Team 16 – Route 0x78

Road Condition Analysis using Deep Learning

The Critical Challenge

Unknown Road Conditions

Teams working in disaster response and UN field missions often navigate unmarked or outdated roads. A route that appeared paved six months ago might now be gravel—or worse.

- Time lost on impassable routes

- Increased operational risk

- Mission delays and inefficiencies

Our Solution Overview

Capture

Record road conditions using Android device camera while collecting GPS and orientation data
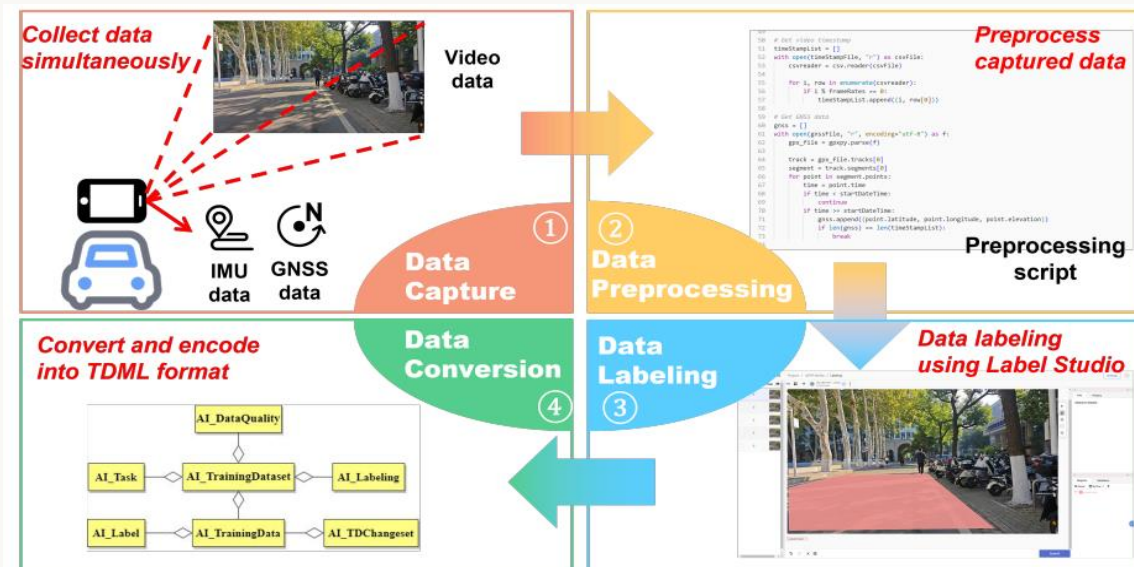
Classify

AI-powered ResNet classifier labels surfaces as asphalt, paved, or unpaved with confidence scores

Visualize

Results rendered on interactive maps using open geospatial standards for universal compatibility

Standards-Based Architecture

GeoPose 1.0 Integration

Each captured frame synchronized with GNSS coordinates and device orientation using OGC GeoPose standard for precise spatial referencing

TDML-AI JSON Structure

Machine learning results packaged in standardized format ensuring labels, confidence scores, and context data travel together seamlessly

Urban Digital Twin Alignment

Built following UDTIP engineering specifications to integrate with larger Urban Digital Twin ecosystems and mission planning systems

Made with GAMMA

Technical Implementation

Deep Learning Pipeline

- **ResNet Architecture:** Chosen for optimal balance of accuracy and mobile efficiency

- **Training Dataset:** RTK-style road dataset augmented with field captures

- **Seven Categories:** Grouped under asphalt, paved, and unpaved classifications

- **Real-time Processing:** On-device inference for immediate results
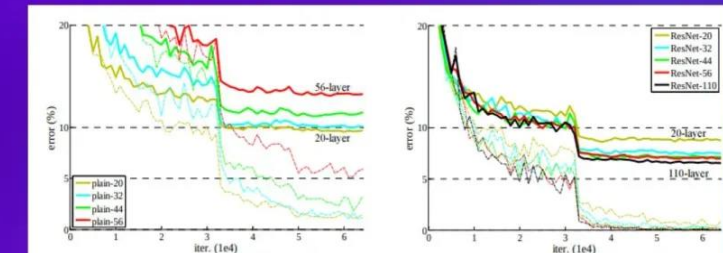
Mobile Application Demo

01

Capture Road Segment

Tap Record for video or Snap for single frame capture with automatic GPS and orientation logging

02

Extract and Process Frames

FFmpeg samples frames deterministically, synchronizes with GNSS timestamps and device pose data
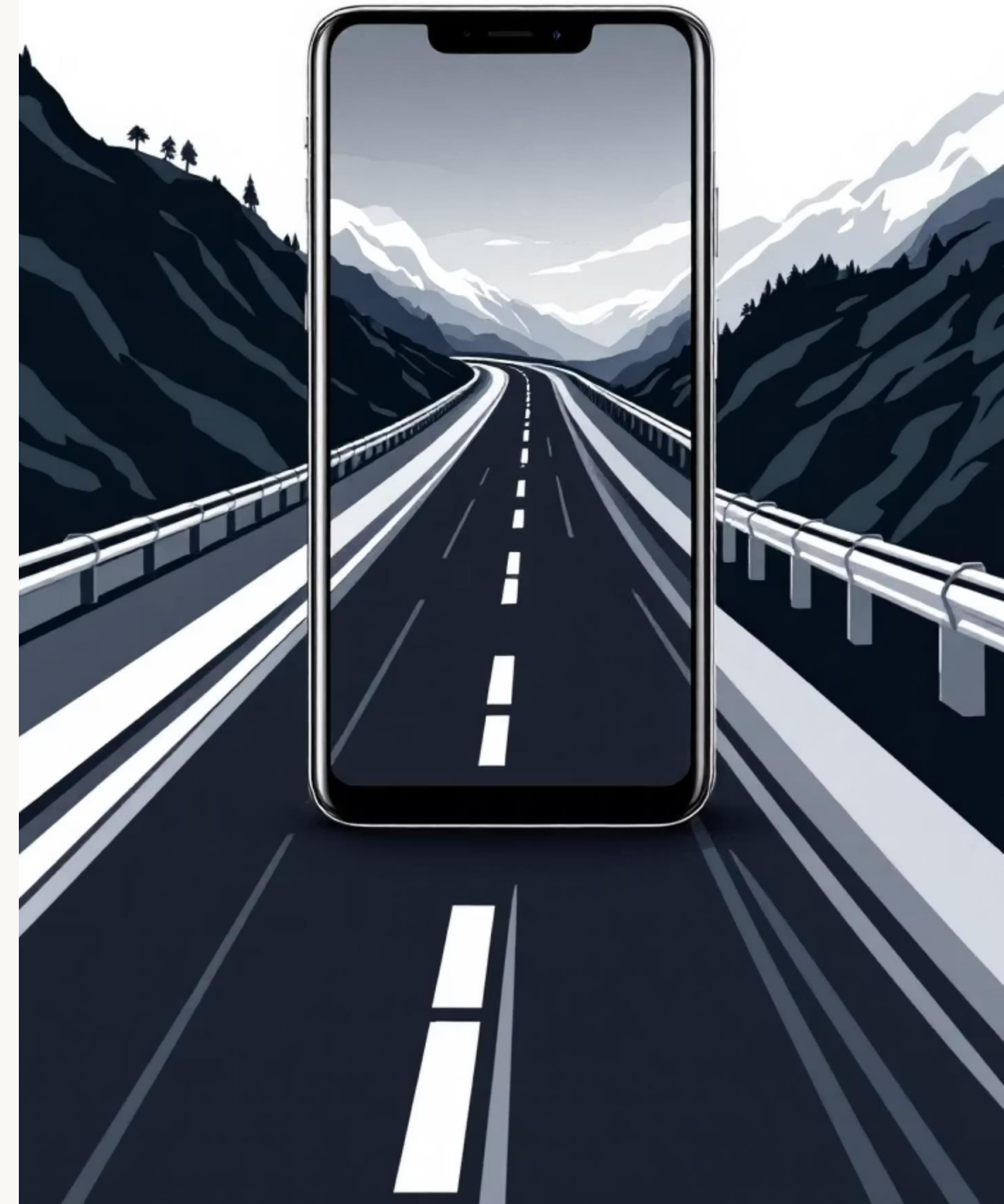
03

Classify Surface Type

ResNet model analyzes each frame and assigns surface classification with confidence metrics
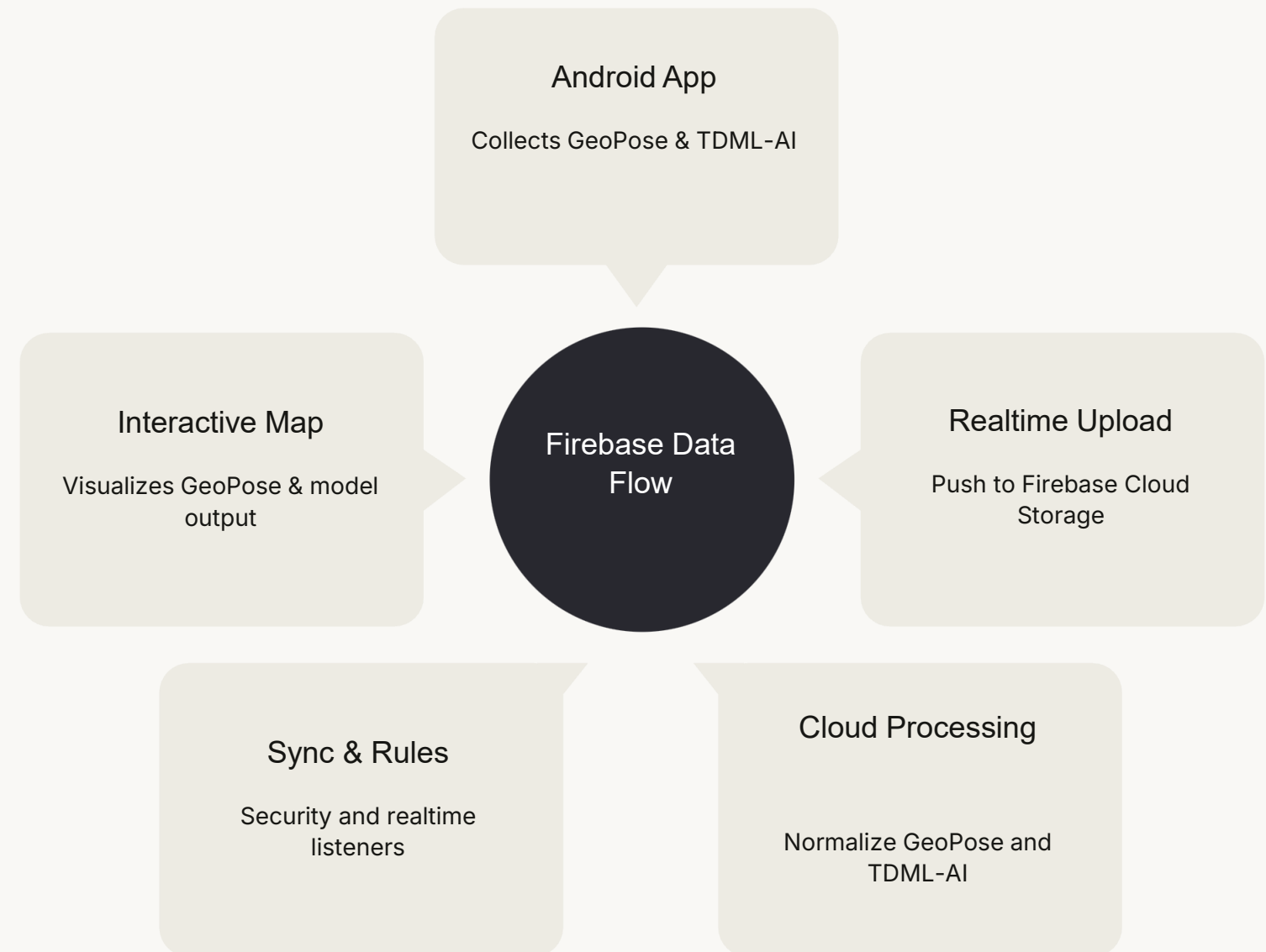
04

Upload to Cloud

Images and GeoPose/TDML files automatically sync to Firebase for instant map visualization

Firebase Integration & Data Flow

Android App

Collects GeoPose & TDML-AI

Interactive Map

Visualizes GeoPose & model output

Firebase Data Flow

Realtime Upload

Push to Firebase Cloud Storage

Sync & Rules

Security and realtime listeners

Cloud Processing

Normalize GeoPose and TDML-AI

Seamless cloud integration enables real-time synchronization between field teams and mission planners using Firebase's robust infrastructure.

Key Challenges Overcome

Data Imbalance

Underrepresented classes like "bad unpaved" required targeted field collection and strategic data augmentation techniques to achieve model accuracy

Mobile Deployment

Converting and optimizing neural networks for Android, integrating camera, GNSS, and storage systems into responsive user interface

Real-time Performance

Balancing classification accuracy with processing speed to maintain smooth user experience during field operations

Development Roadmap

Dataset Expansion

Scale training data through partnerships with humanitarian field teams across diverse geographic regions and road conditions

Enhanced Visualization

Develop richer map layers with 3D context, elevation profiles, and integration with mission planning dashboards

1   **2**   **3**

On-Device Optimization

Implement model quantization and edge computing techniques to reduce inference time and bandwidth requirements

Real Change

With our application, we can tackle the issue we mentioned earlier. Road Condition Analysis using Deep Learning—from phone camera to operational map, in minutes.

Built on open standards, ready for humanitarian logistics teams worldwide.