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Identification of Human Survivors in Natural Disasters Through Body Odor Analysis

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ABSTRACT

Our research addresses the critical challenge of identifying and locating survivors during natural disasters, focusing on the innovative application of body odor analysis. Natural disasters, like earthquakes, demand rapid rescue efforts. Traditionally, canine teams have played a pivotal role, but our study proposes a novel approach using volatile organic compounds (VOCs) found in body odor as biometric markers. We created a comprehensive simulation model based on existing scientific literature, utilizing advanced data resampling techniques and Principal Component Analysis (PCA) alongside clustering methods. Our findings demonstrate convincingly that VOC analysis effectively distinguishes and pinpoints individuals in disaster scenarios. This research opens a new avenue for practical implementation. In summary, our study highlights the promise of VOC-based body odor analysis as a groundbreaking solution for identifying and locating human survivors during natural disasters. This innovation holds significant potential for enhancing disaster response strategies and ultimately saving lives.

1. INTRODUCTION

The search and rescue of survivors in the aftermath of natural disasters, such as earthquakes, stands as a complex and critical imperative within the domain of disaster management [1]. The urgency of locating survivors promptly cannot be overstated, as it directly correlates with reducing mortality rates and alleviating the burdens associated with these catastrophes. While traditional search and rescue methods, including the deployment of sniffer dogs, have proven valuable, the imperative for innovative approaches to enhance their effectiveness is paramount.

A noticeable gap in the current landscape of disaster management [2] lies in the need for more advanced and efficient survivor detection techniques. Although existing methods are tried and tested, they may not be adequate in every circumstance. This study explicitly addresses this research gap by exploring the untapped potential of body odor, comprising an intricate blend of volatile organic compounds (VOCs), as a prospective biometric factor for both identification and the swift location of survivors during natural disasters [3, 4].

The overarching aim of this research is to rigorously evaluate the utility of VOCs derived from body odor in the context of disaster response [5]. To achieve this objective, we have developed a comprehensive simulation model grounded in scientific literature and harnessed Python programming for data resampling. By undertaking this investigation, we endeavor to shed light on a new frontier in disaster management, one that holds promise for expediting survivor detection and enhancing disaster response strategies.

2. LITERATURE REVIEW

2.1 Context of human identification

Search and rescue teams are specially trained to locate and rescue victims of disasters, whether they are natural or man-made disasters or other emergencies. They typically use search and tracking techniques, such as using search dogs, sonars, drones, and GPS systems [6]. On-site experts can also conduct investigations to collect information on victims, including their location, health status, needs, and circumstances, by involving interviews with survivors, collecting samples, and inspecting debris [7].

Missing person registers are databases managed by local authorities, humanitarian organizations, or government agencies to record information on people missing in a disaster. These registers can be used to assist in the search and reunification of families by facilitating the collection and comparison of information on victims [8]. Additionally, local communities can play a key role in the search for disaster victims, as they often have a deep understanding of their region and its inhabitants. Collaboration with local communities can include interviews with community members, mobilizing local resources, and engaging local volunteers [9].

It is important to note that searching for victims in disaster situations can be difficult and emotionally challenging. It requires appropriate coordination and expertise, as well as adherence to protocols and laws. The safety of search and rescue teams, as well as respect for the rights and dignity of victims, must always be taken into account in these situations to ensure effective and respectful management of the rights of missing persons in disaster situations.

In the event of a disaster, identifying human beings can be a complex challenge. Several identification methods can be used depending on the situation and available resources. Visual identification involves visually identifying individuals by witnesses or family members. However, this method can be subject to errors and limitations, particularly in cases of decomposition or bodily trauma [10].

Another commonly used method of identification is dental identification. This method relies on the examination of teeth, including dental radiographs, to identify individuals. Each individual has a unique dental configuration, making it a reliable method of identification [11].

Fingerprints are also a common and reliable way of identifying individuals in the event of a disaster. Fingerprints are unique to each individual and can be compared with existing fingerprint databases for identification [12].

DNA is a powerful tool for identifying individuals, particularly in situations where other identification methods are limited. DNA can be extracted from various biological samples, such as blood, saliva, and hair, and can be compared with DNA databases for identification [13].

Additionally, facial recognition is an increasingly used method of identification in disaster situations. It uses computer algorithms to analyze facial features and compare them with image databases for identification [14]. However, it should be noted that this method can be subject to errors, particularly in cases of physiological changes due to trauma.

Finally, anthropological characteristics, such as height, sex, age, race, and skeletal anomalies, can also be used for identification using forensic anthropology methods [15]. This approach can be used when other identification methods are limited or impossible to use.

In summary, in the event of a disaster, different identification methods can be used depending on the available resources and specific circumstances of the situation. This can include visual identification, dental identification, fingerprints, DNA, facial recognition, and anthropological characteristics. Each method has its advantages and limitations, and it is often necessary to combine several approaches to achieve reliable identification of the individuals involved.

Furthermore, in the event of a disaster, it is crucial to be able to quickly identify individuals to provide them with assistance, aid, or facilitate search and rescue operations. To do this, various identification methods can be used.

Identification bracelets are often used in emergencies to mark victims or survivors, thus facilitating their identification. These bracelets can contain basic information such as name, blood group, and allergies [16].

Another method of identification is the use of evacuation registers, which are documents or databases recording the identification information of people evacuated from a disaster area. These registers can include data such as names, addresses, and phone numbers, to facilitate the location and reunion of families [17].

Communication technologies such as mobile phones, social networks, or messaging systems can also be used to facilitate the identification of individuals in the event of a disaster. They allow individuals to report their situation or communicate with their loved ones, thus providing additional assistance in the identification process [18].

In summary, in the event of a disaster, the use of identification bracelets, evacuation registers, and communication technologies can be essential to quickly identify individuals, facilitate their care, and enable family reunification.

2.2 Proposal for identification using volatile organic compounds (VOCs)

In the event of natural disasters, such as earthquakes, hurricanes, or floods, the rapid identification of survivors is of paramount importance to provide timely medical and logistical assistance. Volatile organic compounds (VOCs), which are chemical substances emitted by living beings, offer a promising avenue for facilitating this crucial task [19].

VOCs can be sampled from the air exhaled by survivors or from their clothing and subsequently analyzed using appropriate detection instruments. Each individual possesses a unique VOC fingerprint, which can be harnessed for accurate and expeditious identification. Information regarding survivors' VOC fingerprints can be securely recorded in a database, enabling rescue teams to consult and compare these records with samples to confirm survivors' identities [20].

The application of VOCs as biometric identifiers proves particularly advantageous in scenarios where traditional identification methods, such as identity cards or medical insurance cards, are lost or rendered unusable due to the disaster's impact. Furthermore, VOCs hold potential for facilitating family reunification, allowing survivors to establish their identities with authorities and locate their loved ones [21, 22].

However, the utilization of VOCs as biometric identifiers [23, 24] introduces considerations regarding privacy and data protection. Protocols for collecting, analyzing, and storing VOC samples must align with legal frameworks and regulations pertaining to the protection of personal data. It is paramount that the rights and privacy of survivors are scrupulously respected throughout the process.

Nonetheless, the viability of VOC-based identification hinges on several factors, which warrant detailed examination. For instance, the reliability of VOC identification under varying environmental conditions remains a pertinent concern. Additionally, the duration for which VOCs persist after an individual has left an area requires thorough investigation to assess the practicality and accuracy of this method.

The proposal to utilize VOCs for identification, while promising, demands a comprehensive evaluation of its limitations and challenges to ensure its effectiveness in diverse disaster scenarios. Further research in this area is essential to address these questions and to refine the methodology for optimal application.

3. MATERIAL AND METHOD

In their article, de Lacy Costello et al. [25] provide a table illustrating over 1800 volatile organic compounds emanating from a healthy individual, which was used in this study. The data from the literature of de Lacy Costello et al. [25] were resampled to increase the size of our data using resampling techniques, to avoid bias towards the majority groups at the expense of the minority groups. Additionally, the combination of Principal Component Analysis (PCA) and clustering models served as our model for identifying survivors.

3.1 Material

Our basic material comes from the scientific literature, in particular from the article of de Lacy Costello et al. [25] where the authors present more than 1800 VOCs spread over several sites of the human body. Table 1 gives us just a part of the data.

3.2 Methods

3.2.1 Conceptual data model

The conceptual data model allowed us to model the data from the literature as a Database. We obtained the model shown in Figure 1.

Table 1. VOCs from the healthy human body

CAS-Number	Compound Name	Feaces	Urine	Breath	Skin	Milk	Blood	Saliva
	A							
75-07-0	acetaldehyde	F	U	Br	Sk	M	Bl	Sa
60-35-5	acetamide	F		Br				
64-19-7	acetic acid	F	U	Br	Sk	M		Sa
…	…	…	…	…	…	…	…	…
	Y							
14912-44-8	ylangene							Sa

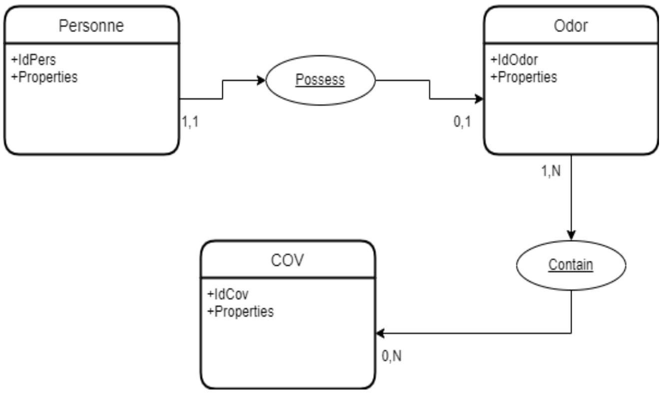

Figure 1. Conceptual data model

3.2.2 Data resampling method (Bootstrap)

The bootstrap method involves drawing random samples with replacements from the original data set to create a new data set of the same or reduced size [26]. In our case, a sample of 1000 observations is drawn with replacement from the original data set. This technique is used to generate random samples from a dataset and thus reduce the bias and error associated with estimating statistics from a single sample.

3.2.3 Principal Component Analysis (PCA) method

PCA is a dimensionality reduction technique that transforms correlated variables into uncorrelated variables called "principal components". It is based on the eigenvalue decomposition of a covariance or correlation matrix and is used to reduce the dimensionality of the data, determine the relationships between variables, detect outliers, and visualise the data [27].

3.2.4 clustering method

Unsupervised classification is a data analysis technique that groups similar objects into sets called "clusters" based on their characteristics. Unlike supervised classification, which uses labels to categorise objects, clustering has no prior information about the groups [28].

4. RESULT AND DISCUSSION

We propose a database of the different volatile organic compounds (VOCs) emanating from the human body, with the conceptual model defined earlier. This database could be extended to include the different compositions of VOCs in the air [29] to understand and minimize the effects of confounding factors.

The representation of the probability density of VOC presence in different zones of the human body (Figure 2) allows us to see that VOCs are mostly less present in these different zones except in respiration, where we have a balance. There are more VOCs in respiration than in other parts of the body. This reflects one of the reasons why several studies on human VOCs focus on respiration [30, 31].

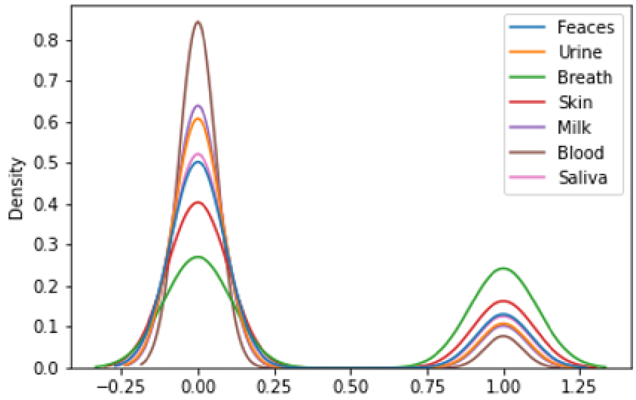

Figure 2. Density probability of the presence of VOCs by zone

The graphical representation of the transposition of raw data indicates that certain VOCs are more present than others, based on their density of presence (Figure 3).

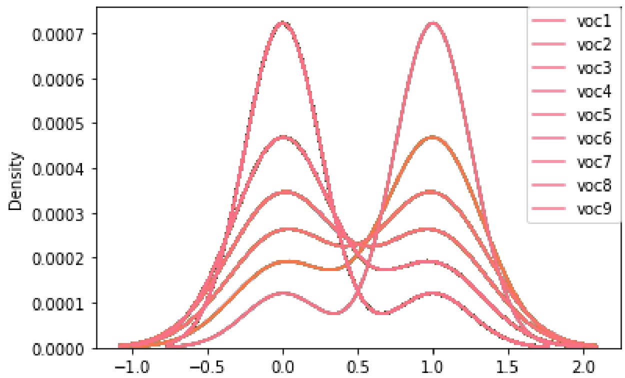

Figure 3. Density of presence of VOCs after transposition of raw data

The resampling of the transposed raw data has rebalanced the densities of COV presence (Figure 4). This suggests that our data is sufficiently representative to be subjected to further processing.

The transposed raw data, resampled to 1,000 individuals and normalized (Figure 5), provide us with a significant overview of the data to be processed.

The Principal Component Analysis allowed us to reduce the dimensionality of simulated odor data and to stop at two principal components, or two dimensions, with the variance explained by each principal component being 0.36575578 and 0.22301861.

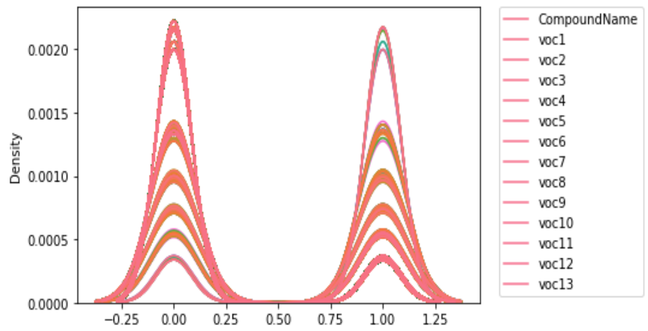

Figure 4. Density of presence after resampling of transposed raw data

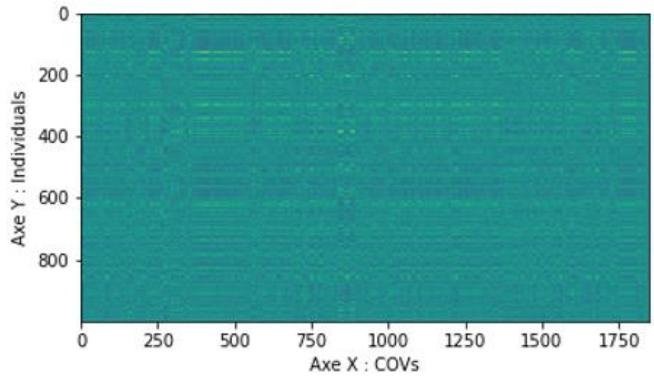

Figure 5. Normalized raw data

The application of the clustering method to the data reduced by PCA allowed us to obtain seven different groups.

The variance explained curve using the Elbow method in Figure 6 shows that the variance starts to stabilize from the third cluster. This leads us to reduce the number of clusters to 3.

The optimal number of clusters is therefore 3, as the distortion remains practically constant beyond this value (Figure 6).

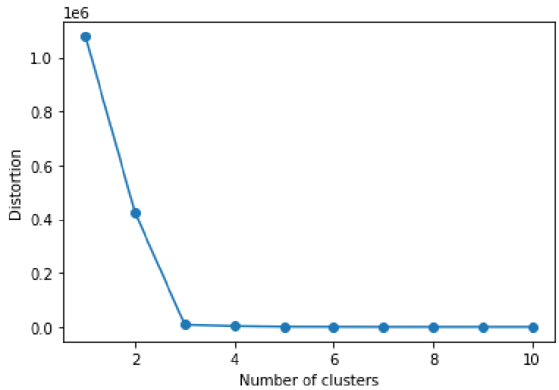

Figure 6. Detection of the optimal number of clusters using the elbow method

The three preceding graphs (Figures 7-9) show the original data and their corresponding clusters in the reduced dimensional space, as well as the new data to be classified and their predicted cluster.

The machine learning and decision support system based on the clustering model prediction allowed us to identify new data, group them, and finally position them in existing groups (Figure 10).

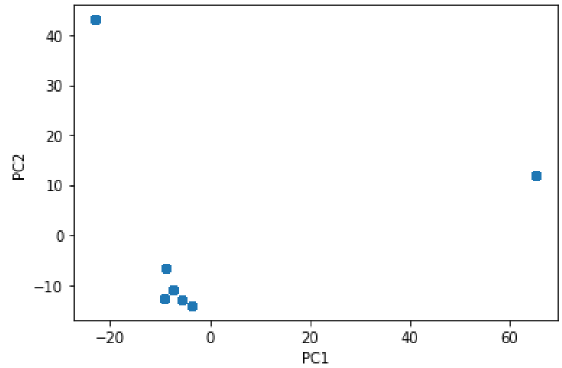

Figure 7. Principal Component Analysis

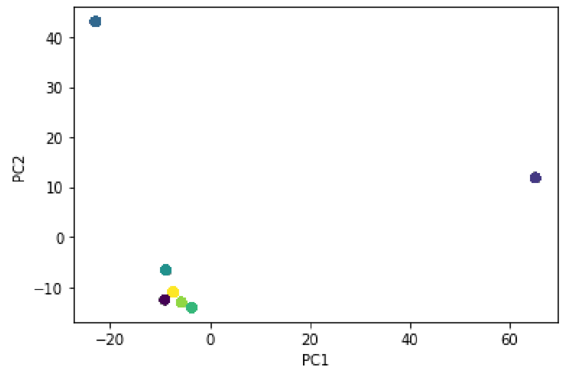

Figure 8. Combination of clustering and PCA models

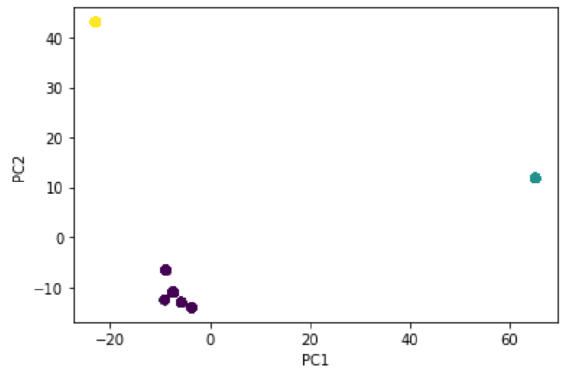

Figure 9. Optimization of the number of clusters to 3

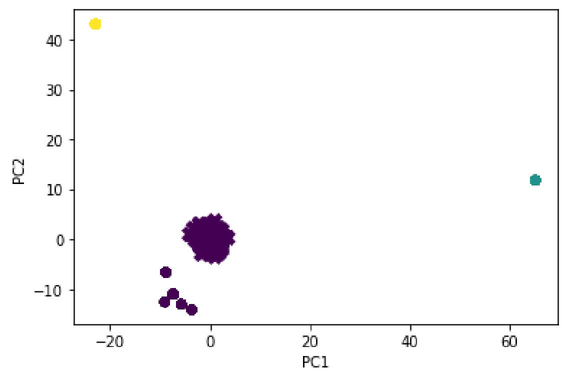

Figure 10. Detecting new data

With further research and development, sensor arrays capable of detecting and discriminating a wide range of VOCs could revolutionize the analysis of human odor VOCs [32].

4.1 Database of VOCs

We've successfully established a database of VOCs from the human body, built upon the conceptual model introduced earlier. This database, as a foundational resource, can be expanded to incorporate the various compositions of VOCs in the ambient air [29]. This extension will facilitate a more comprehensive understanding of the presence of VOCs and their interactions, potentially minimizing the effects of confounding factors.

4.2 Probability density of VOC presence

The graphical representation of the probability density of VOC presence in different zones of the human body (Figure 2) provides essential insights. Notably, VOCs are less prevalent in most body zones, except in respiration, where a balanced presence is observed. This observation aligns with the focus of several studies on human VOCs that emphasize respiration [30, 31].

4.3 Data resampling and balancing

The resampling of transposed raw data to 1,000 individuals and subsequent normalization has resulted in a rebalanced density of VOC presence. This indicates that our dataset is now more representative and ready for further analysis.

4.4 Principal Component Analysis (PCA) and clustering

Principal Component Analysis (PCA) enabled us to reduce the dimensionality of the simulated odor data while retaining meaningful variance. Two principal components, explaining 36.58% and 22.30% of the variance, were retained (Figure 7).

The application of clustering to the PCA-reduced data produced seven distinct groups (Figure 8). The variance explained curve, as shown in Figure 6, demonstrates that the variance stabilizes from the third cluster, leading us to the conclusion that three clusters are optimal (Figure 9).

4.5 Implications and future directions

The results obtained from our data analysis, along with the utilization of machine learning and decision support systems, offer a promising framework for human identification in disaster scenarios. The seven different clusters identified through clustering represent distinct patterns of VOC presence, which could potentially be linked to different individuals or physiological conditions. Further investigation and correlation with known factors may reveal valuable insights.

These findings have significant implications for the broader field of human identification during disasters. By focusing on VOC analysis, we present a novel approach that can complement and expand the existing set of identification methods, especially when traditional means are compromised or inadequate. With ongoing research and development, sensor arrays capable of detecting and discriminating a wide range of VOCs have the potential to revolutionize the analysis of human odor VOCs [32].

4.6 Comparison with previous studies

To further contextualize our findings, it's valuable to compare them with previous studies in the field of human identification during disasters. Previous research primarily relies on traditional methods such as fingerprinting, DNA analysis, and facial recognition. These methods are well-established and highly accurate but can be limited in certain disaster scenarios where samples are degraded or unavailable.

Our VOC-based approach offers a complementary method that capitalizes on the unique odor profiles of individuals. While VOC analysis is still emerging as a reliable identification tool, it provides a valuable alternative, particularly when other methods face limitations. The seven distinct clusters identified in our study indicate the potential for this approach to distinguish individuals or physiological conditions based on VOC profiles. However, it's essential to acknowledge that this method is not a standalone solution but rather a supplement to traditional methods.

4.7 Discussion

Our study brings forth a promising avenue for disaster management, where expeditious human identification is paramount. The seven distinct clusters offer an opportunity to delve deeper into understanding the variations in VOC presence among individuals and their possible link to health conditions, lifestyle, or other factors.

To further validate our findings, additional research should focus on correlation studies between VOC patterns and individual characteristics. Comparative analysis with existing methods, such as fingerprinting, DNA analysis, and facial recognition, would also provide valuable insights into the practicality and effectiveness of VOC-based identification in real disaster scenarios.

In conclusion, our study signifies the potential of VOC analysis as a supplementary tool for rapid and reliable human identification during disasters, offering a versatile approach that may serve as a crucial addition to the existing toolkit of disaster response and management.

5. CONCLUSION

In the face of natural disasters, the demand for rapid analysis systems to locate survivors is poised to increase significantly. This article explores the use of volatile organic compounds (VOCs) emitted by humans as a promising approach to aid in the detection of individuals, contributing to rescue operations and potentially saving countless lives. The studies presented herein offer an encouraging glimpse into the potential of this innovative method.

Our research, driven by a conceptual data model, the resampling technique, and the integration of Principal Component Analysis and clustering models, has demonstrated the feasibility of detecting and identifying survivors of natural disasters based on their distinctive VOC profiles. The results we've achieved signify a significant step forward in the realm of disaster management.

Our study has revealed the potential of VOC analysis as a complementary tool for rapid and reliable human identification during disasters. Notably, we've identified seven distinct clusters, each representing unique patterns of VOC presence. While further research is warranted, these findings hold promise for distinguishing individuals or physiological conditions based on VOC profiles when traditional methods face limitations.

Looking ahead, we envision the evolution of new generations of tools capable of real-time detection of individuals who may be trapped or concealed in the debris of a natural disaster. Chemistry and physics are expected to play pivotal roles in solving technical challenges associated with sensor development and measurement instruments. These advancements could revolutionize disaster response strategies, expediting rescue efforts and enhancing overall disaster management.

Our study makes theoretical and practical contributions to the existing body of knowledge in disaster management and human identification. By introducing VOC analysis as an additional method, we expand the toolkit available for search and rescue teams. This approach offers a versatile means of addressing the critical challenge of identifying and locating human survivors during natural disasters. Moreover, our study highlights the importance of ethical considerations in handling data related to human beings, fostering a holistic approach to disaster response.

In summary, our research underscores the promise of VOC-based body odor analysis as an innovative solution for addressing the critical challenge of identifying and locating human survivors during natural disasters. This has profound implications for enhancing disaster response strategies, ultimately saving lives and fostering hope for the future of disaster management.

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