Artificial Intelligence and Deep Learning in Radar Remote Sensing

2. Symposium „Neue Perspektiven der Erdbeobachtung“
Outline

1. Introduction
2. SAR to Optic Image Matching
3. SAR Image Segmentation
4. SAR Ship Detection
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Big Data in Earth Observation
WorldSAR – Current and Future Missions

WorldSAR Constellation Operation with Hisdesat (ES)

- TerraSAR-X (2007)
- TanDEM-X (2010)
- PAZ (2018)

HRWS (2025)
- incl. 3 companions
- Export partner

WorldSAR Next Generation
- HRWS (1200 MHz, < 25 cm, mono- and multi-static mission incl. 3 passive companions)
- Export partner
- Small Satellite SAR Constellation

Small Sat Const.*

* Small Satellite SAR constellation concepts for massive revisit
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Idea

- Ground Control Points (GCPs) can be extracted from TerraSAR-X imagery with an absolute horizontal accuracy < 0.3 m

- Other sensors e.g. optical typically have a lower geolocation accuracy (e.g. Pléiades Neo < 5 m CE90 at Nadir expected\(^1\))

- **Objective**: Identify the matching points of the GCPs in the optical image and use them to improve the geolocation accuracy of satellite images from other sensors

Data

TerraSAR-X (Radiometrically Enhanced)

Pléiades 1A/B
Data

**TerraSAR-X (Spatially Enhanced)**

**Pléiades 1A/B**
Methodology

During training, the network learns to discriminate between matching and non-matching patch pairs by calculating the Euclidean distance between the two descriptors (similarity score)

- Distance small → matching
- Distance large → non matching

* The CNN was pre-trained on the SEN1-2 dataset (Schmitt, Hughes and Zhu, 2018)
Methodology

- For application/test, one image patch is cropped around GCP in the SAR image and several patches within a search window in the optical image.

- Descriptor distance between SAR and respective optical patch is used as similarity measure to identify the matching point in the optical image → heat map.
Results

Before co-registration

After co-registration

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Validation results of different architectures

SAR

Ground Truth

AdapNet*

GCN*

DeepLabV3*

DeepLabV3+*

* source: https://github.com/GeorgeSeif/Semantic-Segmentation-Suite
Test results of AdapNet

Results of testing the network on another SAR image of the lake of Constance area:

- Average Test Accuracy: 97.71 %
- Average Precision: 97.90 %
- Average Recall: 97.71 %
- Average F1 score: 97.74 %
- Average mean IoU: 88.76 %
Test results of AdapNet

Results of testing the network on two separate regions (left: Wangen/Allgäu, right: Paris)
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Adaptation of CeMore Deep for SAR → CeMore Deep SAR

SAR Training Images

Training of SAR specific CNN feature extractor

New CNN Architecture
→ High spatial resolution
→ Fast processing time
→ Low memory consumption

“Deep Learning Features”
+
“High Speed Support Vector Machine”
Relevant Object Classes for Maritime ATR

- Merchant ships (Cargo / Tanker / Bulk carrier / LNG / ...): large, small
- Passenger vessels (Cruiser, Ocean Liner, Ferries,...)
- Boats (pleasure crafts, fishing vessels, sail boats,...)
- Buoys
- Ambiguities
- Wakes
- Flares
- Icebergs
- Wind parks
- Off-shore and floating platforms (oil rigs, digging/dredging vessels,...)

Up to now no objects available in existing images
Hints for ships → not relevant in case of excellent ship classifier
Ground truth required, discrimination doubtful for low resolution

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ATR Performance Results for Stripmap Mode

Separation ships – ambiguities

Maputo
SM, asc, 31°

Maputo
SM, desc, 52°

Yokohama
SM, asc, 37°
ATR Performance Results for Wide ScanSAR

Overall very good performance ($\geq 0.90$) on ships for wide range of data!
Point of Contact

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