



# *Computer Vision for Automated Subsea Pipeline Inspections*

## Executive Summary



# *Automated Subsea Pipeline Inspection with Computer Vision*



Subsea pipelines are critical for offshore energy transport; current inspection is manual and error-prone.



ROV footage must be reviewed for damage, burial status, debris, etc.—a labor-intensive process.



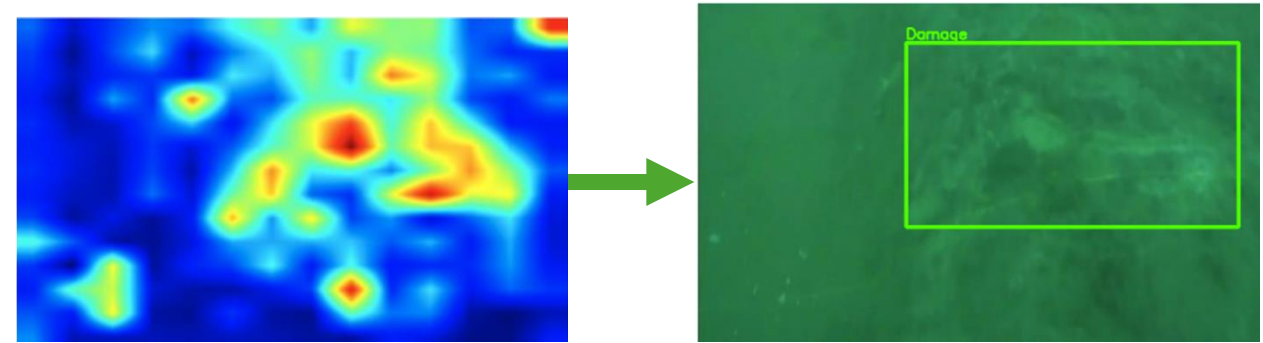
Objective: Automate visual inspection using machine learning, while integrating seamlessly with current workflows.



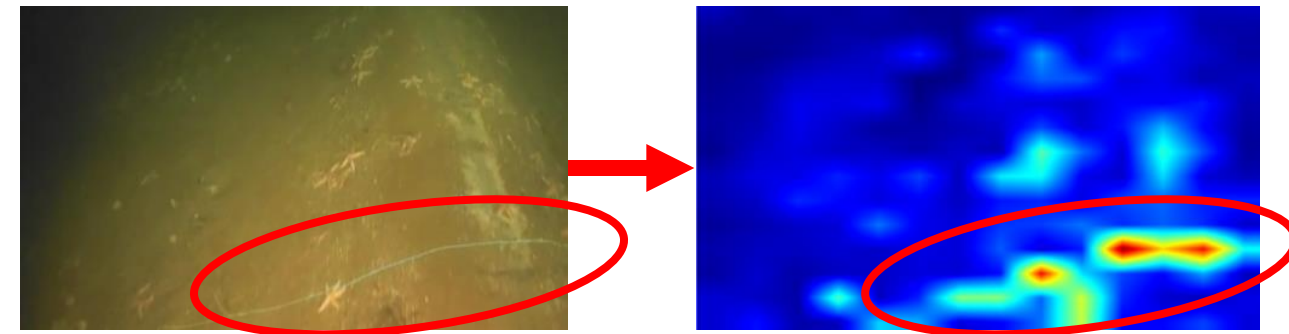
# *Automated Data Extraction and DINO-Based Weak Learning*

- Developed a scalable Python pipeline to extract event-aligned stills and clips from large ROV video datasets.
- Integrated OCR to extract and validate Kilometer Point (KP) metadata from video overlays.
- Used DINO Vision Transformer to generate pseudo-bounding boxes from attention maps without manual labels.
- Weak supervision effective for distinct classes like 'Damage'; struggled with ambiguous features (e.g., 'Soft Debris', laser artifacts).

Classes with salient features  
often generalizable



Struggled with ambiguous features and  
distracting visual characteristics

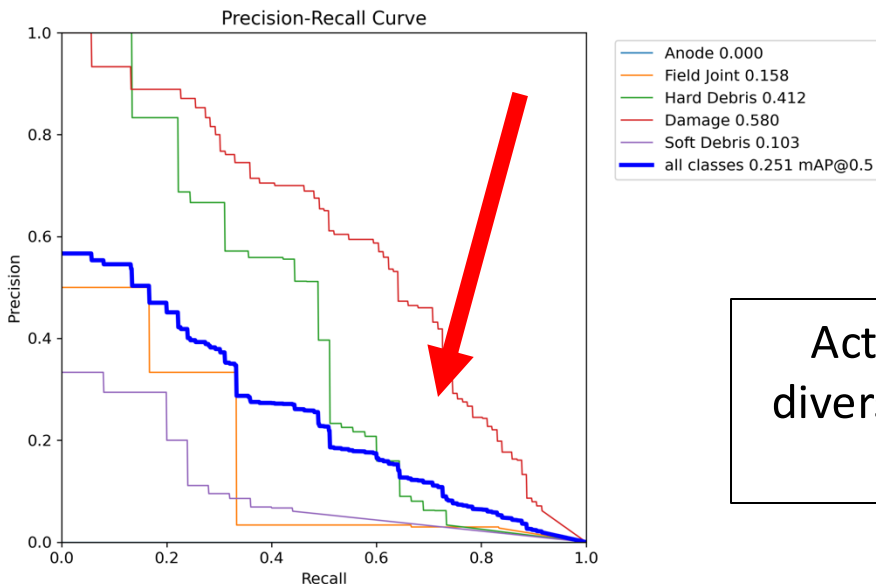


# Event Detection, Exposure Classification, & Active Learning

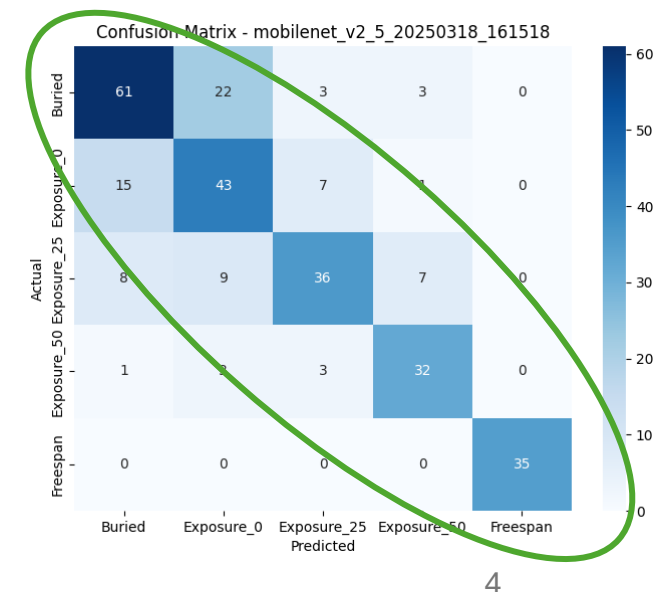


- Detection models trained per camera view; top-down Channel 2 showed highest reliability across events.
- 'Damage' and 'Hard Debris' achieved the best detection performance; but still at a harsh **precision-recall** curve for trade-offs.
- Tracker (BoT-SORT) improved temporal consistency in noisy ROV footage.

- Using horizontally merged multi-view input, states were classified; trained on 5-class scheme.
- Most confusion occurred between adjacent exposure levels; see confusion matrix for misclassification trends.
- Achieved **overall accuracy of 72%**; macro-averaged **F1-score of 0.75** confirms balanced performance across all exposure classes.

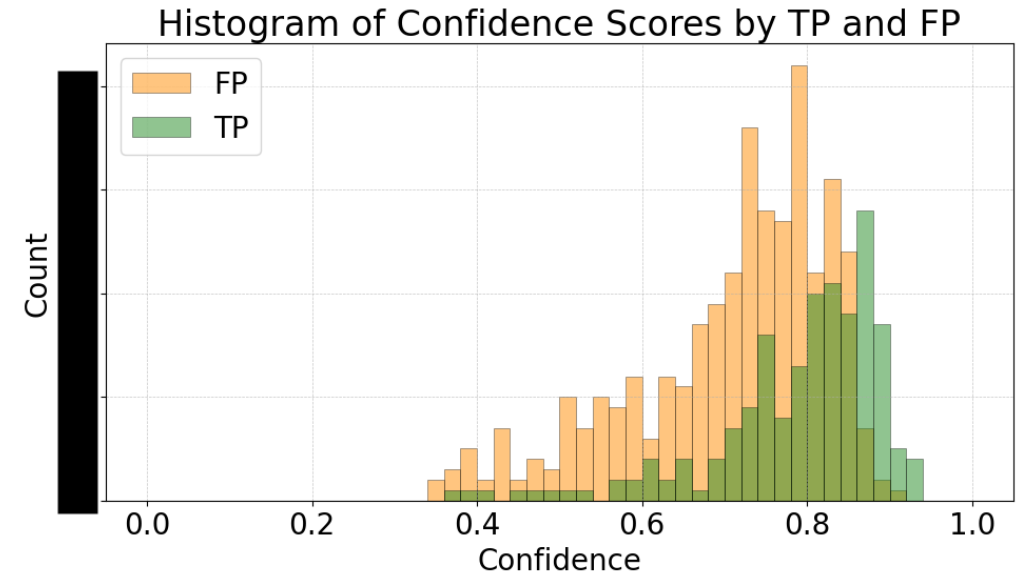


Active learning selected uncertain and diverse samples to improve generalization with minimal annotation.



# Model Evaluation and Workflow Integration

- Deployed detection + tracking on 40 km pipeline segment; predicted [REDACTED] potential events than original labels.
- TP/FP ratio for damage: 31.4% under conservative manual validation.
- Exposure classification model achieved 77% accuracy (F1-score: 0.75); best on Freespan class (F1-score: 1.0).
- GUI enabled practical review of results, streamlined annotation, and export in existing N-Sea formats.



Prediction Sheet

Home Dataset Loader Dataset Management Active Learning Predict Sheet Help Desk

Kilometer Point	Detection Classes	Confidence	Frame Index	Timestamp
[REDACTED]	Damage	0.9385	13366	[REDACTED]
[REDACTED]	Hard Debris	0.9375	32615	[REDACTED]
[REDACTED]	Damage	0.9365	8348	[REDACTED]
[REDACTED]	Hard Debris	0.9365	31370	[REDACTED]
[REDACTED]	Hard Debris	0.936	35544	[REDACTED]
[REDACTED]	Soft Debris	0.9355	30823	[REDACTED]
[REDACTED]	Hard Debris	0.9351	6715	[REDACTED]
[REDACTED]	Hard Debris	0.9346	35545	[REDACTED]
[REDACTED]	Hard Debris	0.9316	40947	[REDACTED]
[REDACTED]	Hard Debris	0.9312	3311	[REDACTED]
[REDACTED]	Hard Debris	0.9287	17571	[REDACTED]
[REDACTED]	Soft Debris	0.9268	43037	[REDACTED]
[REDACTED]	Hard Debris	0.9268	32974	[REDACTED]
[REDACTED]	Soft Debris	0.9263	21423	[REDACTED]
[REDACTED]	Damage	0.9253	25469	[REDACTED]

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Damage 0.94



# *From Operational Prototype to Scalable Inspection Automation*

- **Expand and Restructure Dataset:** Improve class definitions, intra-class diversity, and pipeline/environment coverage to enhance generalization.
- **Enhance Data Modalities:** Archive camera metadata and acquire structured sonar data (e.g., point clouds) to enable 3D spatial understanding.
- **Improve OCR and GUI Tools:** Fine-tune OCR for overlay text; extend GUI with side-by-side comparisons and GIF-based temporal review.
- **Design with Automation in Mind:** Existing ROV data is human-centric—future systems should be sensor-optimized for machine perception.
- **Anticipate Autonomy:** Transitioning to autonomous platforms and new sensing technologies may reshape inspection workflows entirely.

