Algorithms Used in Road Damage Detection and Severity Prioritization System

This document explains all algorithms used in the AI-based Road Damage Detection system trained on the RDD2022 dataset and describes how each algorithm contributes to the complete end-to-end pipeline.

1. YOLO (You Only Look Once) – Core Detection Algorithm

YOLOv8 / YOLOv11 is used as the primary object detection algorithm. It is a single-stage, anchor-free detector that predicts bounding boxes and class probabilities in a single forward pass.

Internal Components:
- CSP (Cross Stage Partial) backbone
- PAN/FPN multi-scale feature aggregation
- Anchor-free detection head
- CIoU loss for bounding box regression
- Binary Cross Entropy loss for classification and objectness
- Non-Maximum Suppression (NMS)

Contribution: Enables accurate real-time detection of thin cracks and potholes with high recall and low latency.

2. Transfer Learning

The model is initialized using COCO pretrained weights, allowing reuse of learned visual features.

Contribution: Faster convergence, improved generalization, and reduced overfitting on road textures.

3. Data Augmentation Algorithms

Training uses Mosaic augmentation, HSV color shifts, motion blur, perspective warp, random shadows, and Gaussian noise.

Contribution: Improves robustness to lighting variation, camera motion, weather conditions, and viewpoint changes.

4. Severity Estimation Algorithm

RDD2022 does not include severity labels. A post-detection computer vision heuristic is used.

Severity Formula:
Severity = 0.45 × BoundingBoxAreaRatio + 0.30 × DamageCountNormalization + 0.25 × TextureRoughness

Sub-algorithms include bounding box area computation, damage density normalization, Sobel edge detection, and weighted linear scoring.

Contribution: Converts raw detections into an interpretable severity score (0–100) for prioritization.

5. Image Processing Algorithms

Sobel operator, gradient magnitude computation, and statistical normalization are applied inside detected regions.

Contribution: Quantifies surface roughness and structural degradation not directly captured by detection alone.

6. Inference Optimization Algorithms

Non-Maximum Suppression, ONNX graph optimization, and optional TensorRT acceleration are used.

Contribution: Ensures low-latency, production-ready inference performance.

7. Geospatial and Clustering Algorithms (Optional)

DBSCAN clustering, reverse geocoding, and spatial indexing (R-tree / PostGIS) are used for city-scale analytics.

Contribution: Enables damage clustering, heatmap visualization, and municipal-level prioritization.

8. End-to-End Algorithmic Pipeline

RDD2022 Dataset → YOLO Detection → NMS → Bounding Box Analysis → Sobel Edge Processing → Severity Scoring → Priority Classification → API Response → Map Visualization