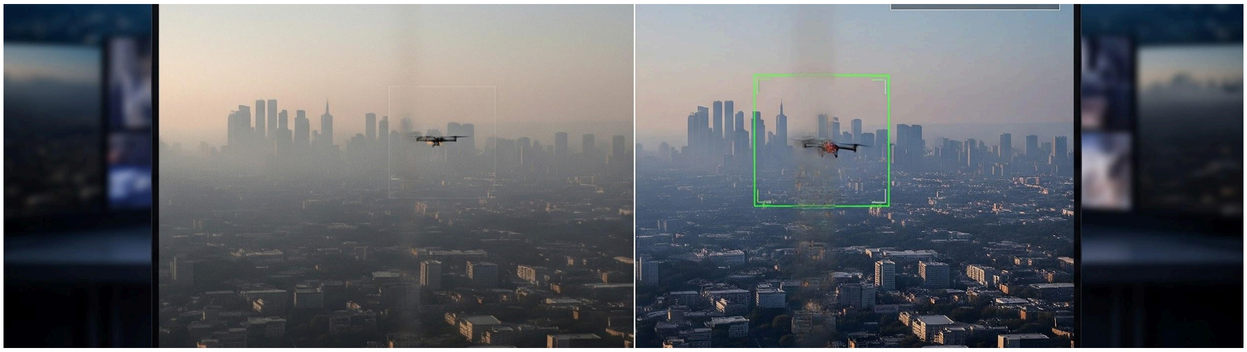
Project brief



Real-Time Turbulence Correction and Dynamic Object Tracking in Long-Range Video

Status In progress

Timing Dec 18, 2025 to May 1, 2026

Overview

Long-range video surveillance and sensing systems are severely affected by atmospheric turbulence, which introduces time-varying, spatially nonuniform distortions such as geometric warping, blur, and intensity fluctuations. These degradations reduce visual clarity and significantly impair the reliable detection and tracking of moving objects. Existing approaches often address turbulence correction or object tracking independently and are computationally expensive, making them unsuitable for real-time deployment. Therefore, the problem is to develop a real-time system that can effectively correct atmospheric turbulence in long-range video streams while simultaneously and robustly tracking dynamic objects, ensuring temporally consistent image restoration, accurate object localization, and stable identity tracking under varying turbulence conditions and strict latency constraints.

How Real-Time Turbulence Correction and Dynamic Object Tracking in Long-Range Video Works

1) Video acquisition under turbulence

A long-range camera captures a live stream where atmospheric turbulence bends light unpredictably. The result is a restless image: local warping, shimmer, blur, and flicker. Objects appear to wobble even when they move smoothly.

2) Motion disentanglement: turbulence vs. true motion

The system estimates **frame-to-frame motion** and separates two components:

- **Apparent motion** caused by turbulence (random, small-scale, spatially varying)
- **True object motion** (coherent, physically plausible)
  This is typically done using dense optical flow or learned deformation fields with temporal consistency constraints.

3) Turbulence correction (restoration stage)

Using a short temporal window of frames:

- Distorted regions are **registered and aligned**
- Stable information from multiple frames is **fused**
- Frames are **dewarped and sharpened**, reducing shimmer and blur

  The output is a stabilized, visually clear frame that preserves object boundaries.

4) Dynamic object detection

On the restored frames:

- Objects (people, vehicles, drones, ships) are detected using a real-time detector
- Background stabilization reduces false detections caused by shimmering artifacts

  This step benefits directly from turbulence correction, as objects now appear more consistent in shape and position.

5) Object tracking with identity preservation

A tracker associates detections across frames by combining:

- Object appearance features
- Motion prediction models (e.g., Kalman or learned trackers)
- Turbulence-aware motion cues

Even when turbulence briefly distorts or blurs an object, the tracker maintains its **identity and trajectory**.

6) Real-time optimization

To meet real-time constraints:

- Lightweight neural networks or pruned models are used
- Processing focuses on regions of interest
- GPU parallelism pipelines restoration and tracking together

The system continuously outputs:

- A **turbulence-corrected video stream**
- **Live object tracks** with bounding boxes and IDs

👤 Member 1: Frontend Developer (UI & Visualization)

Responsibilities

- Design and develop the web-based dashboard
- Implement:
    - Live video streaming interface
    - Corrected vs. uncorrected video comparison view
    - Object tracking visualizations (bounding boxes, IDs)
    - Turbulence severity indicators and analytics
- Implement authentication interfaces (login / signup)

Technologies

- React.js
- HTML5, CSS3
- JavaScript
- Chart.js (for visual analytics)

Deliverables

- User-friendly and responsive dashboard
- Real-time visualization components
- Interactive comparison and analytics views

👤 Member 2: Backend Developer (API & Server Logic)

Responsibilities

- Design and implement RESTful APIs

- Handle user authentication and authorization (JWT)
- Manage video upload, streaming, and request handling
- Integrate frontend with AI/ML services
- Implement role-based access control

Technologies

- Node.js
- Express.js
- JWT
- REST APIs

Deliverables

- Secure and scalable backend server
- API documentation
- Authentication and authorization system

👤 Member 3: AI / ML Engineer (Turbulence Correction)

Responsibilities

- Implement atmospheric turbulence mitigation techniques
- Develop video stabilization and distortion correction models
- Perform frame enhancement and temporal consistency correction
- Evaluate restoration quality

Algorithms & Tools

- Optical Flow
- CNN-based video restoration models
- OpenCV
- PyTorch / TensorFlow

Deliverables

- Turbulence correction module
- Restored (corrected) video output
- Performance evaluation using PSNR and SSIM

👤 Member 4: Computer Vision Engineer (Object Tracking)

Responsibilities

- Implement object detection and multi-object tracking
- Integrate tracking with turbulence-corrected video
- Improve robustness of tracking under severe turbulence
- Maintain object identity across frames

Algorithms & Tools

- YOLOv8
- SORT / DeepSORT
- Kalman Filter
- OpenCV

Deliverables

- Real-time object detection and tracking system
- Tracking logs and visual outputs
- Accuracy evaluation reports

👤 Member 5: Database & DevOps Engineer

Responsibilities

- Design and manage the database schema
- Store video metadata, tracking results, and logs

- Deploy and maintain the application
- Optimize system performance and scalability
- Ensure backup, security, and monitoring

Technologies

- MongoDB
- Docker (optional)
- AWS / Render / Azure
- Nginx

Deliverables

- Scalable and secure database
- Deployed and monitored application
- Backup and performance optimization setup

How Others Can Use the Real-Time Turbulence Correction and Dynamic Object Tracking in Long-Range Video :

1. End Users (Operators / Analysts)

Who: Surveillance operators, security personnel, researchers

How they use it:

- Log in through the web dashboard
- Upload a recorded long-range video or connect to a live camera stream
- Enable turbulence correction and object tracking with simple controls
- View:
  - Original vs. corrected video in real time
  - Bounding boxes and object IDs

    - Turbulence severity indicators
- Download processed videos and tracking reports

Benefit: Clearer visuals and reliable tracking without technical knowledge.

2. Integration with Other Systems

Who: System integrators, smart city developers

How they use it:

- Connect the APIs to:
    - Existing surveillance systems
    - Alerting systems (intrusion detection, anomaly alerts)
    - GIS or command-and-control dashboards
- Use tracking outputs as inputs for higher-level analytics

Benefit: Seamless integration into larger monitoring ecosystems

● Inputs and Outputs

Inputs

- Long-range video stream (live or recorded) affected by atmospheric turbulence
- Video frames with distortions such as blur, shimmer, and geometric warping
- User inputs from the dashboard (video selection, start/stop processing, tracking options)
- System configuration parameters (frame rate, resolution, turbulence level, model settings)

Outputs

- Real-time **turbulence-corrected video stream**

- **Enhanced video frames** with reduced distortion and improved clarity
- **Object tracking results**, including bounding boxes, object IDs, and trajectories
- **Visual analytics**, such as turbulence severity indicators and tracking statistics
- **Stored metadata**, including processed video logs and performance metrics (PSNR, SSIM, tracking accuracy)

Roles in the Project:

👤 **Frontend Developer (UI & Visualization) :** Nallapagari Diwakar

👤 **Backend Developer (API & Server Logic) :** Savara Gnanprakash

👤 **AI / ML Engineer (Turbulence Correction) :** Shanmuka rao

👤**Computer Vision Engineer (Object Tracking) :** Jashwanth Reddy

👤 **Database & DevOps Engineer :** Vedurpathi deepak