Webinar February 19th 2025

Proactive road maintenance and condition monitoring based on satellite location data and image analysis

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About Pluto

Our goal is to make road administration easier through intelligent tools and smarter data collection.

- Active in Denmark, Faroe Islands, Sweden, the UK, Estonia, Hungary
- European Road Safety Excellence Awards finalist, EU 2024
- Danish municipal maintenance departments "Best innovation", 2023

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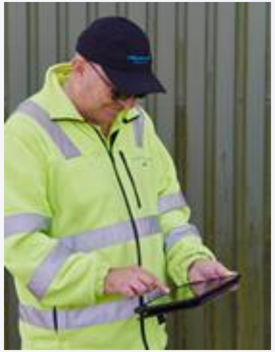
Product suite

Pluto Record

Automate your data collection with just a smartphone. Press record and have the app take care of detections and upload.

Pluto Map

Access to updated data from your office. Prioritize, coordinate, and delegate from a user friendly map in your browser.



Pluto Work

Open, navigate and complete tasks from an IOS or Android app that is tailored for workers who are on the go.

A solution for the full task management

Registration

Automatic and digital registration

Overview

Simple overview for prioritization

Delegate

Creation of tasks and projects

Execution

Documentation of execution

Key activities and results

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Work packages

WP1000	Object Re-identification	Explore how to re-identify and correctly estimate amounts of road assets.
WP1100	Object Location	Explore techniques to improve the location accuracy of GNSS
WP1200	Object Detection	Improve the object detection algorithm and extend capabilities to more fine-grained conditions of the asset.
WP2000	Device Remote Control	Enabled remote control and monitoring of devices deployed in vehicles for data collection
WP3000	Task Grouping and Navigation	Implemented optimized task management by grouping detected hazards based on location
WP4000	Road Hazard Notification System	Developed an alert system for road maintenance teams to prioritize critical hazards
WP5000	Road Digging Monitoring	Integrated data from road digging projects into the monitoring system to explore continuous data-control
WP2100	GeoServer Configuration	Built a GeoServer for managing and visualizing data

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Algorithm update

- Introduce conditions to objects i.e. crack width, pothole depth, etc.
  - Supporting better filtering and hence task prioritization
  - Alternative is that clients would "drown" in data

What does the AI detect?

15 x road damages & repair

Cracks, potholes, patches, etc.

25 x conditions such as severity

10 x road inventory

Signs, drains, edge poles, light poles, etc.

20 x conditions such as faded and tilted

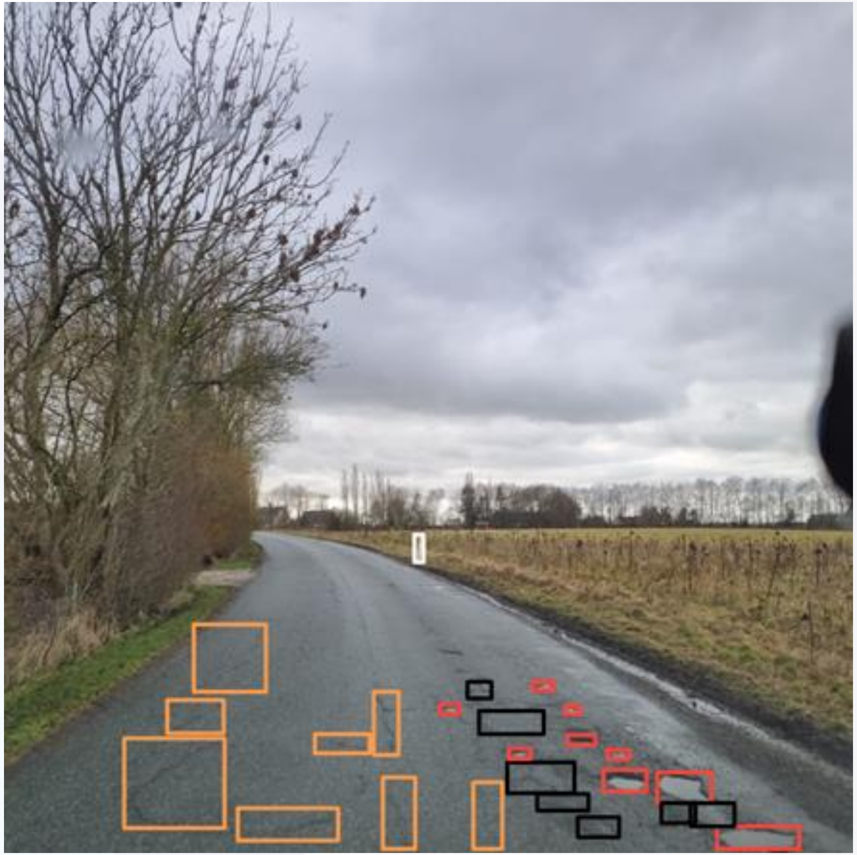
3 x pavement damages

Pavement uplift, cracked tiles, etc.

3 x conditions such as height difference

5 x lane markings

Pedestrian crossing, stop line, shark teeth, etc.



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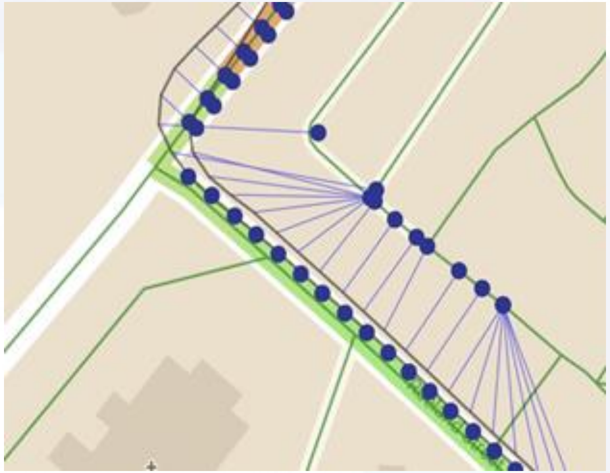
Enhancing Vehicle Location Accuracy with Map Matching



Map Matching Approach

📌 **Objective**: Improve GNSS-based road monitoring by aligning collected data (e.g., road images) with precise map locations.

📌 **Data Integration**: OpenStreetMap (OSM) data stored in a **PostGIS database** for efficient spatial queries to resolve ambiguities in the GNSS data.

Key Map Matching Steps

1. **Initial Map Matching**: nearest road within a 50-meter distance from the reported GNSS location was matched, reducing discrepancies but leaving gaps when GNSS data was too distant from the road
2. **Biasing Road Selection**: Preference given to **previously matched roads**, resolving ambiguities when multiple roads were equally close.
3. **Connected Road Preference**: If the previous road was no longer valid (e.g., vehicle turned), the system prioritized **connected roads**.
4. **Orthogonality Filtering**: **Near-90° angle preference** helped prevent incorrect GNSS-road associations.

Main Achievements

☑ Increased Accuracy
☑ Efficient Processing
☑ Robust Ambiguity Handling
☑ Error Reduction

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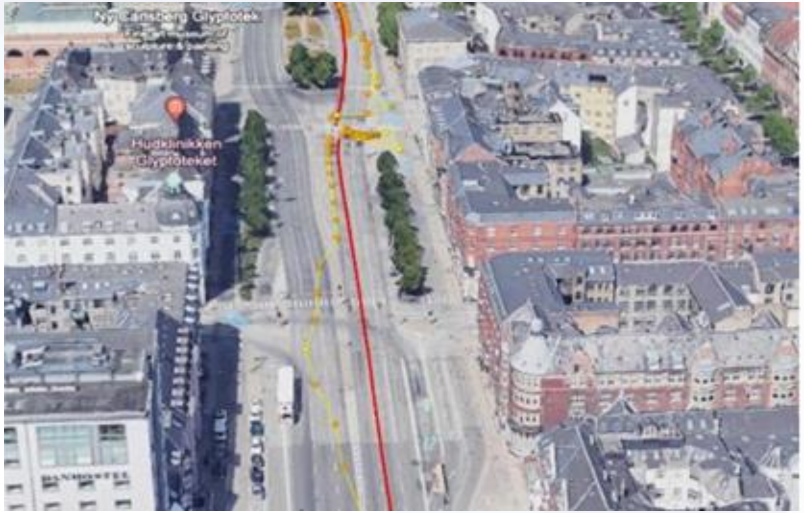
Use of Raw GNSS Data for Improved Positioning



Why Raw GNSS Data?

- ✓ **Goal**: Enhance positioning accuracy using **raw GNSS data** from Android smartphones.
- ✓ **Benefit**: No need for new apps, users maintain a **seamless workflow** within the existing system.

Post-Processing with RTKLib

- **Approach:** Converted raw GNSS logs into RINEX format for processing with RTKLib.
- **Base Station Data:** Used a 40km-radius reference station & daily orbit files for corrections.
- **Test Routes**:
  - **Bike Route** → Evaluated accuracy in varying conditions.
  - **Car Route (Urban Environment)** → Compared **device-processed Smartphone position data (red)** vs. **post-processed raw GNSS signals (yellow)**.

Key Findings & Conclusion

- **Fused Data Impact:** Smartphone position data integrates sensor fusion, proving a very robust output
- **Post-Processing Limitations:** Despite valuable insights, results did not meet expectations.
- **Future Considerations: Will monitor advancements and revisit these techniques** as they mature

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Localization

- Placement of damages and inventory such as road signs.
  - Combination of triangulation and camera calibration
- Offset calculation from car to road is critical for end use-cases

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Counting objects correctly

To avoid "counting" the same object multiple times, we use clustering on the estimated object location.

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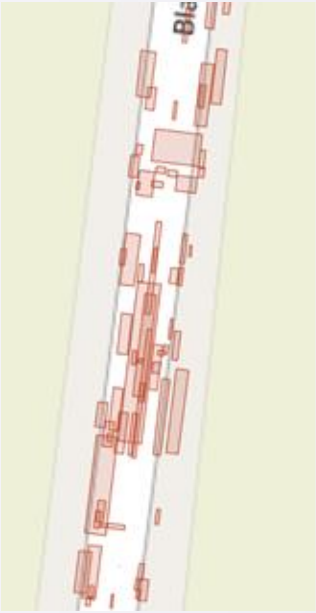

Data processing

Connecting overlapping detections based on location.
Ensuring a representational view of the road condition.

Triangulation

- Addressing Discrepancies in Camera Facing
  - Handle camera facing direction unknown.
  - The system used the driving direction as a proxy introducing errors when the camera did not face forward.
  - This caused incorrect projection of object positions, especially when the camera was slightly angled.
- Uncertainty from Detection Centers
  - The exact center of detected objects, as identified by algorithm, was another challenge, especially for far-away objects.
  - Variations in bounding box tightness or slight shifts in detection centers caused inaccuracies in estimating angles, which in turn led to errors in triangulation results.
- Using Angles Based on Vanishing Point
  - Introduce vanishing point to reduce discrepancies caused by using the driving direction as a proxy
  - This method detected supporting lines in the image and calculated the vanishing point, helping to better estimate the actual direction in which the camera was pointing.

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Demonstration of triangulation

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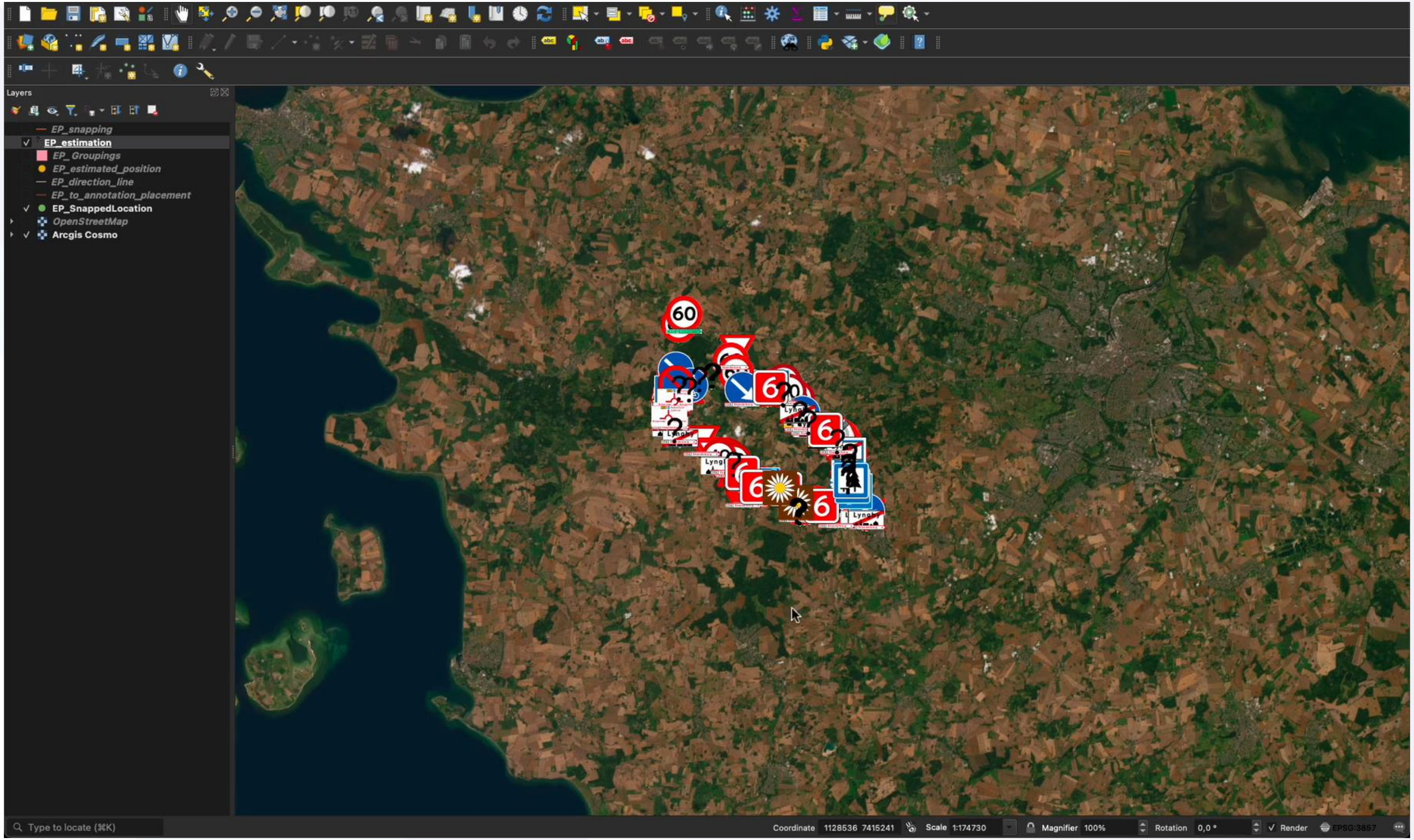
Layers
EP_snapping
EP_estimation
EP_Groupings
EP_estimated_position
EP_direction_line
EP_to_annotation_placement
EP_SnappedLocation
OpenStreetMap
Arcgis Cosmo
Type to locate (⌘K)
Coordinate 1128536 7415241
Scale 1:174730
Magnifier 100%
Rotation 0,0 °
Render

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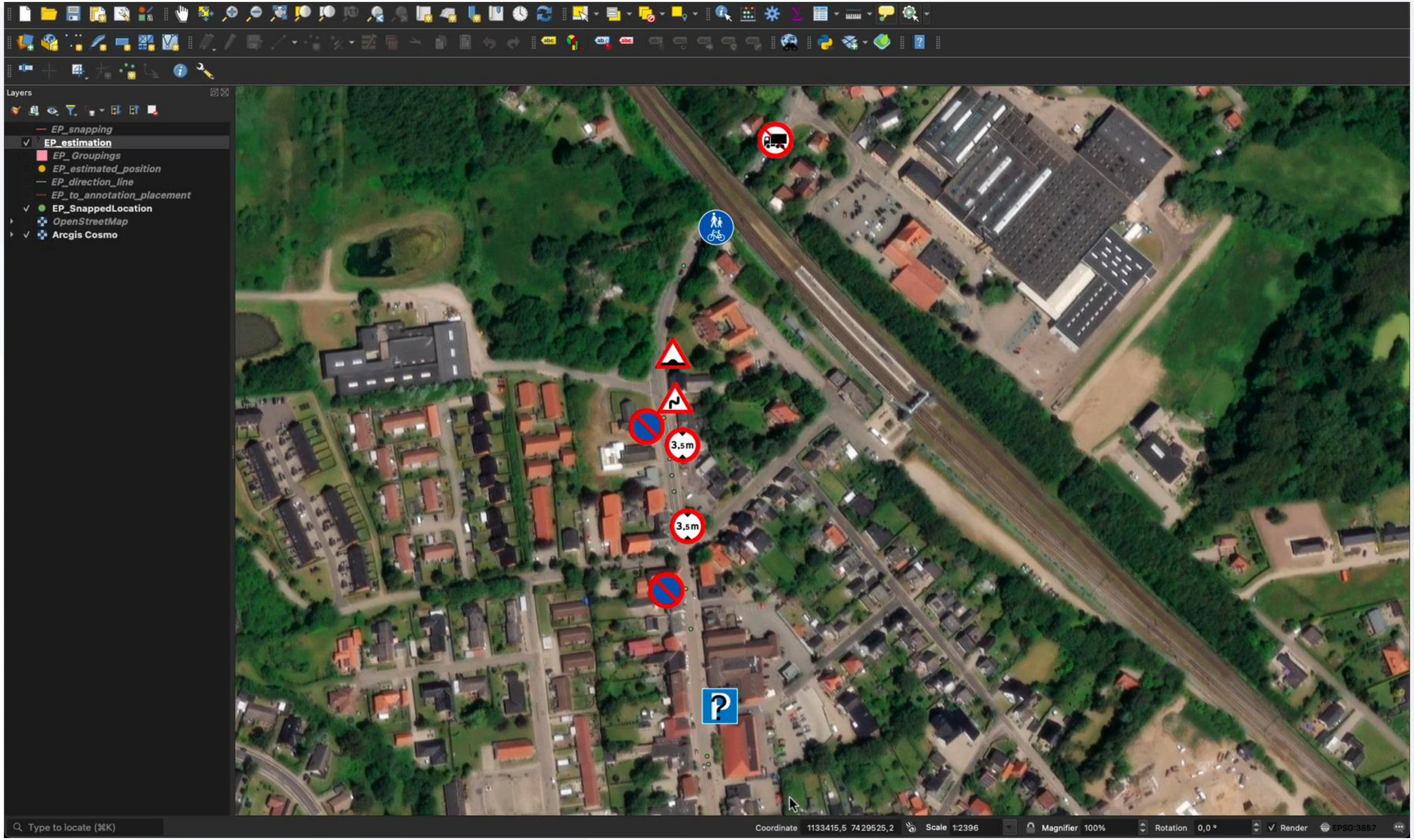
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EP_direction_line
EP_to_annotation_placement
EP_SnappedLocation
OpenStreetMap
Arcgis Cosmo
3,5m
3,5m
Type to locate (⌘K)
Coordinate 1133415,5 7429525,2
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Magnifier 100%
Rotation 0,0 °
Render

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Remote control

- Log dumps from the devices in case of errors. Data stored securely in the cloud.
- Telemetry enhancements allowed better monitoring of device performance.
- Daytime recording features, along with warnings for nighttime operations, were implemented.

Proactive decisions

- **Email Notifications**: Most users prefer receiving notifications via email. This was found to be the most efficient communication channel for decision-makers.
- **Quick Task Creation:** Users wanted the email notifications to include a button that allowed them to create tasks directly, speeding up their response time.
- **Configurable Notifications:** Users expressed a need for the notifications to be customizable, allowing them to choose which road hazards they wanted to be notified

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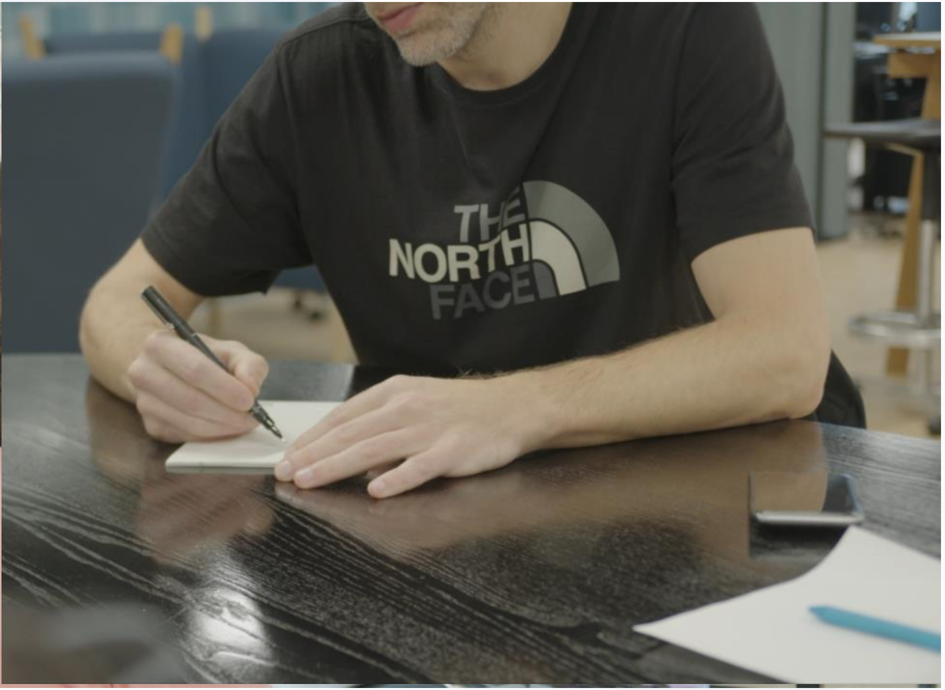
Conclusion



Main takeaways

- Identifying objects with a higher granularity to be able to prioritize on urgency for the individual damage categories and inventory. This is important meta data for correctly grouping road signs.
- Counting objects such as road signs using triangulation is possible, but edge cases will require more work to get 90% accurate solution
- Setting up notification system to communicate potential road hazards over email is the preferred way to receive notifications.
- One of the lessons learned with post-processing GNSS data is that it's difficult to obtain better results than the native sensor fusion on the android device. Certain regions have coverage of stations that allow for post-processing, but the open source libraries to support this doesn't appear to be production ready

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Working with ESA

- We learned about GNSS technologies and explored techniques that were unfamiliar to the company before the project.
- Leaning curve in terms of project management. The requirements were higher compared to other domestic innovation projects.
    - Challenging at first but became easier after the first deliverables

AI road inspections

Organisation: Faxe Kommune
Organisation type: Local authority
Country: Denmark
Target audience: Road workers

Traditionally, road work inspections are conducted manually, often exposing employees to danger as they had to physically enter the street to take photographs or drive while searching for hazards. This manual approach compromises safety and limits the thoroughness of hazard detection.

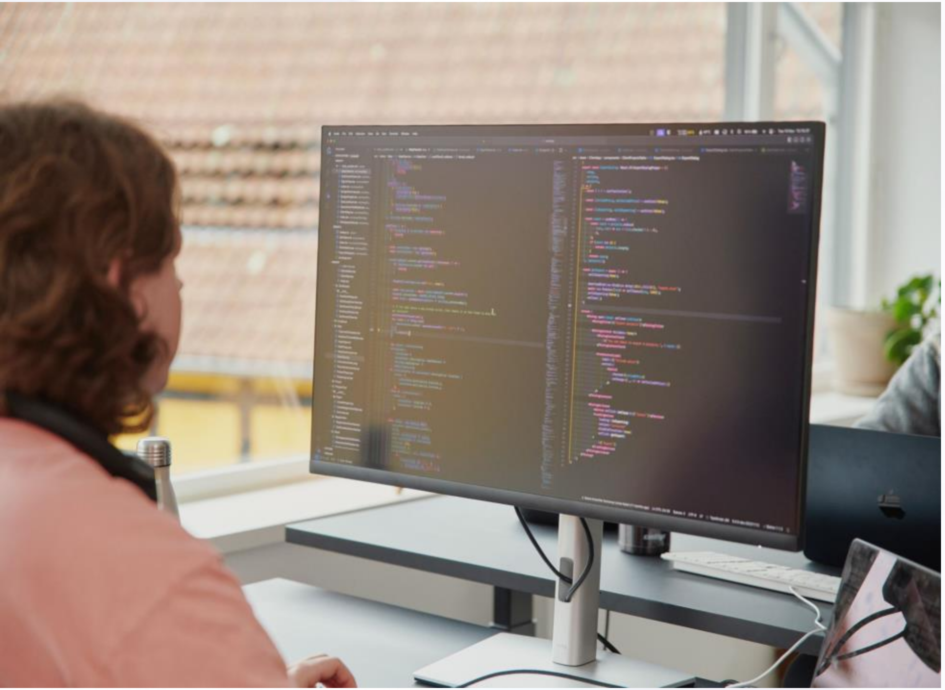
AI-powered automatic road safety inspections have transformed this process, created a safer working environment, and enhanced efficiency. Inspection vehicles equipped with advanced AI technology now identify and catalogue over 60 different types of road hazards, including potholes, cracks, and debris. The AI system analyses real-time data and generates a priority list, which helps road workers address the most critical issues first. This technological upgrade has reduced working time by 50% and identified over 1,569 potholes over a 12-month period. The result is a more effective and safer approach to road maintenance.

The Strategic Road Safety Plan 2021-2030

Organisation: cuerpo de Policía Municipal de Madrid
Organisation type: Local authority
Country: Spain
Target audience: All road users

The Strategic Road Safety Plan 2021-2030 for Madrid implements a comprehensive prevention policy focused on enhancing urban road safety and sustainable mobility, with a particular emphasis on protecting vulnerable groups. It promotes innovative participation, action, and evaluation methods, ensuring coordinated emergency services and the development of a road safety services charter with commitments to citizens.

Future developments



What is next?

- Further development on location and re-identification making it more robust and less reliant on proper camera calibration
- Extend backend functionality to better cache and track changes
- Extend interface for both Pluto Record and Pluto Map to better support specific work flows and customization

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Pluto 2.0

There is more to Pluto coming soon!

We're always listening to our user thoughts on how we can best support the daily operations. Thus, we're upgrading the functionality of many of our core features and look forward to sharing the new Pluto with you all very soon.

Register and stay up to date!

Scan me!

How to get started?

1. You receive a package with smartphone, mount, etc. We help with onboarding
2. Place mount and phone in the windshield of the car, open the app and press play
3. The phone uploads data automatically when you get back to the office

We're hiring!

Questions?

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Thank you for your time


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