INTERNATIONAL JOURNAL OF INFORMATIVE & FUTURISTIC RESEARCH (IJIFR)
ISSN: 2347-1697
VOLUME 13||ISSUE 5|| JANUARY 2026
An Open Access, Peer Reviewed , Globally Indexed & Refereed International Research Journal
Estd Year: 2013 || Website: www.ijifr.org || Email: editors@ijifr.org
Impact Factor=8.057, Index Corpenicus Value:6.62
Published By: Pioneering Journal Publishers

LEVERAGING MACHINE LEARNING, DEEP LEARNING AND NATURAL LANGUAGE PROCESSING FOR INTELLIGENT AND SUSTAINABLE SYSTEMS

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ABSTRACT:
Focus on the urgent need to implement sustainable development has created an accelerated demand for the use of intelligent technologies that provide solutions to environmental, economic, and social issues via the deployment of machine learning, deep learning, and natural language processing to build scalable systems that utilize data in order adaptively consider various aspects of Sustainable Development Goals (SDGs). These two technologies provide opportunities for maximum efficiency through the use of resources predictive modeling and creation of knowledge and wisdom across many domains, including energy, transportation, agriculture, and environmental governance. In this paper, we will provide an overview of how machine learning, deep learning, and natural language processing can be used to create intelligent and sustainable systems. In addition, we will also provide an overview of how different methodologies are being applied within these areas, the different application areas that are benefitting from this transformation, how these technologies are being integrated with other technologies, what challenges must be overcome, and where future research may lead to additional innovations leading to sustainability through the expanded capabilities of artificial intelligence.

KEYWORDS: ***Sustainable systems, machine learning, deep learning, natural language processing, artificial intelligence, intelligent technologies***

PAPER CITATION:
Mehla, R.: "Leveraging Machine Learning, Deep Learning and Natural Language Processing for Intelligent and Sustainable Systems", International Journal of Informative & Futuristic Research (IJIFR), Vol.(13) (5), January 2026, pp. 604-608
DOI: *https://doi.org/10.64672/IJIFR/26.01.13.5.032*

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
Volume 13(5), January2026

1. INTRODUCTION

Due to the combined pressures of rapidly increasing climate change, massive urbanization, resource exhaustion, and ecological degradation, the push for sustainable development has become a global priority. Conventional technology has been unable to effectively adapt to the unpredictable challenges facing our environment, thus resulting in an increase in interest for a more intelligent, flexible technology to assist with the development and implementation of sustainable systems. With the introduction of artificial intelligence which consists of machine learning, deep learning and natural language processing, the capacity of systems to gather and analyze data, develop patterns from that data and autonomously perform actions based on what they have learned has increased tremendously! Without these capabilities, we would not be able to successfully implement innovative solutions to reduce our greenhouse gas emissions, improve our use of resources, and develop resiliency to extreme weather events. In this paper, I will discuss how you can use ML, DL and NLP in order to create sustainable intelligent systems, in addition to their advantages and disadvantages.

2. MACHINE LEARNING FOR SUSTAINABLE SYSTEMS

Machine Learning (ML) has been applied in the field of Sustainable Development through Predictive Modeling & Optimization (PMO). By utilizing Supervised Training techniques to model renewable energy sources and create an Energy Demand forecast, we were able to achieve a better distribution of Electricity and lower our dependence on Fossil Fuels [1][2]. Also, Unsupervised ML techniques (Clustering and Anomaly Detection) have been successfully utilized to identify failures in Electric Distribution Networks, Liquid Leaks, and anomalies in the Performance of Energy Distribution Systems and Critical Infrastructure Systems, including Water & Sewer Systems [1][7]. By employing ML for these purposes, we have reduced operational costs, and significantly reduced resource waste.

Another significant application of ML is in Precision Agriculture. The incorporation of ML into Precision Agriculture allows us to gather and analyze data about Soil Conditions, Weather Patterns, and Crop Health, allowing for more accurate predictions regarding Crop Yield, Scheduling of Irrigation, and Fertilizer Management. Thus, ML provides a decision support service that benefits both food production and conserves Natural Resources [6]. Finally, MLs can also contribute towards Urban Sustainability efforts by enabling cities to improve Traffic Flow, manage Waste more effectively, and monitor Air Quality.

3. DEEP LEARNING IN ENVIRONMENTAL AND INFRASTRUCTURE INTELLIGENCE

Deep learning is capable of analyzing massive volumes of unstructured and high-dimensional data, thus making it a superior technology for addressing the many sustainability challenges presented by large-scale, high-dimensional, and unstructured datasets. For example, a Convolutional Neural Network (CNN) can classify Land Use, monitor Deforestation and assess Damage [4][5] using Satellite Images.

In Meteorology and Climate Prediction, deep learning is utilized to make Regional Energy Prediction via Recurrent Neural Networks (RNN) and Long Short Term Memory (LSTM) architectures, allowing deeper identification of the relationships within Temporal Sequences of data for more accurate future prediction of events, and ultimately helping to develop better Adaptable Energy Management Systems [5].

In addition to supporting improved Traffic Management and the development of Automated Vehicles, deep learning will contribute to reducing congestion and improving Optimal Routing for Fuel and Operational Efficiency, leading to more energy-efficient transportation systems and enabling all-encompassing Sustainable practices through the De-carbonization of Transportation Systems by reducing Green House Gas (GHG) emissions and improving Fuel Efficiency. In addition, using deep learning for Predictive Maintenance and Structural Health Monitoring of Complex Infrastructure Systems will allow those Systems to become more Sustainable and Resilient.

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
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4. Natural Language Processing for Sustainability Intelligence

The development of NLP has greatly improved our ability to process and analyze large volumes of unstructured data (in this case, text) related to the topic of sustainability. By utilizing analytical techniques, we can analyze large volumes of environmental, social, and policy data that are unstructured in nature and can provide recommendations on the future direction of sustainability or sustainable development.

Using topic modeling and text classification methodologies (i.e., supervised and unsupervised), we are able to identify significant areas of concern today and potential new directions in research related to sustainability. Sentiment analysis allows us to assess how individuals perceive, comprehend, and react to the societal alignment of sustainability (or "green") policy to their thoughts and beliefs surrounding sustainability and environmental policy.

In addition, by automating literature reviews and discovery processes and providing automated decision-making capabilities, NLP can facilitate the rapid development of policies based on empirical evidence and increase the effectiveness of collaboration between stakeholders in the development of sustainability policies.

5. Integrated Intelligent And Sustainable Systems

Augmented Intelligence enables the creation of smart and sustainable solutions by integrating Machine Learning, Deep Learning and Natural Language Processing, allowing for the realtime monitoring, predictive management of real and potential activities and dynamic adjustment to both real and anticipated events through feedback from a variety of channels[3][4]. By integrating multiple applications, such as energy optimisation, traffic analytics and customer engagement, Augmented Intelligence creates opportunities for building smart and sustainable cities. In addition to enhancing the efficacy, performance and scalability of the various integrated AI-based solutions, Augmented Intelligence can also enhance the effectiveness of deployed smart cities by enhancing interconnectivity of currently isolated systems (e.g., Environmental System, Urban System and Smart City System) into one seamless entity. Augmented AI Technologies are also instrumental in the development of solutions to the interconnectivity issues of Environmental and Urban Systems that are both more effective, transparent, equitable and accountable [7].

6. Applications of Intelligent and Sustainable Systems

A. Smart Energy Systems and Grids

Machine learning and deep learning techniques have been implemented into energy smart systems so that they can aid with demand forecasting, the integration of renewable energy sources and the balancing of load. By using supervised learning algorithms, we are able to forecast short and long-term global energy consumption, allowing better and more efficient energy distribution to seek out solutions instead of using fossil fuels. Deep learning techniques increase the reliability and robustness of the electrical grid through the provision of capabilities for predicting faults and enabling predictive maintenance. This results in a greater level of energy efficiency, while simultaneously producing a more sustainable environment [1][2].

B. Smart Cities and Urban Sustainability

The use of integrated intelligent systems to enhance various areas of urban living (traffic flow, public services, waste management and energy consumption) is an example of smart city development. Smart cities can leverage deep learning techniques to accomplish these tasks by analysing traffic patterns, reducing congestion and emissions and increasing the quality of urban living through the use of data collected from social media.

Accessing data does not only allow for more equitable and efficient urban planning, but enables smart cities to provide improved governance in response to the needs of their citizens. A greater

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
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understanding of citizen feedback on social media and implementing solutions using deep-learning techniques enables smart cities to create an environment in which citizens feel heard and respected [4][6].

C. Environmental Monitoring and Climate Intelligence

Most of the uses of convolutional neural networks with satellite and remote sensing data in the field of deep learning are for monitoring land-use changes, tracking air pollution or monitoring natural disasters, in addition to being a tool for providing early warning and warning systems (i.e., assessing Climate risk). The aforementioned technologies represent an excellent basis for providing higher quality decision support in terms of the protection of our planet and for more effectively managing disasters. [3]

D. Sustainable Agriculture and Food Systems

Applying deep learning and machine-learning techniques has greatly increased the ability to accurately estimate crop yield, determine soil quality, and assess the level of drought stress through precision farming. By relying on the use of data in determining how much irrigation and fertilization is used, farmers will minimise their input but receive a greater output as a result of improved food security and an increased ability for agriculture to keep pace with the growing needs of the world for food. In addition, these technologies will allow for sustainable food production and environmental protection by preserving the earth's resources [5].

E. Intelligent Transportation Systems

Using deep learning in transportation systems allows for the use of adaptive traffic signal control, autonomous vehicle operation, and proactive maintenance scheduling. In addition to minimizing congestion and optimizing travel routes, these systems also help to decrease greenhouse gas emissions and reduce fuel usage because they use less energy than conventional systems. In addition, intelligent transportation infrastructure is a major player in creating sustainable urban mobility and minimizing our negative impact on the environment.

F. Policy Analysis and Decision Support Systems

Through the extraction of insight from environmental regulations, scientific literature, and public discourse, Natural Language Processing supports sustainability-oriented policy analysis. Evidence-based policymaking and increased collaboration between governments, researchers, and industry stakeholders can be supported using topic modeling, sentiment analysis, and automated document analysis.[1][6]

7. Challenges And Future Research Directions

AI-enabled Sustainable Systems have many advantages. However, there are a lot of Challenges for Sustainable Systems Utilizing AI: An example of this Challenge would be the Environmental Impact Associated with the Training of Large Deep-Learning Models because of the High Computational and Energy Costs. Additionally, other barriers that limit the Global Acceptance and Use of Deep Learning Models include not having enough Quality Data available, problems with Bias in Data, and the inability of users to understand the Models produced by these Algorithms [5][7]. Therefore, further Research is Necessary to create Energy-Efficient Learning Algorithms, Develop Explainable AI Models, and Conduct Federated Learning Methodologies (e.g. based upon Federal Data Security Laws) that Preserve User Privacy. Furthermore, the Integration of Sustainable Design Elements into AI Systems and an Interdisciplinary approach to Creating Sustainable AI Technologies must occur.

8. Conclusion

Intelligent systems development and their environmental/social sustainability relationship need to understand machine learning, deep learning and natural language processing. All three (3) technologies enable Predictive Analytics, System Optimisation, and Decision Support, which can lead to the orderly

ISSN: 2347-1697
International Journal of Informative & Futuristic Research (IJIFR)
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and rational growth of Sustainable Development Solutions across many areas. AI-based technologies will continue to proliferate and provide support for the sustainable development of the environment and socio-economically viable solutions in the future if Responsible Research and Application continue.

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