Preliminary evaluation of the LIRE tool for CBIR of EO products

C. Tona, M. Iapaolo, P.G. Marchetti
European Space Agency
Earth Observation Programme
Research and Ground Segment Technology Section
Outline

1. LIRE overview
2. Experiments and validation exercises
3. Results analysis
4. From LIRE to Caliph-Emir suite
5. A “new” prototype
6. Future work and perspectives
LIRE – Lucene Image Retrieval

1. Tool for image retrieval based on color and texture characteristics
2. Provided as Open Source
3. Creates a "Lucene index" of image features for successive CBIR
4. Provides a series of pre-defined "feature indexes" for searches:
   - Color Layout, Scalable Color, Edge Histogram, Auto-color Correlogram
   - Color and Edge Directivity (CEDD), Fuzzy Color and Texture Histogram (FCTH)
   - RGB Color Histogram
   - Tamura Texture, Gabor Texture
   - JPEG Coefficient Histogram
Phase 1 – Preliminary Analysis

Objective:
Assess the capability of LIRE to handle different types of EO images

Dataset:
MERIS FR, SPOT M (over different regions: Italy, Europe, Africa)

Some pre-processing is needed for:
1. Transforming input images into JPEG format
2. Cutting input images into tiles (1000x1000 pixels)
Phase 1 – Results

1. **RGB Color Histogram** and **Color and Edge Directivity** resulted the most effective features (with respect to other features)

2. **RGB Color Histogram** particularly suitable for large homogeneous areas (sea, desert, etc.)

3. **Color and Edge Directivity** particularly suitable for mixed regions (urban areas, coastal zones, etc.)

4. **Color and Edge Directivity** in general more effective than simple **RGB Color Histogram**
1. LIRE is capable to ingest different types of EO images

2. The tool is also capable to capture some specificities of EO images

3. The tool shows good qualitative results in terms of:
   - Extraction of features relevant for EO images indexing
   - Retrieval performances

4. The tool presents some limitations (solved during the analysis):
   - Number of input images (100 by default, now unlimited)
   - Handling various datasets at the same time (creation of different instances is necessary)
Phase 2 – Extended Analysis

**Objective:**

1. Deeply evaluate all *features* (image descriptors extracted by the tool, e.g. textures) for some relevant EO use-cases

2. Quantitatively assess LIRE retrieval performances in terms of Precision / Recall
   - Precision as a measure of retrieval quality
   - Recall as a measure of retrieval completeness (quantity)

**Dataset:**

MERIS images over desert areas (phase 2a)

Synthetic images (phase 2b)

MERIS and ERS images pre-annotated by the user (phase 2c)
Desert areas present some particular characteristics:

1. Generally homogeneous
2. With some specific “structures” inside

Sahara Desert (Africa)  Arabe Desert (Emirates)  Atacama (South America)  Tirare (Australia)

Are LIRE texture features capable to characterize such areas?

Dataset:
MERIS images over different desert regions
Tiles of 150x150 pixels
Phase 2a – Results

1. Texture features are suitable to identify and retrieve different desert morphologies

2. Fuzzy Color and Texture Histogram (FCTH), Tamura texture features and Gabor texture features do not present significant difference in retrieval performances

3. Also Color and Edge Directivity (CEDD) is capable to discriminate between different desert regions
Phase 2b – Synthetic Images

Objective:
Quantitatively assess LIRE capabilities on different types of images, with very particular colour and textural structures.

Also with different orientations: 30°, 60°, 90°, 120°, 150°
Phase 2b – Results

Precision (P) := Fraction of returned relevant images with respect to the total number of retrieved images

Recall (R) := Fraction of returned relevant images with respect to the total number of relevant images in the database (according to a priori knowledge)

<table>
<thead>
<tr>
<th>Feature Index</th>
<th>BRICK</th>
<th>CHESS</th>
<th>PILLS</th>
<th>GRASS</th>
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</thead>
<tbody>
<tr>
<td>CEDD</td>
<td>0.57</td>
<td>1.00</td>
<td>1.00</td>
<td>0.86</td>
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<tr>
<td>FCTH</td>
<td>0.86</td>
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<td>1.00</td>
<td>1.00</td>
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<tr>
<td>RGB</td>
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<tr>
<td>JPEG</td>
<td>1.00</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

![Graph showing Recall for different Feature Indexes]
Phase 2c – EO Datasets

Objective:
Quantitatively assess LIRE capabilities for typical EO images

1. MERIS FR pre-annotated images (water, land, clouds, snow)
2. ERS SAR pre-annotated images (Water, Fields, Urban, Mountains)

~400 tiles of 1120x1120 pixels
Phase 2c – Evaluation process

EO Dataset → Tiling → Ingestion in LIRE → Retrieval

Performance Evaluation
## Phase 2c - Results

### ERS 2 Images - Classes

<table>
<thead>
<tr>
<th>Feature Index</th>
<th>WATER</th>
<th>FIELDS</th>
<th>URBAN</th>
<th>MOUNTAIN</th>
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<tbody>
<tr>
<td>EDGE HISTOGRAM</td>
<td>0.76</td>
<td>0.74</td>
<td>0.65</td>
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<tr>
<td>AUTOCOLOR CORR.</td>
<td>0.74</td>
<td>0.83</td>
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<tr>
<td>FCTH</td>
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<tr>
<td>JPEG</td>
<td>0.74</td>
<td>1.00</td>
<td>0.75</td>
<td>1.00</td>
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</table>

### MERIS - Classes

<table>
<thead>
<tr>
<th>Feature Index</th>
<th>WATER</th>
<th>ICE</th>
<th>LAND</th>
<th>CLOUD</th>
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</thead>
<tbody>
<tr>
<td>EDGE HISTOGRAM</td>
<td>1.00</td>
<td>0.85</td>
<td>0.80</td>
<td>0.48</td>
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<tr>
<td>CEDD</td>
<td>1.00</td>
<td>0.93</td>
<td>0.91</td>
<td>1.00</td>
</tr>
<tr>
<td>JCD</td>
<td>1.00</td>
<td>0.93</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>RGB</td>
<td>0.40</td>
<td>1.00</td>
<td>0.71</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Phase 2c – Results
Precision-Recall Diagram

1. Choose an annotated sample (e.g. MERIS scene containing water)
2. Ingest in LIRE and perform the CBIR
3. Analyse retrieval results ordered by relevance
4. Calculate the P-R diagram
Conclusions

1. LIRE works correctly both on synthetic and EO images provided

2. Performances are good (standard pc, CPU 3.16 Ghz, RAM 4GB)
   a. Dataset of 400 sub-images (about 170 MB)
   b. Ingestion time: 30 minutes
   c. Retrieval time: 2-3 minutes

3. Poor flexibility on input image format (JPEG images only)

4. Possibility to extend LIRE with Caliph and Emir tools, in order to improve annotation and retrieval of Earth Observation products.
1. Extend the tools to take into account *specific EO products metadata* during the annotation and search process (according to OGC “Earth Observation Metadata profile of Observations & Measurements” standard)

2. Extend tool capabilities for *semantic annotation* of EO image

3. Export of search results and metadata into mpeg-7 format, reusing the OGC standard schema for encoding EO metadata (in support of describing and cataloguing products from sensors aboard EO satellites)
O&M EO Products metadata

Mission Specific EO Products

Thematic EO Products

General EO Products

Generic O&M

Generic, widespread community

Specific, tight community

Other Specific Mission EO Products description

Other Thematic EO Products description

OPT  SAR  ATM  ALT  LMB  SSP  ...

EOP

O&M

Generic, widespread community

Specific, tight community
Annotation, Retrieval and Visualization process

User

Manual Annotation

Load - Search

Retrieval

Visualization

CALIPH

EMIR

GOOGLE EARTH
Workflow

EO PRODUCTS

Geotiff format

TILING OK MAP

JPEG FILES

CALIPH ANNOTATION

Manual annotation

EMIR RETRIEVAL

GOOGLE EARTH VISUALIZATION

KML FILE

SPLIT KML

OkMap

OkMap

OkMap

OkMap

OkMap

OkMap

OkMap

OkMap

Emir
The extended prototype will permit to:

1. Perform manual annotation (structured text according OGC Standards and free text through semantic labels)
2. Perform searches to find EO products by different criteria (EO metadata level, textual level, semantic level, MPEG-7 descriptors level)
3. Visualize data in a virtual environment
4. Create semantic catalogues and “enriched products” in output
   a. JPEG image
   b. Geo-referencing data (KML format)
   c. semantic annotation
   d. textual description
5. Develop new functionalities (open source software)
Thank you for your attention!!