Application of Artificial Intelligence in different Phases of Disaster Management and their Challenges

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Abstract

Floods, earthquake, fire, and explosions are just a few examples of the many natural and man-made hazards that have the potential to inflict significant socioeconomic loss and damage. In recent years, an upward trend in terms of the damage and loss caused by such hazards was discovered to be occurring. As a direct consequence of this, a significant number of disaster managers are drawn to the field of disaster management in order to establish effective management techniques with which to defend their communities. Several research projects with an application of Artificial Intelligence (AI) techniques to analyze data connected to disasters with the purpose of supporting informed disaster management were discovered. This study's objective is to conduct a literature review on the present applications of artificial intelligence (AI) in disaster management for the objectives of limiting the effects of disasters, planning for them, reacting to them, and recovering from them. In it, examples of applications of various AI techniques and their benefits for supporting disaster management at different phases are offered. Additionally, some practical decision support tools that are based on AI are also provided in this document. Most of the studies were focused on AI application in the response phase of disaster management. This study helps to identify the challenges in application of AI techniques to the researchers in their future research work.

Keywords:

Disaster Management, Disaster Recovery, Disaster Mitigation, Policy, Infrastructure, Artificial Intelligence.

Introduction

Disaster causes severe damage to the society within a short period of time and may result in unrecoverable losses to the entire living being including human and animals. Disaster would result in massive damage to the infrastructure, environment and economy for a longer period of time. A disaster happens after major hazards significantly hamper the people in the vulnerable area. Some of the secondary hazards are more disastrous than the primary one such as Tsunami resulting from underwater earthquakes and has the potential to demolish the coastal area. Any hazards may be divided into two categories: natural and man-made. Natural hazards are resulting due to natural causes such as landslides, earthquake, flood, cyclone, heat wave and many more. The chance of mutation of hazard into disaster is higher with natural hazard and may severely affect the geology and living being. Man-made hazard arises due to malfunctioning of technology or human actions which includes fires, explosions, bioterrorism, wars and radio-active leakage.

To combat this, a multi approach tool for disaster management is necessary which would primarily address 4R's including Risk mitigation, Response readiness, Response execution and Recovery. Scientists working in the area of "Disaster Risk Reduction (DRR)" have come to the conclusion that the majority of disasters are caused by humans, and that taking preventative measures in the years leading up to a disaster might lessen the severity of the hazard that will be caused by that disaster. Therefore, it becomesessential to define and implement emergency management steps under different circumstances.

Literature Review

Natural disaster results in geographical destruction along with economic and social loss and the trend is increasing in the recent years (Hoeppe 2016). These losses put on multiple challenges in front of disaster rescue force which requires proper resources and workforce to tackle these obstacles. Several researchers have reviewed applications of Artificial Intelligence (AI) in disaster management including the specific target such as disaster type, infrastructure and data.

Risk Mitigation Boyd et. al. (2012) and Crawford et. al. (2015) discussed the barriers related to data such as accessibility, completeness, security, privacy and ethical issues in the way of implementation of AI for disaster management. Ranzato (2013) suggested use of advanced techniques such as real-world data handling in the absence of human supervision to tackle the issue of lack of manpower. Zagorecki et al. (2014) reviewed machine learning applications in disaster management but not focussing on any conclusive AI based support tools.

Response Readiness Zhang et al. (2016) used computer vision technology for disaster management with the help of data analysisobtained from remote sensing, which includes deep learning technology to recognise the target. Maktar et. al. (2017) used apriori algorithm for predicting flood areas using the water level in different villages of districts. In their research, Fotovatikhah et al. (2018) highlighted the importance of computational intelligence in the management and control of floods. Pouyanfer et al. (2018) highlighted lack of trained personnel in the task force might be one of the important computation related challenges in disaster management. Tanaka et al. (2019) suggested reservoir computing, use of GPUs and AI accelerators to ensure efficient management, storage and processing of large data essential for disaster management.Zarei et. al. (2019) proposed Support Vector Machine (SVM) and Regression Tree (RT) machine learning models for forecasting the flood damage to reservoir operations. Researchers Madhuri et al. (2021) used a variety of “machine learning algorithms, including Logistic Regression, Support Vector Machine, K-nearest neighbor, Adaptive Boosting (AdaBoost), and Extreme Gradient Boosting (XGBoost)", to analyze eight different flood influential factors and determine flooded and non-flooded regions in accordance with climate change scenarios.

Response Execution Yuan et al. (2015) explained the use of neural networks and Gomez et. al. (2016) proposed three-dimensional structure estimation using wavelet analysis for fire detection. Sahoo et. al. (2019) used “Artificial Neural Network (ANN)” model for predicting the storm surge and coastal inundation of Odisha, India. Salam et. al. (2021) used hybrid models like flower pollination and machine learning algorithms like SVM for predicting the seismic attacks in the California region.

Recovery DeVries et. al. (2018) used deep learning techniques and forecast probable locations of seismic cycle after earthquakes. Zhong et. al. (2019) used “K-means and Apriori algorithms” to generate rules for flood hazard and flash floods. Snehil et. al. (2020) used different supervised machine learning algorithm to analyse the damages caused by flood in three different states like Bihar, UttarPradesh and Kerala and suggested Random Forest algorithm outperformed well than others. The detailed analysis of literature review on this disaster management is shown in Appendix 1.

Methods

The main objective of the disaster management is to minimize the loss due to hazard by ensuring a quick response to the victims and aiming for the earliest recovery. The disaster management cycle has four important phases, also termed as 4Rs such as Risk mitigation, Response readiness, Response execution and Recovery, as shown in Figure 1.

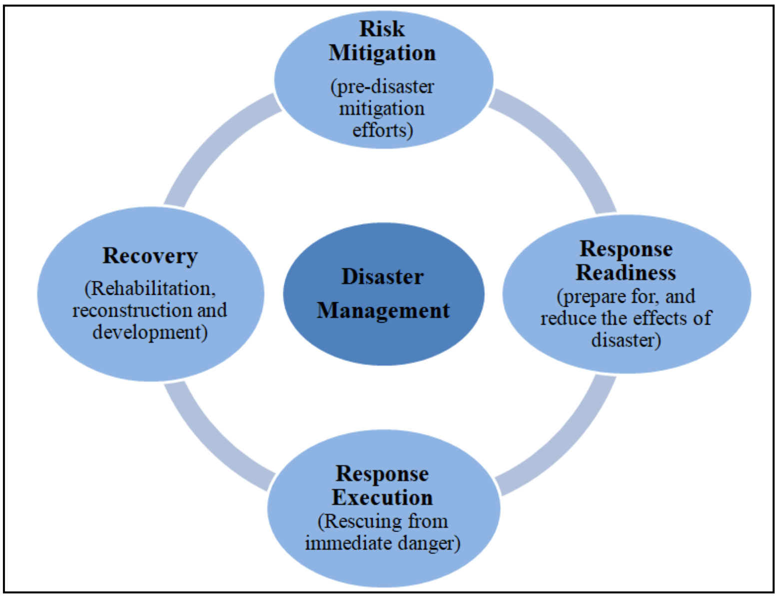


Figure 1.4Rs of Disaster Management Cycle

Proper decision making at every phase of cycle ensures better preparedness to tackle the disaster in an effective manner. The decision making involves providing early warning, reducing the vulnerability, and so on.The primary objective of this study is to assess the efficacy of disaster management techniques based on Information and Communication Technology (ICT), especially in India's disaster-prone states. In order to achieve this objective, the 4Rs need to be addressed with the help of following four methodologies and the expedited challenges.

a) Institutional setup and stakeholder's coordination
b) Policy / Planning framework
c) Use of Artificial Intelligence techniques in policy framework
d) Capacity building and awareness generation through Technology
e) Challenges for ICT -based disaster management

a. Institutional setup for disaster management and stakeholder's coordination

According to the "United Nations International Strategy for Disaster Reduction (UN/ISDR)", the following are the main parties that play crucial roles in the process of disaster management, notably in disaster warning (UN/ISDR, 2006):

Communities A community is a group of people living in a vulnerable area and needs to be addressed through early warning systems. The communities must be known of the potential hazards and their consequences to which they are likely to be exposed and they must be prepared to take necessary measures to encounter the damage. The geology of the vulnerable area helps the system to identify the potential disasters and educate the people in that area to tackle the hazards. For example, people living on the sea-shore needed to be educated with the aspect tsunami and cyclones, whereas people living in the valley can be educated to quick response to an early warning of landslides.

Local governments the local government in the disaster-prone area should be aware of the kind of hazards to which the living being is likely to be exposed. It must take proactive steps to design and maintain the early warning systems and interpret the data obtained. On the basis of interpreted data, the necessary advisory must be issued for the local people to ensure their safety as well as the resources on which they rely.

National governmentsthe role of the national government is to provide required technical resources and facilitate early warning systems in the vulnerable states of the country. This will ensure on time preparation of the state to counter the disaster. The early warnings and corresponding responses must be communicated to the vulnerable community via properly designed disaster response channels at micro and macro level as per the specified need. The support provided by the national government to the local public and body develop the operational capabilities to reduce the risk of disaster.

Regional Institutions and Organizations The role of regional institutions is to give important information and advice in support of national efforts to provide stable operation to curb the disaster. Regional organizations play an important role to connect the international resources to the specific needy countries. It also provides early warning practices to neighbouring areas or countries.

International Bodies The main role of any international body is to support a nation facing disaster through early warnings, data exchanging and knowledge sharing among the countries. The support may also come in the form of advisory services, technological aid, or an institutional framework that validates the growth and operational capabilities of the authorities that are responsible for early warning preparedness.

Non-governmental organizations (NGOs) Apart from the government institutions, NGO's also have an important role in enhancing the awareness across the personnel and institutions incorporating early warnings. Especially at the public level NGOs work for implementation of early warning systems. Apart from this they also support the government for policy making decisions.

The Private Sector Another important link in disaster management institutional setup is the private sector who assist the central authority with their own resources such as ICT based solutions. This sector plays a diverse role in early warnings by providing early warning systems developed in their own organizations. The trained personnel from the private sector who provide a variety of services, such as technical resources, management resources, and donations or memorandums of understanding with the government for the aspects of early warning communication, dissemination, and response.

The MediaThe role of the media is to make people aware about the disaster via early warning. The media would be an important link between the authorities and the common people living in the vulnerable region.

The Scientific Community The role of scientific personnel is to guide the government and apex authority in the development of early warning systems by providing a specialized technical input. The experts from this community critically analyse the hazards affecting the communities and also provide support to design the scientific and systematic monitoring and warning services. In addition to this, the community contributes in exchange of data, interpreting the technical data into convenient messages and giving warnings to those at risk.

b. Policy / Planning Framework

A policy framework starts with locating the potential vulnerable sites. With the use of Geographical Information System (GIS) the potential hazards are identified and their effects on the living being are evaluated. After the hazards are located, the officials start on working their plan to evaluate mitigation, preparedness, response and necessary needs for recovery by considering the risk prone essential infrastructures such as streets, buildings, power lines, schools, hospitals etc. The officer appointed for public safety will ensure the necessary implementation of mitigation efforts, along with focus on preparedness efforts and strengthening of response and recovery efforts. The computer-generated maps obtained with the help of GIS facilities allows planning of multiple combinations for risk management.

c. Use of Artificial Intelligence (AI) in Policy Framework

In the field of artificial intelligence, advances in technology have led to evolutions in some of the study fields. The several subfields that fall under the umbrella of artificial intelligence include "machine learning, natural language processing and voice recognition, expert systems, vision, planning, and robotics". The early warning systems are designed with the help of machine learning, which is one of these techniques. For a long time, researchers in the field of artificial intelligence have been focused on developing ways to make the process of disaster management more efficient.

There are two unique types of artificial intelligence, and they are referred to as weak AI and strong AI, respectively. Weak artificial intelligence is based on the concept of simulating human intelligence in order to complete certain particular tasks. The strong AI requires human intelligence in order to complete any given task similar to a human. Strong AI does not require human intervention to obtain the solution for any unknown problem.

Some of the early warning systems or IOT based systems are developed and incorporated with the use of AI techniques. Geology helps us to study about earth, oceans, rivers, lakes and atmosphere.The existing systems have been significantly improved by introducing GIS and remote sensing which monitors and analyses the physics of Earth and the surrounding. Technology improvements over the decades are capable of predicting the hazards at earliest but the disaster preparedness phase requires knowledge about human psychology pre and post disaster. Following are the different aspects which are needed to be taken under consideration while designing of Early Warning System:

- Use of Geographical model and risk prone zone maps
- Monitoring system with optimum cost
- Acquiring data from sensors
- Accuracy enhancement for the prediction models
- For administrators developing a warning decision tool
- Assessment of warning communication techniques
- Study of human psychology for the response
- Visualizing the impacts resulted post disaster

Figure 2 shows data conversion process into prediction with the help of machine learning in two steps including training step and prediction step.

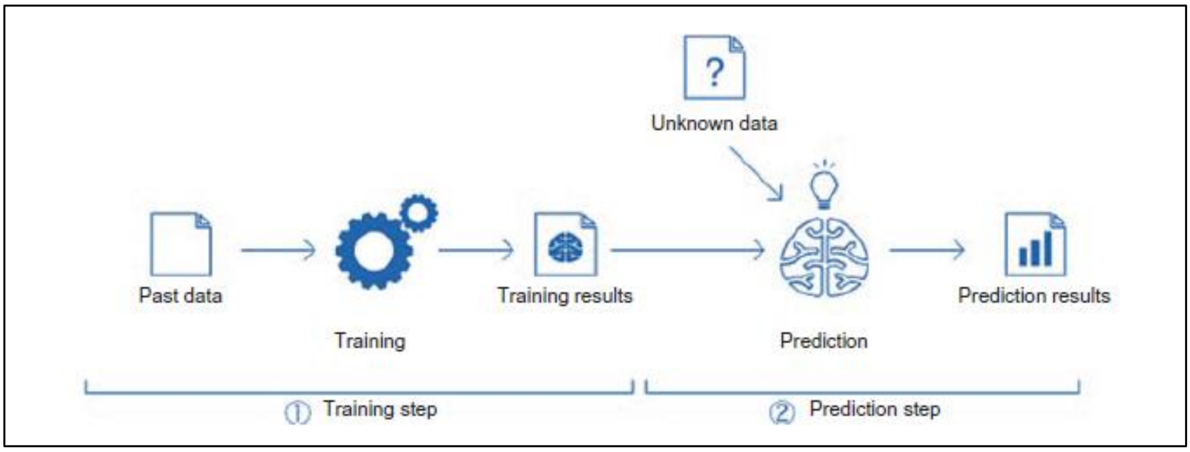


Figure 2. Steps in machine learning data processing

A multi-agent system offers a solution that is decisive when it comes to addressing the challenges that develop in disaster management as a result of the interaction and coordination of response teams. Multi-agent crisis response systems include "DrillSim, DEFACTO, and WIPER", which are examples of real-time aid and simulation systems. A great number of crisis management efforts have already used the utilization of multi-robot systems. Robots are used for the vast majority of "Urban Search and Rescue (USAR)" operations. Finding individuals who are stuck in hazardous areas, rescuing them, and bringing them under control are all aspects of urban search and rescue (USAR). A building that has caved in has a window of time of forty-eight hours in which to locate any survivors before it becomes impossible to discover any victims. Because Twitter contains such a large amount of information, it may be challenging for emergency managers and other stakeholders to filter through individual tweets in real time in order to identify information that is pertinent to their needs. As a consequence of this, the objective is to convince several machine learning algorithms, such as information extraction and classification, to carry out the work on a regular basis.

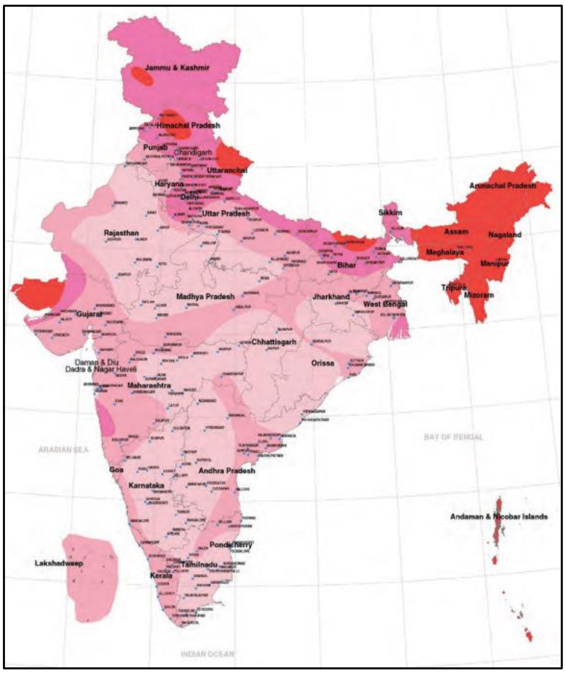
Artificial intelligence (AI) is able to swiftly analyze data in order to come to insightful conclusions because it makes use of high-speed computers that have the capacity to fast handle massive amounts of data as well as complex mathematical algorithms. AI provides professionals working in emergency management (EM) with increased situational awareness, such as the ability to do a comprehensive damage assessment within a few minutes of a crisis occurring. AI may also be used to enhance medical diagnostics and marketing efforts for a variety of products. The proprietary algorithms that heighten seismic concern in the occurrence of earthquakes take into account the design and age of structures, in addition to how well they fared in prior earthquakes and the underlying soil conditions that influence risk levels. These factors all contribute to the overall assessment of a building's seismic vulnerability. In addition to this, the algorithms take into consideration how well the buildings have held up during previous earthquakes. The program takes into consideration parameters such as population density in addition to other essential criteria in order to develop heat maps that highlight the regions that are most at risk. These maps show where people are most likely to be affected by the problem. The data is helpful to experts in emergency management (EM) and other responders in allocating resources and prioritizing their actions. After a disaster has occurred, the algorithms will continue to update and enhance current resource deployments, such as reports from the field, posts on social media, and conversations that originate from the EM ecosystem. Training in seismic awareness, given its significance during natural disasters, has the potential to dramatically boost readiness for future responses. Seismic anxiety keeps teams aware and helps them uncover deficiencies in response plans by delivering genuine simulations based on geophysical data for tabletop exercises and full-scale drills. This makes it easier for teams to identify gaps in their response strategies. The scenarios also give specialists in emergency management with information that these professionals may share with local businesses, hospitals, and schools in order to aid in the recovery of emergency plans and promote the safety of the community.

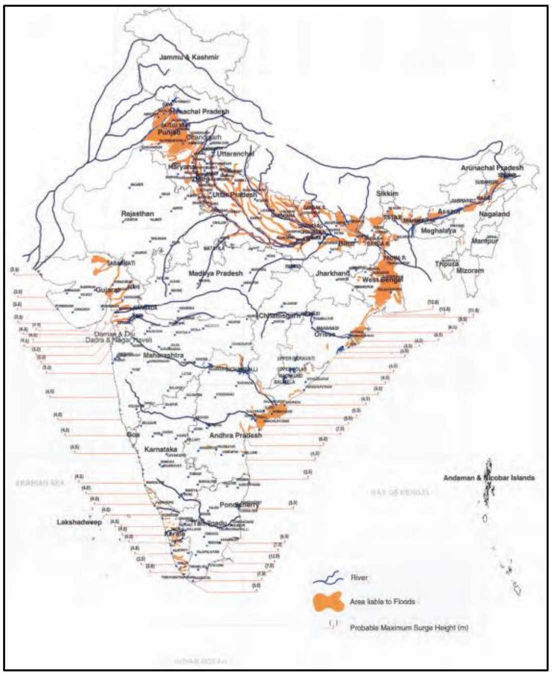
d. Capacity building and awareness generation through Technology

There is no disputing the importance of communication and information in disaster management. Effective catastrophe management starts with having current, accurate information. For comprehensive disaster management, it is vital to have knowledge of the hazards, risks, and vulnerabilities connected with a broad variety of natural disasters. In order to analyze the temporal and regional patterns of disaster impact, it is required to have knowledge on the frequency with which disasters occur as well as the human, social, and financial costs involved with disasters. In both catastrophe management and disaster risk reduction, communication is essential. Community alerting, activity monitoring, and the evaluation of the risks, expenses, and advantages of disaster management are all made possible by communication. Sunita Kuppuswamy claims that "communication increases knowledge of the disaster's hazards. It gives those who live in disaster-prone areas a way to be alerted and given an early warning. It will be useful in developing catastrophe prevention strategies. It is required to educate and train residents of disaster-prone areas about a variety of disaster-related topics. Additionally, it offers information for the precise modelling and simulation of disasters as well as the integration and analysis of spatial and temporal disaster data. It facilitates instantaneous decision-making and strengthens emergency preparedness.”

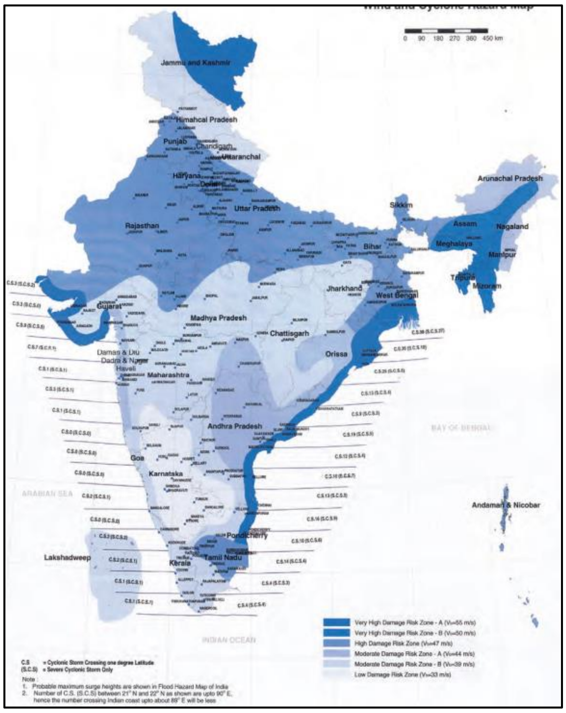
The advancements that have been achieved in information technology and electronic governance have had a trickle-down effect, which can be seen in a number of fields, including disaster management. This is shown by the wide range of diverse applications for information and communications technology (ICT) that have been developed by the many organizations in India that are involved in disaster management. However, the opportunities made available by ICT have not yet been fully used to the extent that they might be. The fundamental contention is that the national and state governments' attempts to exploit the potential of information and communications technology for disaster management are insufficient and unequal. This is the argument's underlying assumption. The phrase "information and communication technology" refers to a broad variety of tools and techniques that are used in both the field of telecommunications, which creates distant communication, and the field of information technology, which stores, maintains, and retrieves data. Together, these two fields make up what is known as "information and communication technology." The term "information and communications technologies" refers to any equipment that is capable of digitally storing data, retrieving it, manipulating it, transmitting it, or receiving it. The term "information and communications technologies" (ICTs) refers to a wide range of technologies and devices, some of which include electronic computers, radios, telephones, broadband internet connections, televisions, and even robots. People are now better able to connect, exchange information, and cooperate regardless of the limits of time and distance brought about by technological improvements in information and communication.

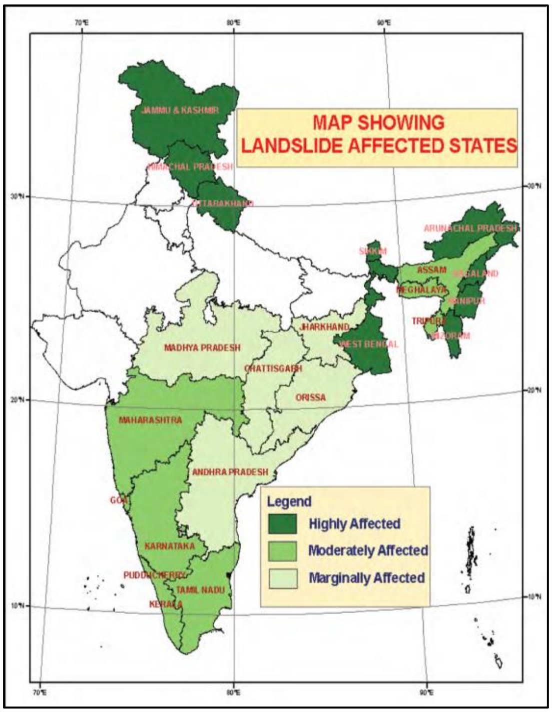
Because of its distinct geology, climate, and socioeconomic conditions, India is very susceptible to calamities of both natural and human origin. The most prone regions to natural disasters in India are illustrated in Figure 3 of the "National Disaster Management policy" report from 2009. In accordance with the findings of the national disaster management division, earthquakes present a risk to 58.6% of the land mass, floods present a risk to 40 million hectares of landmass (12% of the landmass), cyclones present a risk to 8,000 kilometers of coastline, and droughts present a risk to nearly 68% of the total geographical area (MHA, 2011). On steep terrain, the risk of landslides is significantly increased. In the new century, India has become more vulnerable to calamities. India has been hit by some of the deadliest natural disasters in history, including the "Odisha Super Cyclone (1999), the Gujarat Earthquake (2001), the Indian Ocean Tsunami (2004), the Bihar Floods (2007), the Uttarakhand Flash Floods (2013), the Kashmir Floods (2014), and the Kerala Floods (2018)", all of which have occurred only in the new millennium. In order to deal with calamities, India has to build infrastructure and apply appropriate disaster management methods.





(a) Earthquakes Zones in India **(b) Flood Zones in India**





(c) Cyclone Zones in India **(d) Landslide affected Indian States**

Figure 3. Various disaster prone zones in India (NDM_policy, 2009)

The "National Disaster Management Division", often known as the NDMD, is widely regarded as India's premier organization for disaster management. This division operates as a wholly owned subsidiary of the "Ministry of Home Affairs". In the past, India's management of natural disasters was handled in the traditional manner. This method put more of a focus on activities that took place after a disaster, such as response, relief, recovery, and rehabilitation, as opposed to actions that took place before the disaster, such as prevention, preparation, and mitigation. As a consequence, the appropriate administrative departments were also established, and it is clear from the titles of these departments—relief departments, relief commissioners, relief codes/manuals, and so on—that they were established in a way that is analogous to the one described above (MHA, 2011). The National Policy of Disaster Management, 2009 was responsible for the enhancement of the prevention-oriented strategy that is used in disaster management. The titles of the departments of relief and the commissioners of relief were changed to the departments of disaster management, and the office secretary's title was expanded to include disaster management and relief in order to represent the role that risk management plays in the system.

According to the National Disaster Management Policy, 2009, the country's overarching objective is to "build a safe and disaster-resilient India by developing a holistic, proactive, multi-disaster oriented, and technology driven strategy through a culture of prevention, mitigation, preparedness, and response." This is the goal that is explicitly specified in the policy. This objective is reflected in the vision of the policy, which is to "build a safe and disaster-resilient India." The goal of the policy, which is to "build a safe and resilient India," also reflects this objective. The policy wants to accomplish its goals in a variety of different ways, one of which is the building of a technological framework that will support a regulatory environment and a compliance system. This is one of the ways that the policy plans to achieve its goals. The policy stresses the need of include information and communication in disaster management plans in order to promote accurate and up-to-date data exchange via the use of IT infrastructure. This is done in order to minimize the effects of any potential disasters. In addition, the relevant actions need to be taken in order to build up the necessary IT infrastructures, which should contain the necessary IT procedures and skills. In line with the policy, the National Emergency Communication Network was also developed in order to send warnings and information to the population that was potentially at risk.

Numerous national and international organizations are always working to improve the "Information and Communications Technology (ICT)" applications that are utilized in disaster management in India. One such organization is the Indian National Disaster Management Authority (NDMA). "Disaster Risk Management (DRM)" is the name of a joint venture that was started by the "Government of India and the United Nations Development Programmed (UNDP)" in order to promote rapid and prompt response with the use of information and communications technology (ICT). As a result of this, it is feasible to arrive at well-informed judgements and to train professionals who have a significant amount of knowledge. The "Indian Meteorological Department", sometimes abbreviated as IMD, is the primary agency in India that is in charge of predicting and delivering warnings about natural disasters. The "Regional Specialized Meteorological Centre (RSMC) in New Delhi makes use of India's geostationary satellite INSAT in addition to the Indian Meteorological Department (IMD)" in order to gather data and take photos of potential tropical cyclones in the Arabian Sea and the Bay of Bengal. This is done by the "Regional Specialized Meteorological Centre (RSMC) in New Delhi." The early warning signals are broadcast by a variety of various media, including radio, television, print, electronic, telephone network, and the internet, amongst others.

The United Nations Development Program and the Indian Ministry of Home Affairs have collaborated on an initiative called the "India Disaster Resource Network (IDRN)," which has made it possible to access emergency resources online. It is a network-enabled, geographic information system-based resource inventory that is used at the state and district levels to collect and disseminate data on particular pieces of equipment, specific areas of knowledge, and important supply databases (IDRN, 2018). This inventory is used to collect and disseminate data on particular pieces of equipment, specific areas of knowledge, and key supply databases. This inventory is used to gather and distribute information on particular databases pertaining to critical supplies, specific areas of expertise, and specific pieces of equipment. Another GIS-based project called "National Database for Emergency Management (NDEM)" was launched by the Ministry of Home Affairs in conjunction with a large number of other Ministries, most notably the "Department of Science and Technology" and the "Ministry of Communications and Information Technology." The National Database for Emergency Management is what the abbreviation NDEM refers to when it's written out. The primary objective is to bring the decision-support tools up to date as well as to offer the appropriate information and communications technology (ICT) infrastructure for network connection, validation, organization of GIS databases, data transfer, and hosting of disaster management services (NRSC, 2018).

The adoption of the National Telecom Policy 2012 (NTP), which focuses on the use of information and communications technology (ICT) in anticipating, monitoring, and issuing early warnings about disasters and conveying information, has brought additional attention to the application of information and communications technology (ICT) in emergency management. This attention has been brought about as a result of the adoption of the NTP. Access has been provided to a variety of resources, including Standard Operating Procedures (SOPs), the appropriate legal frameworks, call priority, an integrated emergency control room, and a response system with a single number. The recommendations for 2015 for the "National Emergency Response System (NERS)" that were given out by the ministry of home affairs contained the emergency number "112." This number was established with the goal of addressing the emergency response system for women who are in a precarious situation as its primary focus.

e. Challenges for ICT-based Disaster Management

There are some obstacles, requirements, and difficulties in utilising ICT in disaster management. One of the most difficult technological challenges faced by the government is the establishment and integration of the "National Disaster Management Information System (NDMIS)" with various data centers and emergency centers at different levels, including national, state, and district levels, for the purpose of efficient management of information. Continuous software and hardware updating in line with the evolving technical landscape, as well as proper database and system maintenance, call for extra care and consideration. Communication barriers caused by a language barrier are another significant issue, and good ICT development in the relevant local languages would be beneficial.

Like any other tool, information and communication technologies (ICT) benefit most from correct system configuration. The requisite political will, limited cultural and institutional involvement, and cooperation among the governments, market, communities, media, and social influencers are necessary for an ICT deployment in disaster management to be successful. Effective use of ICT in crisis management depends on strong and sage leadership, proper planning, participation of stakeholders, and qualified human resources. Although ICT is a technological word, it has more to do with people and procedures in disaster management. Finding the needs, gaps, and capacities and calculating the appropriate technology to meet the goal are the primary challenges.

The development of a streamlined infrastructure for ICT that allows for quick access to mobile networks, the internet, and other electronics like PCs and other electronics is another difficult task. Governments will use ICT infrastructure as a baseline to highlight new possibilities and opportunities, but doing so demands enormous investments with no immediate benefits.

Review Summary

Artificial intelligence is a process consisting of representation of knowledge, work planning, learning and reasoning, self-corrective ability, processing of language and capability of moving and manipulating objects. The applications of AI are high profile such as recognition of speech, autonomous vehicles, validation of theorems in mathematics, diagnosis in the medical field, individual voice assistance, search engines, filtering of spams, predictive modelling and web targeted commercial advertisements. Research publications regarding use of AI for disaster management have been enhanced on World Cat in the past three decades and the same is shown in Figure 4. Most of the publications are focussed on use of AI in disaster response among four phases. The detailed analysis of literature review on this disaster management is shown in Appendix 1.

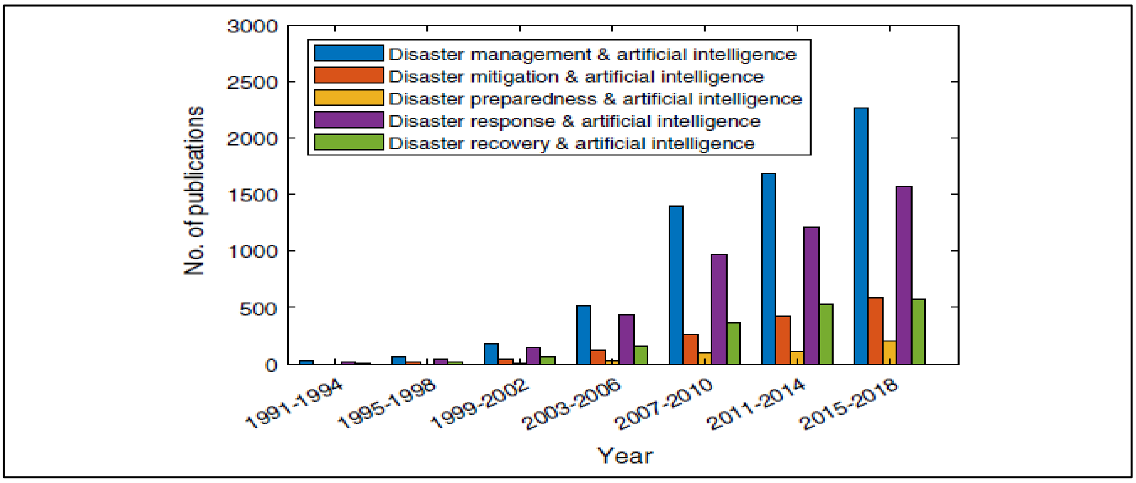


Figure 4. "Number of Publications on use of AI in disaster management"

The following is a summary of the major function that AI plays in disaster management:

- Timely prediction of earthquakes, floods, tsunamis, and landslides
- Prediction of radiation level in various geographical regions
- GIS-enabled remote sensing for autonomous data collection
- Early alert systems would keep humans and animals safe

- Prediction of earthquakes, floods, tsunamis, and landslides
- Machine learning and deep learning algorithms for classification and prediction
- Internet of Things (IoT) enabled systems with AI techniques for decision making

Conclusions

AI is far better than human beings when it comes to the speed of data analysis and volume of data. It can predict considerable forecasts within the predefined range of data beyond which it rejects the data. The concern with AI algorithms is that, whether one can blindly rely on the forecasting and suggestive methods to initiate the supply of resources and designing of plan. Excessive reliance on ICT may result in fall of the basic ICT infrastructure during disaster which may further intensify the damage due to disaster and its mismanagement. Failure of basic infrastructure such as transportation, electric grid, health care and IT systems also influence the efficiency of ICT's. IT infrastructures have to be more reliable themselves, use of ICT does not minimise the risk of disaster but it can help in enhancement of disaster management process. In order to reduce the risk during disaster, a well-built community with a pro disaster resilience approach is necessary and this can be ensured by providing them necessary resources.

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Appendix 1

S. No	Year	Author(s)	Paper Title	AI Technique	Dataset
1.	2013	Ranzato, M. et.al.	“Modeling natural images using gated MRFs”.	Gated Markov Random Field and Deep Belief Network	Natural Images
2.	2014	Zagorecki, A.T. et. al.	“Data mining and machine learning in the context of disaster and crisis management”	Machine Learning Algorithms	All Disasters
3.	2015	Yuan, C. et. al.	“A survey on technologies for automatic forest fire monitoring, detection, and fighting using unmanned aerial vehicles and remote sensing techniques”	Unmanned Aerial Vehicle and Remote Sensing	Forest Fire
4.	2015	Crawford et. al.	“The limits of crisis data: analytical and ethical challenges of using social and mobile data to understand disasters”	Ontologies	Hurricane Sandy and Earthquakes
5.	2016	Zhang, L. et. al.	“Deep Learning for Remote Sensing Data: A Technical Tutorial on the State of the Art”	Deep Learning and Remote Sensing algorithms	-
6.	2017	Makhtar, M. et. al.	“The Application of Apriori Algorithm in Predicting Flood Areas”	Apriori Algorithms	Flood
7.	2018	Fotovatikhah,	“Survey of computational intelligence as basis to big	Soft Computing	Flood

		F. et. al.	flood management: challenges, research directions and future work”	Techniques	hazard
8.	2018	DeVries, P.M.R. et.al.	“Deep Learning of Aftershock Patterns Following Large Earthquakes”	Deep Learning	Earthquakes
9.	2019	Sahoo, B. et. al.	“Prediction of storm surge and coastal inundation using Artificial Neural Network – A case study for 1999 Odisha Super Cyclone”	Artificial Neural Network	Storm surge and Coastal inundation
10.	2019	Tanaka, G. et. al.	“Recent advances in physical reservoir computing: a review”	Recurrent Neural Network	Water Reservoirs
11.	2019	Zarei, M. et. al.	“Machine-learning algorithms for forecast-informed reservoir operation (FIRO) to reduce flood damages”	Supervised Machine Learning Algorithms	Water Reservoirs
12.	2019	Zhong, M. et. al.	“Performance of multi-level association rule mining for the relationship between causal factor patterns and flash flood magnitudes in a humid area”	K-means Clustering and Apriori Algorithms	Flood
13.	2020	Snehil, et. al.	“Flood Damage Analysis Using Machine Learning Techniques”	Classification Machine Learning Algorithms	Flood
14.	2021	Madhuri, R. et. al.	“Application of machine learning algorithms for flood susceptibility assessment and risk management”	Classification Machine Learning Algorithms	Flood
15.	2021	Salam et. al.	“Earthquake Prediction using	Flower	Earthquakes

			Hybrid Machine Learning Techniques”	Pollination and Machine Learning Algorithms	