Advanced Techniques in Urban Remote Sensing

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- Urban Remote Sensing: High Spatial Resolution
- Image Fusion: Iconic
- Image Fusion: Decision Based
- Change Detection
- Proposed SPP
- Conclusions
## Taxonomy of Remote Sensing Systems

<table>
<thead>
<tr>
<th>Recording Platform</th>
<th>Satellite/Shuttle</th>
<th>Aircraft/Balloon</th>
<th>Stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recording Mode</strong></td>
<td>Passive (Electrooptical, Thermal Infrared, Thermal Microwave)</td>
<td>Active (Laser, Radar)</td>
<td></td>
</tr>
<tr>
<td><strong>Recording Medium</strong></td>
<td>Analog (Camera, Video)</td>
<td>Digital (Whiskbroom, Line Array, 2D CCD)</td>
<td></td>
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<tr>
<td><strong>Spectral Coverage</strong></td>
<td>Visible/Ultraviolet</td>
<td>Reflected Infrared</td>
<td>Thermal Infrared</td>
</tr>
<tr>
<td><strong>Spectral Resolution</strong></td>
<td>Panchromatic 1 Band</td>
<td>Multispectral 2 – 20 Bands</td>
<td>Hyperspectral 20 – 250 Bands</td>
</tr>
<tr>
<td><strong>Radiometr. Resolution</strong></td>
<td>Low (&lt; 6 bit)</td>
<td>Medium (6 – 8 bit)</td>
<td>High (8 – 12 bit)</td>
</tr>
<tr>
<td><strong>Spatial Ground Resolution</strong></td>
<td>Very Low &gt; 250 m</td>
<td>Low 50 - 250 m</td>
<td>Medium 10 - 50 m</td>
</tr>
</tbody>
</table>
Remote sensors have different spatial resolution for panchromatic and multispectral imagery.

The ratios vary between 1:2 and 1:8.

Some sensors have only 1 pan band (WorldView 1, EROS B).

Some sensors have only multispectral bands (RapidEye).

For multisensor fusion the ratios can exceed 1:20 (e.g. WorldView/SPOT).
## Multisensor Fusion Case Study: Datasets

### Santo Domingo de la Calzada, Spain (SDOM)

<table>
<thead>
<tr>
<th>Satellite Sensor</th>
<th>Recording Date</th>
<th>Ground Sampling Distance (GSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ikonos II</td>
<td>30 May 2005</td>
<td>1 m (pan only)</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>3 November 2003</td>
<td>20 m</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>24 April 2004</td>
<td>20 m</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>15 May 2004</td>
<td>20 m</td>
</tr>
<tr>
<td>SPOT 5</td>
<td>24 July 2004</td>
<td>10 m (20 m SWIR)</td>
</tr>
<tr>
<td>SPOT 2</td>
<td>10 December 2004</td>
<td>20 m</td>
</tr>
<tr>
<td>SPOT 5</td>
<td>10 April 2005</td>
<td>10 m (20 m SWIR)</td>
</tr>
<tr>
<td>SPOT 4</td>
<td>20 July 2005</td>
<td>20 m</td>
</tr>
<tr>
<td>Formosat 2</td>
<td>12 August 2005</td>
<td>8 m</td>
</tr>
</tbody>
</table>
Original Data: SPOT 5 Sample

Original multispectral Spot 5 image, acquisition date: 20 July 2005 (resampled to 1 m resolution)

Original Ikonos panchromatic image, acquisition date: 3 May 2005
Fusion Results: Brovey

Original multispectral Spot 5 image, acquisition date: 20 July 2005

Fused with Brovey
Original multispectral Spot 5 image, acquisition date: 20 July 2005

Fused with Modified IHS
Original multispectral Spot 5 image, acquisition date: 20 July 2005

Fused with Principal Component
Additive Wavelet Intensity Proportional (AWLP)

Original multispectral Spot 5 image, acquisition date: 20 July 2005

Fused with AWLP
Original multispectral Spot 5 image, acquisition date: 20 July 2005  

Fused with Ehlers

**Concept: Ehlers Fusion**

**Basis: IHS Transform and Filtering in the Fourier Domain**

![Diagram of Ehlers Fusion process]

1. **Multispectral Image**
2. **Panchromatic Image**
3. **Fourier Spectrum**
4. **HPF**
5. **Pan$^\text{HP}$**
6. **FFT$^{-1}$**
7. **IHS$^{-1}$**

**Steps:**
- Multispectral Image $\rightarrow$ FFT
- Panchromatic Image $\rightarrow$ FFT
- Fourier Spectrum $\rightarrow$ HPF
- Pan$^\text{HP}$ $\rightarrow$ FFT$^{-1}$
- IHS$^{-1}$

**Formulas:**
- $R^\prime, G^\prime, B^\prime$
- $I^\text{LP} + \text{Pan}^\text{HP}$
- $I^\text{LP} \rightarrow$ LPF
- $\text{FFT}$
- $\text{IHS}$
Case Study: Decision Based Fusion

- Problem: Extent of New Settlement Areas
- Fast & Accurate Update
- Satellite Based Method
- High Accuracy (> 90%)
- Low Cost
- Statewide Inventory Possible
- Pixel Based Fusion not Suitable
Results: Test Site

Test area near the city of Aachen (Size: 25 km$^2$)

KOMPSAT (panchromatic)  ASTER (multispectral)
Basic Principle: Decision Based Fusion

High resolution panchromatic satellite image

Low resolution multispectral satellite image

Segmentation

Shape parameter

Texture parameter

NDVI parameter

Decision based fusion:
Remaining areas = settlement candidates
Methodology: Increasing threshold values with each lower level of the segmentation network

Classification attributes for class „settlement“:

- Texture parameter (GLC-Matrices)
- Shape parameter (degree of compactness, length)
- NDVI (elimination of vegetated areas)
- Relations within the network (determination of non-settlement areas)
Results

Level 0: Possible settlement areas (red)
Level 1: Possible settlement areas
Level 2 + fine tuning: Settlement areas
### Overall Accuracy

<table>
<thead>
<tr>
<th>Level</th>
<th>Users‘ accuracy:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 3</td>
<td>19.79 %</td>
</tr>
<tr>
<td>Level 2</td>
<td>76.31 %</td>
</tr>
<tr>
<td>Level 1</td>
<td>92.06 %</td>
</tr>
<tr>
<td>End level</td>
<td>93.51 %</td>
</tr>
</tbody>
</table>
Change Analysis

Catastrophe

Archive

Reference image

Action

Automated change detection and analysis
CEST: Decision Tree
Quickbird Subsets of Abu Suruj

Quickbird panchromatic image: March 2, 2006 (T1)

Quickbird panchromatic image: February 28, 2008 (T2)

Manually digitized change image
Result: Image Difference
Result: PCA
Result: Post Classification
Accuracy Assessment: $\kappa$ Coefficient

![Bar chart showing accuracy assessment results for various methods: Difference, Ratio, PCA, Delta Cue, Post Classification, CEST. The values range from 0.00 to 0.90.](chart.png)
Before event

Post event

Attribute information

Selected objects

Change detection

Objects geometry and spatial location

GIS Information
Methodology

=> Information about contour integrity

*Detected Part of Contour (DPC)*

=> Information about area inside the contour

*Textural Information (Homogeneity, Uniformity)*
Classification technique: unsupervised k-means clustering

Test set: 218 vector objects

| Correct class | Prediction | |
|---------------|------------|
| C1 | 88 | 0 | 88 |
| C2 | 1  | 129 | 130 |
| 89 | 129 | 218 |

Confusion matrix

Classification accuracy

<table>
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<tr>
<th>Evaluation results</th>
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<tbody>
<tr>
<td>Classification accuracy</td>
</tr>
<tr>
<td>Matthew correlation coefficient</td>
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Multisensor Remote Sensing for Landscape Dynamics Assessment (MultiSense):

- Provision of means for an integrated analysis of multisensor RS datasets for operational change analysis and monitoring within three key regions of global environmental change
- Development of new algorithms and methodologies for robust geo-biophysical parameter extraction from multisensor RS for landscape dynamics assessment
- Development and allocation of a powerful Open Source image processing system for multisensor RS analysis
Remote Sensing Space Missions

- SORCE
- QuikScat
- SeaWiFS
- SeaWinds
- SPOT 4, 5
- Orbview 2, 3
- ERBS
- Radarsat
- QuickBird
- Grace
- UARS
- Envisat
- Aura/Aqua/Terra
- Sage
- CBERS
- SPIN-2
- TRMM
- DMC
- SAC-D/Aquarius
- ACRIMSAT
- EROS A1
- ALOS
- Toms-EP
- Landsat 7
- Jason
- About 12 projects total
- 24 Ph.D. and 4 Postdocs
- 2 x 3 years
- 2.3 – 2.5 Mio €/year
Conclusions

- VHR Data: Important/Necessary
- Fusion Techniques: Iconic to Decision Based
- RS: From Data Sparse to Data Rich
- Automated Change Detection: Cooperative + GIS