Usage of AI techniques and IOT devices for Disaster Recovery

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Abstract: This paper outlines a comprehensive framework that integrates Artificial Intelligence (AI), machine learning techniques, Internet of Things (IoT) devices, and autonomous Bots to aid in disaster recovery operations. The system focuses on using AI and IoT to scan disaster-affected areas for traces of life while reducing the risks faced by rescue teams through the deployment of automated drones and bots in hazardous environments. Additionally, it incorporates planning for post-rescue operations, including disease prevention and mental health counseling. By syncing AI-driven data analysis with real-time sensing from IoT devices and autonomous bots, the system enhances the efficiency and safety of rescue operations. Real-time updates through heat maps enable dynamic resource allocation and targeted rescue efforts, significantly improving survival rates and minimizing risks to the task force.

Keywords— *Disaster Recovery, Artificial Intelligence (AI), Internet of Things (IoT), Autonomous Robots, Machine Learning, Drones, Heat Mapping, Survivor Detection, Emergency Response, Data Visualization, Rescue Operations, Infrared Technology, Communication in Disasters, Disaster Risk Management, Predictive Analytics, Agile, Scrum, Kanban, Framework Agnostic, Lean, Extreme Programming (XP), Transformation.*

I. INTRODUCTION

Disasters, both natural and human-made, pose significant threats to human life, infrastructure, and the environment. Events such as earthquakes, floods, and hurricanes have repeatedly demonstrated the limitations of traditional disaster recovery methods, particularly in locating survivors and minimizing risks to rescue teams. The need for more efficient and intelligent systems in disaster recovery has become increasingly apparent, given the complexity and urgency of such operations.

Technological advancements in Artificial Intelligence (AI), the Internet of Things (IoT), and autonomous systems offer promising solutions to enhance disaster recovery efforts. AI, with its capacity to analyze vast amounts of data rapidly, can play a critical role in identifying survivors, predicting high-risk areas, and optimizing resource allocation. IoT devices, equipped with sensors and communication technologies, provide real-time data from disaster zones, enabling rescue teams to assess the situation more accurately. Drones and Bots, once limited to experimental and niche applications, now provide autonomous solutions to reach areas that are dangerous or inaccessible to human responders.

This paper presents an integrated framework that leverages AI, IoT, and autonomous Bots to enhance the efficiency and safety of disaster recovery operations. By utilizing AI to process data from IoT sensors, thermal imaging, and environmental monitoring, the system enables precise identification of survivors. Additionally, the framework reduces the risks to human rescuers by deploying autonomous Bots and drones in hazardous areas. Beyond immediate rescue efforts, the system incorporates post-rescue services such as disease prevention and mental health counseling, addressing the broader impact of disasters on affected communities.

The proposed system aims to improve survival rates, reduce human losses, and increase the speed and accuracy of disaster response efforts. By synchronizing AI-driven data processing with real-time updates from IoT devices and autonomous rescue technologies, this approach represents a significant advancement over traditional methods, offering a scalable, efficient, and safer solution for disaster management.

Integration of IoT, Drones, and AI-Driven Robots in Disaster Recovery

IoT devices equipped with Grid-EYE sensors detect human presence by capturing infrared radiation emitted from the human body. This technology plays a vital role in disaster recovery by identifying survivors under debris through temperature changes (2). Drones, once used primarily for recreational purposes, now serve crucial functions in disaster zones by quickly reaching remote or dangerous areas that are inaccessible to human rescuers. These drones, equipped with sensors and cameras, work in tandem with IoT devices to create heat maps—data visualizations that display concentrations of human life based on thermal readings (3). Heat maps provide critical insights into the spatial distribution of survivors, allowing rescue teams to allocate resources effectively and prioritize high-impact zones. According to recent studies, the integration of AI-driven analytics with these technologies enhances situational awareness, enabling faster and more informed decision-making during emergencies (7)(ai for disasters).

AI-powered technologies, such as FINDER (Finding Individuals for Disaster and Emergency Response), have further revolutionized rescue efforts by detecting heartbeats and breathing under rubble. Developed by JPL and the Department of Homeland Security, FINDER has been deployed globally, including during the Mexico earthquake in 2017, in Puerto Rico after Hurricane Maria, and after the 2015 Nepal earthquake (4). The effectiveness of AI in processing large volumes of data quickly is crucial in time-sensitive disaster scenarios, helping responders prioritize rescue operations and manage logistical challenges (8)(Edge_Technologies_for_D…). Robots, once considered toys, now perform critical tasks such as locating buried victims, defusing bombs, and dismantling decommissioned nuclear plants. Rescue robots, equipped with night vision, microphones, and optical cameras, use heat detection to locate individuals (4). Some robots can even administer first aid, such as remote-controlled robots built to help soldiers in battlefields by performing CPR (5) and flying robots designed to deliver defibrillators to emergency locations (6).

Recent advancements in machine learning algorithms further enhance the capabilities of these robots, allowing for improved detection and response in dynamic environments (7)(ai for disasters). By synthesizing data from IoT devices, drones, and AI, disaster recovery operations can achieve greater efficiency and effectiveness, ultimately leading to higher survival rates and reduced risks to rescue personnel. This integrated approach exemplifies the transformative potential of emerging technologies in enhancing disaster resilience and response strategies(Edge_Technologies_for_D…).

Bot Forces Approach with no network

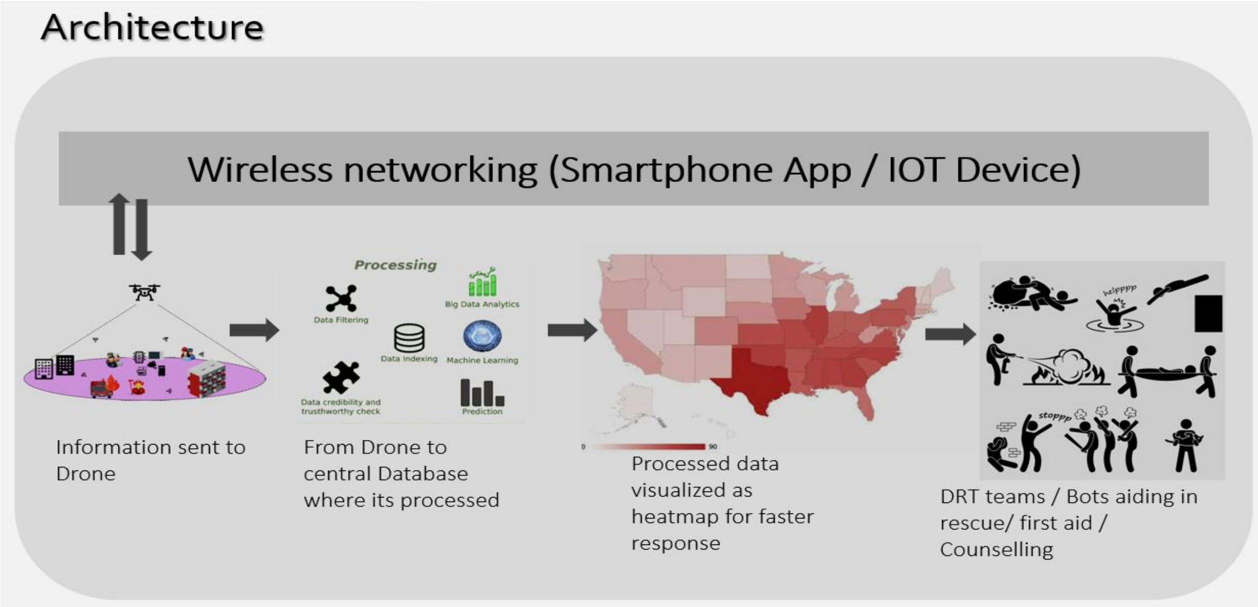
- An IOT device/ Grid eye will be attached to any household device which would draw power from solar panels, and it will be in active stand-by mode.
- This IOT device will be trained for movement recognition and or heat recognition. This will communicate with the Drones and Bots using available communications channel/satellite or beacon signals.
- The Bots/Drones will collect information from the Device and send it to the central database which can be trained to dynamically update the heat maps.
- Based on the concentration of the Heat map rescue team and other humanitarian agencies can decide where to conduct aerial assessments. Based on the determination, bots/rescue teams will be deployed immediately.
- As a part of the relief activity the bots can be trained using Animal Instincts to identify people in SOS mode under different environments (Land / Water / Debris) and rescue the lives as well.
- Once the lives are rescued first aid is given immediately by the bots and the rescue people will be moved to the nearby camps for further aid and counseling.
- The Bots and Drones are synched to update the information dynamically for creating new heat maps and this rescue operation continues till the heat map is completely light and its is determined all possible lives have been rescued.

Use Case Scenarios:

- The IOT device should be switched on and completely charged all the time. The device has a chip which charges the battery using solar energy. The device has to be waterproof, fireproof and unbreakable (like a black box).

- Be it natural or man-made disaster the damage to lives cannot be estimated. Finding lives under debris or under water or in fire will be a Himalayan task for the rescue team. Using this device which can recognize movement and will send signals to the drones. The drones will send the information to the central database where a dynamic heatmap is populated and based on the concentration of the heat map the impact is assessed and the animal bots will be deployed to rescue the life under water, or under debris or in fire. Once the lives are rescued the information is sent back to the database and the heat map is updated. The people rescued are then sent to the rehabilitation center and there they are provided First aid and first counseling session by Human Bots. This is a continuous process till all lives are rescued.

ARCHITECTURE



AI Techniques & Devices

1. Machine Learning (ML):

Machine learning (ML) techniques can manage the massive influx of data collected during disaster recovery. Depending on the specific task, different ML models are employed:

- Supervised Learning Models: In supervised learning, algorithms like Random Forests or Support Vector Machines (SVM) are trained on labeled datasets of past disaster scenarios. These datasets might include sensor data, geographic information, and rescue outcomes, helping the model predict high-priority zones for rescue teams. For example, sensor data from IoT devices could indicate temperature, movement, or sound patterns, which a trained ML model would analyze to predict the location of survivors or assess structural risks.

- Unsupervised Learning Models: Unsupervised learning models such as K-Means Clustering or Gaussian Mixture Models (GMM) are used to group unlabeled data. In disaster situations, IoT sensors spread across the affected area collect data that unsupervised models can cluster, identifying new patterns like the emergence of critical hotspots. This is particularly useful in identifying areas with unexpected concentrations of survivors or evolving risks.

2. Deep Learning:

Deep learning excels in disaster scenarios where complex data such as images, videos, or sound needs to be processed rapidly. Different architectures like *YOLOv8*, *ResNet*, and *DenseNet* serve distinct purposes based on their design.

- **YOLOv8 (You Only Look Once Version 8):** YOLOv8 is a real-time object detection model, designed for high-speed, high-accuracy detection tasks. In disaster recovery, drones equipped with cameras can fly over affected areas, capturing real-time video and image feeds. YOLOv8 can process these frames rapidly to detect survivors, debris, and obstacles within milliseconds. Here's how YOLOv8 fits into disaster scenarios:
- Object Detection in Real Time: YOLOv8's architecture is streamlined for fast inference, making it ideal for drone feeds where speed is crucial. YOLOv8 can detect multiple objects like human bodies, debris, or blocked pathways in a single frame. The detection bounding boxes produced by YOLOv8 can be sent to rescue coordinators in real-time, enabling rapid decision-making on where to focus rescue efforts.
- Deployment in Drones: By integrating YOLOv8 into drones, the model runs on the edge using small yet powerful computational platforms like NVIDIA Jetson or Raspberry Pi. These edge computing systems enable the YOLOv8 model to process images locally, reducing the delay caused by cloud computing. This is critical when operating in remote or network-constrained environments.
- Improvement with Transfer Learning: YOLOv8 can be fine-tuned with transfer learning using labeled disaster-specific datasets (e.g., images of debris or survivors from past disasters). This specialized training ensures the model detects relevant objects in a disaster context, increasing accuracy compared to general-purpose models.
- **Residual Networks (ResNet):** ResNet's ability to train deep networks without the vanishing gradient problem makes it perfect for complex classification tasks, such as differentiating between human figures and debris in chaotic disaster environments. With its skip connections, ResNet efficiently extracts features from cluttered images, improving the accuracy of detecting survivors even in low-quality or partially obscured imagery.
- Post-**Processing and Fine-Tuning:** Post-processing techniques such as non-maximum suppression (NMS) are used after ResNet's inference to filter out redundant bounding boxes, ensuring only the most relevant detections are highlighted for rescue teams.
- **Dense Convolutional Networks (DenseNet):** DenseNet's design, which connects each layer to every other layer, facilitates efficient feature propagation across deep networks. This feature propagation is crucial in disaster recovery, where low-visibility conditions (e.g., smoke or darkness) complicate the detection of survivors. DenseNet ensures that even subtle features, such as heat signatures or faint movements, are effectively captured and identified by the model.
- **Low-Visibility Adaptations:** DenseNet can be combined with infrared or thermal imagery captured by drones or ground robots, further enhancing detection in poor lighting conditions. This makes DenseNet highly suitable for night operations or areas with dense smoke.

3. Natural Language Processing (NLP):

NLP models play a critical role in processing vast amounts of text-based data generated during disasters, including social media updates, emergency call transcripts, or official reports.

- **Sentiment Analysis Using Pretrained Models:** NLP techniques can leverage pretrained models like *BERT* (Bidirectional Encoder Representations from Transformers) or *GPT* to analyze emergency-related social media posts. These models can extract meaningful insights from unstructured text, such as identifying the areas of greatest distress based on language used by affected populations.
- **Speech-to-Text Models for Real-Time Communication:** NLP speech recognition systems, such as *DeepSpeech* or Google's *WaveNet*, can convert audio from emergency calls into text, allowing AI-driven systems to prioritize calls based on urgency or content. This real-time transcription and analysis ensures rapid and accurate information flow between affected individuals and rescue teams.

4. Reinforcement Learning (RL):

Reinforcement learning is particularly useful for autonomous systems in disaster scenarios, where robots and drones must adapt to unpredictable environments. RL algorithms like *Deep Q-Networks (DQN)* or *Proximal Policy Optimization (PPO)* allow autonomous agents to learn optimal actions through trial and error.

- **Autonomous Navigation:** Robots or drones in debris-heavy environments can use RL to learn efficient navigation strategies. For example, a ground robot searching for survivors inside a collapsed building would encounter different obstacles. An RL-trained navigation algorithm allows the robot to explore the space efficiently, identifying survivors while avoiding hazards like unstable structures.
- **Simulated Training:** RL models are typically trained in simulated environments that mimic real-world disaster conditions. This allows the robot to learn various behaviors, such as avoiding falling debris or finding alternative routes around blocked areas, before being deployed in the field.

AI Devices in Disaster Recovery

1. IoT Sensors:

IoT devices form the backbone of data collection during disasters. These sensors continuously monitor environmental conditions and human activity, providing critical data for AI algorithms to analyze.

- **Grid-EYE Infrared Sensors:** These sensors are capable of detecting heat signatures from human bodies, even through light debris. By feeding the sensor data into AI models, especially CNN-based architectures, the system can identify survivors in hard-to-reach areas.
- **Edge AI for On-Site Processing:** Edge AI platforms like *TensorFlow Lite* or *OpenVINO* can process sensor data in real-time at the disaster site, allowing for immediate decisions without needing to send data to the cloud. This approach reduces latency and enables faster responses.

2. Drones:

Drones equipped with advanced imaging sensors and AI algorithms play a vital role in providing an aerial perspective of the disaster site. Their versatility makes them indispensable in both urban and rural disaster settings.

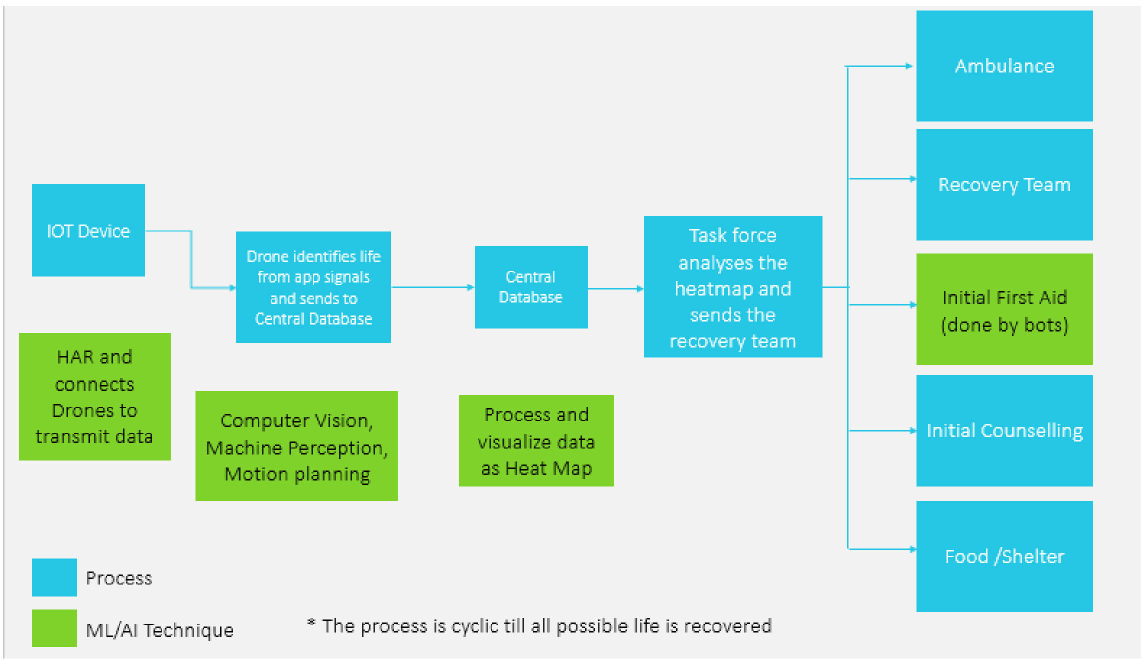
- **Drone Imaging with YOLOv8 and CNNs:** As mentioned, drones equipped with high-resolution cameras and thermal sensors can feed data into AI models like YOLOv8 for object detection. The drone's footage is processed in real-time, providing a detailed map of survivors, debris, and blockages that rescue teams can use for immediate interventions.

3. Robotic Systems:

Autonomous robots provide valuable ground support, particularly in areas that are too dangerous or inaccessible for human rescuers.

- **Search-and-Rescue Robots with RL Models:** These robots, equipped with advanced RL-based navigation systems, can traverse unstable terrains, find survivors, and deliver emergency supplies. The continuous learning ability of RL models ensures these robots improve their navigation efficiency with each deployment, adjusting to new types of obstacles or terrain.
- **Equipped with ResNet/DenseNet:** Robots with onboard ResNet or DenseNet models can perform image recognition tasks with high accuracy. For instance, they can differentiate between a person trapped under debris and a non-critical object, streamlining the rescue process.

COMPONENT LEVEL ARCHITECTURE



CHALLENGES & LEARNINGS

Throughout the development of our disaster recovery solution, we encountered several challenges that arose from brainstorming sessions, real-world experiences, and insights from various references. These obstacles ultimately guided us toward a more robust solution.

One significant challenge was illustrated during the Chennai floods and Vardha Cyclone, where complete network failure left communities stranded without any connectivity. This experience highlighted the critical need for reliable communication methods in disaster scenarios. Discussions with military professionals further emphasized the importance of maintaining operational confidentiality during such calamities, leading us to consider alternative communication methods like HAM radio and infrared signals as part of our solution.

Another challenge we faced was the lack of resources necessary to create a functional working model. Without access to the required bots and systems to establish a comprehensive database, we needed to find innovative ways to demonstrate our concept. To address this, we developed an animation that effectively illustrated our idea, allowing us to communicate the proposed solution despite the limitations.

Additionally, integrating heat maps with our database emerged as a crucial component of our system. The concept stemmed from the incident heat maps generated during service quality assessments, providing valuable insights into the spatial distribution of affected areas. This integration not only enhances situational awareness but also aids in making data-driven decisions during disaster recovery efforts.

CONCLUSION

The integration of AI-driven systems, IoT devices, and a drone-based rescue system has redefined the landscape of disaster recovery operations. By employing sophisticated AI techniques such as machine learning, deep learning, and reinforcement learning, these systems can process vast datasets in real time, leading to quicker, more accurate decisions. In particular, deep learning models like YOLOv8 enhance object detection and situational awareness, allowing drones to locate survivors and obstacles in disaster zones swiftly.

The **Bot Forces Approach with no network** further amplifies the effectiveness of rescue missions. IoT devices such as Grid-EYE sensors, powered by solar energy, remain in a continuous standby mode, trained to recognize movement or detect heat signatures. These sensors communicate directly with drones and bots using satellite or beacon signals, enabling real-time updates to centralized systems. The gathered data is used to dynamically generate heat maps, indicating areas with higher chances of survivors. Based on this data, drones and bots are deployed to assess and perform rescue operations, minimizing the risks to human responders.

Moreover, the system incorporates an innovative approach by training bots with animal-like instincts to rescue individuals in diverse environments such as water, fire, or debris. These bots not only locate and rescue survivors but also provide first aid before transferring them to nearby camps for further medical assistance and counseling. The seamless synchronization between drones, bots, and IoT devices ensures continuous updates to heat maps, guiding ongoing rescue efforts until all survivors are located.

By merging AI, IoT, and autonomous systems, this integrated solution ensures faster, safer, and more efficient disaster recovery, offering a scalable model that can adapt to both natural and man-made disasters, significantly improving survival rates and reducing the workload on rescue teams.

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