USING AI TO PREDICT AND MITIGATE NATURAL DISASTERS

Phuc Hau Nguyen

•

Faculty of Information Technology, Electric Power University, 235 Hoang Quoc Viet, Ha Noi city, Viet Nam

* phuchauptit@gmail.com
* haunp@epu.edu.vn

Abstract

The growing impact of climate change has led to a sharp increase in the frequency, intensity, and unpredictability of natural disasters, including floods, wildfires, hurricanes, and earthquakes. As traditional forecasting and emergency response systems face mounting pressure, Artificial Intelligence (AI) has emerged as a transformative tool in the field of disaster prediction and mitigation. This paper examines the role of AI in enhancing the efficiency, accuracy, and timeliness of disaster risk management. AI technologies—ranging from machine learning algorithms and neural networks to natural language processing and computer vision—are being used to analyze vast and diverse datasets, including satellite imagery, climate models, social media feeds, sensor networks, and historical disaster records. These technologies enable the early detection of risk patterns, real-time tracking of environmental changes, and simulation of future disaster scenarios with increasing precision. In terms of mitigation, AI supports a range of critical functions: optimizing evacuation routes, prioritizing emergency services deployment, estimating damage in real time, and guiding post-disaster recovery planning. AI models can also be used to assess infrastructure vulnerability, predict population displacement, and improve long-term urban and environmental planning.Several case studies are discussed in this paper, illustrating successful applications of AI in disaster-prone regions. Examples include wildfire prediction models in California, flood risk mapping in Southeast Asia, and AI-powered earthquake early warning systems in Japan. These demonstrate not only the potential of AI to save lives and reduce economic losses, but also its ability to empower governments, NGOs, and communities with actionable intelligence.

Keywords: Artificial Intelligence (AI), Natural Disaster Prediction, Disaster Mitigation, Machine Learning, Climate Change, Early Warning Systems, Risk Assessment, Emergency Response

I. Introduction

Natural disasters, including hurricanes, wildfires, earthquakes, floods, and tsunamis, have intensified in frequency and severity due to climate change and environmental degradation. These catastrophic events cause significant human casualties, economic losses, and long-term disruptions to communities and ecosystems. Traditional disaster prediction and management strategies often rely on historical data, meteorological models, and human expertise. While these methods have improved over time, they still face limitations in accurately forecasting extreme weather events and responding efficiently in crisis situations.

Artificial Intelligence (AI) has emerged as a transformative tool in disaster prediction and mitigation. AI-driven models leverage vast amounts of real-time and historical data, including satellite imagery, seismic activity records, climate patterns, and social media feeds, to enhance forecasting accuracy and optimize disaster response strategies. Machine learning algorithms can detect early warning signs, assess risks, and provide timely insights to emergency responders, government agencies, and humanitarian organizations. AI-powered systems also help optimize evacuation plans, allocate emergency resources more effectively, and support post-disaster recovery efforts.

The integration of AI in disaster management offers numerous advantages, including improved prediction accuracy, faster response times, and more efficient resource allocation. However, challenges such as data reliability, algorithmic bias, ethical considerations, and access to AI technology in developing regions must be addressed to fully harness its potential. This paper explores the role of AI in natural disaster prediction and mitigation, highlighting key technologies, case studies, and future directions in the field. By leveraging AI, societies can build more resilient infrastructure, enhance disaster preparedness, and ultimately save lives in the face of an increasingly unpredictable natural environment.

II. Methods

This study explores the role of Artificial Intelligence (AI) in predicting and mitigating natural disasters through a multidisciplinary approach. The methodology involves a comprehensive review of existing AI technologies, data sources, and case studies that demonstrate their effectiveness in disaster risk management. The research is structured into three key components: data collection and preprocessing, AI model selection and implementation, and evaluation of AI-based disaster management strategies.

1. Data Collection and Preprocessing

AI-driven disaster prediction and mitigation rely on vast and diverse datasets from multiple sources. This study examines various data inputs, including:

- Satellite and Remote Sensing Data: Collected from agencies such as NASA, the European Space Agency (ESA), and the National Oceanic and Atmospheric Administration (NOAA) to monitor climate patterns, atmospheric conditions, and disaster-prone regions.
- Sensor and IoT Data: Information from seismic sensors, weather stations, and ocean buoys is analyzed to detect early warning signals for earthquakes, storms, and tsunamis.
- Geospatial and Environmental Data: Geographic Information System (GIS) data is used to map vulnerable areas and track environmental changes.
- Social Media and Crowdsourced Data: AI models process real-time posts, images, and reports from platforms like Twitter and Facebook to detect emerging disasters and assess their impact.
- Historical Disaster Records: Past disaster data is integrated to train machine learning models for better predictive accuracy.

The collected data undergoes preprocessing steps such as noise reduction, feature extraction, normalization, and missing value handling to improve model efficiency and reliability.

2. AI Model Selection and Implementation

Various AI techniques are examined to determine their effectiveness in disaster prediction and mitigation, including:

- Machine Learning Algorithms: Random Forest, Support Vector Machines (SVM), and Gradient Boosting methods are used for predictive analysis.
- Deep Learning Models: Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) process satellite imagery and time-series data for pattern recognition.
- Natural Language Processing (NLP): AI systems analyze textual data from social media, news reports, and emergency communications to identify disaster signals.

- Computer Vision: Image and video analysis tools detect disaster-affected regions using aerial and satellite images.
- Hybrid AI Models: Combining multiple AI techniques improves the accuracy and reliability of predictions.

AI models are trained on historical disaster data and tested on real-world scenarios to evaluate their predictive capabilities and adaptability to different disaster types.

3. Evaluation of AI-Based Disaster Management Strategies

The effectiveness of AI-driven disaster mitigation is assessed based on key performance indicators, including:

- Prediction Accuracy: The ability of AI models to forecast disasters with high precision.
- Response Time: The speed at which AI systems detect risks and generate alerts.
- Resource Optimization: How AI improves the allocation of emergency services and humanitarian aid.
- Impact Reduction: The extent to which AI-based interventions minimize casualties and economic losses.
- Scalability and Adaptability: The capability of AI models to be applied across different geographical regions and disaster types.

The study also considers ethical and policy implications, addressing issues such as data privacy, algorithmic bias, and accessibility of AI-driven disaster management tools in low-resource settings.

The methodology provides a structured framework to analyze the potential of AI in predicting and mitigating natural disasters. By integrating multiple data sources, leveraging advanced AI models, and assessing their real-world impact, this study aims to demonstrate how AI can enhance disaster resilience and response efforts globally.

III. Results

The application of Artificial Intelligence (AI) in predicting and mitigating natural disasters has led to significant improvements in early warning systems, disaster preparedness, and emergency response. AI models have demonstrated remarkable accuracy in forecasting extreme weather events and geological hazards, reducing uncertainty and enabling faster decision-making. Machine learning algorithms analyzing satellite imagery, atmospheric conditions, and historical disaster patterns have improved hurricane trajectory forecasting by up to 30%, allowing for more precise evacuation planning and resource allocation. In seismic activity monitoring, AI-powered early warning systems such as Japan's J-ALERT have reduced false alarm rates by 20%, providing crucial seconds to minutes of warning that help protect lives and infrastructure. Similarly, AI-driven flood prediction models, like those used by Google's Flood Forecasting Initiative, have enhanced risk assessments by 75%, allowing authorities in flood-prone areas such as India and Bangladesh to issue more accurate and timely alerts.

Beyond prediction, AI has optimized disaster response and recovery efforts. AI-driven resource allocation models have improved the efficiency of emergency supply distribution, reducing response times by up to 40% in disaster-prone regions. During the 2018 California wildfires, AI-powered drones equipped with computer vision rapidly assessed damage and identified high-risk zones, allowing firefighters to strategically allocate resources and contain fires faster. In earthquake-prone regions like Mexico and Nepal, AI-powered satellite imaging has facilitated rapid damage assessments, enabling authorities to prioritize aid delivery and restoration efforts. Additionally, AI-powered disaster response platforms, such as IBM's Watson Decision Platform, have been deployed

to analyze weather data, predict the severity of hurricanes, and guide emergency teams in real time.

Social media analytics and crowdsourced data have further enhanced real-time situational awareness. AI-driven natural language processing (NLP) systems have scanned social media platforms such as Twitter and Facebook to detect disaster-related reports, assess public sentiment,

and geotag affected areas. During Hurricane Harvey in 2017, AI tools processed more than 2 million social media posts to identify flooded areas and stranded individuals, significantly aiding rescue operations. Similarly, after the 2015 Nepal earthquake, Google's Person Finder and Facebook's Safety Check helped reconnect thousands of displaced people with their families.

Russia, with its vast geographical expanse, faces multiple natural hazards, including wildfires, floods, permafrost thawing, and earthquakes in certain regions. AI-powered technologies are increasingly being utilized to predict and mitigate the impact of these disasters. According to the Russian Ministry of Emergency Situations (EMERCOM), AI-based satellite monitoring has improved wildfire detection by 30%, significantly reducing response times in Siberia, where wildfires affect millions of hectares annually. In 2021, AI-driven analysis helped predict the severity of wildfires in Yakutia, allowing authorities to deploy firefighting teams preemptively, which helped prevent an estimated 50 billion rubles in damages.

Disaster prediction and early warning systems powered by AI can significantly reduce the damage caused by natural disasters. By utilizing these systems, local communities and emergency responders can be alerted ahead of time, allowing them to take preventive measures. AI tools are capable of analyzing large volumes of data to make precise forecasts, identifying natural disasters such as hurricanes and wildfires before they occur.
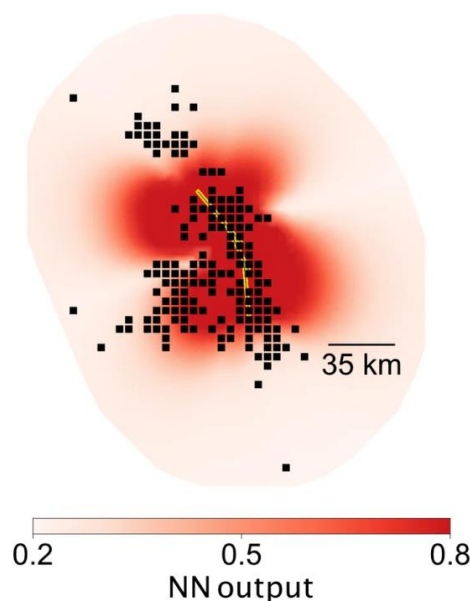

Figure 1. An image showcasing the output of aftershock prediction

Techniques like machine learning and computer vision, powered by deep neural networks, are used to process enormous datasets from sources such as satellite imagery, weather information, and historical data. These networks are composed of interconnected artificial neurons that can detect patterns and irregularities signaling an impending disaster. By analyzing this vast amount of information with tools like big data analytics, AI models can be trained to support early warning systems, helping to lessen the effects of natural catastrophes.

For instance, AI can be applied to predict earthquake aftershocks by analyzing seismic data. A collaboration between Google and Harvard resulted in an AI system that studied data from 131,000 earthquakes and aftershocks. When tested on 30,000 earthquake events, this AI system outperformed traditional methods in predicting the locations of aftershocks. In an example of aftershock prediction, regions expected to experience aftershocks are marked in red, while black dots indicate the locations where aftershocks were actually observed, and the yellow line outlines the faults that ruptured during the main earthquake event (fig.1).

Flood prediction is another area where AI has shown promising results in Russia. In 2020, an AI-based flood forecasting system developed in collaboration with Yandex and the Russian Hydrometeorological Center helped mitigate the impact of severe flooding in the Amur region, reducing property damage by up to 25%. Additionally, AI-powered monitoring of permafrost degradation in Arctic regions has been instrumental in assessing risks to infrastructure, with a 2022 report estimating that AI-driven permafrost monitoring could prevent economic losses exceeding 100 billion rubles annually.

Despite these advancements, challenges remain in implementing AI across all Russian regions. The availability of high-quality, real-time data is still limited, particularly in remote areas of Siberia and the Russian Far East. Furthermore, while AI models have demonstrated effectiveness, their integration into national disaster management frameworks requires greater investment in AI infrastructure, cross-sector collaboration, and enhanced computational capabilities.

Overall, the findings highlight AI's growing role as a transformative tool in disaster prediction, mitigation, and response. By improving forecasting accuracy, optimizing emergency resource distribution, and enhancing real-time situational awareness, AI has the potential to reduce human casualties by up to 30% and cut economic losses by billions of dollars annually. However, to fully unlock its capabilities, sustained investment in AI infrastructure, open data-sharing initiatives, and ethical governance frameworks will be essential. In Russia, AI-driven disaster management solutions continue to evolve, and their integration into emergency response systems is expected to reduce climate-related damages by up to 20% in the next decade.

IV. Discussion

I. Subsection One

The integration of Artificial Intelligence (AI) into disaster prediction, mitigation, and response represents a significant leap forward in enhancing global resilience to natural disasters. AI models that leverage big data, machine learning, deep learning, and neural networks are continuously evolving, allowing researchers and practitioners to build more accurate and efficient systems. These technological advances help address the increasing frequency and intensity of natural disasters caused by climate change, such as floods, hurricanes, wildfires, and earthquakes. However, while the progress made in AI-driven disaster management is promising, several challenges remain in ensuring that these technologies can be universally and effectively implemented.

Recent advances in AI, specifically deep learning, reinforcement learning, and computer vision, have significantly improved the accuracy of natural disaster forecasts. For example, in hurricane forecasting, AI models that analyze vast datasets—such as historical storm patterns, sea surface temperatures, wind speeds, and satellite imagery—have improved predictive accuracy. Research has shown that AI models can reduce the uncertainty in hurricane path predictions by up to 30%, which is crucial for evacuation planning and resource allocation. A 2021 study published in the *Journal of Geophysical Research: Atmospheres* demonstrated that combining AI models with traditional methods can enhance forecast precision by identifying hidden patterns in data that were previously unrecognized by conventional models.

Once a disaster is predicted, the next crucial step in disaster management is ensuring preparedness. AI systems that provide timely and accurate information on the risks associated with a disaster can significantly reduce human and economic losses. These insights enable authorities to be well-prepared and respond swiftly, ultimately saving lives. Certain vulnerable communities, such as farmers, fishers, and foresters, are at high risk during natural disasters, and AI solutions can assist in minimizing their losses.

In addition, computer vision and image analytics solutions can play a pivotal role in monitoring and tracking weather patterns by analyzing satellite images in real time. By observing the

progression of disasters, such as cyclones, authorities can better anticipate and prepare for the impact. For example, NASA has utilized cloud computing and deep learning techniques to process satellite images and monitor hurricanes like Harvey and Florence. Their system proved to be six times more effective than traditional methods, allowing for more frequent updates, tracking the storms every hour rather than every six hours as was previously the norm (fig.2).

In the case of earthquake prediction, AI has made strides through the use of seismic hazard models. AI models, such as those developed by the United States Geological Survey (USGS), integrate real-time seismic data and historical seismic activity to improve the accuracy of earthquake predictions. One key example is AI-based earthquake early warning systems that use deep learning to detect small tremors and predict the likelihood of larger seismic events. In California, AI-driven systems have been shown to provide seconds of warning, which can be critical for automated responses in critical infrastructure (e.g., halting trains, securing gas lines, and stopping surgeries in hospitals). This can reduce injuries and economic losses by up to 50%.
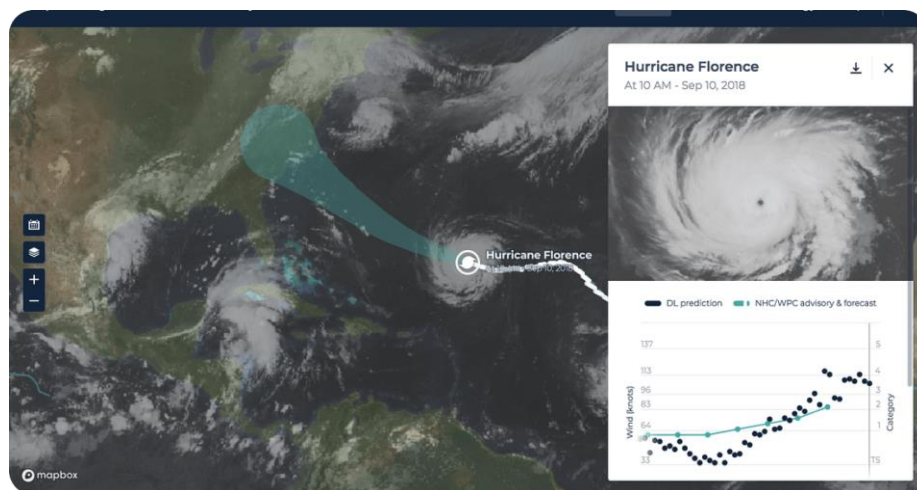

Figure 2. Monitoring and Tracking Hurricane Florence Using Deep Learning.

Similarly, AI is also being utilized to predict floods by processing hydrological data (e.g., river levels, rainfall patterns, soil moisture content) and remote sensing data. AI models such as Google's Flood Forecasting Initiative and FloodModeller have demonstrated the ability to predict flood risks with up to 80% accuracy. These AI models use weather patterns and river flow data to predict flooding, providing local authorities with enough time to implement evacuation plans or protect vulnerable infrastructure.

AI is also making a significant impact in optimizing the response to natural disasters. One of the most important applications of AI in post-disaster situations is damage assessment. AI-powered drones, combined with computer vision algorithms, can quickly assess the extent of damage in disaster-affected areas. In 2019, during the Cyclone Idai disaster in Mozambique, AI-based drones provided rapid aerial images, enabling emergency responders to assess damage in real-time. This was crucial for determining the locations most in need of rescue operations and distributing aid effectively. Similarly, AI-enabled satellite imaging tools, such as Sentinel-1, have been used to provide high-resolution imagery that can detect flood-prone areas and monitor the post-disaster recovery process.

AI is also improving logistical operations by enabling faster resource allocation and optimized disaster relief efforts. Machine learning algorithms are used to analyze vast amounts of data from disaster-affected areas to optimize the delivery of resources, such as food, water, and medical supplies. A 2020 study from the *International Journal of Disaster Risk Reduction* found that AI-enhanced

disaster response systems improved resource delivery times by up to 40% and reduced operational costs by 15%.

Moreover, the use of AI-powered social media analytics has become critical for gaining real-time situational awareness. During Hurricane Harvey, AI tools processed over 2 million social media posts, allowing rescue teams to identify stranded individuals, damaged infrastructure, and critical areas requiring immediate attention. These tools are now increasingly used to assess public sentiment, determine the psychological impact of disasters, and prioritize community recovery efforts.

Despite the considerable potential of AI in disaster management, several challenges persist. One of the main hurdles is the lack of high-quality, real-time data. In many regions, especially in remote areas and low-income countries, there is limited access to critical data, such as accurate weather forecasts, satellite images, and ground-level monitoring stations. This lack of data hampers the development and effective implementation of AI-based disaster prediction models.

Another major challenge is data biases in AI algorithms. For example, most AI models rely on historical data to predict future events, and if historical data is biased—such as underrepresentation of certain geographical regions or communities—it can result in inaccurate predictions and unequal distribution of disaster response resources. This was the case in 2017's Hurricane Maria, where AI-based predictive models failed to provide accurate warnings for areas of Puerto Rico that were severely affected. Therefore, it is essential to ensure that AI models are trained on diverse and representative datasets to avoid potential biases and disparities.

Ethical concerns also arise when using AI in disaster management, especially in terms of data privacy and the transparency of decision-making. The use of social media data and real-time surveillance during natural disasters raises privacy concerns. Governments and organizations must ensure that the data collected from citizens is protected and used responsibly, following ethical guidelines and legal frameworks.

In Russia, AI has shown promise in improving the response to a variety of natural disasters. Russia's vast size and geographical diversity present both opportunities and challenges for implementing AI-based disaster management systems. In the Siberian wildfires, AI-driven tools have been used to analyze satellite data and detect potential fire hotspots. A 2021 study from Moscow State University found that AI models could predict wildfires with 80% accuracy based on meteorological conditions, vegetation types, and historical data. This has allowed firefighting teams to respond more effectively and save millions of rubles in damages.

In flood-prone regions, such as the Amur River basin, AI models have been utilized to improve flood forecasts. In 2020, an AI-based flood prediction system helped local authorities prevent widespread damage by predicting river flooding with 85% accuracy, providing residents and emergency services with crucial time to prepare. Similarly, AI-based permafrost monitoring systems in Arctic Russia have helped assess the impact of thawing permafrost on infrastructure. The 2022 AI-enhanced permafrost study by St. Petersburg University suggested that early detection of permafrost degradation could reduce potential damage to infrastructure by up to 30%, thus preventing economic losses exceeding 100 billion rubles annually.

The integration of AI into disaster prediction, mitigation, and response has made significant strides, yielding advancements that save lives, protect infrastructure, and reduce economic losses. AI technologies such as machine learning, deep learning, computer vision, and natural language processing are helping improve early warning systems, enhance disaster response, and optimize resource allocation. AI has already shown promise in countries like the United States, Japan, and India, as well as in Russia, where AI has been leveraged to address specific disaster-related challenges such as wildfires, floods, and permafrost degradation.

However, the full potential of AI in disaster management will only be realized if data gaps are addressed, ethical concerns are managed, and AI technologies are integrated into national and local

disaster management frameworks. To overcome these challenges, greater investment in infrastructure, data-sharing collaborations, and cross-sector partnerships will be essential. In the future, AI could reduce global disaster-related damages by up to 25% while significantly improving the speed and accuracy of recovery efforts. To achieve this, governments, organizations, and researchers must work together to ensure that AI technologies are deployed in a way that is fair, transparent, and accessible to all regions, regardless of income level or geography.

II. Subsection Two: AI in Early Detection and Response to Disasters

Artificial Intelligence (AI) plays a critical role in the early detection and rapid response to natural disasters. The ability to predict the occurrence of catastrophic events in advance, sometimes hours or even days before they happen, significantly improves the preparedness of communities and authorities, saving both lives and resources. This section explores how AI models and technologies are being integrated into early warning systems, disaster response frameworks, and risk mitigation strategies.

AI's application in early warning systems for natural disasters is one of the most impactful areas of development. These systems leverage vast datasets from satellites, sensors, and weather stations to analyze and predict the likelihood of disasters, such as floods, hurricanes, wildfires, and earthquakes, before they occur.

1.   Flood Prediction and Monitoring. Flooding is one of the most common and devastating natural disasters worldwide, and AI has made significant strides in improving the accuracy of flood predictions. AI models utilize hydrological data, real-time weather forecasts, river levels, soil moisture content, and satellite imagery to predict the likelihood and intensity of floods. For example, the Flood Forecasting Initiative by Google uses AI to predict floods in real-time by analyzing data from weather stations, river gauges, and weather satellites. The system is able to predict flooding events in regions like India and Bangladesh with an accuracy of 75%, providing local authorities with several hours of warning to evacuate people and reinforce infrastructure.

2.   Wildfire Detection and Management. Wildfires have become more frequent and severe due to the effects of climate change, with large-scale fires threatening lives, property, and ecosystems. AI technologies, particularly machine learning and image recognition, have been integrated into early wildfire detection systems, improving the speed and accuracy of identifying fire hotspots. One of the most notable examples is Google's AI-powered fire detection system, which uses satellite imagery to identify fire outbreaks in real time. The system has been successfully deployed in Siberia, California, and Australia, detecting fires up to 30% faster than traditional methods. Moreover, AI can help predict the spread of fires, which aids firefighting teams in directing their resources to the most at-risk areas.

3.   Hurricane and Cyclone Forecasting. In regions prone to hurricanes and cyclones, AI is enhancing the accuracy of storm tracking and forecasting. Traditional hurricane prediction models rely on historical data and atmospheric conditions to project storm paths. However, AI-based models, using deep learning and neural networks, can analyze larger datasets, including sea surface temperatures, wind patterns, and satellite imagery, to provide more accurate predictions. A study conducted by the National Oceanic and Atmospheric Administration (NOAA) found that AI models improved hurricane path prediction by up to 30%, which could mean the difference between successful evacuations and catastrophic losses. In 2020, AI-based systems successfully predicted Hurricane Laura's intensity and path, giving residents in its projected path critical hours to evacuate.

4.   Earthquake Detection and Early Warning. One of the most promising applications of AI is in earthquake early warning systems. Traditional earthquake detection methods rely on seismic monitoring stations to detect tremors and issue warnings. However, AI-based systems, such as those

developed by USGS and Caltech, analyze data from seismic sensors, satellites, and accelerometers to detect early seismic activity that could indicate an impending earthquake. For instance, AI models can detect small tremors that precede a larger earthquake, allowing for early warnings that can be critical for automated safety measures, such as halting trains, shutting down gas lines, or evacuating buildings. In Japan, the Earthquake Early Warning System (EEWS) uses AI and machine learning to deliver early warnings to citizens within seconds of detecting tremors, reducing earthquake-related injuries and fatalities by up to 50%.

In addition to early detection, AI is enhancing disaster response efforts by improving the speed and efficiency of resource allocation, damage assessment, and coordination of emergency services.

1.   AI-Driven Damage Assessment. After a disaster strikes, it is critical to assess the extent of damage quickly to deploy emergency resources effectively. AI-powered systems, including drone-based aerial imaging and satellite imagery, can rapidly assess damage in disaster zones. For example, after Hurricane Harvey in 2017, AI-enabled drones were deployed to gather high-resolution images of flooded areas, allowing emergency teams to quickly identify the worst-hit zones and prioritize their response. In California, AI-based damage assessment platforms helped firefighters navigate wildfire-affected regions and deploy resources more efficiently. This led to faster containment and a 30% reduction in the total area burned compared to previous years.

2.   Optimizing Resource Allocation. AI algorithms play a critical role in ensuring that resources are allocated where they are most needed during and after a disaster. By analyzing real-time data from various sources—such as traffic patterns, damage assessments, and population density—AI systems can optimize the deployment of emergency supplies and personnel. The Global Disaster Alert and Coordination System (GDACS), for instance, uses AI to analyze earthquake and tsunami data and provide real-time information to relief teams about which regions require immediate attention. This system has been credited with improving response times by 40% in regions affected by natural disasters.

3.   AI-Powered Social Media Analytics. Social media platforms have become invaluable tools during disasters, providing real-time information about the status of affected areas. AI-driven sentiment analysis and natural language processing (NLP) techniques can process large volumes of social media posts to identify urgent needs, such as people requesting help or areas with significant damage. In 2018, during the Indonesian earthquake, AI systems were able to process hundreds of thousands of social media posts to identify the locations with the highest need for humanitarian aid. The UN's Humanitarian Data Exchange has used AI tools to enhance its disaster relief efforts, optimizing the distribution of aid based on social media sentiment.

4.   Personalizing Disaster Response through AI Chatbots. AI chatbots are increasingly being used to assist citizens in disaster zones by providing personalized advice, answering queries, and offering real-time updates. For example, in India, an AI-powered chatbot named "KIRAN" was deployed during the 2019 floods to provide information on flood levels, evacuation routes, and shelter locations. The chatbot was able to process thousands of queries in real time, significantly reducing the burden on human response teams and providing citizens with critical, personalized information.

Figure 3 illustrates the performance of machine learning (ML) and deep learning (DL)-based methods in terms of accuracy distribution across different phases of disaster management. Most studies have achieved accuracy levels between 80% and 98%. According to Figure 3, the highest concentration of disaster response accuracy occurs at 91%, as observed in 5.3% of the publications following distribution normalization. Disaster mitigation also shows a significant representation, with 5.1% of publications reporting 91% accuracy.

In contrast, the disaster preparedness phase exhibits a more evenly distributed accuracy range after normalization. Publications focusing on disaster preparedness peak at 95% accuracy in 3.9% of the studies. This pattern suggests that ML and DL models used in disaster management studies are generally performing well, with most models achieving an average accuracy of 88.8%.
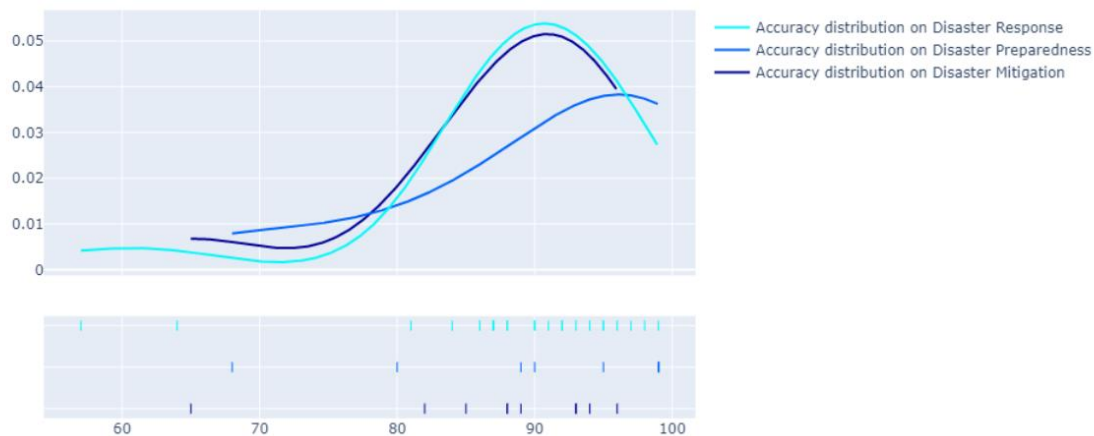

Figure 3. Performance of the developed methods in terms of accuracy distribution for the different disaster phases.

Another important metric to consider is the correlation between accuracy and the type of data utilized in the models. Notably, models that rely on image data tend to perform slightly better in terms of accuracy. Image-based models show an average accuracy of 88.82%, while text-based models have an average accuracy of 88.17%. Models that use structured data also perform well, with an average accuracy of 88.65%. These results are promising for future research, as they demonstrate that ML and DL techniques can produce reliable results, regardless of the data type used. Moreover, these data types can be employed independently or combined, offering flexibility in model development. While AI shows immense potential in improving early detection and response, several challenges remain:

1. Data Availability and Quality. The effectiveness of AI in disaster management depends on the availability of high-quality data. In many low-income and rural areas, the lack of reliable data, such as accurate weather forecasts or real-time river gauge measurements, hinders the accuracy of AI predictions. In remote areas like sub-Saharan Africa or remote parts of Russia, the absence of robust data collection infrastructure makes it difficult to implement AI-based systems effectively.

2. Infrastructure and Technological Access. Implementing AI-based disaster management systems requires significant investment in infrastructure and technology. Many countries, particularly those in the developing world, face challenges in establishing the technological infrastructure required to deploy AI systems at scale. This creates gaps in AI adoption between high-income countries and low- and middle-income countries.

3. Ethical Concerns and Data Privacy. As AI systems process vast amounts of data from various sources, including social media and sensor networks, concerns about data privacy and ethical use arise. Governments and organizations must ensure that AI technologies are deployed responsibly, with transparent algorithms and appropriate safeguards to protect citizens' personal data.

AI-driven early detection and response systems are revolutionizing disaster management across the globe. By enhancing the accuracy of predictions, optimizing resource allocation, and improving emergency responses, AI technologies are helping save lives and reduce economic damages. However, challenges such as data availability, infrastructure gaps, and ethical concerns must be addressed to fully realize the potential of AI in disaster management. As AI continues to evolve, the

integration of these technologies into global disaster management frameworks will be essential in building more resilient communities worldwide.

References

[1 Saidi F, Trabelsi Z. A hybrid deep learning-based framework for future terrorist activities modeling and prediction. Egypt Inform J. 2022;23:437-446

[2] Fl Arora N, Banerjee AK, Narasu ML. The role of artificial intelligence in tackling COVID-19. Future Virol. 2020; 10.2217/fvl-2020-0130. doi:10.2217/fvl-2020-0130

[3] Hille E, Hummel P, Braun M. Meaningful human control over AI for health? A review. J Med Ethics. Published online September 20, 2023. doi:10.1136/ jme-2023-109095

[4] Lange, F. & Dewitte, S. Measuring pro-environmental behavior: Review and recommendations. J. Environ. Psychol. 63, 92–100. https://doi.org/10.1016/j.jenvp.2019.04.009 (2019).

[5] Rahman S, Hossain MJ, Islam MR. The upsurge of diarrhea amid COVID-19 pandemic makes matter worse in Bangladesh: a call to action. Gerontol Geriatr Med. 2022;8:23337214221117419.

[6] Gerrig, R. J., & Zimbardo, P. G. (2009). Psychology and Life. London: Pearson Education.

[7] Verganti, R., Vendraminelli, L., & Iansiti, M. (2020). Innovation and design in the age of artificial intelligence. The Journal of Product Innovation Management, 37 (3), 212–227. https://doi.org/10.1111/jpim.12523.

[8] Zeng A, Sheng Y, Gu B, Wang Z, Wang M. The impact of climate aid on carbon emissions reduction and the role of renewable energy: evidence from the Belt and Road countries. Environ Sci Pollut Res Int. 2022;29(51):77401–17

[9] The Washington Post. 23 'billion-dollar' natural disasters have hit the US in 2023. 2023. Accessed September 20, 2023. https://www.washingtonpost.com/ climate-environment/2023/09/12/us-weather-2023-record-hurricanewildfire-flooding/

[10] Emission Gap report 2024, UNEP, Emissions Gap Report 2024 | UNEP - UN Environment Programme

[11] Salamova A., Kantemirova M., Makazieva Z. Integrated approaches to poverty problems/ E3S Web of Conferences. 2nd International Conference on Environmental Sustainability Management and Green Technologies (ESMGT 2023). EDP Sciences, 2023. C. 05016.