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Artificial Intelligence (AI) to Build Climate Models to Improve Weather Forecasting as Torrential Rains, Floods and Droughts Proliferate Across the Vast Country

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Abstract: *Global warming has triggered more intense clashes of weather systems in India in recent years, increasing extreme weather events, which the independent Centre for Science and Environment estimates have killed nearly 3,000 people this year. Weather agencies around the world are focussing on AI, which can bring down cost and improve speed, and with a recent Google-funded model found to have outperformed conventional methods. Accurate weather forecasting is particularly crucial in India, a country of 1.4 billion people, many impoverished, and the world's second-largest producer of rice, wheat and sugar Using AI with an expanded observation network could help generate higher-quality forecast data at lower cost. The increasing frequency and intensity of torrential rains, floods, and droughts due to climate change present significant challenges to weather forecasting and disaster preparedness. Artificial Intelligence (AI) offers transformative potential in building advanced climate models to address these challenges. By integrating vast datasets, including satellite imagery, historical weather records, and real-time sensor data, AI enhances the accuracy and resolution of climate predictions. Machine learning algorithms can identify complex patterns, simulate localized weather phenomena, and predict extreme weather events with greater precision. This paper explores the role of AI-driven climate models in improving weather forecasting, enabling proactive responses to mitigate the impacts of climate-induced disasters across diverse regions. Enhanced forecasting through AI not only safeguards lives and livelihoods but also supports sustainable resource management in the face of escalating climate uncertainties*

Keywords: AI, ML, Flood, climate change, disaster relief, weather forecasting

I. INTRODUCTION

Artificial Intelligence (AI) vs. Machine Learning (ML)

You might hear people use artificial intelligence (AI) and machine learning (ML) interchangeably, especially when discussing big data, predictive analytics, and other digital transformation topics. The confusion is understandable as artificial intelligence and machine learning are closely related. However, these trending technologies differ in several ways, including scope, applications, and more.

Increasingly AI and ML products have proliferated as businesses use them to process and analyze immense volumes of data, drive better decision-making, generate recommendations and insights in real time, and create accurate forecasts and predictions.

What is Artificial Intelligence?

Artificial intelligence is a broad field, which refers to the use of technologies to build machines and computers that have the ability to mimic cognitive functions associated with human intelligence, such as being able to see, understand, and respond to spoken or written language, analyze data, make recommendations, and more.

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Although artificial intelligence is often thought of as a system in itself, it is a set of technologies implemented in a system to enable it to reason, learn, and act to solve a complex problem.

What is Machine Learning?

Machine learning is a subset of artificial intelligence that automatically enables a machine or system to learn and improve from experience. Instead of explicit programming, machine learning uses algorithms to analyze large amounts of data, learn from the insights, and then make informed decisions.

Machine learning algorithms improve performance over time as they are trained—exposed to more data. Machine learning models are the output, or what the program learns from running an algorithm on training data. The more data used, the better the model will get.

Differences between AI and ML

Now that you understand how they are connected, what is the main difference between AI and ML?

While artificial intelligence encompasses the idea of a machine that can mimic human intelligence, machine learning does not. Machine learning aims to teach a machine how to perform a specific task and provide accurate results by identifying patterns.

Let's say you ask your Google Nest device, "How long is my commute today?" In this case, you ask a machine a question and receive an answer about the estimated time it will take you to drive to your office. Here, the overall goal is for the device to perform a task successfully—a task that you would generally have to do yourself in a real-world environment (for example, research your commute time).

In the context of this example, the goal of using ML in the overall system is not to enable it to perform a task. For instance, you might train algorithms to analyze live transit and traffic data to forecast the volume and density of traffic flow. However, the scope is limited to identifying patterns, how accurate the prediction was, and learning from the data to maximize performance for that specific task.

Artificial intelligence

AI allows a machine to simulate human intelligence to solve problems

The goal is to develop an intelligent system that can perform complex tasks

We build systems that can solve complex tasks like a human

AI has a wide scope of applications

AI uses technologies in a system so that it mimics human decision-making

AI works with all types of data: structured, semi-structured, and unstructured

AI systems use logic and decision trees to learn, reason, and self-correct

Machine learning

ML allows a machine to learn autonomously from past data

The goal is to build machines that can learn from data to increase the accuracy of the output

We train machines with data to perform specific tasks and deliver accurate results

Machine learning has a limited scope of applications

ML uses self-learning algorithms to produce predictive models

ML can only use structured and semi-structured data

ML systems rely on statistical models to learn and can self-correct when provided with new data

Ai for flood adaptations and disaster relief

If, like me, you feel like the amount we hear about devastating floods has drastically increased in the last few years, know that it is not just a feeling. While I can't say whether the media is more likely to pick up and report on floods, according to new research from NASA the proportion of people across the world living in flood-prone areas has risen by 20% to 24% since 2000. This is 10 times greater than the number previous models had predicted.

Floods can be devastating. I am Italian, so I felt very emotional this past May when I followed the news about what has been defined as Italy's worst flooding in 100 years around the areas where my dad grew up. 14 people died, and the

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affected areas are still struggling to recover. While the floods in Italy have quite literally hit close to home for me, they are just a small example of what a flood can do. In Pakistan, the floods of 2022 have caused more than 1,700 deaths. Then there's the aftermath: floods leave a trail of destruction that takes a long time to overcome. Debris and hardened mud need to be cleaned up; houses and infrastructures need to be rebuilt; rivers banks need to be secured; crops might be irreparably damaged.

As for many climate-related events, scientifically identifying a direct causal link between climate change and floods can be challenging, because of the many variables that play a role in flooding events. In its 2012 report on extreme events and disasters, the Intergovernmental Panel on Climate Change (IPCC) noted how, while climate change may not induce floods directly, it exacerbates many of the factors that do, increasing the likelihood and the intensity of floods. For instance, in September 2023 massive flooding in Libya led to two dams bursting and a catastrophic death toll of more than 11,300 people. A study from the World Weather Attribution reported that the amount of rain that fell in Libya was up to 50% higher than it would have in a world where people had not changed the climate, although the study has a high level of uncertainty.

Floods and Climate Change

There are several reasons that might cause floods: heavy rains, ocean waves coming on shore, or snow melting quickly. As we have mentioned, climate change has impacted many factors connected to floods, increasing the likelihood and the intensity of floods. Moreover, floods are also worsened by our land management practices, which might affect the risk of floods by eliminating many natural features that would have otherwise slowed and absorbed rainwater. Paved roads, for instance, block water from being absorbed, while deforestation increases rainwater runoff and the risk of mudslides.

Floods may also be affected by other climate-related events. For instance, flash floods might increasingly follow wildfires in what the New York Times has defined as "a deadly cascade of climate disasters," as wildfires destroy vegetation, making the soil less permeable.

While floods can happen within minutes or over a long period of time, flash floods are the ones we are likely to hear about the most, as they are responsible for the greatest number of flood-related fatalities. Flash floods rise quickly, combining the hazard of floods with speed and unpredictability, and are most often caused by heavy rains over a short period (usually six hours or less). Scientists expect that, as the climate warms, flash floods will get "flashier," meaning that the timing of the floods will get shorter while the magnitude increases.

With floods likely to continuously increase in likelihood and impact, improving our ability to mitigate and respond to floods is both vital and urgent. AI can lend a (data-based) hand.

AI Help

AI is a good instrument to analyse large amounts of data quickly and relatively cheaply. This ability can be useful in the longer term, to inform adaptation plans to mitigate the impacts of potential floods, but also in the immediate aftermath, for disaster management.

Before Floods: Developing Adaptation Plans

AI can be used to analyse different data sources — such as climate models, satellite imagery and weather patterns — to identify areas with a higher vulnerability to floods. These insights can be used by decision makers and communities to create tailored adaptation plans to improve the resilience of their local area and provide resources to high-vulnerability areas.

For instance, in the case of coastal communities, AI can be used in flood modelling to help predict the potential impact of sea-level rise or extreme weather events on infrastructures and homes. AI can analyse data on topography, land use, and urban development to identify areas that are more vulnerable to flooding. Decision makers can use this information to plan and implement proactive measures such as building sea walls, reinforcing or relocating infrastructure, or implementing zoning regulations to avoid constructions on the high vulnerability areas, therefore reducing risk.

The use of AI is of course not limited to coastal communities. For example, a 2021 study used AI to assess flood vulnerability assessment in Dire Dawa, Ethiopia. Researchers used several flood-causing factors, including rainfall, slope, land use, elevation, vegetation density, river distance, geomorphology, road distance, and population density to train a model to generate a hazard map of the area. In short, the results were compared with data from historic floods in 2006, and the errors were fed back into the model until the result was appropriately close to the actual historic data. After several rounds of iteration, the model was able to provide an assessment of flood vulnerable zones for this city and its catchment, providing useful information for flood management.

After floods: post damage relief and recovery

AI can also play a role in disaster response. In a comprehensive review of uses of Machine Learning for Climate Change, Kris Sankaran highlights two types of machine learning tasks that have proven useful to support post disaster relief: creating maps from aerial imagery, and retrieving information from social media data.

First, machine learning can create accurate maps from aerial imagery to inform evacuation planning and the delivery of relief. This imagery can also be used to compare scenes pre and post disaster, which can inform damage assessment, and therefore decision making on the allocation of relief resources and reconstruction efforts.

A practical example of an AI tool for disaster management is the deep-learning

model DAHiTrA, used to to classify building damages based on satellite images after natural disasters. The model recognises the geographic features in different locations and compares images of a building, road, or bridge taken before and after a disaster to determine the level of damage. The damage assessment of homes and buildings after a natural disaster can usually take months. Since satellite images are available within 24 hours, and the model is fast, DAHiTrA allows authorities to determine the number of buildings and infrastructures impacted, as well as the extent of the damage the day after the event took place. Faster and more accurate damage assessments can help communities and governments allocate resources more effectively. The DAHiTrA team is working with government agencies, emergency management offices, and international organisations to use their model to assess building damage.

Machine learning can also be used to analyse information posted on social media. While this might sound slightly dystopic, social media data after a natural event can contain "kernels of insight." Information posted by users about places without water, or clinics without supplies which can inform relief efforts. Machine learning can analyse large volumes of these social media data and summarise it into key insights, which can inform action and plans of disaster managers.

The potential of AI in natural disaster relief has caught the attention of major international organisations. In 2021, the World Meteorological Organization (WMO), the International Telecommunication Union (ITU) and the United Nations Environment Programme (UNEP) formed the expert Focus Group on AI for Natural Disaster Management, to help lay the groundwork for the use of AI for natural disaster management.

We covered applications of AI specifically relating to floods. Even so, the same capabilities can be used for other natural events. The same applications of AI for disaster relief can also apply to tsunamis, or earthquakes. Similarly, AI can inform climate adaptation plans tailored to other climate events. Of course, the variables necessary to measure an area's vulnerability to heatwaves, for instance, might be different from those to floods, and each face their individual challenges. What doesn't change is AI's ability to process large volumes of raw data, which, with the right training datasets, can inform decisions on climate adaptation plans and disaster relief.

We have seen the use of AI before and after floods. What about during floods? Can AI be used to predict floods, even, and in particular, flash floods? Can AI help inform local communities and notify them of the need to evacuate before it's too late? The next blog of our series will focus on these questions, as we look at AI during floods: AI for early warning systems.

Man-made climate change has increased the frequency and the severity of calamities such as droughts, floods, famines, and hurricanes. This has led to automating disaster preparedness and recovery actions using AI and ML solutions. In the past 50 years, the number of recorded disasters has increased five times, and the resulting economic losses have increased seven times, according to the 2020 State of Climate Services Report by the World Meteorological Organization (WMO). Disaster Management committees are adopting technology such as Artificial Intelligence (AI) and Machine Learning (ML) to minimize the damage caused by such disasters by predicting their occurrences with great accuracy and assisting with the relief efforts.

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Drone imagery, satellite data, and climate data can train AI and ML models as Disaster preparedness technology. They can study weather patterns to predict the intensity of rain or heat waves. They can also analyze sensor data and satellite imagery to forecast the location of future hurricanes.

Role of Data and AI in Disaster Preparedness

Disaster management personnel can use data to warn residents in high-risk areas. It can also help them assess the severity of a forthcoming calamity and prepare accordingly. Insights from trained AI and ML models can help disaster management teams assign risk scores to public and private properties, enabling them to gauge infrastructure vulnerability in the event of a catastrophe.

Using Drone Imagery for Disaster Assessment

Portability, ease-of-use, and improved imaging capabilities have led to the widespread applications of drones or Unmanned Aerial Vehicles (UAV) technology. With capabilities like flight altitude and high-resolution cameras, they can help create detailed 2D images and 3D maps more precisely than satellite imagery.

Predicting Hurricanes and Cyclones with Analytics

Predicting natural disasters poses a challenge due to the many variables involved — changing wind patterns, ocean currents, tides, etc. Predictive Analytics can be invaluable tools for natural disaster management. They can assimilate new data automatically, create better physical schemes and provide high-resolution results.

Modern disaster management teams have developed high-resolution prediction models for meteorological events like winter storms, hurricanes, and tropical cyclones. These models can deliver realistic simulations of seasonal variations, global distribution, and the structure of these events.

Predicting Intense Rainfall With Past Climate Data

Extreme precipitation events in the US Midwest account for more than half of all the flood disasters in the country. Stanford University researchers have trained a Machine Learning tool to identify the conditions that lead to such events. Using AI for disaster planning and recovery, these researchers analyze the factors behind long-term changes in extreme weather events that could help predict them more accurately. To calculate the number of days with excessive rainfall, they used climate data from 1981 to 2019 that was publicly available.

They trained a Machine Learning algorithm developed to analyze grid data such as images to identify atmospheric patterns associated with severe rainfall. The algorithm outperformed the conventional statistical methods, identifying more than 90 percent of the days with an extreme downpour.

This AI technology for disaster response can predict severe precipitation in the future. It can also be applied to other disaster-prone regions.

Augmenting Satellite and Climate Data with AI

Atmospheric, Climate Science and Services (ACROSS) is an initiative of the Ministry of Earth Sciences (MoES), Govt. of India. MoES is tasked with predicting natural disasters such as tsunamis and earthquakes, ocean states, climate and weather changes such as monsoons, etc.

MoES uses Machine Learning algorithms and AI technology for disaster response to make complex mathematical calculations and analyze high-resolution spatial images for accurate forecasts. One of the objectives of ACROSS is to build an ecosystem that uses Artificial Intelligence and Machine Learning framework to deliver Big Data Analytics solutions. Using Artificial Intelligence and Machine Learning algorithms, MoES intends to improve its weather forecasting capabilities vastly. It also wants to improve the skill set of its current models across time scales.

Anticipate Flood-Related Disasters

Floods are one of the most devastating, naturally occurring disasters. Hundreds of millions of people worldwide are affected by floods each year, costing billions of dollars in damage. Unfortunately, the current forecasting and warning systems often fail to alert the authorities in time to prevent loss of life and property.

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Google has now incorporated AI for disaster recovery into its Public Alerts to predict floods with higher accuracy. The AI models are trained using information such as elevation and terrain of a given region, river level readings, and historical events. Using this knowledge, these models generate maps and simulate innumerable scenarios that involve flooding. The AI models have demonstrably predicted the frequency, location, and severity of river floods with greater precision than most traditional forecasting methods.

Twenty percent of all flood-related deaths in the world occur in India. Google has collaborated with the Ministry of Water Resources, Govt. of India, to pilot its AI flood-warning model in the Patna region.

II. CONCLUSION

Artificial intelligence has improved weather prediction technology, enabling more accurate weather fore-casting and modeling to better prepare for and respond to extreme weather events via early warning systems. Artificial intelligence enables a deeper comprehension of natural fac-tors such as climate and geography, thereby facilitating the selection of optimal sites for renewable energy. It can predict renewable energy production, adjust grid output, and guar-antee a continuous electricity supply. Moreover, artificial intelligence can optimize residential architecture by deter-mining optimal house orientation and window placement, thereby reducing energy consumption and enhancing living conditions. Addressing traffic emissions is also essential, and artificial intelligence can enhance bus systems by utilizing large data samples to develop neural networks that optimize routes, vehicle rounds, and passenger traffic. Using AI for disaster planning and recovery, these researchers analyze the factors behind long-term changes in extreme weather events that could help predict them more accurately. Artificial Intelligence (AI) has emerged as a powerful tool for advancing climate modeling and improving weather forecasting amidst the growing challenges posed by torrential rains, floods, and droughts. By leveraging vast datasets and employing sophisticated machine learning techniques, AI can enhance prediction accuracy, support early warning systems, and inform decision-making at local and national levels. The integration of AI-driven climate models provides an opportunity to better understand and mitigate the impacts of extreme weather events, ensuring more resilient communities and sustainable resource management. As climate change continues to exacerbate weather variability, investing in AI technologies and fostering interdisciplinary collaboration will be pivotal in addressing the complexities of a rapidly evolving climate system.

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