Masking by Moving: Learning Distraction-Free Radar Odometry from Pose Information

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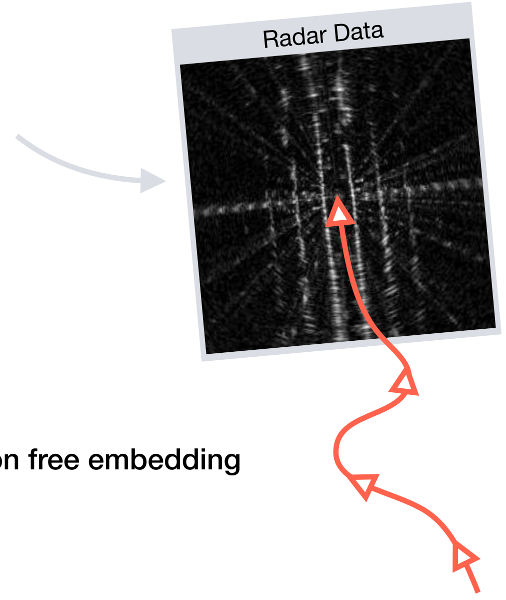
Overview

Accurate real-time radar odometry in urban environments

Radar Challenges

→ Exhibits significant sensing artefacts
→ Ambiguous occupancy from returns



Our Approach

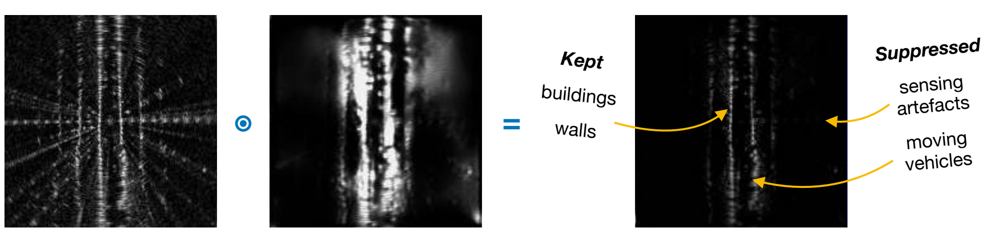
✔ State of the art performance
✔ State of the art speed
✔ Calibrated uncertainties
✔ Interpretable artefact and distraction free embedding
✔ Self-supervised dataset generation
✔ Supervised by pose only

Formulation

Given two sequential radar scans:

1. Learned Radar Masking

Predict and apply masks to radar data for improved motion estimation:

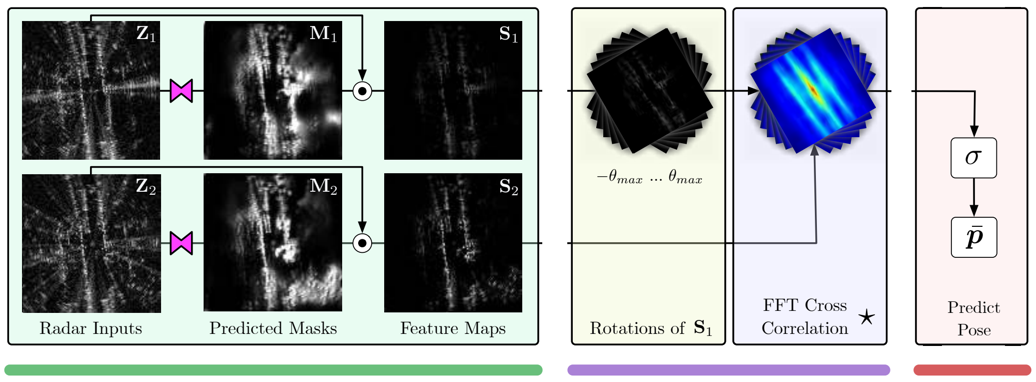


2. FFT Cross Correlation Volume

Efficiently compute cross-correlation volume between scans (x / y / θ)

3. Estimate Pose and Uncertainty

Apply soft-argmax on the correlation volume to estimate pose & uncertainty



Training

Entire formulation is ***fully differentiable*** and trained on pose error alone:

$$\mathcal{L} = ||\tilde{x} - x||_2 + ||\tilde{y} - y||_2 + \alpha\ ||\tilde{\theta} - \theta||_2$$

The Oxford Radar RobotCar

280 km publicly released dataset including:

- Navtech CTS350-X radar data (+ lidar / camera / gps)
- Optimised radar odometry

`ori.ox.ac.uk/datasets/radar-robotcar-dataset`

"The Oxford Radar RobotCar Dataset: A Radar Extension to the Oxford RobotCar Dataset".
Dan Barnes, Matthew Gadd, Paul Murcutt, Paul Newman and Ingmar Posner

Results

Odometry Performance

✔ Translational Drift → **over 68% lower**
✔ Rotational Drift → **over 68% lower**
✔ Runtime → **over 10x faster**

Systems Benefits

✔ Flexible trade-off between speed and performance
✔ Interpretable artefact and distraction free embeddings

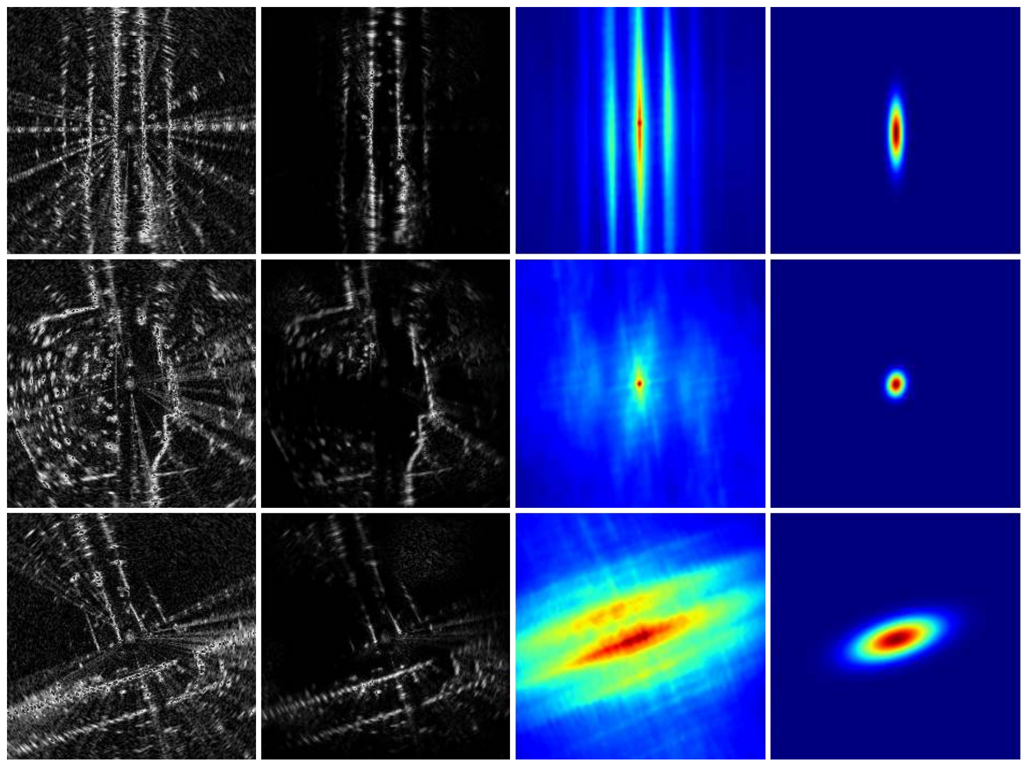
Uncertainty Evaluation

→ Interpret correlation scores as pose probabilities
→ If pose distribution is Gaussian and uncertainty is well calibrated
→ Mean Mahalanobis distance equals degrees of freedom = 3

$$\bar{d}^2 = \frac{1}{N}\sum_n d_n^2, \quad d^2 = (\boldsymbol{p} - \bar{\boldsymbol{p}})^T \bar{\boldsymbol{\Sigma}}^{-1}(\boldsymbol{p} - \bar{\boldsymbol{p}}), \quad d^2 \sim \chi^2(3)$$

✔ Achieve $\bar{d}^2 = 2.992$ by calibrating soft-argmax temperature

Qualitative Results



Radar Scan | Masked Radar | Correlation | Covariance

Conclusion

Evaluated on 64km of real world urban radar data:

✔ State of the art radar odometry in performance and speed
✔ Calibrated pose uncertainties for real-world robotics
✔ Interpretable artefact and distraction free embedding
✔ Self-supervised dataset generation

More Information

For paper and video please scan QR code or visit:

`dbarnes.github.io/projects/masking-by-moving`

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