Mapping Changes in marble quarries: a combined classifier for environmental monitoring of the Apuan Alpes

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Arguments

Challenges in marble quarries’ environmental monitoring

HiRes & Very HiRes images role

Classification challenges

The composite classifier

Ongoing activities
Environmental Monitoring

### Waste management
- Volume/open air waste disposal changes (so-called “Ravaneti”)
  - HiRes images (basin scale) (*)
  - Very HiRes Images/ UAVs (*)/ Terrestrial LIDAR (single quarry scale)
  
### Water management
- Prescriptions monitoring
  - Water filtering
  - Rainfall drainage
  
### Water pollution
- Impact prediction
  - Surface Water modelling (*)
  - Rainfall peak events correlation with water quality info
  - Groundwater modelling (*)

(*) With the collaboration of the Earth Science Department of Florence University (working group headed by prof. Sandro Moretti)
A priori knowledge

Authorization data (raster project maps)

Production data (weights + volumes)

Quarries’ location and open-air waste disposals mapping (LAMMA)

Aerial LIDAR survey (october 2017) with precision 4-bands photos (RGB+IR) and DSM/DTM
Basin scale - HiRes Images

Basin-scale coverages can be used for surface water modelling and big areas CD → Sentinel-2 supervised classification (RGBA bands) is enough

...but only marble coverage, bare soil and vegetation can be distinguished!

→ Resolution & information content must be improved to isolate active areas
Quarry scale monitoring goals

6 months surface & volume CD are required

Changes sensing require at least a doubled resolution referring to target unit CD
(surface ~5m², volume ~5m³)

Very High Resolution Images (max pixel size ~2m) are required
High vs. Very High Resolution

- Sentinel-2 (10m RGB)
- Pléiades ms (2m RGB)
- Aerial photo (20cm RGB)

Aerial Photos allow good visual classification of active areas, infrastructures and waste disposals → images with pixel size <1m are required!
# Very HiRes vs. HiRes satellite

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Pixel size</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Sentinel-2 (ESA)</td>
<td>10x10m</td>
<td>• Revisiting time (1 week)</td>
<td>• Resolution not so good for quarry area recognition</td>
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<td>• Free</td>
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<tr>
<td>Sentinel-1 (ESA)</td>
<td>10x10m</td>
<td>• Revisiting time (1 week)</td>
<td>• Resolution not so good for precise DSM/DTM</td>
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<td></td>
<td></td>
<td>• Free</td>
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<tr>
<td>Pléiades (Airbus)</td>
<td>0.5x0.5m (p) 2x2m (xs)</td>
<td>• Good resolution for quarry area recognition</td>
<td>• Archived products availability</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Image saturation in quarry areas</td>
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<tr>
<td>Cosmo Skymed (ASI)</td>
<td>3x3m (stripmap)</td>
<td>• Good resolution for quarry area recognition and precise DSM/DTM</td>
<td>• Complex DSM/DTM generation (ascending and descending data must be merged due to foreshortening and layover)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ascending/descending data available (Italian National Monitoring Plan)</td>
<td>• Resolution not so good as Pléiades images</td>
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UAVs vs. satellite images

**PROS:** optimum precision for 6-month changes’ detection

**CONS:** too expensive
- AOI: 10x10km with 80 quarries
- Complexity (nadiral / oblique / free flights / terrestrial photos)

**SOLUTION:** Check Very HiRes Satellite images’ usability for building changes’ indicators both at basin and quarry scale
Supervised Spectral Distance Classifiers

**PROS:** easy to use and train

**CONS:**
- high sensitivity to shadows
- cannot isolate active areas from quarry infrastructures

**SOLUTION:** integration of height (slope) and texture informations
Supervised Spectral Distance Classifiers

Water Management areas (Pléiades MS vs 20cm Aerial LIDAR)
Multidimensional Classifier

Data

- Spectral content (ms - RGB+IR)
- Texture Content (pan)
- Slope (LIDAR / Radar data)

**PROS**: slope is useful in isolating working areas and roads from debris

**CONS**: weights’ optimization + texture parameters’ choice not trivial / texture parameters sensitive to shadows

**SOLUTION**: evaluate AI and ML techniques + BW Histogram Equalization
Multidimensional Classifier - unsupervised

Aerial LIDAR - Active areas and roads classification: ms + height vs. ms + height + texture info

Shadows
Multidimensional Classifier - supervised

Aerial LIDAR - Active areas and roads classification: ms + slope + texture info and probability map
LIDAR vs Pleiades (textures, linear SVM)

Waste

Roads

Active Areas

Texture-based Classification
DTM & SVM – Pléiades

In SVM slope add valuable information to Pléiades images
The combined classifier

**PROS:** obtain the best results for each class minimizing shadow problems

**CONS:** data preprocessing (feature extraction) and classifier training are time expensive and computationally intensive; decision rules are complex

**SOLUTION:**
- AOIs’ restriction
- process automation with Orfeo Toolbox
The combined classifier

Classes:
- Water → spectral
- Active areas → slope
- Roads → slope + textures
- Debris disposals → slope + textures

One single classifier per class/couple of classes

Decision Rules
Slope Thresholding

Aerial LIDAR – Slope

Aerial LIDAR – Slope = 0, Areas > 100m²
Ongoing activities

Composite Classifier’s improvements

- SFS on equalized images to get rid of shadows problems
- Computer Vision techniques integration
- other models test (Boost, Decision Tree, Bayesian)
- Decision Rules

Using Very HiRes SAR (on-demand CSK 1m) and/or tristereo optical images to get precise 3D data (3m CSK under test – ESA Project Proposal #44094)

Classification Automation
Computer Vision Techniques

OpenCV (https://opencv.org/) - Javascript porting

**PROS:** many Segmentation & Feature Detection Techniques

**CONS:** work only on BW and RGB images (require ML techniques to deal with multidimensional data)

**SOLUTION:** combine Multispectral Info, Segmentation and ML techniques
Computer Vision Techniques

Simple vs. Adaptive Thresholding
https://docs.opencv.org/3.4/d7/dd0/tutorial_js_thresholding.html

Aerial LIDAR – slope
(5 pts/m)

Canny Edge Detector vs. Probabilistic Hough Line Detector
https://docs.opencv.org/3.4/d7/de1/tutorial_js_canny.html
https://docs.opencv.org/3.4/d3/de6/tutorial_js_houghlines.html
Thanks for your attention

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