TerraSAR-X Along-Track InSAR Data Processing for GMTI: Overview and Results

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Overview

- Introduction

- TerraSAR-X Along-Track Interferometry

- Operational TerraSAR-X Traffic Processor TTP

- Traffic Detection
  - Aperture Switching
  - DRA Mode
  - Further Results

- Other Applications
Introduction

- TerraSAR-X Traffic Project
  - Demonstration of large-scale, weather independent and worldwide traffic measurement using space borne SAR Along-track interferometry

- Development of an automatic NRT processing system

- Applications
  - Integration of data into traffic information services
  - Evaluation of conventional traffic sensors
  - Traffic information in case of natural disasters

- Other GMTI applications
  - Surface current measurement
  - Ship detection
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TerraSAR-X ATI Modes

**Aperture Switching**
- One receiver electronic (RE) for both channels
- Alternating 20 dB attenuation of antenna parts on receive
- Half prf per channel
- Used for most of traffic data takes

**Dual-Receive Antenna**
- Separate RE for each channel
- Simultaneous receive with two antenna parts
- Full prf for both channels possible
TerraSAR-X ATI Modes and Effective Baseline

Aperture Switching Mode

- Contribution of attenuated antenna parts to antenna diagram not negligible
- Effective phase centers are closer than expectable from geometry

Dual-Receive Antenna Mode

- Effective baseline is almost as predicted from geometry (unless combined with AS)

Baseline Estimation in Range-Doppler Domain

Baseline characterization

<table>
<thead>
<tr>
<th>ATI mode</th>
<th>AS</th>
<th>DRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna parts</td>
<td>half/half</td>
<td>third/third</td>
</tr>
<tr>
<td>$B_{eff}$ [m]</td>
<td>0.82</td>
<td>0.99</td>
</tr>
</tbody>
</table>

ATI phase sensitivity

$$\phi_{ATI} = \frac{4\pi \cdot B_{eff}}{\lambda \cdot v_s} \cdot \vec{R}_n \cdot \vec{v} \rightarrow \sim 3.0 \ \text{deg} / \text{1ms}^{-1}$$

@ $\theta=35\text{deg}$, $B_{eff}=1.43 \text{ m}$, $v_s=7500\text{m/s}$
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TerraSAR-X Traffic Processor TTP: Overview

1. Two-channel LO Data
2. Modified TMSP
3. Geometry Estimation
4. Co-Registration
5. Channel Balancing
6. GIS Import
7. Filter Prediction
8. Adaptive Filtering
9. DPCA Image Formation
10. Interferogram Formation
11. DPCA Detector
12. ATI Detector
13. Detection Mask Fusion
14. Peak Localization
15. Velocity Estimation
16. Consistency Check
17. Traffic Parameter Generation

GIS data base

DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft
TerraSAR-X Traffic Processor: Near-Real Time Workflow

- TS-X dual-channel data acquisition
- Downlink to Neustrelitz ground station
- 4 x Sun Fire X4600, 8 x Opteron dual-core 2.8 GHz each
- TTP installation in operational processor system environment
- Email distribution of TTP data product (KML file)
- Remote visualization with GE by user
- 15 min
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AS Mode: Traffic Detection, West of Munich, 16.9.08

Demonstration of large-area traffic measurement

Acquisition parameter: Stripmap-AS, $\theta = 34.4^\circ$, prf = 3353 Hz, $B_{rg} = 150$ MHz, $B_{eff} = 0.84$ m
AS Mode: Empirical Evaluation of TTP Traffic Detection

Joint TS-X - Airborne camera traffic detection, 4.8.08, A4, Dresden

- Detection in TS-X data (Subset)
- Reference from airborne camera system: 81 measured and classified vehicles

### Acquisition Parameter & Detection Results, 4.8.08

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX imaging mode</td>
<td>AS-Stripmap, 1/3 Ant.</td>
</tr>
<tr>
<td>Az. sampling freq. prf</td>
<td>3.3 kHz</td>
</tr>
<tr>
<td>Range bandwidth $B_{rg}$</td>
<td>300 MHz</td>
</tr>
<tr>
<td>Incidence angle $\gamma$</td>
<td>28 deg</td>
</tr>
<tr>
<td>Clutter type</td>
<td>Open land</td>
</tr>
<tr>
<td>Completeness trucks</td>
<td>72 %</td>
</tr>
<tr>
<td>Completeness cars</td>
<td>26 %</td>
</tr>
<tr>
<td>Correctness</td>
<td>94 %</td>
</tr>
<tr>
<td>Velocity error (RMS)</td>
<td>3 km/h</td>
</tr>
</tbody>
</table>

Reference from airborne camera system: 81 measured and classified vehicles

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DRA Campaign 2009: TTP Detection for A4, Dresden

Reference data from ground video

\[ v, p = f(\Delta s, t_1, t_2, t_{TSX}) \]

Acquisition parameter: Stripmap-DRA, Third/Third-Ant, 25.4.09, \( \theta = 27^\circ \), \( B_{\text{eff}} = 1.43 \, \text{m} \)
DRA Campaign 2010, Vienna: TTP Detections vs. Ground Sensors

DT5051, 20.4.2010
Amstetten, Austria

Cooperation with ITS Vienna Region (induction loop data & evaluation)
DRA Campaign 2010, Marseille: TTP Detections vs. Web Ref.

TS-X Traffic Detection
10.5.2010 Marseille, France

Traffic info reference for time of imaging

http://maps.google.fr/

In cooperation with INRETS
DRA Campaign 2010, Lyon: TTP Detections vs. Context Reference

TS-X Traffic Detections 15. / 26. 4.2010 Lyon, France

Speed-reducing tolling station

In cooperation with INRETS
DRA Campaign 2010, Oberhausen – TTP Detections vs. Web Ref.

TS-X Traffic Detections 29.4. 2010
Oberhausen, Germany

Traffic info for time of imaging

In cooperation with TÜV Süd / NavCert
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Munich: Change Detection for Indication of Congestions (1)

Munich, Einsteinstrasse / Leuchtenbergring

TS-X HS SSC, 2.5.2010, UTC 16:51:17

TS-X HS SSC, 13.5.2010, UTC 16:51:17

TS-X HS SSC, 24.5.2010, UTC 16:51:17

Resolution (grg x az): 1.13 m x 0.87 m
Munich: Change Detection for Indication of Congestions (2)

Change detection pattern of congestion

Changes between TS-X HS data of 13./24.5.2010 (multi-looked, geo-coded)

Extracted Google Earth product for congestion

Reference image
Actual image

Change Ratio
Thresholding
Congestion pattern identification

Extracted Google Earth product for congestion
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Ship Detection, English Channel
DRA-DT06454, May 12, 2010

- TTP processing mode that does not require GIS data
- Ship detection, measurement and position correction
Surface Current Velocities from TerraSAR-X ATI (AS-Mode)
Orkney Islands, 2009

Flight direction
Illumination

Nov 12
Nov 23
Dec 26

Ground-range current velocity from TerraSAR-X

3 m/s towards Radar
3 m/s away from Radar

Current estimation: R. Romeiser (University of Miami), Pre-Processing: S. Suchandt (DLR)
Thank you for your attention!