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DLR German Aerospace Center

Identifying pure urban image spectra using a learning urban image spectral archive (LUISA)

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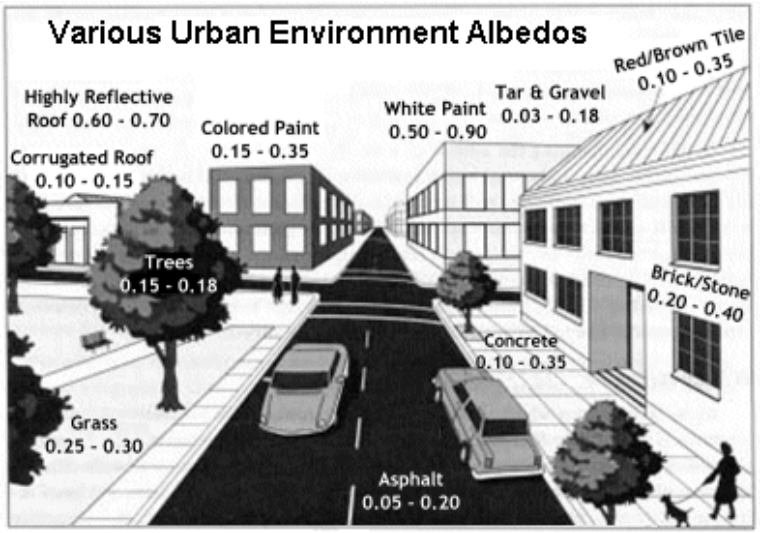
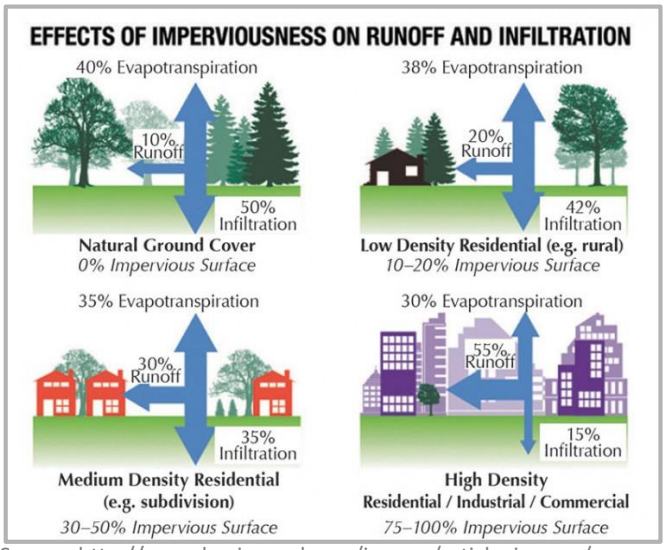
Introduction

- **Urban surface materials** are essential for several urban studies (e.g. urban microclimate, surface runoff)



Source: http://www.ghcc.msfc.nasa.gov/urban/urban_heat_island.html



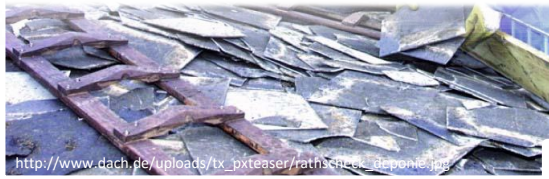
Source: http://www.bayjournal.com/images/article_images/large/2015-07-utility-1.jpg

Urban complexity

Coating

http://bst-dachprofi.de/02c5ce98c20783a01/index.php

Trends

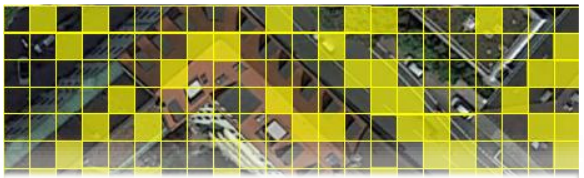


http://www.dach.de/uploads/tx_pxteaser/rathscheck_deponie.jpg

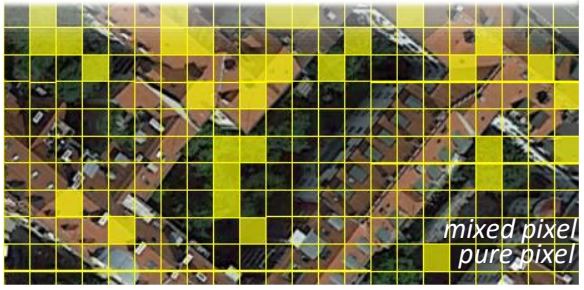
Usage of material

Aging

http://www.loudmouthpress.org/wp-content/uploads/2015/08/roof-tiles-620x350.jpg



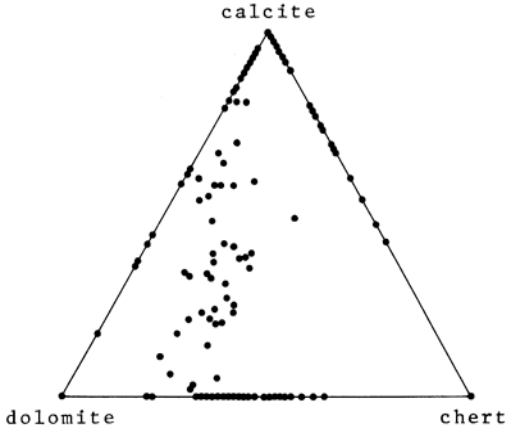
Spatial Resolution



http://www.coeser.de/impressions/bilder/hua-hin-06-colored-rooftops-bunte-hausdaecher-christian-oeser.jpg

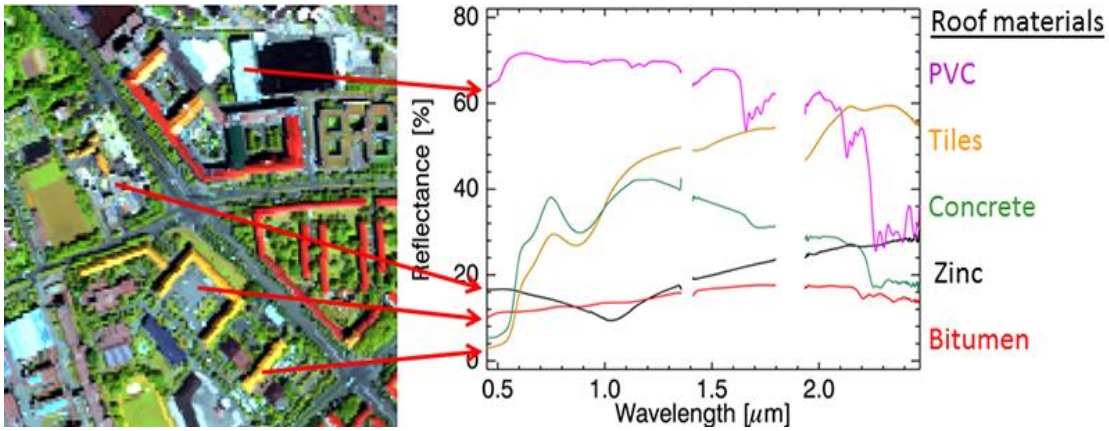
Pure urban surface materials

Automated endmember extraction



Source:
http://www.kgs.ku.edu/Publications/Bulletins/PS3/gifs/fig23.gif

Comparison with spectral libraries



Source: http://www.enmap.org/?q=terrestrialUrban

LUISA – Learning urban image spectral archive

→ Image-based identification of urban surface materials

→ Generic urban spectral archive – consideration of incompletness

→ Usage of extracted pure material spectra for further applications

LUISA - Concept

High resolution hyperspectral imagery

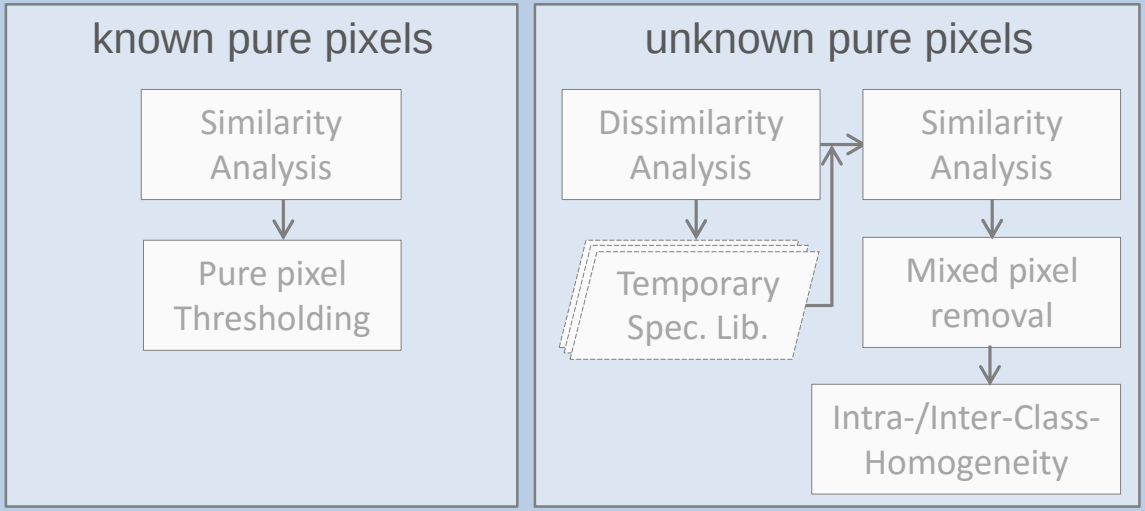
Learning urban image spectral archive (LUISA)

LUISA-A

- Spectral archive
- Generically structured
- Continuously expandable
- Universally applicable due to:
  - sensor-based resampling
  - spectral redundancy reduction (ISODATA)
- Based on >5,200 image spectra and different areas
- Focus on artifical materials

LUISA-T

- Automatic identification of pure pixels



→ mask of pure labeled pixels

→ mask of categorized unknown pure pixels

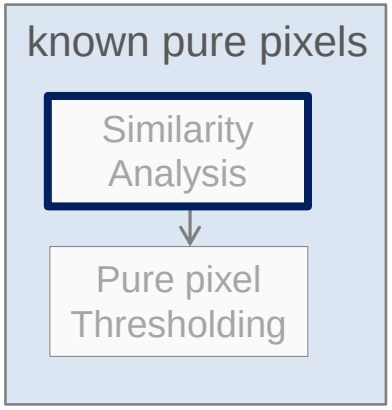
Result: scene-based spectral library of pure material spectra

LUISA-A Hierarchy

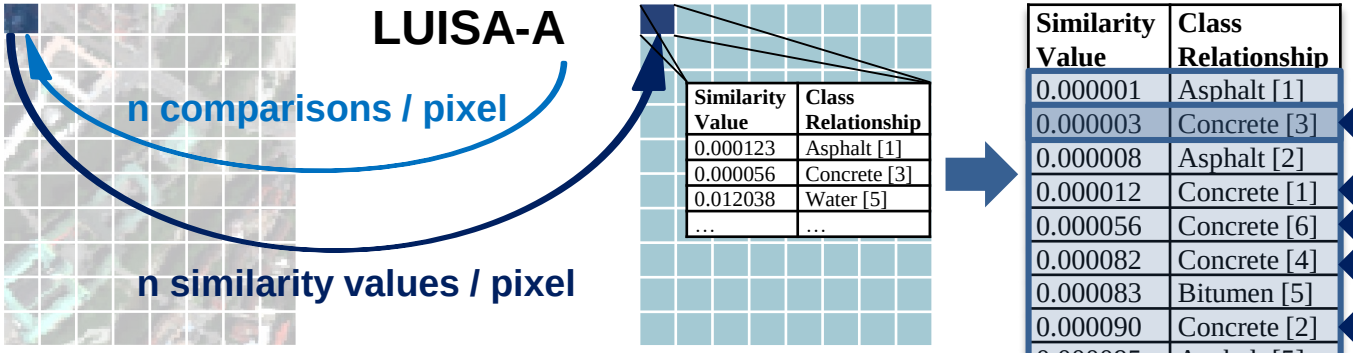
EAGLE * (EIONET Action Group on Land Monitoring in Europe)				extended LUISA Hierarchy		
Abiotic	Natural Surfaces	Unconsolidated	Exposed soil	Non-contaminated	Soil	
					Sand	
				Contaminated		
			Gravel			
		Consolidated	Rocks			
	Artificial surfaces	Impervious and partially pervious	Overbuilt	Mineral	Clay tiles	[instances]
					Concrete	
				Metallic	Copper	
					Aluminum	
					Zinc	
				Hydrocarbon	Polyethylene	
					Bitumen	
					Tar paper	
					Polyvinylchloride	
				Biomass		
				Opaque		
			Non-overbuilt (other constructions)	Mineral	Concrete	
					Cobblestone	
					Loose chippings	
				Hydrocarbon	Tartan	
					Synthetic turf	
					Asphalt	
		Pervious (not partially pervious)	Waste materials			
			Other artificial surfaces			
Biotic	…	…	…	…	…	…
Water	…	…	…	…	…	…

* *Arnold et al. (2013): The EAGLE concept - A vision of a future European Land Monitoring Framework*

LUISA-T: Pure Pixels



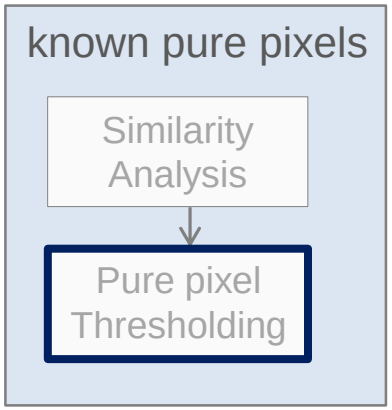
Similarity Analysis



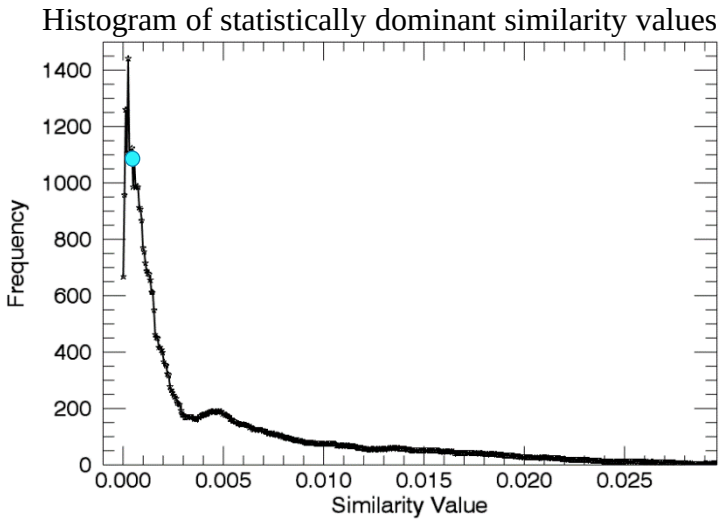
- Selection of similarity measure
- Pixel-wise comparison with LUISA-A spectra
- Ranking of similarity values
- Determination of statistically dominant similarity class (pre-classification)

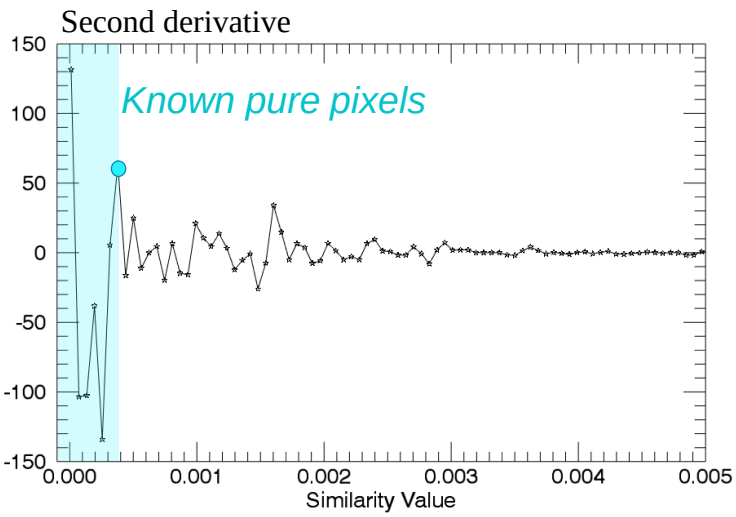
Similarity Measure
SAM (Spectral Angle Mapper)
SID (Spectral Information Differgence)
SID-SAM
SCM (Spectral Correlation Measure)
SCA (Spectral Correlation Angle)
SID-SCA
JMD (Jeffries-Matusita Distance)
JMD-SAM

LUISA-T: Pure Pixels



Automated pure pixel thresholding

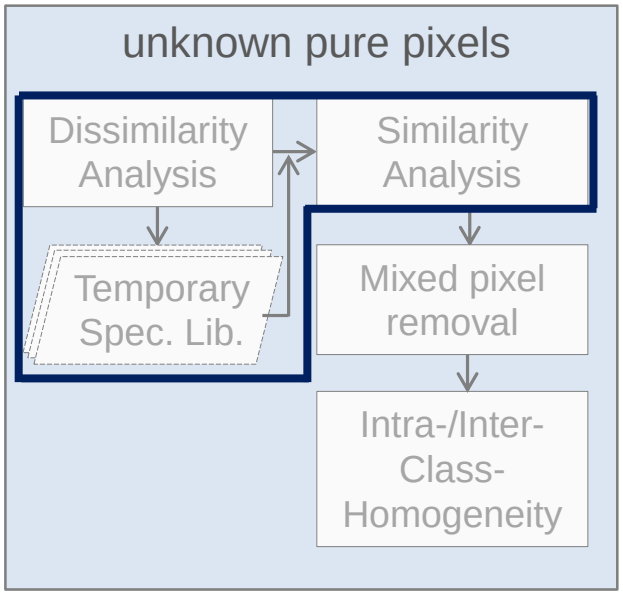




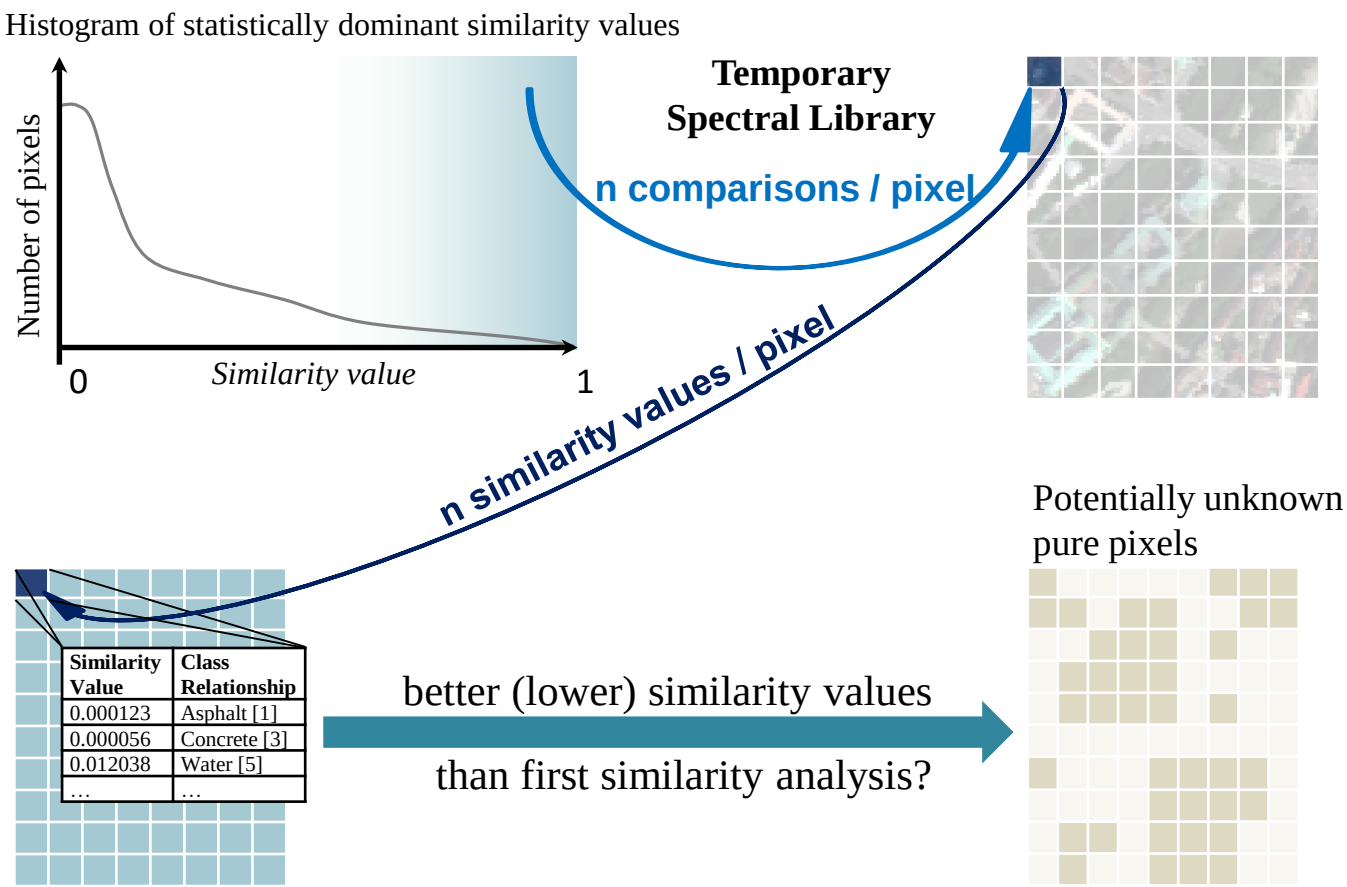
- Separation of artifical and natural pixels
- Histogram statistics of statistically dominant similarity values
- Median filtered histogram
- Thresholding point: highest change between similarity and dissimilarity → local maxima of second derivative

→ mask of pure labeled pixels

LUISA-T: Unknown Pure Pixels

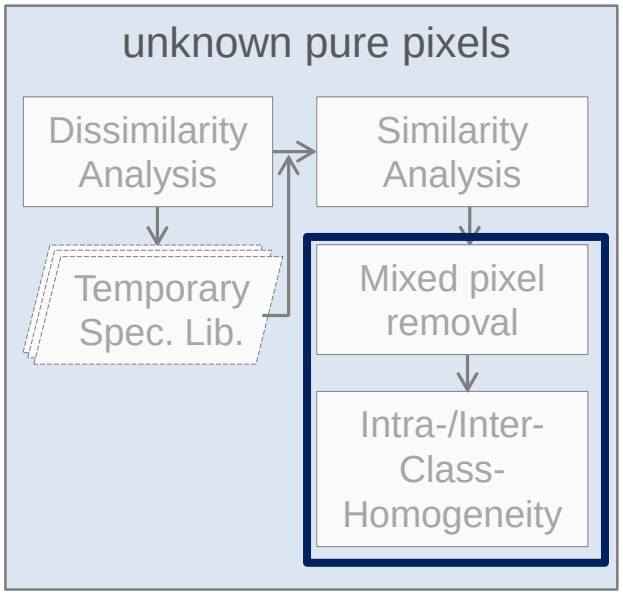


Potentially pure unknown pixels



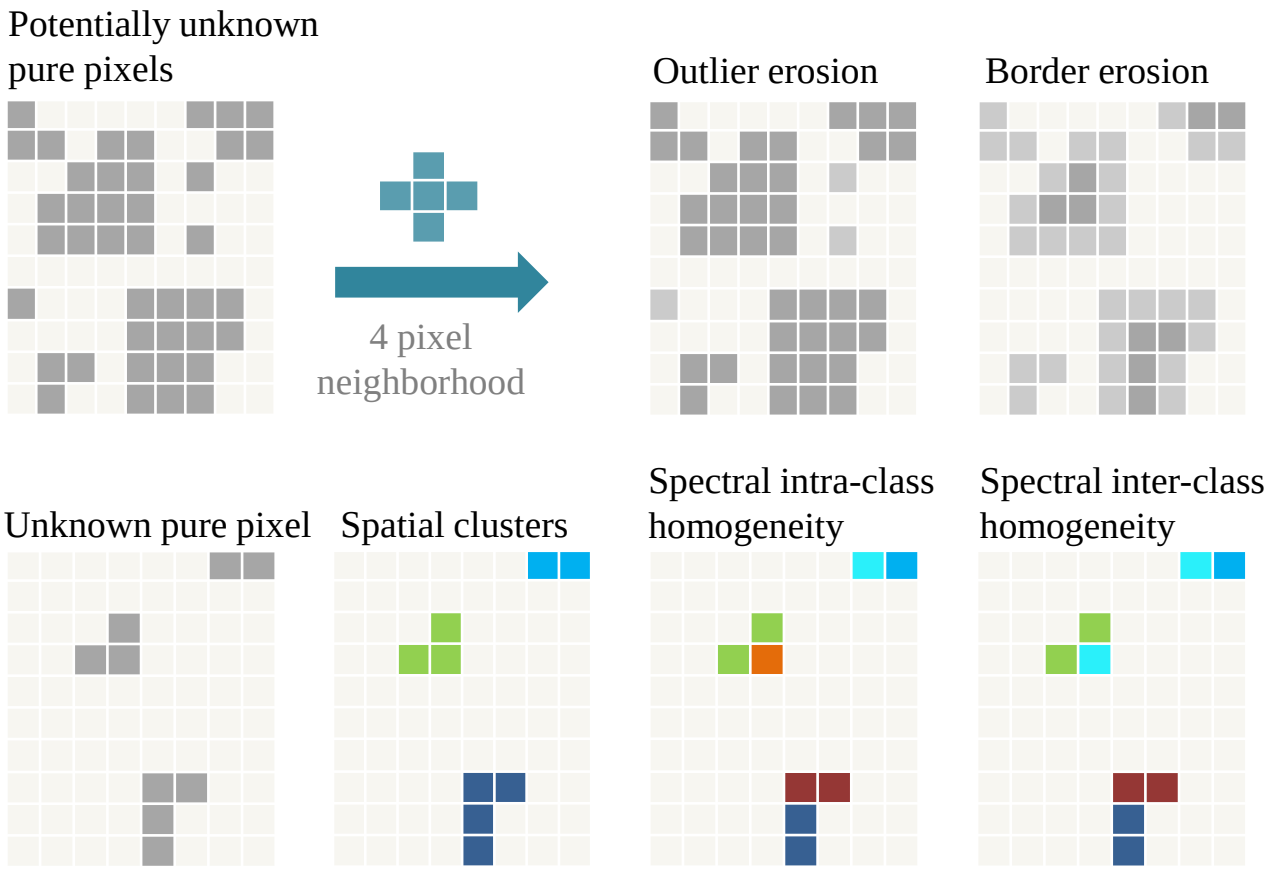
- Extraction of unsimilar spectra (dissimilarity analysis)
- Integrate outliers (similarity analysis)
- Spectral mixtures or pure unknown pixels

LUISA-T: Unknown Pure Pixels



→ mask of categorized unknown pure pixels

Mixed pixel removal and identification of material classes



- Mixed pixels typically occur at/in object borders and single pixels (too small objects)
- Material classes are spectrally homogeneous and spatially independent

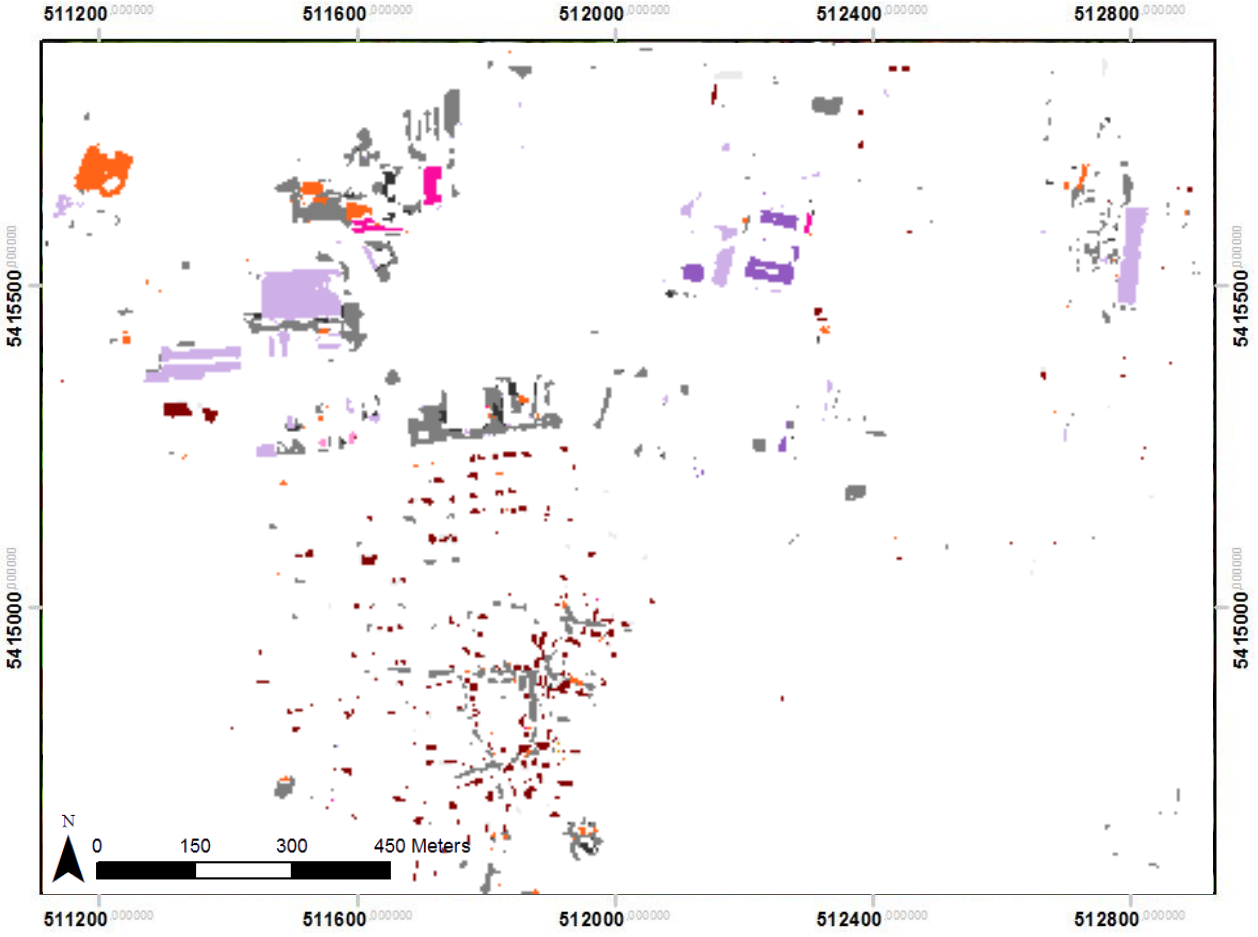
Applying LUISA

Ludwigsburg, Germany

Sensor: HyMap
Date of acquisition: August 4th, 2010
Spatial resolution: 4m
Number of spectral bands: 110
Band combination: R=1671nm, G=727nm, B=544nm
LUISA Pre-processing: iAS filtered (Rogge & Rivard, 2010)

Rogge, D. and Rivard, B., —Iterative spatial filtering for reducing intra-class spectral variability and noise,‖ Proc. Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), 1-4, (2010).

Applying LUISA



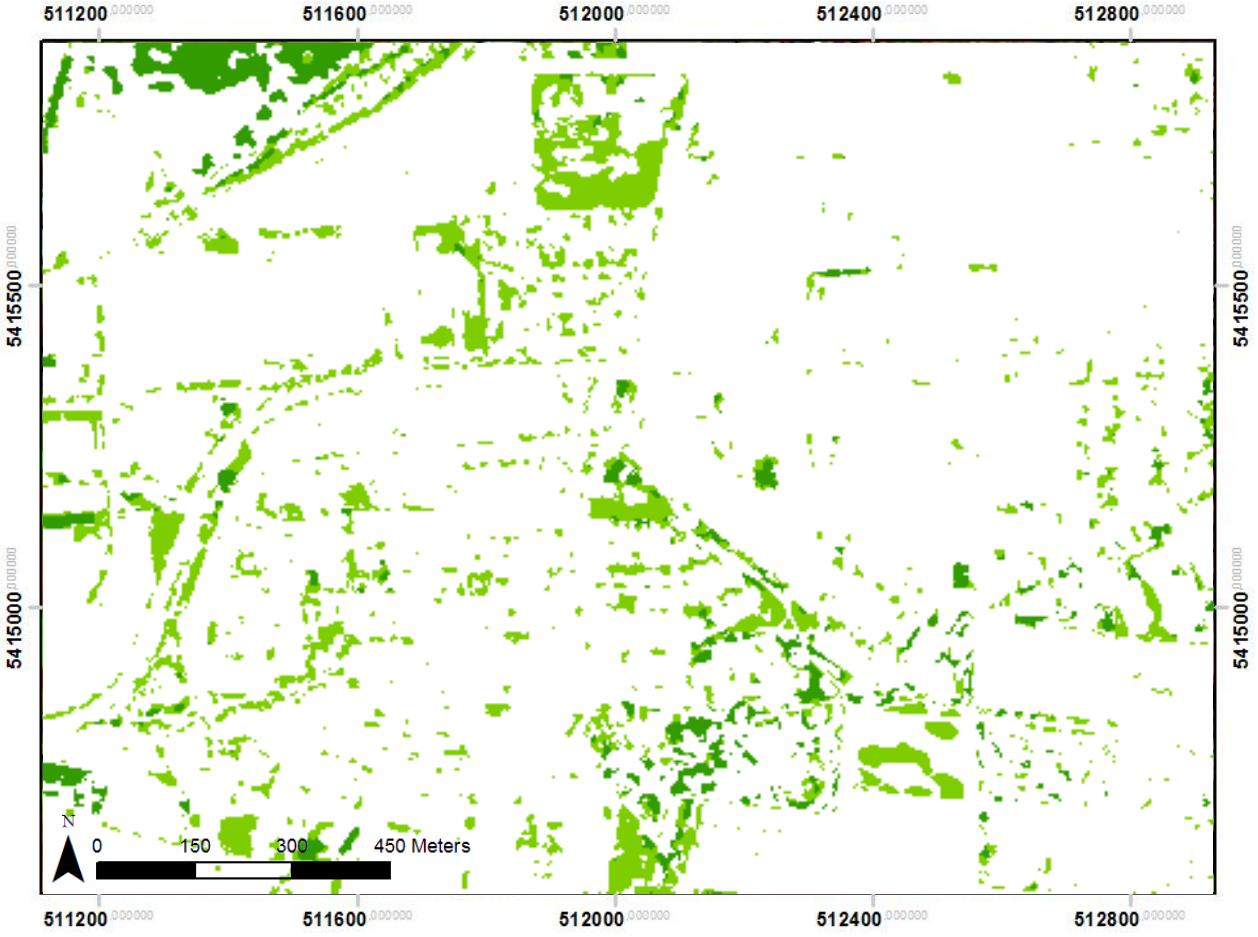
Legend material classes

- bitumen
- polyethylene
- PVC
- aluminium
- concrete on roofs
- roofing tiles
- red loose chippings
- concrete on streets
- asphalt
- vegetation
- unknown abiotic material class 1
- unknown abiotic material class 2
- unknown or material mixture

Artifical pure materials:

- Similarity Measure: SID-SCA
- 11.8% pure urban pixels
- Similarity threshold: 0.000378329

Applying LUISA



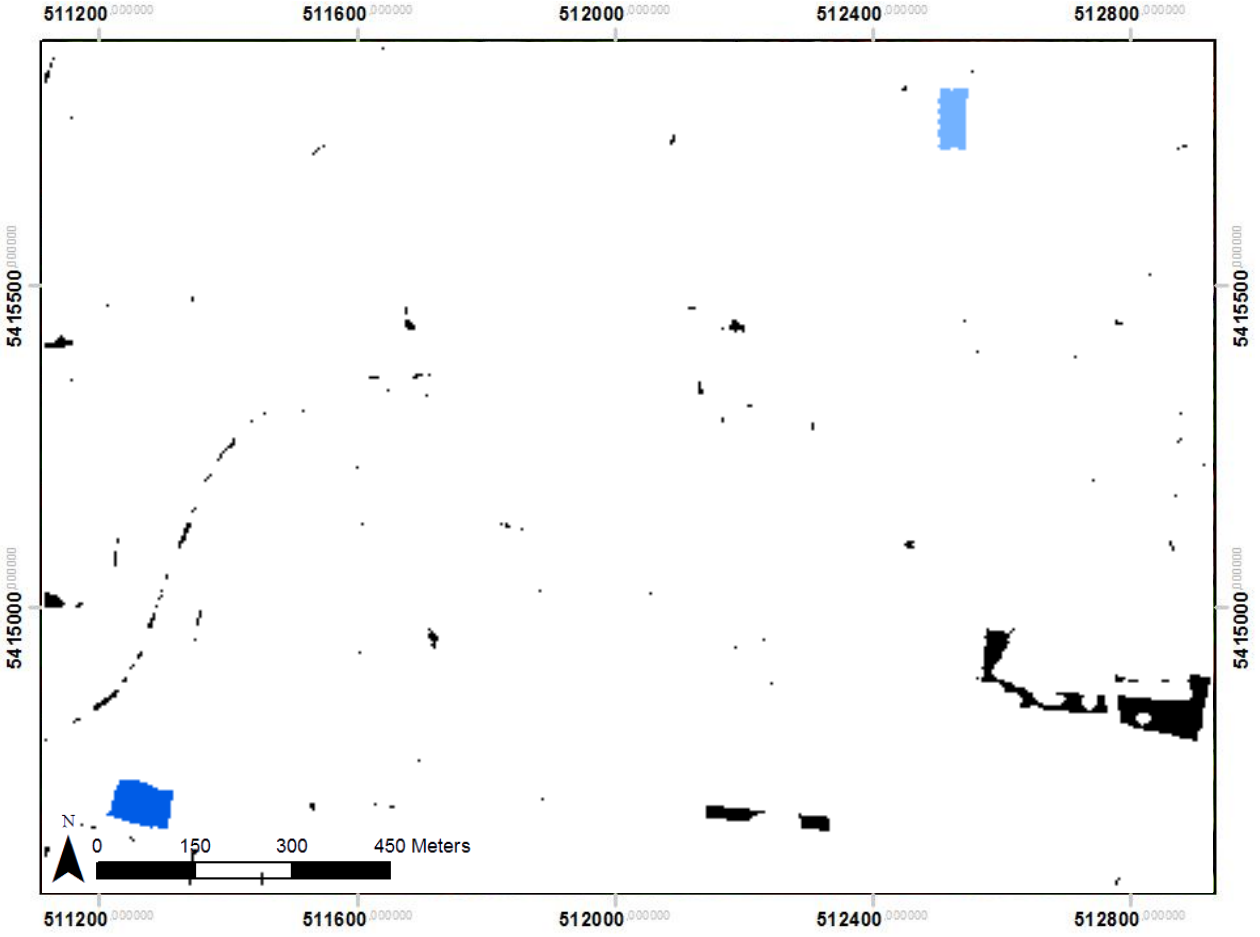
Legend material classes

- bitumen
- polyethylene
- PVC
- aluminium
- concrete on roofs
- roofing tiles
- red loose chippings
- concrete on streets
- asphalt
- vegetation
- unknown abiotic material class 1
- unknown abiotic material class 2
- unknown or material mixture

Natural pure materials:

- Similarity Measure: SID-SCA
- 21.01% pure natural pixels
- Similarity threshold: 0.00006465168

Applying LUISA



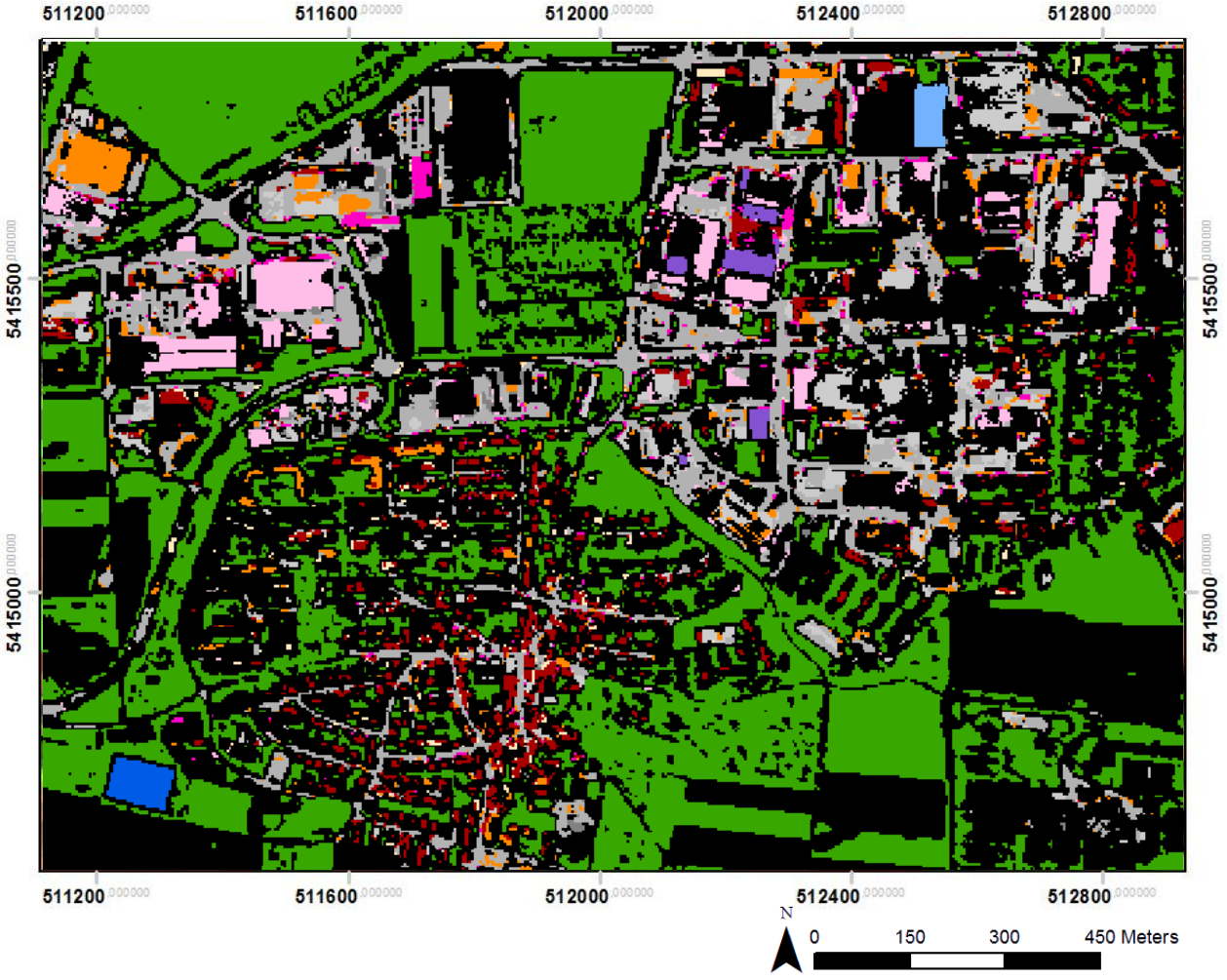
Legend material classes

- bitumen
- polyethylene
- PVC
- aluminium
- concrete on roofs
- roofing tiles
- red loose chippings
- concrete on streets
- asphalt
- vegetation
- unknown abiotic material class 1
- unknown abiotic material class 2
- unknown or material mixture

Unknown artifical pure materials:

- 8 unknown material classes
- Similarity threshold (SAM): 0.1

Validating LUISA results



Post-classification:

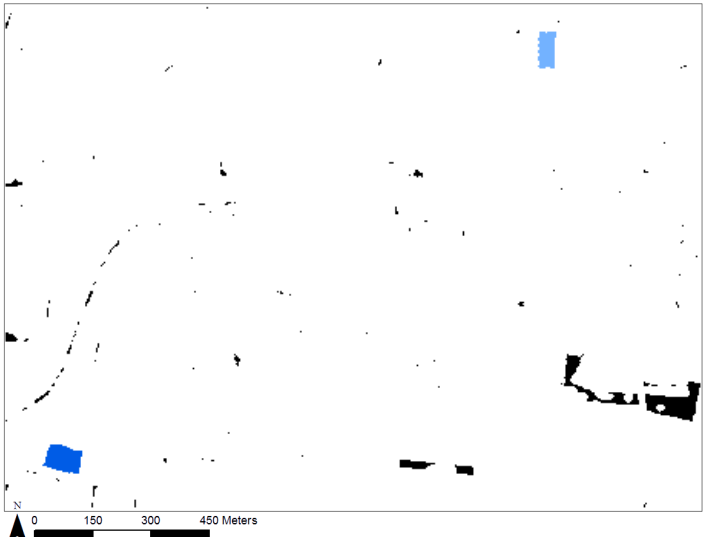
- Maximum likelihood classifier
- Applying extracted pure pixels as training data
- Validation based field data and expert knowledge

Overall accuracy: 79.8%
Kappa: 0.76

Conclusion and Outlook

- **Automatic derivation of pure material spectra** from an urban high resolution hyperspectral imagery
- Derivation of **unknown material** spectra
- Consideration of an **incomplete spectral archive** → universally applicable
- **Usage** of extracted pure material spectra for **further application**

- **Removal of remaining mixed pixel** from mask of unknown pure pixels
- Consideration of **albedo** is crucial for mapping urban surface materials!!




Thank you for your attention!