

Artificial Intelligence (AI) for disaster mitigation: how smart technology helps save lives

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Introduction

A disaster is a sudden and extreme event caused by natural or manmade processes in the earth that results in severe damage to the human life, property and the environment. These events are not caused merely by humans, but they can become more severe due to human activities such as deforestation, poor urban planning, and climate change due to environmental pollution. Earthquakes, floods, cyclones, landslides, tsunamis, volcanic eruptions, and droughts are common examples for natural disasters while crowd disasters, industrial hazards, and CBRN (Chemical, Biological, Radiological and Nuclear) disasters are human-made disasters. If disasters are identified early, safety precautions can be taken in advance, and the damages to the human lives, properties and the environment can be minimized. Further, the government funds, which should be allocated for relocation and rehabilitation, can be saved. Traditional methods of identifying disasters may not be sufficient as

the climate is changing rapidly and the population is growing fast. This is where Artificial Intelligence (AI) emerges as a powerful tool. By analyzing large amount of data, identifying patterns, and providing early warnings, AI can help predicting disasters, improving emergency response, and supporting recovery efforts. This article explores how AI supports the disaster management and contributes to building safer and more resilient communities.

Disaster management

Efficient and responsive disaster management systems minimize the loss of human lives and the environment. Disaster management has four main phases viz., preparedness, mitigation, response, and recovery as presented in Figure 1. Also, the disaster management is an ongoing process by which the responsible organization may plan for handling any emergency situation that happens due to a disaster. This will support to minimize or nullify the adverse effects due to the disaster.

Preparedness includes the plan for the emergency responders where any type of emergency situation can be handled. The main aim of this phase is developing short and long term strategies, developing early warning systems, and spreading awareness among communities. Disaster mitigation is an action to reduce or minimize the impact of adverse disaster before it happens. Mitigation parameters include building codes assessment, vulnerability analysis, hazard zonation mapping, land use management, risk mapping, and public awareness. The purpose of disaster response is to provide basic needs to victims. This includes providing food, clothes, shelters, medicine etc. During the disaster recovery, long term sustainable plans are developed to bring back all victims to their normal life. AI can be used in any phase of this disaster management cycle.

Instead of only reacting after the disaster, early actions help to minimize loss of life, property and environmental damage through

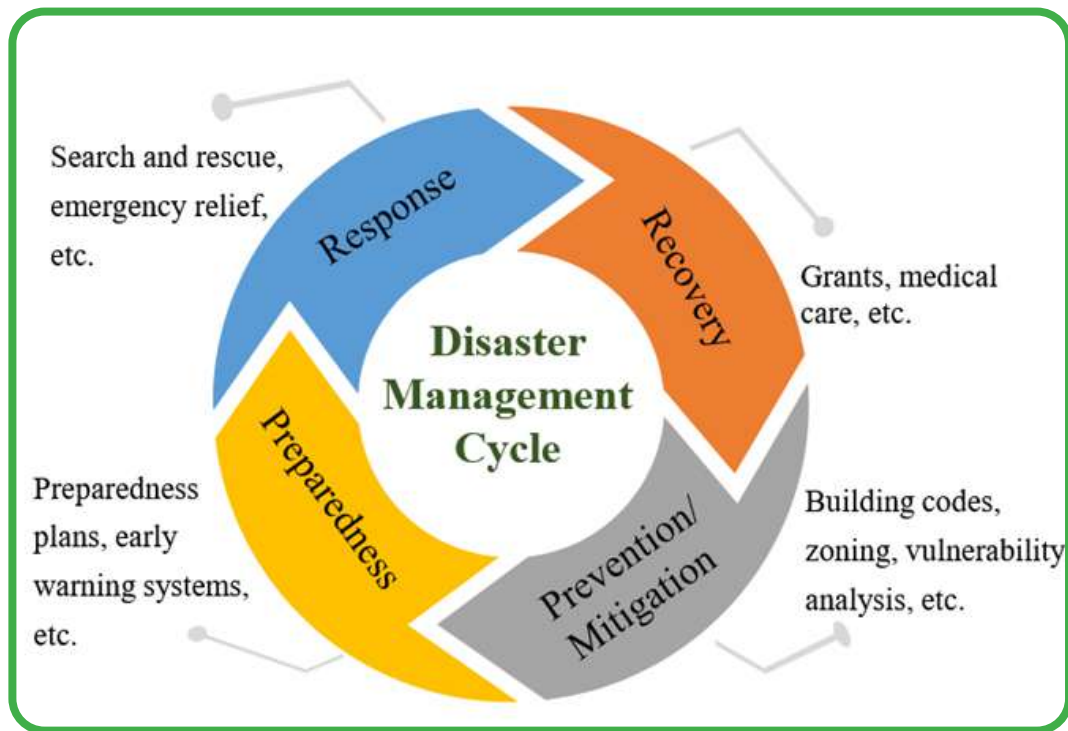


Figure 1: Disaster management cycle (Source : Gupta and Roy, 2024)

pre-planning, safety measures and risk reduction strategies. By investing in disaster management, communities become better prepared, more resilient and less vulnerable to future disasters making it the most effective and cost-efficient approach. Hence, AI can play a significant role in supporting disaster management in different steps such as analyzing large amount of data for predictions, generating early warnings, identifying the possible risks, and detecting the possibility of disasters etc.

How AI helps manage disasters

Early predictions on disasters can minimize the damages that can happen for both humans and the environment. The applications in AI in disaster management are

composed with diverse methods of overcoming the challenges in disaster prediction, mitigation and response. These methodologies force classical Machine Learning algorithms and advanced deep learning models to extract significant insights from complex data sets.

In earthquake management, AI models such as Long-Short-Term-Memory (LSTM) systems analyze temporal seismic data for forecasting earthquakes and aftershocks, while Random Forests, Neural Networks and explainable AI techniques support rapid building damage assessment and risk mapping. For landslides, hybrid models combining Support Vector Machines (SVMs), dynamic neural networks and adaptive model-switching strategies utilize

satellite, geological, and real time sensor data to deliver reliable day-ahead predictions and early warnings. Flood prediction benefits from deep learning frameworks, and video based severity classification systems that generate timely warning alarms using rainfall, soil and environmental data. Volcanic eruption prediction leverages Convolutional Neural Networks (CNNs), attention based models like VepNet, and seismic/geological data analysis for hourly forecasts and ash particle classification to support timely evacuations. AI tools for hurricanes and wildfires satellites imagery processed by CNNs, decision trees for storm intensity prediction, and deep learning for path tracking, fire detection, and propagation simulation. In addition to natural disaster management, AI techniques

How smart technology helps save lives

can be used for managing the human-made disasters such as crowd disasters, CBRN materials disasters and industrial hazards. K-Nearest Neighbor (KNN) algorithm is used for human activity recognition, and Deep Learning Algorithms are used for analyzing images for abnormal behaviors in high density crowd. In CBRN disasters, machine learning algorithms are used for analyzing sensor data and detecting CBRN compounds quickly and accurately. Further dispersion prediction models are used to forecast how dangerous materials spread to

enable faster, targeted emergency responses. These AI techniques focus on real-time detection, prediction, simulation, and response optimization related to disasters. Deep learning techniques are heavily used for visual and behavioral analysis. These techniques focus on prevention and rapid response to reduce loss of life and property in high-risk industrial or crowd settings.

From the literature, it is clear that Artificial Intelligence (AI) and Machine Learning (ML) techniques can perform a significant role

in early prediction, prevention, mitigation and recovery process in disaster management.

According to a study done by Gupta and Roy (2024), after referring to 72 research studies, it is found that AI techniques are most frequently used for preparedness (60%). It is identified that for recovery step AI techniques are least frequently used (Figure 2). In future, experts in system development should focus on developing more support systems using AI for disaster mitigation, recovery and response.

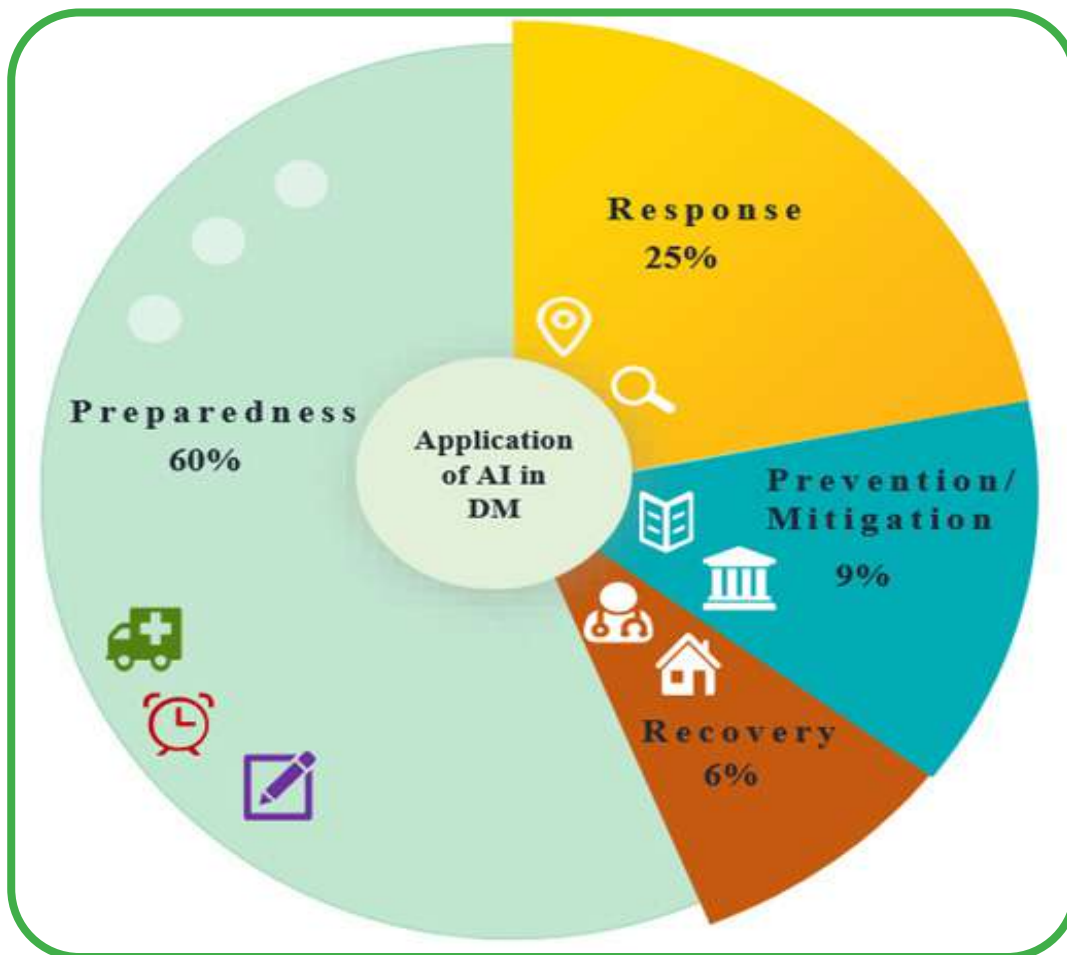


Figure 2: Percentage use of AI techniques in different phases of disaster management (Source: Gupta and Roy, 2024)

Challenges in using AI in disaster management

As the AI solutions significantly depend on data for predictions, sending early warnings and analyzing environmental states, the use of good quality data is an essential factor. Issues such as recording data using low quality instruments and having lots of incomplete data lower the accuracy of the output. Having lack of proper instruments and technology for collecting data in some areas, disturbs the data collection process. If the sufficient amount of data is not used for training the algorithms for forecasting, there is a higher probability

of creating wrong predictions. In addition to that, the cost of system developing, testing and maintenance can be a huge cost for the government, which create less motivation. Further, there is need to employ trained staff for data collection, operating the instruments and generating all the necessary information on time. These types of challenges can create some resistance for using AI solutions for disaster management. Hence it is the responsibility of the government and relevant authorities to allocate adequate funding for the adoption of advanced technologies in disaster management and create positive discussions with the communities on using technology for disaster management. The substantial costs associated with post-disaster recovery and rehabilitation efforts often far exceed the initial investment required for

developing and implementing such technological systems.

Conclusion

If the disasters can be identified early, all the necessary precautionary actions can be initiated in advance and the loss of human lives and properties can be reduced significantly. AI based systems can be introduced aiming to simulate, detect and forecast disasters. By processing real-time data and identifying real indicators, AI techniques give emergency responders a critical head start, enabling faster and more effective issuance of early warnings to at-risk communities. AI is a powerful tool that helps us find the most vulnerable areas and people. This allows responders to focus their efforts and provide more effective support where it is needed most. AI will support not only

to predict but also to determine where it would hit the hardest, which communities are at the most risk and which disaster plans are more likely to fail. The ability to anticipate, adapt, and take action has the potential to fundamentally improve how societies prepare for and respond to disasters, creating a path toward greater resilience and sustainability.



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