From Detection of Underground Archaeological Relics to Monitoring of World Heritage Sites in Danger: Ongoing Research Activities in the Frame of the ATHENA Twinning Project

Daniele Cerra¹, Athos Agapiou², Simon Plank¹, Vasiliki Lysandrou ², Jiaojiao Tian¹, Kiriakos Themistocleous², Diofantos G. Hadjimitsis ², and Gunter Schreier ¹

1. German Aerospace Center (DLR), Earth Observation Center (EOC), D-82234 Wessling, Germany
2. Cyprus University of Technology (CUT), Limassol, Cyprus

daniele.cerra@dlr.de
ATHENA: a funded project under the H2020-TWINN-2015

Remote Sensing Science Center for Cultural Heritage

What is ATHENA?
Cooperative Research: DLR & CUT - Highlights

• Cooperation between DLR and CUT in the frame of ATHENA:
  • Staff Exchange
  • Virtual Seminars
  • Summer Schools
  • Joint Research

• Image Analysts at DLR and archaeologists and image analysts at CUT worked together on several topics

• Highlights reported here are from two applications:
  • Hyperspectral indices for the detection of crop marks
  • Monitorin of sensitive cultural heritage sites
Hyperspectral

Buddingtonite

Alunite

Chalcedony
Vegetation Health Analysis

Crops (False Color Composite)  Health Status of Potato Fields

Healthy  Unhealthy
About Vegetation Health: Crop Marks

Evident crop marks in Grezac, France
RGB True Color Composite
(source: wikipedia)
An interesting application

– Dataset: Carnuntum
  – Capital of the former Roman province *Pannonia superior*
  – Centuries IV BC – I AD

– Airborne HS campaign
  – AisaEAGLE
  – 65 bands
  – 400-1000 nm
  – 0.4 m GSD
  – Courtesy of prof. Michael Donus

Michael Doneus et al., „New ways to extract archaeological information from hyperspectral pixels“, Journal of Archaeological Science, Volume 52, December 2014
Not always that easy...
Which band is better?

- Let's have a look at all available bands…
Mutual Information

- Derivation of a reference image (manual)
- Analysis restricted to yellow rectangle
PC 1

Band 43, NIR (787 nm)

Red Edge Position

MI 0.01

Bands 28/15/5 (RGB)

MI 0.11

MI 0.12

MI 0.42

PC 1
<table>
<thead>
<tr>
<th>Rank</th>
<th>Index</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BAI</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>VRE1</td>
<td>98.9%</td>
</tr>
<tr>
<td>3</td>
<td>SR</td>
<td>93.9%</td>
</tr>
<tr>
<td>4</td>
<td>NLI</td>
<td>93.3%</td>
</tr>
<tr>
<td>5</td>
<td>GRVI</td>
<td>92.7%</td>
</tr>
<tr>
<td>6</td>
<td>TDVI</td>
<td>92.7%</td>
</tr>
<tr>
<td>7</td>
<td>RENDVI</td>
<td>92.4%</td>
</tr>
<tr>
<td>8</td>
<td>SAVI</td>
<td>92.0%</td>
</tr>
<tr>
<td>9</td>
<td>IPVI</td>
<td>92.0%</td>
</tr>
<tr>
<td>10</td>
<td>NDVI</td>
<td>92.0%</td>
</tr>
<tr>
<td>11</td>
<td>GEMI</td>
<td>91.8%</td>
</tr>
<tr>
<td>12</td>
<td>ARVI</td>
<td>91.0%</td>
</tr>
<tr>
<td>13</td>
<td>NDSI</td>
<td>90.4%</td>
</tr>
<tr>
<td>14</td>
<td>GNDVI</td>
<td>90.4%</td>
</tr>
<tr>
<td>15</td>
<td>RDVI</td>
<td>90.2%</td>
</tr>
<tr>
<td>16</td>
<td>GDVI</td>
<td>89.6%</td>
</tr>
<tr>
<td>17</td>
<td>GARI</td>
<td>89.0%</td>
</tr>
<tr>
<td>18</td>
<td>DVI</td>
<td>88.5%</td>
</tr>
</tbody>
</table>
Ranking of several spectral indices for archaeological research purposes

19 - MCARI2, 87.6%
20 - MTVI, 87.0%
21 - TVI, 86.7%

22 - EVI, 83.2%
23 - VARI, 79.5%
24 - NDMI, 66.1%

25 - CRI1, 59.9%
26 - ARI1, 54.0%
27 - PSRI, 52.7%

28 CRI2, 48.2%
29 - MRENDVI, 47.0%
30 - IronOxide, 37.1%

31 - MCARI, 36.2%
32 - TCARI, 35.9%
33 - SIPI, 33.6%

34 - SGI, 32.6%
35 - ARI2, 29.1%
36 - PRI, 20.4%
Towards Automatic Monitoring of Endangered Cultural Heritage Sites

• Since spring 2015: Islamic State (IS) proclaims the destruction of cultural heritage sites, including Palmyra (Syria) and Nimrud (Iraq)

• Difficulties in confirming these damages at first
  • Non-accessible areas
  • Sources: Reports in social media (e.g., Facebook, Twitter): unreliable or sometimes contradictory

• Remote Sensing as independent & objective information source
Example: Palmyra – Temple of Bel: destroyed by IS (30.08.2015)

Pre-Event (Image: WorldView 2, Date: 27. August 2015)

Post-Event (Image: WorldView 2, Date: 02. September 2015)

©European Space Imaging / DigitalGlobe
Motivation

- Similar tasks are usually carried out through **visual analysis**

- Would it be possible to help experts by providing automatic maps in which damages are likely to have occurred?

- Could several images be automatically combined to estimate the evolution in time of damages?
Gabor Texture Features

Selected filter bank
Texture Classification: Example

Bam, Iran, suffered an earthquake in 2003

IKONOS image acquired in the aftermath of the earthquake

Classification obtained on the basis of the texture parameters only
Palmyra, Syria

Temple of Bel

Tower Tombs
WorldView-2 Pre-Desaster Image

27th August 2015
WorldView-2 Post-Desaster Image

2nd September 2015
Palmyra: Difference of Gabor Features
(based on texture values)
Palmyra: Enhanced Gabor Features (using robust brightness differences)
Detected Damages
Detection of Damaged Areas

27th August 2015
What about previous damages? Google Earth image 20 02 2014
Palmyra – Baalshamin Temple: destroyed by IS (24.08.2015)

Image: Google Earth
Date: 20th February 2014

Image: WorldView-2
Date: 2nd September 2015
Detected Damages (from 02-2014 to 09-2015)
Validation (ASOR*, 3.09.2015)

Multitemporal Damages

- Damages 20.02.2014 - 27.08.2015
- Damages 27.08.2015 - 2.09.2015
ATHENA: a funded project under the H2020-TWINN-2015

Thank you!