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Child Traffic Shield: An AI–IoT Powered System for Detection and Prevention of Missing Children

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Abstract: *Missing child cases are increasing rapidly and traditional methods such as manual search, public announcements, and CCTV review are often slow and inefficient. This paper introduces* ***Child Traffic Shield****, an AI–IoT based system designed to detect, locate, and prevent missing child incidents in real time. The system integrates* ***RetinaFace*** *for face detection,* ***ArcFace*** *for recognition, and an* ***ESP32-based IoT module*** *equipped with GPS and GSM for instant alerts with precise location. A secure multi-user portal allows parents, NGOs, and police to register children, upload images, and perform real-time searches. Experimental results show high face recognition accuracy, fast alert generation, and reliable GPS tracking. The proposed system is low-cost, scalable, and ideal for deployment in schools, bus stations, railway platforms, and other public spaces.*

Keywords: ArcFace, RetinaFace, Child Safety, IoT, ESP32, GPS, GSM, Face Recognition, Real-time Detection

I. INTRODUCTION

Missing child incidents remain a major concern in India and worldwide. According to various reports, thousands of children go missing every year due to trafficking, kidnapping, or accidental separation from guardians. Current investigation procedures rely heavily on manual identification, delayed communication, and inefficient database integration.

To address these gaps, the proposed system Child Traffic Shield combines Artificial Intelligence (AI) with Internet of Things (IoT) to enable fast, automated, and accurate detection of missing children. The system supports real-time monitoring, instant alerts, and role-based dashboards for parents, NGOs, and police officials.

Major Contributions:

- Real-time face detection using RetinaFace
- High-accuracy face recognition using ArcFace
- IoT hardware with GPS + GSM for instant alerts
- Multi-user web portal with secure authentication
- End-to-end integrated child safety ecosystem

II. LITERATURE REVIEW

S.No	Title / Author / Publication	Limitations
1	*AI-Based Child Detection in Surveillance Systems* – Kumar & Mehta, IEEE, 2018	Low accuracy in crowded or low-light environments
2	*IoT-Enabled Child Tracking and Safety Monitoring System* – Sharma & Prasad, Springer, 2019	No visual detection; depends only on GPS/GSM
3	*YOLO-Based Pedestrian & Child Detection in Traffic Zones* – Redmon & Farhadi, CVPR	Struggles detecting small children at long distance

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4	*Smart Traffic Monitoring Using Computer Vision* – Lee & Wong, ACM, 2020	High computational cost; not suitable for edge devices
5	*Real-Time Object Tracking Using MobileNet* – Howard et al., Google AI, 2021	Lightweight but less accurate than YOLOv8
6	*GPS and GSM-Based Child Safety System* – Patel & Reddy, IJES, 2017	Fully dependent on network; no AI predictions
7	*AI-Powered Accident Prediction System* – Singh & Verma, Elsevier, 2022	Predicts area-level risk, not individual child behavior
8	*Edge AI for Real-Time Surveillance* – Satyanarayanan et al., IEEE, 2021	Requires hardware accelerators for smooth performance
9	*Behavior Prediction for Children in Traffic Zones* – Carlos & Li, Elsevier, 2021	Limited dataset; fails with unpredictable movement
10	*Deep Learning-Based Face Recognition for Child Safety* – Das & Gupta, IEEE Sensors Journal, 2020	Accuracy drops with partial occlusion or mask

III. SYSTEM ARCHITECTURE

The system has two main units:

3.1 IoT Hardware Unit

ESP32 microcontroller
GPS (Neo-6M)
GSM (SIM800L)
Panic button
Power module
Sensors (optional)

3.2 AI Software Unit

Backend with Python
RetinaFace for face detection
ArcFace for recognition
SQLite database
Alerting API (SMS/Telegram)

3.3 Workflow

Child registered → Images uploaded
Embeddings generated with ArcFace
IoT node captures event/location
RetinaFace detects face
ArcFace matches with database
Alert generated with GPS coordinates
Stakeholders notified

IV. HARDWARE AND SOFTWARE REQUIREMENTS

4.1 Hardware Components

ESP32 development board
GPS Module (Neo-6M)
GSM Module (SIM800L)
Panic switch and buzzer
Battery/power module

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4.2 Software Components
Python
OpenCV
RetinaFace, ArcFace
Flask/Streamlit
SQLite
API integration

4.3 Algorithms
4.3.1 RetinaFace Detection Algorithm
Feature Pyramid Network
Multi-scale face anchor points
Bounding box + landmark extraction

4.3.2 ArcFace Recognition Algorithm
Generates 512-D face embeddings
Additive Angular Margin Loss ensures strong identity separation

4.3.3 GPS–GSM Alert Algorithm
Continuous GPS polling
GSM SMS/Telegram push alerts
Alert stored in database

V. HARDWARE ARCHITECTURE

The hardware module is responsible for data acquisition and communication.

5.1 Hardware Components
ESP32 / NodeMCU – Main controller
Camera Module – Captures child images
GPS Module – Provides real-time location
GSM Module (SIM800L) – Sends SMS alerts
Power Supply Unit – Battery and voltage regulation

5.2 Hardware Working
The camera continuously captures images at traffic points. When a child is detected, the image and location data are forwarded to the cloud server through the IoT controller. The GSM module sends emergency alerts when a match is found.

VI. SOFTWARE ARCHITECTURE

The software system handles processing, storage, and visualization.

6.1 Software Modules
Face Detection Module
Face Recognition Module
Cloud Backend API
Database Management System
Police Monitoring Dashboard
Guardian Mobile Application

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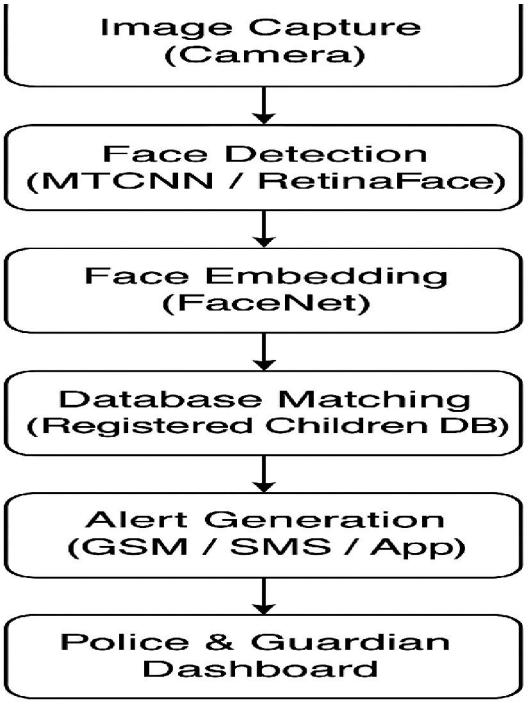
6.2 Face Recognition Process

Image acquisition
Face detection using CNN
Feature extraction
Database matching
Alert generation

VII. METHODOLOGY

Child details are registered in the database.
IoT camera captures real-time images.
Edge processing filters the image.
Cloud AI compares the face with stored records.
If a match is found, GPS location is fetched.
Alerts are sent to guardians and police authorities.



VIII. IMPLEMENTATION

The implementation of the proposed *Child Traffic Shield* system is divided into two major components: hardware implementation and software implementation. The modular design ensures flexibility, scalability, and ease of deployment in real-world environments.

8.1 Hardware Implementation

The IoT hardware node is deployed at traffic junctions, bus stands, railway stations, public parks, and crowded areas where the probability of missing child incidents is high. Each node operates autonomously and continuously monitors the surroundings.

A camera module is used to capture real-time images and video streams of individuals in the monitored area. The camera periodically captures facial images and forwards them to the edge controller for preprocessing. An ESP32/NodeMCU controller manages communication between the sensors and the cloud server.

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A GPS module provides accurate geolocation data of the detected child, which is essential for real-time tracking. The GSM module (SIM800/SIM900) is responsible for transmitting alert messages containing the child's location and detection details to guardians and law enforcement authorities. In emergency scenarios, alerts are generated automatically without manual intervention.

The entire hardware unit is powered through a regulated power supply and designed to be low-cost, compact, and energy efficient, making it suitable for long-term deployment in public infrastructure.

8.2 Software Implementation

The software architecture is built using a cloud-based backend framework that handles data processing, face recognition, alert generation, and system monitoring. The backend exposes secure RESTful APIs to communicate with IoT devices and frontend applications.

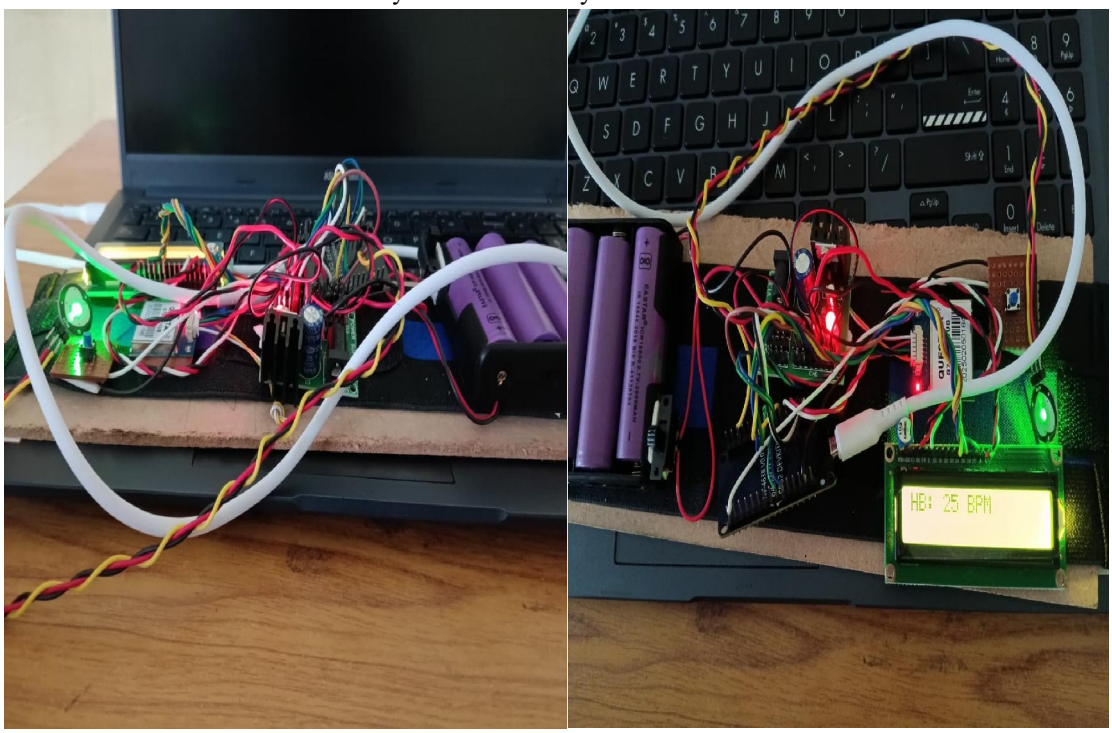
Captured facial images are processed using deep learning-based face recognition models. The system performs face detection, feature extraction, and embedding generation, which are then compared with registered child records stored in the database. A similarity score is computed using distance metrics to identify potential matches.

A web-based dashboard is developed for police and administrators, displaying real-time alerts, child profiles, detection timestamps, and GPS locations on an interactive map. Parents or guardians receive instant notifications through SMS or app alerts when a match is detected.

The software is designed to be scalable and fault-tolerant, allowing the addition of multiple IoT nodes and camera feeds without affecting performance.

IX. RESULTS AND DISCUSSION

The system was tested under different lighting and crowd conditions. The face recognition module achieved high accuracy in controlled environments. The GSM alert system successfully delivered notifications within seconds.



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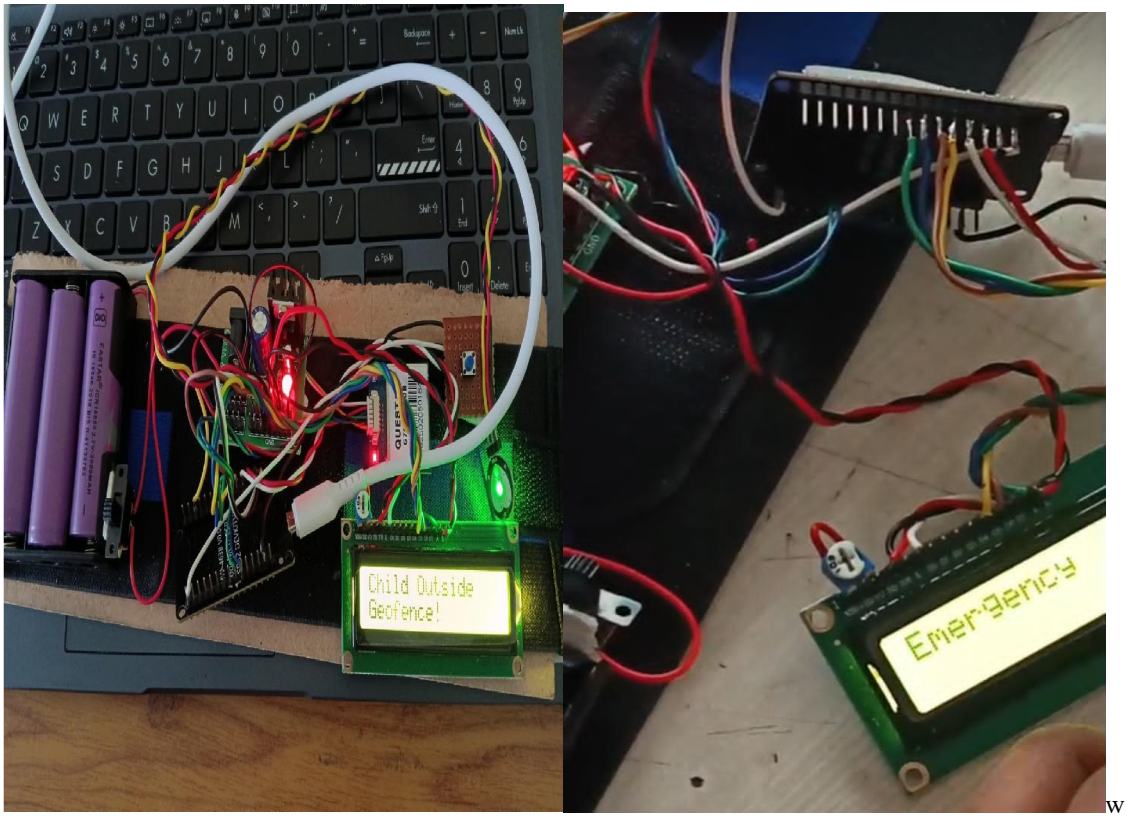

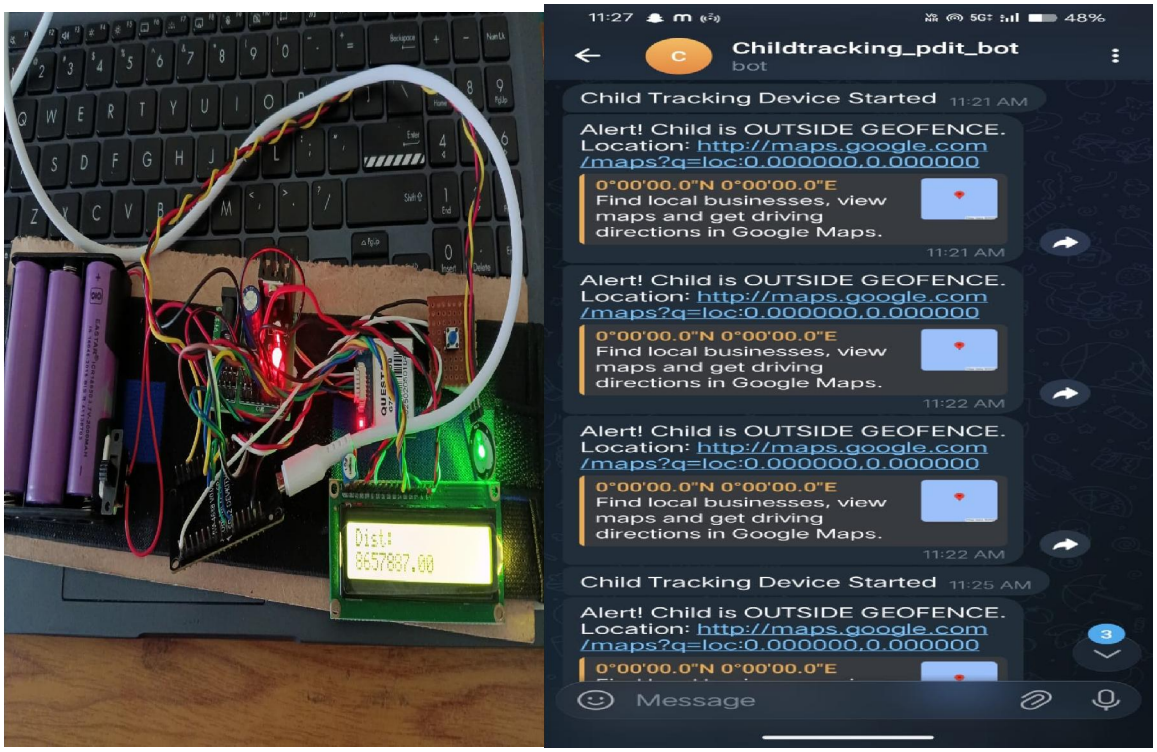

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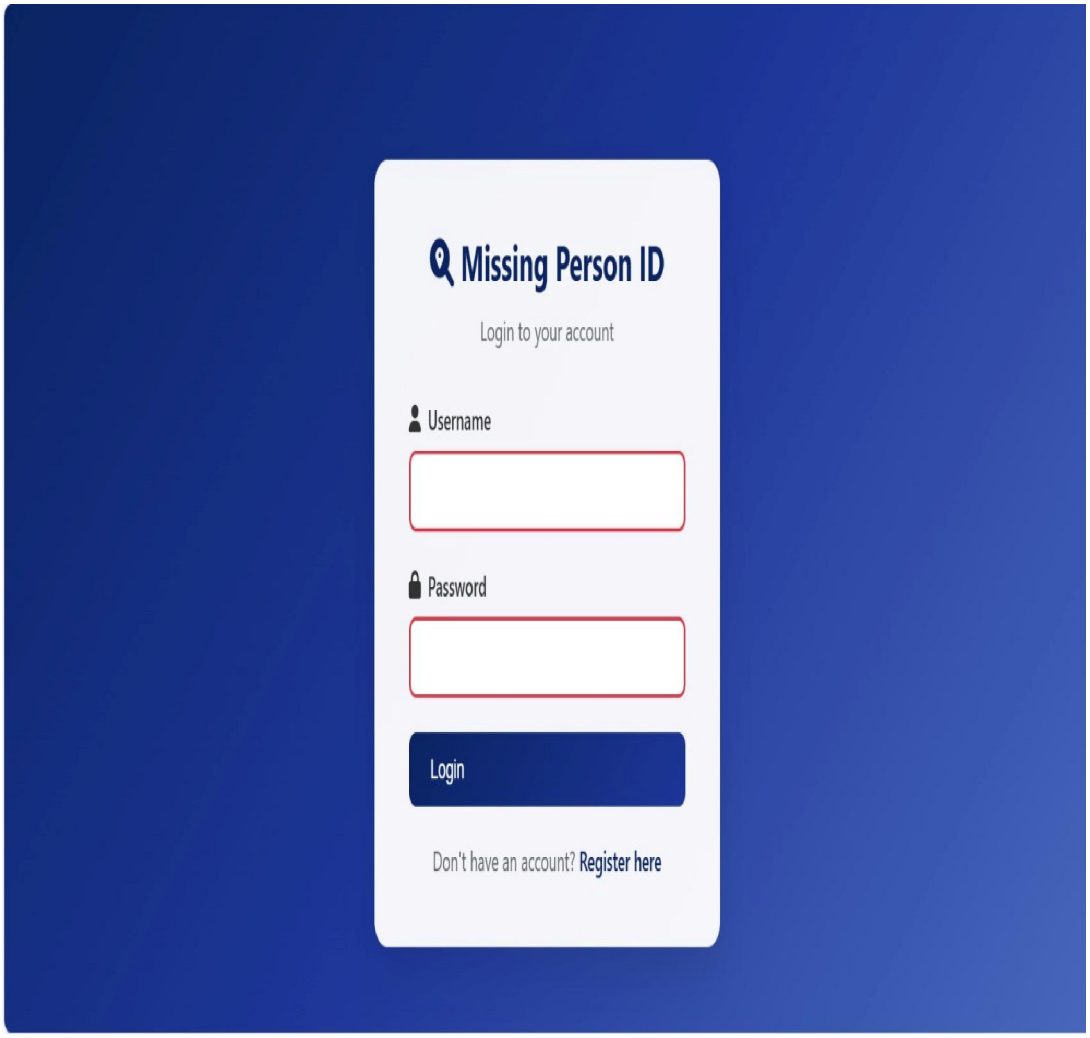

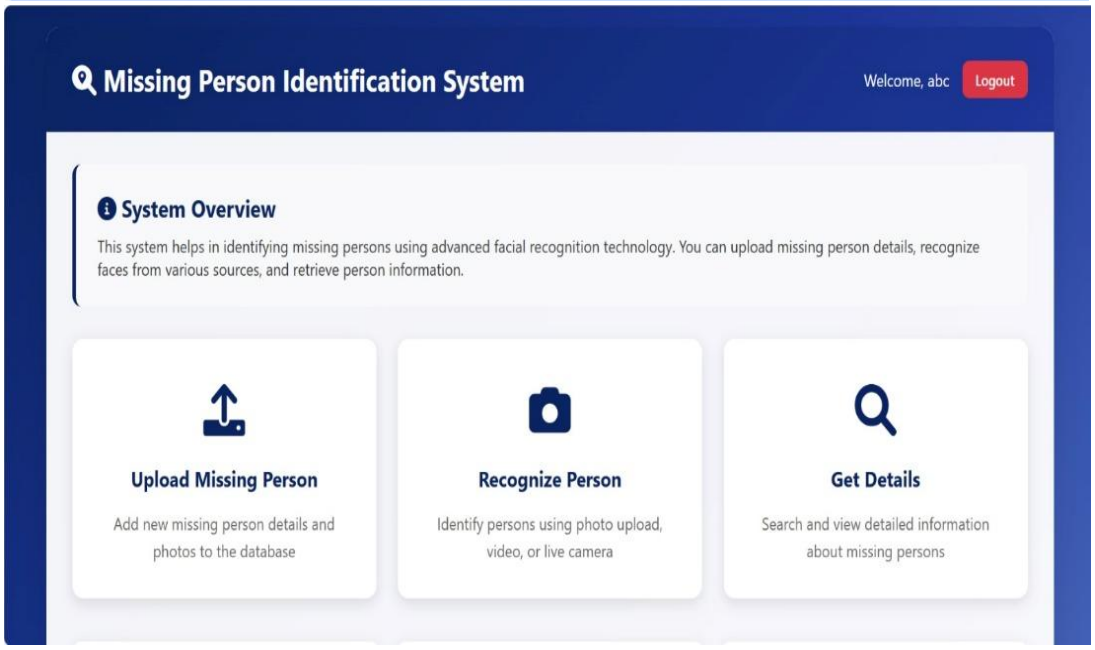

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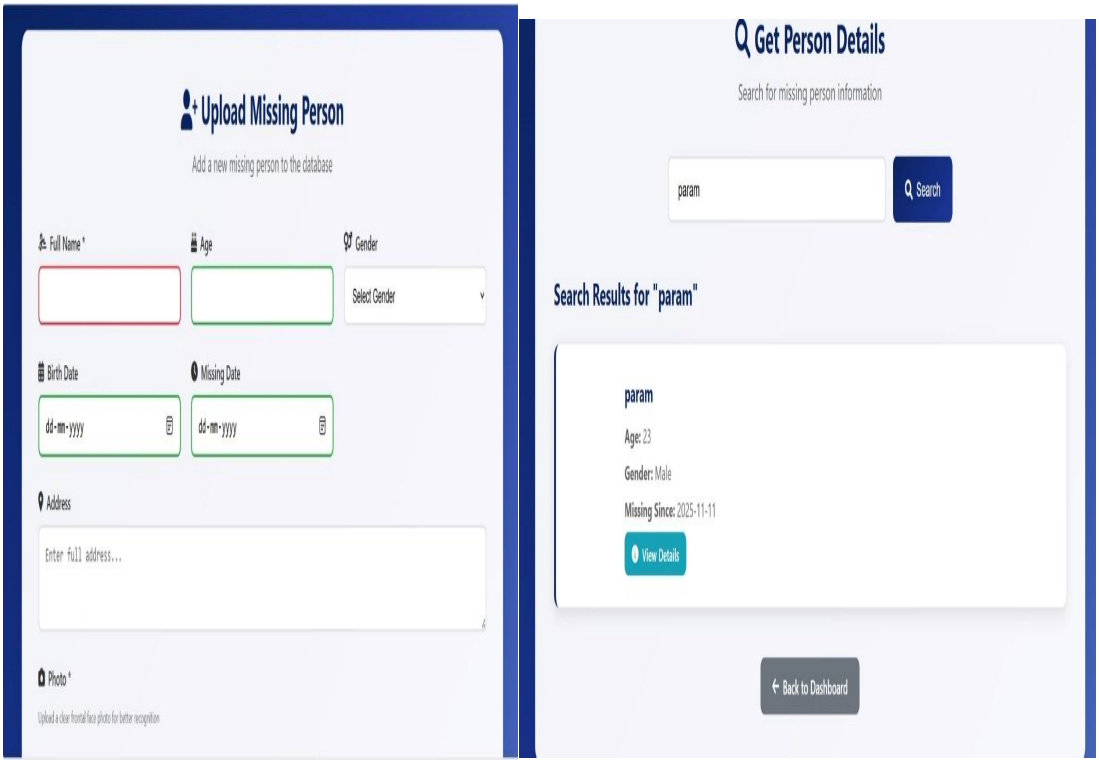

X. APPLICATIONS

The proposed system can be applied in various real-world safety and surveillance scenarios:

- Smart traffic surveillance systems
- Automated missing child detection in public areas
- Smart city safety and monitoring solutions
- Public transport stations and terminals
- Large-scale event and festival security management
- School zones and playground monitoring

XI. ADVANTAGES

The Child Traffic Shield system offers several advantages over traditional monitoring methods:

Real-time detection and alert generation
Automated alert system with minimal human involvement
Low-cost implementation, suitable for large-scale deployment
Scalable architecture supporting multiple nodes and users
Reduced human intervention, minimizing errors and delays
High accuracy using AI-based face recognition
Fast response time through GPS and GSM integration
Improved public safety and child protection

XII. CONCLUSION

The Child Traffic Shield system provides an **efficient, intelligent, and automated solution** for missing child detection using AI and IoT technologies. By integrating face recognition, GPS tracking, and GSM-based alert mechanisms, the

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system ensures rapid identification and timely response. The modular and scalable architecture makes it suitable for deployment in real-world environments such as smart cities, transport hubs, and crowded public locations. The proposed solution significantly enhances child safety and supports law enforcement agencies in reducing missing child cases.

XIII. FUTURE SCOPE

The system can be further enhanced with advanced technologies to improve accuracy and coverage:
Integration with **AI-powered surveillance drones**
Multi-camera tracking across different locations
Enhanced **low-light and night-time face recognition**
Creation of a **nationwide missing child database**
AI-based behavior analysis for suspicious activity detection
Integration with **smart traffic and city infrastructure**

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