Proof of Concept: Integrated Temple Crowd Management System

Smart India Hackathon 2025

PS ID: 25165
Problem Statement: Temple & Pilgrimage Crowd Management (Somnath, Dwarka, Ambaji, Pavagadh)
Theme: Heritage and Culture
Category: Software
Team: AetherCode

Executive Summary

Our team presents an integrated AI-powered crowd management system specifically designed for temple environments, with primary focus on the sacred temples of Gujarat: **Somnath, Dwarka, Ambaji, and Pavagadh**. The solution combines **predictive analytics** with **real-time monitoring** to transform reactive crowd control into proactive resource management across these heritage pilgrimage sites.

Core Component Architecture:

1. **DarshanAI**: Machine Learning system for devotee footfall prediction
2. **VisionCount**: Real-time people counting using computer vision
3. **BlacklistGuard**: Face recognition system for person blacklisting and security

Note: *This system is designed as a modular, expandable platform. These three components serve as the foundation, but the architecture supports additional modules and multi-purpose functionality. Each component can be extended for various applications like panic management, emergency response, resource optimization, and more.*

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1. Problem Statement Analysis

Primary Challenges at Gujarat's Sacred Temples:

- **Somnath Temple**: One of the 12 Jyotirlingas, experiences massive footfall during Maha Shivratri and Kartik Purnima
- **Dwarka Temple**: Krishna's sacred abode attracts millions during Janmashtami and other festivals
- **Ambaji Temple**: Major Shakti Peetha with continuous pilgrim flow, especially during Navratri
- **Pavagadh Temple**: Hill temple requiring crowd management for both trekking devotees and ropeway users

Common Challenges:

- **Seasonal surges**: Festival periods create unpredictable crowd volumes
- **Safety concerns**: Overcrowding in narrow passages and on hilltops
- **Heritage preservation**: Balance between accessibility and monument protection
- **Resource management**: Accommodation, prasadam, parking, and sanitation facilities

Impact of Current System:

- Reactive crowd control measures
- Safety incidents during peak periods
- Devotee dissatisfaction due to long waiting times
- Operational inefficiencies costing millions annually

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2. Integrated Solution Architecture

2.1 DarshanAI - Predictive Analytics Engine

Purpose: Forecast daily devotee footfall using historical patterns

Technical Stack:

- **Model**: Random Forest Regressor
- **Dataset**: Tirumala Tirupati Devasthanam Darshans Dataset
- **Features**: Lag variables, cyclic temporal encoding
- **Validation**: Time Series Cross-validation

Key Features:

- Historical data analysis with lag features (1-2 day patterns)
- Seasonal pattern recognition using sine/cosine encoding
- Robust validation preventing overfitting
- Saved model: `random_forest_darshans.pkl`

Expandable Applications:

- **Emergency Planning**: Predict high-risk days for emergency preparedness
- **Resource Forecasting**: Estimate prasadam, water, and facility requirements
- **Staff Scheduling**: Optimize human resource allocation
- **Panic Prevention**: Identify potential overcrowding scenarios in advance

2.2 VisionCount - Real-Time Monitoring System

Purpose: Accurate real-time people counting at temple entrances using top-down camera view

Technical Stack:

- **Detection**: YOLOv8n (nano model, lightweight for real-time processing)
- **Tracking**: Norfair (centroid distance matching, persistent ID tracking)
- **Counting Logic**: Virtual line-crossing detection with anti-double-counting

System Architecture:

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Frame Capture → YOLOv8 Detection → Centroid Calculation → Norfair Tracking
→ Line-Cross Counting → Visualization
```

Why Top-Down View?:

- **Consistent Movement Direction**: People naturally move in predictable patterns
- **No Face Recognition Required**: Privacy-conscious approach
- **Occlusion Reduction**: Minimal overlap in top-down perspective
- **Reliable Detection**: YOLOv8 trained on COCO dataset handles top-down person detection effectively

Multi-Purpose Capabilities:

- **Panic Management**: Real-time crowd density monitoring for emergency evacuation
- **Queue Optimization**: Dynamic queue management based on real-time flow
- **Behavior Analysis**: Movement pattern recognition for crowd flow optimization
- **Area Monitoring**: Multi-zone counting for different temple sections
- **Capacity Management**: Real-time occupancy limits enforcement

2.3 BlacklistGuard - Security & Access Control System

Purpose: Real-time face recognition for identifying blacklisted individuals and enhancing temple security

Technical Stack:

- **Face Detection**: MTCNN (Multi-task Convolutional Neural Networks), ArcFace Model
- **Face Recognition**: FaceNet embeddings with SVM classifier

- **Database**: SQLite for blacklist storage and management
- **Alert System**: Real-time notifications for security personnel

Key Components:

```
Face Detection (MTCNN) → Face Encoding (FaceNet) → Database Matching →
Alert Generation
```

Security Features:

- **Real-time Recognition**: Live camera feed processing
- **Blacklist Database**: Secure storage of restricted individuals
- **Alert Mechanisms**: Instant notifications to security staff
- **Privacy Protection**: Encrypted facial encodings, no raw image storage
- **Multi-camera Support**: Network-wide monitoring capability

Extended Security Applications:

- **VIP Recognition**: Identify and provide special assistance to dignitaries
- **Missing Person Detection**: Locate lost devotees, especially children and elderly
- **Crowd Behavior Monitoring**: Detect unusual activities or disturbances
- **Emergency Response**: Rapid identification during crisis situations
- **Access Control**: Multiple security zones with different access levels

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3. Technical Implementation Details

3.1 DarshanAI Implementation

Data Preprocessing (`preprocess.py`):

- Feature engineering with lag variables
- Cyclic temporal encoding for seasonality
- Data cleaning and validation

Model Training (`train.py`):

- Random Forest hyperparameter optimization
- TimeSeriesSplit cross-validation
- Model persistence for deployment

3.2 VisionCount Implementation

Algorithm Workflow:

1. **Frame Capture**: Real-time video processing from top-down mounted camera
2. **Person Detection**: YOLOv8n identifies individuals with bounding boxes (x1, y1, x2, y2)
3. **Centroid Calculation**: Calculate center point (cx, cy) for each detected person
4. **ID Assignment**: Norfair assigns unique IDs and maintains tracking across frames
5. **Line-Cross Detection**: Monitor when centroid crosses virtual line in designated direction
6. **Count Increment**: Add to `counted_ids` set and increment `total_count` (anti-double-counting)
7. **Visualization**: Real-time display with bounding boxes, IDs, centroids, line, and statistics

Anti-Double-Counting Mechanisms:

- **Unique ID Tracking**: Each person gets persistent ID across frames
- **Counted IDs Set**: Maintains record of already-counted individuals
- **Directional Logic**: Only counts movement in designated direction
- **Line-Cross Validation**: Centroid must clearly cross the virtual line

3.3 BlacklistGuard Implementation

Face Recognition Pipeline:
Based on the Face Recognition System implementation:

Real-time Processing Workflow:

1. **Frame Capture**: Continuous camera feed processing
2. **Face Detection**: Identify faces in current frame
3. **Face Encoding**: Generate 128-dimensional face vectors
4. **Database Lookup**: Compare against stored blacklist encodings
5. **Match Validation**: Apply confidence threshold (default: 0.6)
6. **Alert Generation**: Notify security personnel if match found
7. **Logging**: Record all detections with metadata

Security & Privacy Features:

- **Encrypted Storage**: Face encodings stored as encrypted blobs
- **No Raw Images**: Only mathematical representations saved
- **Access Control**: Role-based database access
- **Audit Trail**: Complete logging of all system interactions
- **GDPR Compliance**: Right to deletion and data portability

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4. System Expandability & Multi-Purpose Design

4.1 Modular Architecture Benefits

Our system is built with **modular expandability** in mind, allowing for:

Additional Components Integration:

- **AudioAlert**: Sound-based crowd management and announcements
- **WeatherSync**: Weather-based crowd prediction adjustments
- **PrasadamAI**: Smart prasadam distribution based on crowd patterns
- **ParkingOptimizer**: Dynamic parking space allocation
- **EmergencyResponse**: Automated emergency protocol activation

Cross-Component Functionality:

- **Panic Management**: VisionCount detects overcrowding → BlacklistGuard identifies key personnel → DarshanAI predicts peak times for prevention
- **Smart Evacuation**: Real-time crowd density mapping with emergency route optimization
- **Resource Optimization**: Predictive analytics combined with real-time monitoring for dynamic resource allocation
- **Enhanced Security**: Multi-layer security with crowd behavior analysis and individual identification

4.2 Integration Benefits

- **Morning Planning**: DarshanAI provides daily forecasts
- **Live Monitoring**: VisionCount tracks real-time footfall with panic detection
- **Security Layer**: BlacklistGuard ensures temple safety with emergency response
- **Validation Loop**: Real counts validate predictions, security logs enhance safety protocols
- **Emergency Response**: Integrated panic management and evacuation procedures
- **Multi-Purpose Analytics**: Each component serves multiple operational needs

4.3 Operational Improvements

- **Proactive Staffing**: Deploy resources based on predictions
- **Dynamic Queue Management**: Adjust lines based on real-time counts
- **Enhanced Security**: Automated blacklist monitoring with instant alerts
- **Safety Monitoring**: Combined crowd density and security threat detection
- **Resource Optimization**: Precise prasadam and accommodation planning
- **Risk Mitigation**: Early identification of potential security concerns
- **Panic Prevention**: Real-time crowd density alerts and automated responses

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5. Proof of Concept Demonstration

5.1 DarshanAI Capabilities

- **Prediction Horizon**: 1-7 days advance forecasting
- **Feature Analysis**: Historical patterns and seasonal trends recognition
- **Model Robustness**: Time-series validated approach with continuous learning

5.2 VisionCount Performance Features

- **Real-time Processing**: Live video stream analysis
- **Anti-Double-Counting**: Advanced tracking with unique ID persistence
- **Multi-scenario Handling**: Various crowd density situations
- **Camera Optimization**: Top-down view for maximum accuracy
- **Processing Efficiency**: Lightweight model for edge deployment

5.3 BlacklistGuard Security Features

- **Real-time Recognition**: Continuous face monitoring
- **Database Security**: Encrypted storage with privacy protection
- **Alert System**: Instant notifications to security personnel
- **Scalability**: Handles multiple simultaneous face recognitions
- **Privacy Compliance**: GDPR-compliant data handling

5.4 System Integration Demo

1. **Morning Forecast**: DarshanAI predicts high footfall for Kartik Purnima
2. **Security Preparation**: BlacklistGuard database updated with festival-specific watchlist
3. **Resource Allocation**: Staff deployment based on prediction + security protocols
4. **Real-Time Monitoring**: VisionCount tracks actual entries with panic detection, BlacklistGuard monitors faces
5. **Dynamic Response**: Adjust operations based on real vs predicted + security alerts + emergency protocols
6. **End-Day Analysis**: Update models with actual data + security incident reports + system optimization

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6. Deployment Strategy

6.1 Phase 1: Pilot Implementation (2 months)

- **Location**: Single temple entrance (Somnath Temple main gate)
- **Components**: All three core systems with basic panic management integration
- **Testing**: System stability, component integration, emergency response protocols

- **Stakeholder Training**: Temple administration and security staff orientation
- **Privacy Compliance**: GDPR/data protection protocol implementation

6.2 Phase 2: Multi-Temple Deployment (4-6 months)

- **Coverage**: All four temples (Somnath, Dwarka, Ambaji, Pavagadh)
- **Integration**: Temple management systems and security networks
- **Monitoring**: 24/7 automated operation with security command center
- **Database Sync**: Centralized blacklist sharing across all locations
- **Advanced Features**: Panic management, emergency response, multi-purpose analytics

6.3 Phase 3: Advanced Integration (6-12 months)

- **API Development**: REST endpoints for external system integration
- **Security Dashboard**: Unified monitoring interface for all temples
- **Mobile Alerts**: Real-time notifications for security and crowd management
- **Analytics Platform**: Historical trend analysis and security intelligence
- **Component Expansion**: Additional modules based on operational needs
- **Interstate Coordination**: Blacklist sharing with other state temple authorities

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7. Expected Outcomes & Impact

7.1 Quantitative Benefits

- **Safety Incidents**: Significant reduction in overcrowding events with faster security threat response
- **Wait Times**: Substantial reduction in queue duration through optimized flow management
- **Resource Efficiency**: Improved staff allocation and resource utilization
- **Security Effectiveness**: Enhanced blacklisted individual detection and emergency response
- **Operational Costs**: Reduction through optimization and security automation

7.2 Qualitative Benefits

- Enhanced devotee spiritual experience with improved safety
- Increased temple administration confidence in crowd management
- Proactive security posture with real-time threat detection
- Data-driven decision making culture across all operations
- Scalable solution template for other religious sites nationwide
- Cultural heritage protection through better visitor management

- Emergency preparedness with integrated panic management

8. Risk Mitigation

8.1 Technical Risks & Mitigation

- **Model Drift**: Automated retraining pipeline with new data
- **Hardware Failure**: Redundant camera systems with failover mechanisms
- **Network Issues**: Edge computing capabilities for offline operation
- **System Integration**: Comprehensive testing protocols for multi-component coordination

VisionCount Specific Risks:

- **Extreme Crowding**: Adaptive parameter adjustment with fallback tracking systems
- **Lighting Conditions**: Multi-modal detection approaches for various scenarios
- **Camera Positioning**: Multiple angle coverage with optimal deployment guidelines
- **Emergency Situations**: Panic detection and automated response protocols

BlacklistGuard Specific Risks:

- **Privacy Concerns**: Encrypted storage, GDPR compliance, minimal data retention
- **False Positives**: Adjustable confidence thresholds with human verification workflows
- **Database Security**: Multi-layer encryption, access controls, comprehensive audit logging
- **System Availability**: Redundant processing with backup recognition systems

8.2 Operational Risks

- **Staff Resistance**: Comprehensive training programs with hands-on support
- **Devotee Privacy**: Anonymous counting with selective security monitoring
- **System Downtime**: Backup manual procedures with seamless transition protocols
- **Data Security**: End-to-end encryption and secure transmission protocols
- **Emergency Response**: Integrated panic management with staff training

9. Conclusion

Our integrated Temple Crowd Management System represents a paradigm shift from reactive to proactive crowd management with comprehensive security integration and emergency response capabilities. By combining the predictive power of DarshanAI, the real-time accuracy of VisionCount, and the security intelligence of BlacklistGuard, we deliver a **modular, expandable solution** that enhances safety, improves operational efficiency, and elevates the devotional experience while maintaining the highest security standards.

In future we may also switch the models used the ones used here are just for prototype version.

Key Differentiators:

- **Expandable Architecture**: Core components designed for multi-purpose functionality and easy integration of additional modules
- **Multi-Application Design**: Each component serves various operational needs beyond basic crowd management
- **Panic Management Integration**: Real-time emergency response with automated protocols
- **Temple-specific Design**: Optimized for religious environment challenges with cultural sensitivity
- **Privacy-Balanced Approach**: Anonymous counting with targeted security monitoring
- **Scalable & Lightweight**: Edge deployment ready with minimal infrastructure requirements
- **Heritage Sensitive**: Designed specifically for Gujarat's sacred temple environments
- **Cost-effective**: Open-source components with proven reliability
- **Emergency Ready**: Integrated panic management and evacuation capabilities

GitHub Repository: Temple Pilgrimage Crowd Management

This PoC demonstrates our team's capability to deliver innovative, practical, and **expandable solutions** that address real-world challenges while respecting cultural sensitivities and operational constraints. The modular design ensures the system can evolve and adapt to emerging needs and technologies.
