment, wildlife tracking and biodiversity analysis. This paper focus on the of responsible development, equitable access and ethical considerations in harnessing AI's true potential for the well-being of entire planet earth. In this paper, theoretical concepts and some of practical examples are demonstrated in depth and breadth of AI's capabilities in unravelling the intricate patterns of the natural world. Practical examples, such as tracking elephant poaching routes in Africa and identifying illegal logging activities in the Amazon rainforest, serve as powerful illustrations of AI's tangible impact on conservation efforts.

Olawade et al, (2024) in their paper they emphasized on integration of AI in environmental monitoring that offers transformative benefits across several domains, which includes air, soil and water quality monitoring, traffic management, and tracking carbon footprints. They advocated that these advancements can significantly contribute to environmental protection, as well as sustainable development. We can utilize AI capability of precise predictions and real-time monitoring can increase the efficiency and effectiveness of environment management. They have also acknowledged the drawbacks which are associated with AI technologies. The main concern is the amount of energy requirement by data centres and the supply chain, which leads to increased emission of greenhouse gases.

Adefemi et al, (2023) in their paper they have discussed integration of AI in environmental health and public safety, they have taken up a case study from USA. This case study focused on real time monitoring of air quality to predict air diseases and overall air quality. They found AI can prove itself as a better monitoring system which can analyse voluminous data for real time forecasting. They have taken privacy as the main concern with AI models. AI models utilize huge data, for this storage of data can be a difficulty.

Objectives of this paper

- To identify and analyse the main trends in the publication of research articles related to AI in environmental monitoring.
- To discuss the implications of the findings for future research and practice in environmental monitoring.

Research Methodology

This paper utilizes analytical review of articles to analyse the previously published articles on ‘environmental monitoring using AI’. The articles were selected from academic database (google scholar, semantic scholar). The articles were selected on basis of citations i.e., the paper chosen were cited most.

Results and findings

The main findings this study is that the trends of publication of papers on environmental monitoring has increased from 2010. Globally, the researchers are concerned about their environment, but countries like China, USA, India, Italy and United Kingdom are top five countries, where largest number of environmental researches have been conducted. The studies have been conducted on different environmental issues which shows concern on climate changes, increase in pollutions, drastic growth in human population, rapid rate of deforestation, increasing industries and increase in number of vehicles which not causes only air pollution but its emission pollute water, soil, etc. In this paper, also it has been found that by implantation of AI and ML can help in real time monitoring of environment and on the basis of analysed report policies and regulations can be framed to protect the whole environment. AI helps in monitoring of every aspect of environment like soil, air, water, climate change, biodiversity, natural disasters, natural habitats, forest cover, and greenhouse gas emission.

There are various new AI tools and models have been developed across the world, which proof themselves worthy in environmental monitoring as by providing results with accuracy and precision in each real-time frame.

AI models for Environmental Monitoring: Environmental monitoring AI models are chosen on the basis of availability of data, computational efficiency and expertise. On the basis of computational requirement, data, energy requirement for training, etc, models are as support vector machines (SVM), decision trees, random forest, convolutional neural networks (CNNs), recurrent neural networks (RNNs), and hybrid models. Some of the main features and limitations of various AI models for environmental monitoring is given in following table:

AI Models	Features	Limitations
Support Vector Machines (SVMs)	- It can deal with high-dimension data. - It quickly learns difficult relations among variables. - It works with various varieties of data types, text and images.	- Classification of Images (e.g. wildlife identification, detecting shedding forest areas, etc,). - Natural language processing (e.g. information extraction from reports on environmental changes). - Forecasting time series (e.g. predicting events with extreme weather).
Decision Trees	- Simple in training and interpreting - It also works with variety of data-types.	- Monitoring forest area cover. - Air quality monitoring. - Water quality monitoring
Random Forest	- Ensemble method enables learning methods that combines together the predictions of various decision trees.	- Detecting forest cover areas, wildlife detection). - Natural language processing (e.g. information

	- Healthier to precede over single decision trees.	extraction from reports on environmental changes). - Forecasting time series (e.g. predicting events with extreme weather).
Convolutional Neural Networks (CNNs)	- Works well with images and its classification and also with spatial data - Utilizes image to learn complex patterns, without any explicit programming.	- Classification of Images (e.g. wildlife identification, detecting shedding forest areas, etc,).
Recurrent Neural Networks (RNNs)	- Designed well for the tasks which involves sequential data, such as natural language processing and forecasting time series. - It learns long-term dependency in data.	- Natural language processing (e.g. information extraction from reports on environmental changes). - Forecasting time series (e.g. predicting events with extreme weather).
Hybrid Models	-Combine together the strengths of both deep learning and machine learning models. - It is more accurate and durable as compared to individual models.	- Can perform any type of environmental monitoring with high accuracy and durability.

Table 1: AI models with its features and limitations

Benefits of Artificial Intelligence in Environmental Monitoring: AI can be used for environmental monitoring because of the following reasons like data integration, speed, accuracy, cost, scalability, maintenance and environmental impact. AI with help of advanced bio sensors facilitates large data collection from several sources, cloud storage helps in big data storage and increasing the accuracy of computation and interpretation. It not only enables large data gathering but also increases the sample size in terms of scalability that means larger area could be real-time monitored. AI has tremendous speed starting from data collection, data arrangement, data filtration, data analysis, data interpretation and providing relevant information about upcoming threats. The initial cost of AI training models is higher in comparison to traditional models, but become functional its monitoring coat is too low. It requires periodic update of software and lower maintenance of hardware; it reduces human labour cost and makes system almost error free. Once implemented it put low impact on environment in terms of carbon emission.

Challenges of AI integration in environmental monitoring:

Technology is double sided sword as much useful it is, it is as much harmful too. Same is the case with artificial intelligence, on one hand, it facilitates us as reduces stipulated time of our works, provide handful information from vast database, etc. and on the other hand it can pose threat to society in many terms as data leak, unethical use of data, etc. Some of the challenges associated with AI integration in environmental monitoring are as followings:

- Transparency in working of AI: As these models become intricate and sophisticated, their decision-making processes become increasingly opaque. This opacity, often referred to as the "black box" problem, can lead to mistrust and reluctance to adopt AI technologies (Fan, Z. et al, 2023). Transparency in AI models need more openness in terms of policies and its way of utilizing data. For protection of common people there must be vigilance on AI systems and the governments should develop a robust framework.

- Data Storage: About 2.5 exabytes (2,500,000,000 gigabytes) of big data is generated every day (VoPham et al. 2018). As AI model work on analysing data so they keep on compiling data every moment. For AI data is food, the place where data is stored is its brain, data is its tool for providing information. AI model uses very large amount of data for its predictive use and validity without data AI is worthless. So, it become one the issue in handling and storing such a huge data.

- Power Consumptions: AI training models requires high energy for training and re-training. Also, energy is required for computation process, maintenance of data storage, maintaining backups, collection of data, etc. due high demand of energy the production house feel pressurized and in meeting the requirements they produce more energy which results in high environmental pollution.

- Ethical Issues: The AI has main concern of ethics in its implementation across the world. Ethical considerations mainly focusing on algorithmic bias, and privacy of data.

Conclusion

AI has potential to transform the pattern of environmental monitoring through analysing large data with accuracy and precision. By using AI tools, we can cover large range of area and we can consider whole pullulation as sample. AI's capability to provide precise predictions and real-time monitoring enhances the efficiency and effectiveness of environmental management practices. AI can analyse big data gathered from various sources and can make very accurate predictions. Also, it can provide real time analysis which can enable us in identify upcoming natural disasters like heavy rain, hail-storm's, floods, famine, etc.

With the help of AI models for air quality detection, we can get information's of minute changes in air quality in specific region and can also identify the causes of such changes. With this real time monitoring we can act accordingly to manage air quality e.g.; we can manage traffic in specific area where vehicle emission has increased and divert traffic to other areas, also, we can streamline the peak timings of industrial operations, we can choose green zone areas for old age people and children s with real time monitoring.

For water quality management, we can use AI for monitoring pH level, level of dissolved oxygen in water, presence of pollutants particles, variation in temperature of water bodies or sources, etc. For water quality monitoring purpose, we can use some of the most suited AI models like Artificial Neural Networks (ANN) models, The Long Short-term Memory (LSTM) models, or Non-linear Autoregressive Neural Network (NARNET). With the help of these AI models, we can identify the sources of contamination of water, we can regulate pure water supply and maintain good public health.

For soil quality monitoring, some of the most reliable AI models are Random Forest, Decision tree, con Convolutional Neural Networks (CNNs), and Recurrent Neural Networks (RNNs). We consider some factors for soil monitoring such as, moisture contained in soil, nutrient content of soil, pH value, soil infertility level, organic carbon in soil, and changes occurred in soil.

Natural disasters are not easy to predict but still geological scientist is trying to make models for accurate predictions for volcanic eruptions, earth quakes, tsunami, and floods etc, out these flood and rain can be easily predicted and required preventive measures can be taken. For prediction various factors are analysed such as metrological forecast, change in temperature, humidity wind patterns, etc. For AI monitoring, latest sensors like seismic sensors, and satellite images are used for data collection from number of sources.

AI is capable of transforming the whole system of monitoring and also can provide accurate real-time prediction on basis of huge data analysis. AI is as harmful as good it is. So, it's we who has to decide that how we are going to use this AI.

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