A Machine Learning-Driven Crisis Management System: Real-Time Incident Reporting and Response Optimization

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Abstract: The Crisis Management System seeks to improve the coordination of emergency management through real-time incident reporting and the categorization of crises. The two major end users of the system are the normal users who have the privileges to submit reports and undergo crisis management training, and the admins who review the reports, give follow- up on current crises, and coordinate with the responders. At the center of the system is a Convolutional Neural Network that may be employed for accurate predictions in the type of crisis at hand and, in its essence, hurries decision-making processes. The platform will be best complemented with modern machine learning techniques and cutting-edge web technologies to optimize crisis management and, by default, increase response times and coordination. It is fully developed using Next.js, with MongoDB Atlas for data storage security.

1 INTRODUCTION

Whether it be a natural disaster, a security threat, or an accident, at the time of every emergency, crisis management plays a very important role. Traditional systems for handling crises come with serious limitations in handling and a number of other issues. Issues like delayed reporting, methods of outdated communication, and slow responses may worsen the case. For example, an absolute reliance on phone calls and site reports results in repetition of information at the top, thus creating bottlenecks leading to a snail's pace reaction by the authorities and lousy coordination at critical junctures. Lack of a common platform on the training which is to be imparted, incident reporting, and monitoring of performances results in less preparedness of the responders and administrators in handling the crisis effectively.

For today's emergencies, our approach needs to be wiser and responsive—so that it maintains the speed of real-time data, enables clear communication, and quickly moves toward informed decisions. That's where the new Crisis Management System comes in: it streamlines reporting, amplifies coordination in crisis, and adds insight via machine learning for better resource allocation and fast responses. There are two major types of users for this system: the regular users and the admins. This would provide ease for regular users in creating their profiles, submitting incident reports, and accessing useful resources such as detailed guides on how to respond in various emergencies and quizzes to help them test and improve their skills in crisis management. Feedback from such quizzes helps the users to assess their knowledge and become more confident to handle any response when called upon.

The admins serve as the bridge between the users and the authorities. They receive the reports, review them, and pass on the critical information to the right responders. In return, they avail data of the incidents to the admins, who develop a log of the crisis with its status and continued communication with the user for better timely and coordinated response.

Equally impressive is the application of a machine learning model—a Convolutional Neural Network, or CNN—that automatically analyzes incident descriptions to predict the type of crisis. Quick classification of a crisis cuts down time taken for situational understanding and therefore yields better response accuracy.

Information about users, incident reports, and quiz results is safely stored in MongoDB Atlas for scalability and reliability of the system. The system's

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frontend is designed using Next.js to ensure a seamless, dynamic user experience when taking up training courses, submitting reports, or getting in contact with an admin.

In all, this new Crisis Management System takes the cumbersome, inefficient processes of traditional systems and replaces them with a streamlined, real-time platform for re- porting, crisis classification, training, and communication. The system predicts crises with the help of machine learning and classifies them, while its ground on recent web technologies makes life much easier for one and all. Indeed, both users and admins are likely to respond to any emergency more speedily, effectively, and safely. These tools enable the unexpected to be far better dealt with by society, because crisis responses are much quicker and more accurate at all levels.

2 RELATED WORKS

Wodak, Ruth., In the context of the COVID-19 pandemic, governments worldwide have utilized various methods to legitimize and communicate their restrictive measures. Based on comparative discourse-historical analysis of Austria, Germany, France, Hungary, and Sweden during the lockdown from March to May 2020, four main frames can be identified: religious, dialogic, trust-building, and war-oriented. These framing strategies thus serve a double function: addressing public fears while legitimizing specific actions, such as border closures and renationalization within the EU. Such measures underlined the importance of biopolitics, emphasizing the priorities of common health in a global crisis.

Lai, Ivan Ka Wai, and Jose Weng Chou Wong., 2021, The Macau hospitality industry also responded dynamically to the pandemic. In one study on strategies adopted by hotels in early 2020, six critical practice categories were identified: pricing, marketing, maintenance, human resources, government assistance, and epidemic prevention. In the initial phase, epidemic prevention was the top priority, with selective pricing and maintenance strategies. As the pandemic developed, emphasis shifted toward deferred maintenance and furloughs, showing adaptability in crisis management approaches.

Gu¨ndog˘an, Mete, and Murat Ata. 2021, Fair distribution of resources is a major concern in any crisis situation, especially when the resources are not sufficient. A resource management model was proposed that can monitor individual consumption and needs in real time by leveraging technological tools for ethical and data-driven decision- making. While voluntary compliance is ideal, transparent and fair resource allocation mechanisms are critical in coercive scenarios. This model, developed using the ’Structured System Analysis and Design Method,’ serves as a practical framework for ensuring fairness and efficiency.

Grissa, et al., 2023, Organizations are able to show flexibility in any given situation and thus exercise effective crisis management. The introduction of the OSminer algorithm brought out relationships such as power, control, and coordination among actors in organizational structures that evolve in crises. Application of this algorithm to a flood crisis in southwest France revealed a network comprising 24 actors. However, this is powerful, and limitations in robustness and adaptability suggest that there is still room for refinement with regard to organizational analysis tools.

Dai, et al, 2020, The problems involved in environmental crises require a systematic research framework due to their intricacies. In analyzing the literature using NoteExpress and Ucinet, there is evidence that climate change forms one of the central issues in research regarding environmental crisis management. Some of the important identified research topics are environmental crisis types, governance strategies, technology applications, and micro-governance. Therefore, it helps give the direction for the future by identifying the categorization based on management practices, uses of technology, and theoretical approaches so far used.

Munawar, et al, 2020., Effective crisis management must address both the psycho- logical and material aspects of crises. Governmental communication strategies in the time of the pandemic have illustrated how framing of policies can be used to reduce fear without losing trust. Similarly, technological solutions, such as real-time monitoring of resource use, ensure equity and transparency, paving the way for resilient and ethical crisis management systems.

Anju Paul, et al, 2015, Collaborative strategies are crucial in reinforcing crisis response frameworks. As identified, the OSminer algorithm establishes that the analysis and optimization of stakeholder interaction strengthen organizational structures toward adapt- ability. When utilized with environmental crisis management strategies, such tools bridge immediate crisis response with long-term sustainability goals, allowing societies to build up resilience against future challenges.

In pandemic management, considerable emphasis has been placed on how trust and leadership have fundamental roles in crisis communication. Leaders acting as the ’faces of crisis management’ utilize rhetoric to align the sentiments of the public by framing government action as an enactment of collective solidarity, a moral obligation, or national resilience. These communication strategies were very useful in maintaining compliance by the public with health measures and mitigating fear, according to discourses of EU member states during the COVID-19 pandemic. Anju Paul., et al, 2015, The metaphor ’fighting a war’ was generally used to unite citizens under one cause and also as a way to reinforce the perceived legitimacy of far- reaching policy measures, including lockdowns and movement restrictions. Ramasamy, V., et al., Beyond crisis communication, technological advancements also shifted the resource allocation model. Real-time data analytics and AI are increasingly being used to forecast demand and improve the distribution of resources during emergencies. Vimala, S., et al, 2013, For instance, embedding AI-based decision-support systems into traditional frameworks of resource management has shown improvements in both equity and efficiency, especially in urban areas characterized by high demand volatility. Mukherjee and D. Saha, However, such systems also raise ethical concerns about surveillance and data privacy, emphasizing the need for trans- parent governance mechanisms.

Sandhya Harikumar, et al., 2013 While the pandemic severely dampened the hospitality sector, certain lessons in resilience through different adaptive strategies can also be garnered. Case studies indicate that diversification of revenue streams, adopting stringent safety protocols, and embracing digital marketing enabled hotels to weather the crisis more successfully. For example, the move to contactless technologies, such as mobile check-ins and automated cleaning systems, resolved safety concerns and further enhanced customer trust and satisfaction. These innovations highlight how technology has been instrumental in transforming crisis management practices across industries.

3 METHODOLOGY

The proposed system for Crisis Management incorporates a comprehensive multi-component architecture that offers efficient handling of various crisis-related activities, including incident reporting, crisis prediction, training modules, and real-time chat functionalities. This methodology outlines the step-by-step implementation and integration in the system, by making use of modern web technologies, machine learning, and cloud-based database systems.

3.1 Incident Management

The system allows the user to report crises efficiently through its user-friendly web interface. The incident management steps are as follows:

3.1.1 Incident Reporting

Next.js has a nicely designed frontend, through which users can submit detailed reports regarding crises, including title and description of the incident, criticality level, location, and whether optional files are attached or not.

3.1.2 Incident Data Storage

Each incident will be persisted in the MongoDB database via Prisma ORM. Key fields in this database schema will include incident_id, user ID, type, severity level, description, and status.

3.1.3 Real-time Updates

Admins can view the submitted incidents through their dashboard, which categorizes incidents based on their status: Not Viewed, Viewed, and Action Taken. Figure 1 shows the incident report.

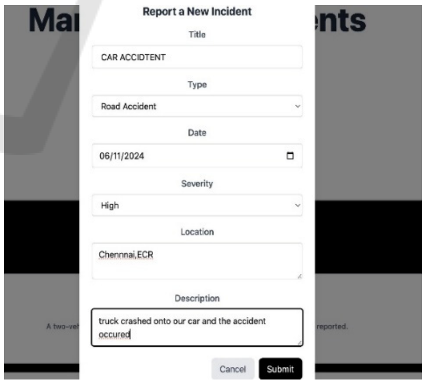

Figure 1: Incident report.

3.2 Crisis Prediction Model

The system utilizes a CNN-based machine learning model designed to categorize crisis incidents into different classes. The process follows these steps:

3.2.1 Preparing the Dataset

The datasets are preprocessed and tokenized, with each crisis type being mapped to an integer value, such as:

- Infrastructure and Utilities Damage
- Volunteering for Rescue Efforts and Donation Ef- forts
- Medical and Humanitarian Needs
- Affected Individuals
- Other Relevant Details
- Not Relevant

3.2.2 Word2Vec Embeddings

Pre-trained Word2Vec embed- dings are used to convert the text into vector representations.

3.2.3 Data Preprocessing

Incident descriptions are tokenized, padded to a length of 100, and the labels are transformed into categorical formats.

3.2.4 Model Architecture

The architecture of the CNN model includes:

- An embedding layer with frozen Word2Vec weights
- A 1D convolutional layer with 128 filters and a kernel size of 5
- Global max-pooling, a dense layer with 128 units, and dropout
- An output layer with a SoftMax activation function for multi-class classification

3.2.5 Model Training

The model is trained using categorical cross-entropy loss and the Adam optimizer, for 10 epochs with a batch size of 32. The best-performing model is saved using Model Checkpoint.

3.3 Training and Quiz Modules

The system provides a training module with crisis-specific pages and quizzes to enhance preparedness. This methodology will include:

- **Training Topics:** There is crisis-specific training mate- rial that might be included, such as Road Accidents or Cyberattacks. It is presented as pages of an interactive nature with illustrations.
- **Quiz Framework:** Current Training on any particular topic presents a specially prepared quiz regarding user testing. Questions, Options, and Answers will dynamically be fetched from the database.
- **Quiz Result Analysis:** It performs the analysis and provides the statistics of the user regarding his quizzes through charts; for example, pie charts for correct vs. wrong answers and bar charts for topic-wise performance. These are implemented using Recharts.
- **Leaderboard:** A leaderboard showing the performance against their peers can act as a motivator to learn continuously.

3.4 Real-Time Chat Capability

Apart from all mentioned, the system will include an embedded chat module where users could engage in discussions with admins. Figure 2 shows the chat interface. The methodology includes:

- **Integration with Chat:** It allows users and admins to send messages regarding incidents. Messages are stored in the ChatMessage table of the database, including sender ID, message, and timestamp.
- **UI/UX Designing:** The user interface is clean and intuitive, enabling users to view chat history and send messages in real time.
- **Polling Mechanism:** The frontend uses polling every 5 seconds to fetch the latest chat messages, ensuring real- time communication without overloading the server.

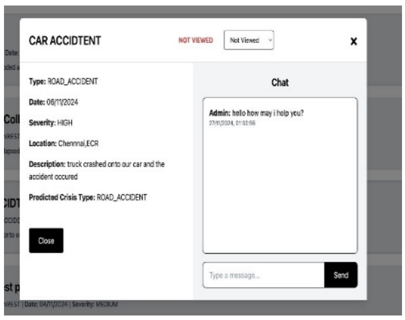

Figure 2: Chat interface.

3.5 Admin Dashboard

Figure 3 shows the admin dashboard serves as the control panel for managing all system features and includes the following:

- **Incident Overview:** Incidents are displayed as cate- gorized tabs with visual indicators on each incident's status, such as a color-coded badge. Admins can mark the status of an incident (e.g., Not Viewed, Viewed, Action Taken) and leave comments via chat.
- **Contact Submissions:** Users can submit queries or feedback through the" Contact Us" form, and admins can view these submissions on a dedicated dashboard page.
- **Prediction Monitoring:** The admin dashboard displays crisis predictions for maximum transparency in crisis categorization. If a prediction is unavailable, admins can manually trigger the prediction script.

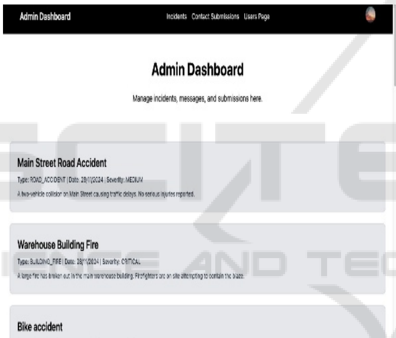

Figure 3: Admin dashboard.

3.6 User Authentication and Authorization

The system uses Clerk for user authentication and role- based authorization to securely grant access to resources. The methodology includes:

- **User Roles:** The platform supports two types of users: Users and Admins. Each role has specific privileges, such as incident reporting for users and incident management for admins.
- **Authentication Integration:** Clerk's API is used both on the frontend and backend, enabling seamless login and secure API calls using user-specific tokens.
- **Role Verification:** API endpoints verify user roles to prevent unauthorized access.

3.7 Database Design

Our database schema, implemented with Prisma and Mon- goDB, follows these basic design principles:

- **Incident Table:** Stores all reported incidents with fields for type, severity, description, and status.
- **Prediction Table:** Stores crisis predictions associated with each incident.
- **ChatMessage Table:** Logs all chat messages exchanged between users and admins.
- **QuizStat Table:** Tracks quiz performance statistics, including total attempts, correct answers, and wrong answers.

3.8 UI/UX Design Principles

The frontend stack involves Next.js, Tailwind CSS, with authentication handled by Clerk. Figure 4 shows the homepages. This makes sure that the user interface is modern and responsive. Key design principles include the following:

- **Consistency**: Uniform design elements, such as color schemes (white backgrounds with black/gray text), animations, and spacing, ensure a polished look.
- **Accessibility**: High contrast text, proper labeling, and keyboard navigation make it accessible for all types of users.
- **Responsive Design**: The platform adapts seamlessly to various screen sizes, from desktops to mobile devices.

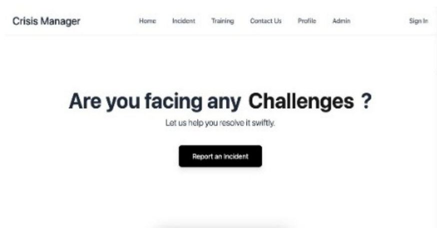

Figure 4: Homepage.

The application is deployed on AWS, which has the following setup:

- **Frontend Hosting**: Next.js app
- **Backend APIs**: The Next.js APIs
- **Database Hosting**: MongoDB Atlas for secure, scalable, and cloud-based database management hosted on Vercel.

4 RESULTS AND EVALUATION

This project integrates incident reporting, crisis prediction, training, and real-time communication into the crisis management system. Users will report incidents via a Next.js frontend; data is maintained on a real-time-updating MongoDB for admins. Predictions for efficient decision-making are provided as incidents get categorized into their respective classes by a CNN-based machine learning model. A training module comprising interactive content and quizzes is there for better preparedness; a leaderboard will keep up the motivation among the users.

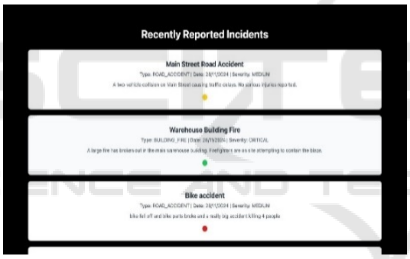

Figure 5: Recent incidents.

Figure 5 displays the list of incidents that is reported in recent times. This would enable real-time chat display to users and admins who are going to communicate regarding incidents. Incident status, predictions, and feedback on the admin dashboard will also show up. Use Clerk for implementing secure user authentication and support of role-based authorization within this. The ORM data storage shall be used within this application, maintaining data for incidents, pre- diction models, and messages in a chat. It is cloud-deployed, and continuous scalability can be maintained with the help of CI/CD pipelines.

5 DISCUSSION

The proposed Crisis Management System presents a well-structured framework that integrates incident reporting, crisis classification, real-time communication, and training modules to improve emergency response efficiency. The use of a Convolutional Neural Network (CNN) for crisis classification is a notable strength, as it facilitates quick and automated identification of crisis types based on incident descriptions. The incorporation of Next.js for frontend development ensures a seamless user experience, while MongoDB Atlas enhances scalability and security in data management. Additionally, the integration of Clerk for authentication strengthens role-based access control, ensuring secure interactions within the system.

However, while the system demonstrates significant improvements over traditional crisis management approaches, certain aspects can be enhanced for greater effectiveness. Firstly, the CNN model relies on text-based crisis descriptions, which may lead to misclassification due to ambiguities in reporting. Incorporating multimodal inputs, such as image and video analysis using deep learning techniques, could improve classification accuracy. Secondly, the system lacks an automated decision-support mechanism that suggests optimal response strategies based on crisis severity and available resources. Implementing reinforcement learning models or optimization algorithms could further enhance decision-making. Additionally, while real-time chat enables direct communication, introducing a chatbot powered by natural language processing (NLP) could assist users in submitting well-structured reports and provide instant guidance. Lastly, the training module, while interactive, could be expanded with scenario-based simulations using gamification techniques to better engage users and improve crisis preparedness.

Overall, the Crisis Management System offers a promising solution for improving emergency response efficiency, but further enhancements in crisis classification, decision support, and user engagement could significantly refine its impact and usability.

6 CONCLUSIONS

This holistic crisis management and incident response framework provides a focused approach to crisis management and minimizing risks. The framework ensures timely detection of incidents, accurate assessment, and rapid resolution of incidents through the integration of advanced technology, effective communication channels, and optimized processes. It emphasizes proactive planning, real-time collaboration, and post-incident evaluation for continuous improvement in readiness and resilience. This strategy gives businesses the ability to reduce interruptions, safeguard assets, and guarantee the security and welfare of all parties involved in a crisis.

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