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Data Science

Sentinel AI:
Smart City Emergency Response System

Group No. 4

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Project Guide
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Abstract

Real time problems and challenges

With increasing urbanization, there is a growing risk of emergencies due to the higher concentration of people in densely populated areas. Emergency response teams often face delays because of the lack of real-time data, making it difficult to respond quickly and effectively. Additionally, insufficient communication between various emergency services further complicates coordinated efforts in handling emergency situations. At the same time, the collection of data in public spaces to improve response times raises concerns about privacy and the proper handling of personal information.

Overall Idea

“Sentinel AI” revolutionizes urban safety by integrating personal and smart city sensors into a centralized hub. It utilizes multimodal AI on edge nodes to autonomously detect emergencies such as gas leaks, fires, and accidents. Once an emergency is identified, authorities are instantly notified, with privacy and data security ensured throughout the process. The solution also includes a user-friendly mobile app for reporting incidents and provides a dashboard for emergency services, enhancing communication and improving response times.

Introduction

Real-Time Observation of Problem Domain:

- **Urban Safety Concerns:** Rapid urbanization increases fires, gas leaks, and accidents in cities
- **Inefficient Emergency Response:** Traditional systems lack real-time data, causing delays and safety risks
- **Fragmented Communication:** Fragmented communication between agencies hampers emergency responses
- **Privacy Issues**: Existing systems collect excessive data without proper safeguards

Current Solutions and Issues:

- **Basic Alarm Systems:** Smoke detectors and gas alarms aren't integrated with wider emergency networks, reducing their effectiveness
- **Manual Reporting Mechanisms:** Emergency services rely on calls or texts, causing delays and possible misinformation
- **Lack of Analytics:** Current systems lack advanced analytics, preventing cities from improving infrastructure or predicting future incidents

Motivation:

- **Personal Experiences:** Witnessing delays in emergency responses during critical situations fueled a desire to find a more effective solution
- **Technological Advancements:** The rapid development of AI and IoT technologies presents a unique opportunity to create a system that can transform urban emergency response
- **Community Impact:** A strong commitment to enhancing community safety and quality of life by ensuring rapid and efficient emergency responses

Objectives

- **Automate Emergency Detection:** Use sensors and AI to detect gas leaks, fires, and accidents, ensuring rapid reporting to authorities
- **Enhance Coordination Among Emergency Services:** Centralized platform enhances communication and data sharing for efficient crisis management
- **Develop a User-Friendly Mobile App:** Develop an app for citizens to report emergencies, triggering instant alerts to response teams
- **Implement Advanced Analytics for Infrastructure Improvement:** Create a dashboard for emergency trends, helping city planners improve safety and infrastructure

Literature Review

Sr.no	Title	Author(s)	Year	Methodology	Drawback
1 [1]	An Accident Detection and Classification System Using Internet of Things and Machine Learning	Mohammed Balfaqih, Soltan Abed Alharbi, Moutaz Alzain, Faisal Alqurashi, Saif Almilad	2022	Data from sensors processed by a microcontroller; accidents classified by machine learning algorithms	GMM has the highest time complexity; implementation requires a reliable IoT infrastructure and the hardware setup involves multiple sensors
2 [2]	A Smart Building Fire and Gas Leakage Alert System with Edge Computing and NG112 Emergency Call Capabilities	Evangelos Maltezos, Konstantinos Petousakis, Aris Dadoukis, Lazaros Karagiannidis, Eleftherios Ouzounoglou, Maria Krommyda, George Hadjipavlis, Angelos Amditis	2022	Multisensor-based system with edge computing and automated NG112 emergency call functionality, using IoT devices, sensor nodes, and a distributed edge computing platform (DECIoT).	Limited to certain types of sensors, potential false positives requiring confirmation, does not handle image or video processing.
3 [3]	Fire Detection Method in Smart City Environments Using a Deep-Learning-Based Approach	Kuldoshbay Avazov, Mukhriddin Mukhiddinov, Fazliddin Makhmudov, Young Im Cho	2022	Developed a novel convolutional neural network based on an enhanced YOLOv4 algorithm for fire detection	False positives in certain scenarios like sunrise/sunset due to color intensity, complexity in handling real-time systems

Literature Review

Sr.no	Title	Author(s)	Year	Methodology	Drawback
4 [4]	City Alerts: Smart City Notification Platform Based on Public Open Data	Daniel Rusu, Silviu Vert	2014	- Collection and integration of open data from various public agencies - Use of public APIs and file uploads	- Challenges in integrating diverse data formats from public agencies - Limited to non-emergency alerts
5 [5]	A Distributed Multi-Tier Emergency Alerting System Exploiting Sensors-Based Event Detection to Support Smart City Applications	Daniel G. Costa, Francisco Vasques, Paulo Portugal, Ana Aguiar	2020	Distributed multi-tier system with sensors-based event detection to generate georeferenced emergency alarms based on scalar sensor data, GPS, and risk zones.	Limited to scalar sensor data, reliance on specific hardware (e.g., Raspberry Pi), potential challenges in scaling to very large cities without optimization
6 [6]	Object Tracking for a Smart City Using IoT and Edge Computing	Hong Zhang, Zeyu Zhang, Lei Zhang, Yifan Yang, Qiaochu Kang, Daniel Sun	2019	Proposed a region proposal correlation filter for object tracking in IoT and edge computing, using a lightweight computing algorithm for real-time tracking	Limited to visual object tracking, challenges with long-term tracking under occlusion or fast motion

Literature Review

Sr.no	Title	Author(s)	Year	Methodology	Drawback
7 [7]	Design and Implementation of a Smart IoT Based Building and Town Disaster Management System in Smart City Infrastructure	Sangmin Park, Soung Hoan Park, Lee Won Park, Sanguk Park, Sanghoon Lee, Tacklim Lee, Sang Hyeon Lee, Hyeonwoo Jang, Seung Min Kim, Hangbae Chang, Sehyun Park	2018	AR-based disaster management system providing real-time fire alerts and evacuation guidance using IoT, AI, and big data, integrated with smart city infrastructure for rapid response.	Relies heavily on sensor accuracy, possible delays in real-time updates, limited testing on large-scale deployments.
8 [8]	Geospatial Dashboards for Monitoring Smart City Performance	Changfeng Jing et al.	2019	Literature review	The veracity of geospatial data affects geospatial dashboards.2 Existing applications focus on data fusion to provide city performance measurements, rather than developing a big geospatial data analysis model for knowledge extraction.
9 [9]	Triangulum City Dashboard: An Interactive Data Analytic Platform for Visualizing Smart City Performance	Mina Farmanbar and Chunming Rong	2020	The researchers developed a three-tier architecture for their data visualisation platform: a data layer, an application and analysis layer, and a presentation layer.	The researchers encountered a number of challenges while building the platform, including different data resolutions, heterogeneity of data types, data quality heterogeneity, legal restrictions regarding data privacy, and variations in data structure. In addition, there are issues related to data access and reuse. The validity of analysis drawn from a dashboard is contingent on the veracity of the data.151617

Research Gap

Current State of the Problem:

- **Unresolved Issues**:
  - Systems not fully integrated across various emergency scenarios.
  - Persistent challenges with false positives and data quality.
  - Limited real-world testing of integrated Smart City systems in a large urban environment.
- **Gap from a Completely Solved Problem**:
  - Existing solutions lack comprehensive scalability and cross-functional capabilities.
  - Need for a more robust integration of diverse technologies such as Real Time streaming, Machine Learning and AI Agents

Research Gap

Observations & Improvement Possibilities:

- **Better Performing Technologies**:
  - **IoT and Edge Computing**: Effective for real-time processing (Maltezos et al., Zhang et al.)
  - **Advanced Machine Learning Models**: High potential in reducing false positives (Avazov et al., Balfaqih et al.).
- **Improvement Areas**:
  - Enhance network sensors to cover more emergency types
  - Integrate advanced analytics for better decision-making
  - Focus on data veracity and real-time processing capabilities

Research Gap

Confidence in Addressing Issues

- **Confidence Level:** High confidence in contributing solutions in identified gaps
- **Justification:**
  - Proposed solution integrates multiple levels of processing on data and prioritizes quick response leveraging multiple machine learning models to analyze and notify authorities
  - Existence of good quality datasets and multiple deep learning models for various sensors including camera feeds, gas sensors and thermal imaging sensors enables us to focus on building a prototype and fine tuning the models to our specific use cases rather than reinventing the wheel
  - Experience working with technologies such as pytorch, Django/fastapi and htmx ensures seamless implementation

Problem Definition

- Rapid urban growth increases emergency management complexity, such as fires, accidents, and disasters
- Current emergency systems struggle with delayed detection, inefficient data processing, and poor resource allocation
- These limitations slow response times and increase public safety risks
- "Sentinel AI" aims to develop a smart city emergency response system
- It uses real-time data from sensors, machine learning algorithms, and citizen engagement
- The system enhances emergency detection, analysis, and management, reducing response times and improving urban safety

Key issues addressed:

- **Delayed Incident Detection**: "Sentinel AI" uses IoT sensors for real-time emergency detection, reducing delays
- **Inefficient Data Processing:** Machine learning in "Sentinel AI" processes data in real-time to identify emergencies
- **Resource Allocation**: Predictive analytics in "Sentinel AI" improves resource deployment for quicker responses
- **Citizen Engagement**: : A mobile app lets citizens report incidents, verified by AI for accuracy
- **Data Privacy and Security:** "Sentinel AI" ensures encryption and secure communication for protecting sensitive data

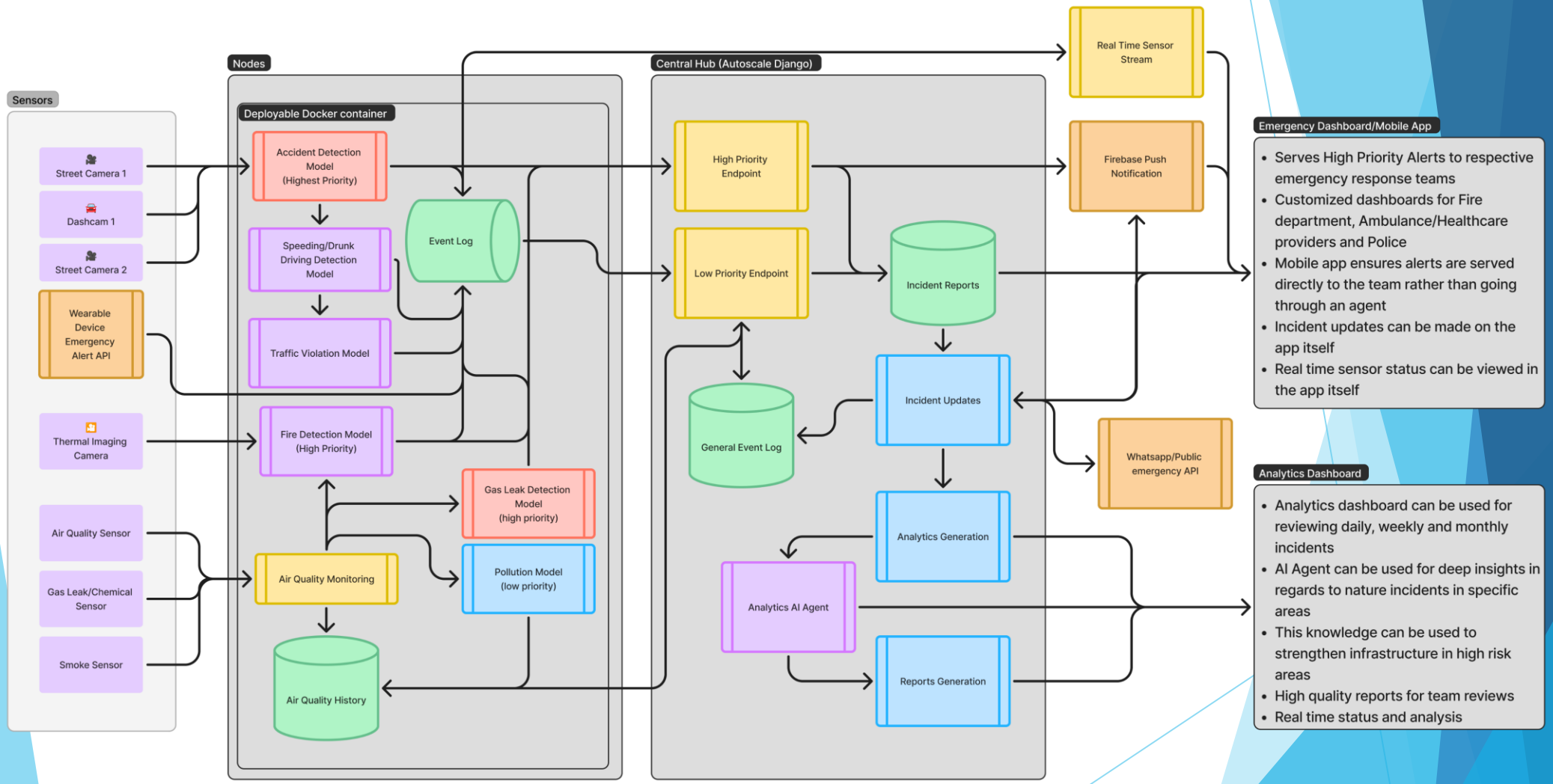
Scope

- **Smart City Integration and Multi-Agency Coordination:** Use existing infrastructure for improved emergency communication among services like police, fire, and medical responders
- **Focused Coverage in High-Density and Critical Areas:** Focus on residential, commercial, and public spaces for rapid emergency response
- **Industrial Zone Application and User Engagement:** Extend coverage to industrial areas and involve citizens through a mobile app for reporting incidents
- **Data-Driven Insights and Privacy Focus:** Use analytics for emergency patterns while ensuring data privacy and consent mechanisms

Technological Stack

- Docker, Kubernetes, VMWare Pro for deployment
- Django 5.0 with async views for centralized hub
- Django Channels for websockets
- Django Rest Framework for Rest API
- Nginx/S3 for storing and serving media and static files
- FastAPI for edge nodes
- Tensorflow, PyTorch, Keras for fine tuning and deploying pretrained models
- React Native/Flutter for mobile app, Tailwind CSS, DaisyUI, ChartJS and AlpineJS for web interface
- OpenCV for video capturing and processing
- Custom simulations using Smart Phone Sensors, Prerecorded CCTV feeds and time series Datasets of air quality

Proposed system architecture/Working



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- Jing, Changfeng, et al. "Geospatial dashboards for monitoring smart city performance." *Sustainability* 11.20 (2019): 5648.
- Farmanbar, Mina, and Chunming Rong. "Triangulum city dashboard: an interactive data analytic platform for visualizing smart city performance." *Processes* 8.2 (2020): 250.

Datasets

- Accident Detection from CCTV: https://www.kaggle.com/datasets/ckay16/accident-detection-from-cctv-footage
- Accident Severity dataset: https://universe.roboflow.com/razan-sendi/accident-severity-detection-dataset
- Thermal Camera Flame detection dataset: https://www.mdpi.com/2571-6255/5/5/172
- Smoke Detection dataset: https://www.kaggle.com/datasets/deepcontractor/smoke-detection-dataset
- Chemical Gas Leak dataset: https://universe.roboflow.com/gas-leak/pipeline-leak-prediction/dataset/11
- Fire, Smoke and gas leakage detection dataset: https://zenodo.org/records/6616632
- Traffic Signal Violation Detection System: https://github.com/anmspro/Traffic-Signal-Violation-Detection-System
- LISA Traffic Light Dataset: https://www.kaggle.com/datasets/mbornoe/lisa-traffic-light-dataset
- NHTSA FARS Dataset (Fatality Analysis Reporting System): https://www.nhtsa.gov/file-downloads?p=nhtsa/downloads/FARS/

Thank You...!!