The STUN algorithm for Persistent Scatterer Interferometry

1. Theory
2. PSIC4 Processing
3. Conclusions

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STUN Algorithm

- **Spatio-Temporal Unwrapping Network (STUN)**
  - 1D temporal + 2D spatial phase unwrapping

- **Goal:**
  - Unwrap the phase in a single-master stack
  - Optimal estimation of displacement parameters

- **Key Features:**
  - Integer Least-Squares (ILS): estimator
  - Variance Component Estimation (VCE): weights
  - Alternative Hypothesis Tests: robust
STUN Processing Steps

- **Point selection:**
  - ~4 PS/km² in reference network
  - ~200 PS/km² for estimation
  - Discard ~99%

- **Reference Network Computation**
  - Optional interferogram trend correction

- **Tie more points to network**

- **Explicit phase unwrapping**
  - Sparse grid Minimal Cost Flow (MCF)

- **Optional Atmospheric Correction**
  - Kriging Interpolation

- **Final Estimation**
Integer-Least Squares (ex. 1)

- 16 samples, 10 years
- Noise $\sigma = 69.2$ [deg]
- Signal = -2.92 [rad/y]

**ESTIMATED:**
- 67.7 [deg] ($\gamma=0.55$)
- -2.83 [rad/y]

**2nd BEST FIT:**
- ($\gamma=0.41$)
- -17.9 [rad/y]
Integer Least-Squares (ex. 2)

- 14 samples
- $\sigma = 32.3$
- $b_1 = 5.79$, $b_2 = 1.35$

**ESTIMATED:**
- $27.1$ [deg] ($\gamma = 0.91$)
- $5.75$, $1.35$

**2nd BEST FIT:**
- $-2.72$, $-1.35$
Integer Least-Squares

- Readily extendible for more parameters:
  - Search of ambiguities solution space
  - Efficient search strategy exist (GPS application)
  - No increase in computation time

- Weighted least-squares:
  - Stochastic model for double-difference phase observations
  - Variance Component Estimation (VCE)

- Software available at Delft University of Technology
  - [http://enterprise.lr.tudelft.nl/mgp/](http://enterprise.lr.tudelft.nl/mgp/)
Variance Component Estimation (ex. 1)

- 31 SLC images
- 30 interferograms
- 400 PS points
- 200 arcs (double-differences)
Variance Component Estimation

- “Weights” of the SLC scenes
  - Improves quality of estimated parameters
  - Reduces number of incorrectly estimated ambiguities
  - Automatically detect incorrectly processed interferograms
  - Realistic quality description of estimates

- Iterative estimation procedure

- See paper for equations
• Real data application
Initiated by ESA at *FRINGE 2003*

“Cross-Comparison of Persistent Scattering Processing Techniques”

Marseille, France
Processed Area

- 25 x 40 km²
- Rural area
- Mountainous: 0-1000 m
- Subsidence due to mining
Baseline Distribution

- 80 SLC selected
- No extreme Doppler/large Baseline
Processed Interferograms

- Differential Interferograms
  - SRTM DEM
- Single Master
  - 20460
  - ERS-2
  - March 1999
- Coregistration
  - Geometry
  - Point Targets
- Sorted according to perpendicular baseline
Selected Points

Area:
- rg: 2400
- az: 20000
- ~50 million pixels

Points:
- SCR > 1.5
- ~200,000 PS
- Phase data extracted at sub-pixel peak positions
Variance Component Estimation

- Average of estimated components at ~600 independent arcs

- SLC sigma ~15 -- 45 [deg]

- Accounts for random noise and atmospheric difference signal at arcs of typical length (1250 m)
Reference Network

- Points in reference network selected based on amplitude dispersion index:
  - Expected to be temporally coherent
- Network constructed
  - ~10 arcs per point
- At all arcs, estimate:
  - DEM error differences
  - Displacement rate differences
- Integer least-squares Estimator
  - Weighted
Parameter Integration

- Least-squares adjustment of estimates between PS points
- Yields DEM errors and Displacement rates at the PS points
- Alternative Hypothesis Tests
- Red: rejected arcs
Parameters at Reference Network

- Reference network
- ~1600 PS

- DEM error
- Displacement Rate
Estimated Parameters at PS

- 60,000 PS accepted
- Subsidence
  - -13 mm/y
- Uplift
  - +5 mm/y

- DEM update
- Displacement Rate
Estimated Quality

- A posteriori variance factor
- Unwrapped data
  - Not yet corrected for atmospheric signal
- Precision decreases the further away from reference point (asterisk)
- Subsidence area: this factor is locally larger:
  - Functional model not correct?
Residual Phase

- Residual phase in interferogram
  - DEM error corrected
  - Displacement rate
- This is interpreted as
  - Random noise +
  - Atmospheric signal
- $\rightarrow$ Kriging Interpolation
Structure Functions

- Each panel shows the structure function of the residual phase in an interferogram.

- Atmospheric signal:
  - power-law
  - slope in loglog plot

- Red: estimated slope
  - input for Kriging
Kriging Interpolation

- Residual Phase
- Kriging
Final Estimation

-11.45 mm/year

• Data corrected for estimated atmospheric signal
GIS Interface (geoTIFF)
• Conclusions
Conclusions

- STUN = Spatio-Temporal Unwrapping Network
  - Integer Least-Squares
  - Variance Component Estimation
  - Alternative Hypothesis Tests

- PSIC4 Processing Report
  - Point Selection
  - Reference Network
  - Unwrapping

- Our paper gives more details on theory and displacement models

- Visit our Poster:
  - “DLR’s Results of the PSIC4 Study”
Thank you!