ENHANCING FLOOD RESPONSE IN ROMANIA: THE ROLE OF AI AND INTEGRATED ALARM SYSTEMS

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Abstract: *Introducing combined alarm systems for Romania flood zones is critical for constructing a disaster response as well as for people's safety. Communication, evacuation and flood relief involve advanced technology. Image processing also facilitates assessment of flood impact on roads, bridges and other infrastructures. By using AI in algorithms across large datasets organizations can upgrade their operations and decision-making in real-time. The concerns of rehabilitation can therefore be helped by AI to assess the floods in the infrastructures and hasten its rehabilitation process. Moreover, the AI generated models can actualize flood scenarios hence enabling the authorities improve their preparation for different levels of floods. It aids in identifying the data and off-loading it which makes flood control more effective and intelligent. These smart sensors with the help of AI may assist communities in getting the first warning and preventing the situations. The use of actual data as the basis of simulations and real-time data gathering may enhance existing evacuation plans so that authorities can better organize those routes and make faster decisions with better information. These integrated solutions might help to improve the existing technical infrastructures aimed at the prevention and management of floods in Romania by improving preparation and assessment of flood hazards and disasters. The implementation of real-time gathered data alongside actual data from simulations can improve current evacuation strategies by helping authorities better manage evacuation paths and respond through more informed choices.*

Keywords: *Flood Risk Management, Integrated Alarm Systems, Artificial Intelligence, Remote Sensing, Flood Forecasting, Disaster Preparedness, Real-Time Data Processing, Infrastructure Rehabilitation.*

1. INTRODUCTION

The more frequent and severe occurrence of floods and other natural catastrophes has been largely linked to climate change, which represents an eminent threat to both the developing and the developed countries. In Romania flood risks have emerged as a real problem, often the impacts resulting to damage property and several fatalities [1]. These natural events most especially floods require efficient early warning system and efficient means of managing the impending disasters. Although natural phenomena are unavoidable measures must be put in place to curb the effect of disasters to save lives and property. Current research shows that warning systems are critical particularly in the forecasting phase as this would enable authorities to make early interferences/allocations [2]. In the disaster, efficient action reduces the first loss and, after the tragedy, the restoration process and support for the victims are significant. Like other countries, Romania wants to improve its flood risk management capacities now.

IEMS founded in 1993 helped the countries to navigate the storms of emergency management and provided how to respond to the disaster based on common procedures [39]. Failure to which the target of the millennium development Goals 2015 may not be achieve, thanks to information and communication technology that facilitate communication between the authorities and the affected region thus reducing on further damages. The proposed systematic review will concern itself especially with the state-of-art technologies employed in Romania for flood risk management with reference to integrated alarm systems. The review shall use approaches such as image processing and artificial intelligence and integrated approaches of data capture and analysis. It will compare/contrasting these technologies based on their efficiency and areas in which they can be implemented/useful to identify the extent to which they can be useful to the authorities.

2. LITERATURE REVIEW

The literature review of the current disaster management field revealed that there is a significant research void especially in the application of new technologies to tackle flooding disasters. The proposed direction should remain oriented on identifying effective methods of the early alerting system, based on algorithms, frameworks, or even sensor networks to inform the process of floods adequately. Disaster risk reduction is one of the United Nation's proposed sustainable development goals for the year 2030, and Romania also seeks to enhance its structures for the same reason [3]. Combining the human resource, modern technology, and sound planning can optimize floods prevention by authorities and minimize the effect of floods on the economy. The incorporation of innovative disaster management solutions, such as machine learning, artificial intelligence (AI), and information and communication technologies (ICT), can streamline flood risk management across all stages: planning: before an occurrence of the disaster, during the occurrence and after the occurrence [4]. These technologies when put in the context of integrated alarm systems, result into a faster and accurate decision making thus improving on anticipatory mechanisms [40]. However, the local authorities, scientific communities and other stakeholders who are involved in this line of business may come up with better systems that can cope with the actual management of floods risks in their areas of operation.

For instance, like Japan or China, Romania has been looking for specific configurations of emergency management solutions to decrease flood effects. An example from the Japanese approach to multi-level emergency management and risk planning and Chinese application of computational intelligence in disaster response can give lessons for flood management in Romania. Both systems incorporate the use of high-end computational applications for data analysis, weather forecasting and operational decision making on a real-time basis that will enhance the response of the systems in accelerated flood events [5]. Accurate management of flood requires big data analytics and real-time algorithms to support the management information systems decisions. All these systems involve use of computational intelligence to undertake data analysis, fitting models, and finding floods risks and produce displays for the decision makers. AI technologies developed over the years for accurate prediction of weather conditions and mapping of flood risks, has brought a significant change in controlling floods [6]. On the same note, drones and satellites provide means of capturing up-to-date information where disasters have occurred, or where the paths for evacuations have not been affected.

Several practical directions related to the integrated alarm systems for flood management in Romania can be used for improvement: the usage of the remote sensors, drones, and analysis based on artificial intelligence technologies [41].

These technologies can be used to forecast the occurrence of floods, estimate the extent of the problem, and design an efficient evacuation path that would help cope with floods in the shortest possible time [7]. Incorporation of emergent solutions is critical within the construction of sustainable flood mitigation frameworks for reactions to disasters as well as for preventing more similar damage in the future.

3. MATERIALS AND METHODS

The objective of this systematic review is dual: examining the state of developments in combined alarm systems for flood risk zones in Romania and evaluating how these alarm systems improve the nation's flood mitigation and early warning systems. The review process was conducted in two phases: articles in entry and review. For this purpose, articles were searched in Scopus, Google Scholar, Science Direct, Elsevier, Springer to select recent and interdisciplinary articles on flood alarm systems. The next process that entailed was to develop a set of specific questionnaires which could be used across these avenues. Starting with the primary goal of searching these databases till the fag end to find out as many articles relating to integrated alarm systems for flood risk management in Romania as possible.

By using three types of words for searching it would be possible to find resources giving different perspectives of the subject. The first set of keywords that were used for article selection were: ''flood alarm systems''; ''flood risk monitoring''; ''early flood detection'') as well as ''integrated alarm systems.'' The second category focused on searching the articles with technologies such as "remote sensing," "sensor networks", "IoT based flood monitoring", and "real time data for flood alarm systems." The third category dealt almost exclusively with cross-disciplinary approaches, employing such terms as 'disaster management,' 'emergency response systems' and 'flood warning infrastructure.' Number of articles retrieved from each keyword category is presented in Fig.1 below;

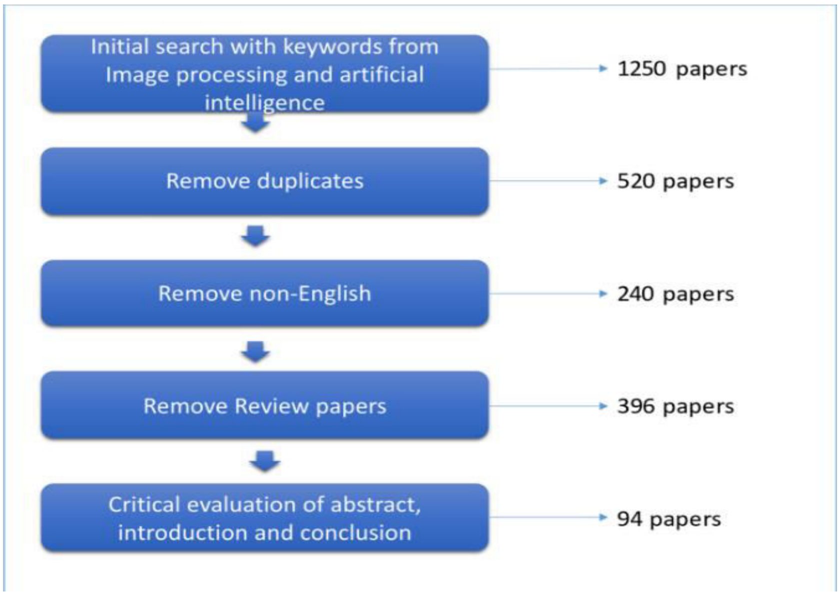

FIG. 1 The detailed screening process of the latest articles for flood management (Munawar et al., 2021)

After the initial phase of article retrieval, the selected articles underwent a screening process to refine the selection criteria. Four specific assessment criteria were defined to evaluate the articles:

1. No Duplicates
2. Time Interval: 2010–2021
3. Document Type: research article, abstract, book chapter
4. Language: English only

By applying these filters only, the beautiful research articles in just the English language published in the last couple of years which is also very rare and unique is acquired only. Using the above criteria the first phase of the study yielded 1250 articles out of which only 94 contained all the four elements. As a result, 94 articles have been screened for this systematic review. Figure 1 illustrates the distribution of articles into bailors including image processing, artificial intelligence, integrated approaches for flood risk. Thus, screen salvage excluded about 502 duplicate citations, 240 non-Eng articles, and 396 review papers. Consequently, 94 papers were filtered for the review. As is depicted in Fig. 2, the number of articles published in each category at year-wise is as follows. It was found to have a more significant concentration on image processing and artificial intelligence technique experimentations in the past decade as compared to integrated approaches to flood risk management. On the other hand, significantly fewer articles explored implementation of these technologies in post-disaster situations, and even fewer explored multi-method applications to floods. The search was expanded to further encompass reports, magazine articles and web pages from scholarly sources for this review. Only the articles published after December 31, 2009, were considered with the exclusion of early pervasive papers introducing the foundational technologies associated with the explored technologies.

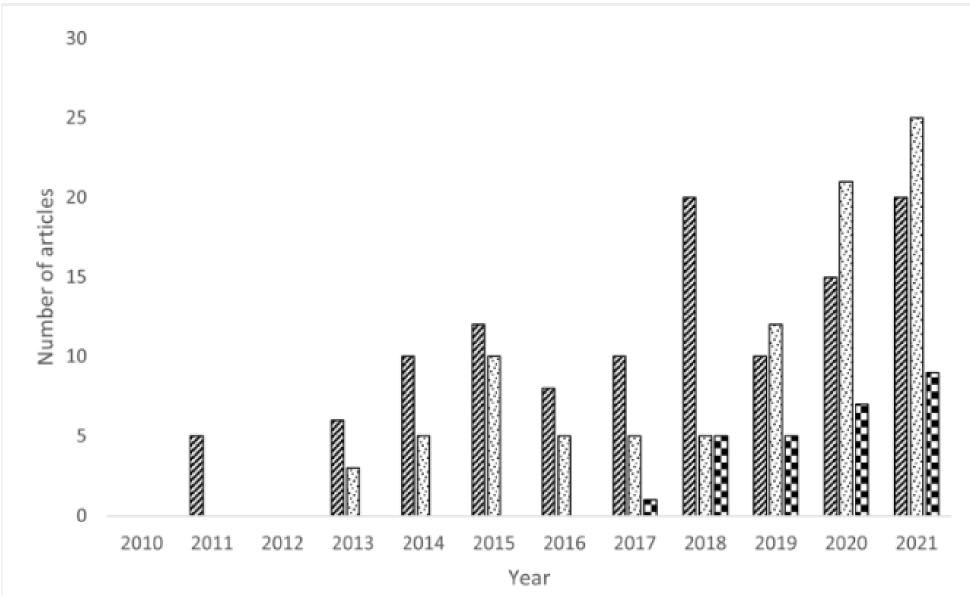

FIG. 2 Yearly distribution of the papers published in the selected domains (Al-Rawas et al., 2024)

4. RESULTS

Image Processing for Flood Detection

Edge Detection

Preprocessing techniques especially edge detection methods have been widely used in assessment of floodwater levels in Romania.

These techniques encompass several procedures comprised of Region of Interest (ROI) selection, image pre-processing, edge detection toward estimation of water surface. The primary steps in this process include:

Region of Interest (ROI): This is used to zoom onto portions of the image in which the flood water levels are to be calculated; it minimizes distortion of other segments of the image which are not of interest. The feature of the algorithm is the isolation of the area flooded making it easier and more accurate to filter out noise [7]. The ROI technique is advantageous because the scope is limited to factors applicable to the flood situation.

Image Pre-processing: Lighting and contrast improvements the image to improve the recognition and accuracy of the image. When the brightness and contrast bar is moved to the middle, then the water levels stand out clearly so that the edges become easier to identify [8]. This is very important in flood detection since one need clear edge along which to gauge the water level.

Edge Detection: After this, the point of interest concentrates on edge detection for the demarcation of boundary of water surface. These algorithms isolate a water region with the image, and the water level computed using the coordinates of the edge pixel. If the edge has a higher height measurement, the coordinates of the edge are changed, and a flooding alert may be activated [9]. Correct tuning of the system enables prediction of the flood levels which in turn is useful especially in the provision of early warning systems in Romania.

Landmark Detection: Additional analysis requires identifying important signposts, including bridges, roads, and structures that will help to figure out if the area is flooded or not. The identification of such features is paramount in formulating strategies for evacuation, flood effects' evaluation, and as a confirmation of a disaster's occurrence [10][42]. Some of the recent developments are Edge detection used on multispectral aerial images for proper disaster management.

Integrated Flood Alarm System (IFAS)

The IFAS or Integrated Flood Alarm System is a flood warning system that consists of an apparatus for real pictures that enable the monitoring of the water levels. In Romania, examples of flood sensors are used to capture video feeds around the rivers and the resultant videos are converted into still images for flood detection. The system improves on these images to make them contrasty and sharp as these will help during flood monitoring [11]. The IFAS predicts water surfaces from the adjacent structures by means of point-based, edge-based, region-based, as well as point, edge, and region hybrid algorithms. Nevertheless, smoke, storms, and reflections are considered among the environmental factors that may delete segments or distort flood computation [43]. To counteract this, the system incorporates flood-risk classifiers that assist in adjusting the flood prediction thus enhancing the capability of the system to provide accurate flood warnings for Romania [12]. The system works in two primary modules: image analyses and risk identification. The first module refines and further categorizes the images, and the second one raises an alarm as soon as the level of flooding is identified. This offers real-time flood mapping which is handy and very valuable especially to the rescue squads and helpful in disaster response in flooded areas in Romania.

Post-Disaster Assessment Using UAVs

Post-earthquake UAVs with camera have been broadly adopted as an essential tool for rapid assessment in Romania. AUVs are used for the aerial photography with an imagery that is influential in assessment of flooded regions. With this technology one is in a position to undertake a very fast assessment the damage caused, be it structures, vegetation and extent of flood water. Further, aerial imagery acquired by UAV also helps assess the quantity of water and effects on the floodplain [13].

Multispectral cameras and RGB imagery help in assessing the actual volume of damages done to crops and part of the infrastructural supports [44]. Besides, the collected information contributes to the preparation of the recovery activities and then directs the government's actions to the right place. Assessments using UAVs are essential in Romania after floods because they provide Recovery programs and decisions with the needed information promptly [14]. By implementation of these integrated technologies, Romania can be enabled with better access to detect flood risks and therefore, have better prepared management strategies.

Artificial Intelligence (AI) for Post-Disaster Flood Management in Romania

The AI techniques have been found to be quite valuable in flood management in Romania both in the pre and post disaster situation. The use of AI in predicting and managing floods would provide both systematic view of flood hazards, improved identification of floods, and quick post-flood crisis recovery. Contemporary research has identified and discussed several AI methods that make a crucial contribution to flood risks reduction and, therefore, flood damages minimization in Romania [15]. Alphabets have been designed as well as deployed several AI-related tools to assist with the venation of flood-related problems especially in the post-flood phase. These tools harness information from AI to identify, locate and visualize flood occurrences [45]. For example, the QCRI tool initially designed for disaster informatics in Qatar has also proved effective at identifying disaster information in real-time. It processes Twitter and textual data from several input data sources and develops immediate recovery plans [16]. However, this tool was not specifically developed for the flood management in Romania but after observing its features in similar disastrous prone areas demonstrates that, this tool has a capability of easy flood disaster response operations.

The Concern tool which is integrated into the process of managing flood disasters is another example of large regions that have introduced integration with artificial intelligence at the next level. It provides a live image of the flood situations during an emergency and helps the emergency management organizations to identify the situation and respond to the needy as and when required [17]. This tool is also fitted with a planning component that identifies areas vulnerable to disasters and guides the evacuation of people thus minimizing on the actual human loses. In Romania for an instance, tools like Concern could be of uttermost importance in pointing out areas that are susceptible to floods in addition to other related information like evacuation drills all in preparation for as well as making sure that any likable rescue operations are launched on time [18][46]. An essential and another related tool that is used for AI-based post-disaster rehabilitation is BlueLine Grid. Created in the United States, this communication tool is used by relief workers and disaster emergency responders. It works more as a movable communication hub where different rescue teams, security squads and local administrative bodies are networked in a single interface [19]. Such a system may well play an important role in the context of Romania identified as having high susceptibility to flood phenomenon, in that it enhances information exchange in the course of flood response and recovery.

AI-Based Flood Prediction Models

Apart from response post-disaster, current AI models are also applied in flood forecasting and prediction.

Google partnered with several agencies to maintain a close watch on Google Maps and Google Search in using AI for flood forecasting and subsequent prevention. In Romania, such system could use information concerning rainfall, historical floods, and other climate indicators to provide precise flood prognosis [20].

Machine Intelligent Flood Prediction Models will be of great benefits to Romania flood management strategies since authorities will be in a better position to manage any floods particularly since they will receive warning. Random Forest method and Decision Trees (DT) are among the outstanding tools utilized in flood prediction systems nowadays. These models are dependent on the influx of data flowing from various outlets; weather data among them to forecast future flood occurrences from past floods [47]. Some of the flood-related reconstructions contain patterns that can be learned by artificial intelligence to predict such floods in the future [21]. In Romania the incorporation of these models into current flood forecasting systems could have impacts of raising the capacity of Romania of coping with floods.

Flood Susceptibility Mapping Using AI

Studies have also recently centered on the creation of flood susceptibility maps through the use of the AI. Method such as the Bagging Logistic Model Tree (LMT) which is an amalgamation of ensemble method and machine learning to generate detailed flood susceptibility map. When the above analytical approach is applied to regions such as the Haraz region in Northern Iran this Gis based approach yielded a 95.5% overall accuracy [22]. As in Romania, the similar mapping tools supported by the AI, can be employed for the same purposes, forming the base for more precise evaluations and better planning of the actions to minimize the impact of the floods [23]. These AI models help in improving flood risk assessment and in preparing for disaster, since these models consider various flood-conditioning factors.

Integration of Statistical Methods and AI for Improved Performance

In another effort to make flood predictions even more precise, theorists have complemented statistical assessment with forecasts generated by machine learning algorithms. For instance, to predict floods, researchers integrate the Frequency Ratio (FR) and the Support Vector Machine (SVM) for spatial modelling. This approach makes it easier to determine correlation between different conditioning factors and flood occurrences [24]. In Romania, the use of statistical techniques in conjunction with AI models could help enhance flood forecasting and guarantee that threat of floods is detected with a very high level of precision in regions that are not frequently monitored or those which have complicated terrain. Also, disaster predictions have also incorporated Artificial Neural Networks (ANN), which have had significant improvements in flood disaster management [25][48]. In this research, SAE and BPNN are used to forecast floods based on input data, including rainfall trends and past flood data. Through analyzing specific floods situations, ANN models can be used for flood behavior anticipation, thus the Romanian authorities can more effectively confront flood hazards.

5. DISCUSSION

Technological Advances in Flood Management

Currently, alarms in areas prone to flooding in Romania could highly benefit from new technologies such as image processing, machine learning, and UAVs. It has been revealed that these technologies have played the roles in diverse DM systems; nonetheless, they could be integrated with existing systems for flood monitoring for the improvement of flood preparedness, response, and rehabilitation.

Advanced image processing strategies, which have been adopted over conventional image analysis methods, include three-dimensional geodetic data for improved measurements of slope and flood fluctuations.

Given the fact that photogrammetric, LIDAR, and UAV are useful methods for obtaining accurate and high-resolution GIS data for the assessment of existing conditions as well as flood impact simulations, they remain critical technologies in flood management frameworks [26]. These technologies help in collection of large data in short span of time, using which predictions about the areas that are most prone to floods can be made and better strategies to deal with floods can also be prepared. But, as of now, there are some challenges connected with their usage. Lighting conditions during flood occurrences, level of contrast, pollution of environment, and other atmospheric interferences have impact on the quality of pictures obtained [49]. These interferences make it hard to achieve precise results, therefore affecting the efficiency of image processing methods [27]. To address these issues, several correction techniques; radiometric and geometric corrections must be done. Still, such discrepancies appear rather often, as well as when images from different time and space are processed with the help of certain pre-define variants. This inconsistency underlying the significance of developing improved machine learning to improve accuracy and dependency of image processing performance.

Integration of AI and Machine Learning

AI and machine learning can intensively enhance flood management. A progress of machine learning models on large data resources can contribute to the improvement of the monitoring systems' ability to make accurate predictions. These models can recognize patterns and outliers in the typical flood areas and assist with the best strategies for evacuation as well as decision-making procedures to best allocate their resources [28]. For instance, control centers can utilize UAVs to gather information during a flood event, if these UAVs are accompanied by machine learning models or not. Additionally, if data from the camera was automatically fed into an analyzer using artificial intelligence, then the problems with inconsistent picture quality would not affect the flood response reliability. Supplementing the AI classification with image processing tools will improve the classification between flood and no flood areas by utilizing slightly complicated elements such as edges and deep learning [50]. This method helps to determine areas affected and to increase the rate of decision-making and thus develop an effective and timely response. It is shown [29] that with the use of machine learning techniques, flood related images can be efficiently processed by AI models useful for post disaster management hence reducing time and increase accuracy of impacts of floods. This integration, however, is heavily dependent on the existence of big data for training, which is sometimes a bottleneck. To resolve this problem, one able to utilize Generative Adversarial Networks (GANs) for generating realistic severities from little datasets for increasing the realism of the training data [30]. These synthetic datasets can be to enhance areas of artificial intelligence with managing the aspects of floods, thereby yielding improved predictive faculties.

Use of UAVs for Flood Monitoring

Unmanned Aerial Vehicles UAVs central to the contemporary flood management systems provide valuable, adaptable and cheap means to register actual imagery in the disaster zones. Combined, UAVs in formation can cover significantly large areas with speed, and efficiency as a swarm in a very short time allowing for faster capture of geospatial data [31]. The use of advanced sensors and cams in UAVs enables the acquisition of high-definition images that can be used to determine areas affected by floods as well as the barriers to disasters response.

Authorities can use UAVs in certain areas and keep track of the flood advancement while responding in the real time, including changes of the evacuation routs and emergencies etc. [32].

Current research has established that incorporating machine learning into UAV's is effective particularly when faced with dynamic floods, because it will process the images faster and accurately than fixed methods. The planning of UAV paths, as postulated by [51], increases efficiency through increased utilization of limited resources. UAVs can in addition be used to develop flood maps and check on the viability of aerial drops to affected regions. Nevertheless, such factors as restricted battery power and the need for high-intensity communication networks still persist.

The Role of Social Media and Cloud Computing

IT items that can be utilized as applicable to the flood management are social media and cloud computing which have vital role in sharing real-time information and actual situation. Many people use the internet especially the applications in their smart phones for update from the authorities as they get data concerning the current flood situation [33]. Another advantage of using artificial intelligence is that through posts, images and videos from the public, the algorithms will help the authorities determine where to focus on first. Further, through cloud computing, information can also be stored and shared across many agencies, and hence there are improved interactions as well as decision-making [34]. This communication can be supported by more frequently utilizing the AI-based techniques for real-time disaster identification and analysis. According to a recent study, data processing task can be managed externally on cloud base platform to make the whole system more responsive and scalable in the event of disaster occurrence.

Improving Flood Response with Cutting-Edge Technologies

Such measures should be employed to improve the existing manage flood system in Romania: Cloud computing, image processing, and AI technologies. These integrated systems can offer constant situational establishment and help the authorities to evaluate the levels of flood and dispatch resources [35]. Appropriate artificial intelligence algorithms can be employed for the most effective routing in emergencies to fasten the rescue operations and prioritize areas where they are needed most. In addition, integrating these technologies with sensor networks including infrared sensors for capturing human motion enables early warning and best evacuation practices [36]. In informing and planning efficiently in case of a flood, it is possible for AI to work with data from sensors in real-time to determine the flow of the floods and identify the viability of the possible routes for evacuation. Emergency preparation can be made regarding floods, and the right evacuation plan can help prevent the loss of lives and property.

6. CONCLUSIONS

Flood has always remained a natural disaster-prone area in Romania and to protect the safety of the community integrated alarm systems has been the main core. Hence, communication, evacuation, and even flood relief are said to be aided by use of this technology. Comparative studies between these technologies are necessary to find the limitations of the existing system and determine whether the two technologies can be integrated. Since flood catastrophes are as a rule characterized by excessive flow rate and hence time-sensitive these devices can help save lives and this is especially true with the third world or underprivileged communities. Due to development in the procedures of mapping, it became possible to generalize the instruments that indicate the risks of floods, as well as to develop the procedures of evacuation. In real-time processing it is also very simple for the officials to identify the safe evacuation areas that are likely to be affected before flood disaster strikes. Image processing can also affect inwards the quantity of the flood impact on roads, bridges and structures.

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