

TELEIOS

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Deliverable

D6.2.1

Ontologies for the VO for TerraSAR-X data

Corneliu Octavian Dumitru, Mihai Datcu,
Manolis Koubarakis, Michael Sioutis, Babis Ni-
kolaou

and

Consortium members

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Executive Summary

This document is the second deliverable for WP6 (A Virtual Observatory for TerraSAR-X data) of TELEIOS. The objective of WP6 is to build a Virtual Earth Observatory for TerraSAR-X data and demonstrate its functionality by developing selected rapid mapping applications. The present document continues the work started with Deliverable D6.1 “Requirements specification for the VO for TerraSAR-X data and applications” where the user requirements for the TerraSAR-X Earth Observatory were presented.

From the WP6 description in the TELEIOS Technical Annex, we can see that WP6 has two goals:

- To demonstrate how DLR can go beyond its current EOWEB portal to enable queries that capture the semantics of the content of TerraSAR-X data by using the knowledge discovery framework developed in WP3 and the semantic technologies developed in WP2 and WP4. The current version of the EOWEB portal simply offers a hierarchical organization of the DLR archive together with a temporal and geographic selection menu. The Earth Observatory on the other hand will be able to answer queries such as “find images appropriate for SAR interferometry for DEM derivation”, “find images with parameters appropriate for seismic displacement measurements”, “find images appropriate for building detection”, “find all last year's coliseum images closer than 50 km to the Vienna disaster area”, “find all smoke plume images from the last 5 weeks where the Lisbon-Gibraltar motorway was occluded”, “find all images of Greek airports north of Athens with an altitude of more than 100 m above sea level” etc. These queries are of huge importance for a broad community of users and the query itself needs to capture the nature and properties of the SAR products, a complicated piece of information which currently remains hidden in the EOWEB portal of DLR.
- To apply the TELEIOS knowledge discovery framework developed in WP3 to rapid mapping as currently practiced by the ZKI group at DLR. Examples of rapid mapping that are considered include:
 - flood monitoring and support for further avoidance of effects
 - evaluation of infrastructure damages in cases of earthquakes, and
 - evaluation of tsunami effects.

This document targets both of the above goals and makes the following contributions:

- We present the first version of the **DLR ontology**, an RDFS ontology developed within TELEIOS which offers a conceptual view of the standard products of the TerraSAR-X archive. The ontology captures important metadata associated with TerraSAR-X standard products together with feature vectors and semantic classes extracted from the products using the knowledge discovery framework of WP3. The ontology is populated with stRDF triples encoding the results of the WP3 KDD algorithms applied to relevant TerraSAR-X products.

We present a classification of useful queries that are **not** possible in the current EOWEB portal but can be posed in the extended EOWEB portal studied within TELEIOS given the knowledge extracted from the TerraSAR-X products using the methods of WP3 and captured in the DLR ontology. We give examples of such queries using the stSPARQL++ query language of the Strabon system implemented in WP5.

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Contact Person

Prof. Mihai Datcu

Email Mihai.Datcu@dlr.de

Phone +49 8153281388

Fax +49 8153281444

Project Information

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| Partner | Acronym | Contact |
|--|--|--|
| National and Kapodistrian University of Athens Department of Informatics and Telecommunications (Coordinator) | NKUA  National and Kapodistrian UNIVERSITY OF ATHENS | Prof. Manolis Koubarakis National and Kapodistrian University of Athens Dept. of Informatics and Telecommunications Panepistimiopolis, Ilissia, GR-15784 Athens, Greece Email: koubarak@di.uoa.gr Tel: +30 210 7275213, Fax: +30 210 7275214 |
| Fraunhofer Institute for Computer Graphics Research | Fraunhofer  IGD | MSc. Thorsten Reitz Fraunhofer Institute for Computer Graphics Research Fraunhofer Strasse 5, D-64283 Darmstadt, Germany Email: thorsten.reitz@igd.fraunhofer.de Tel: +49 6151 155 416, Fax: +49 6151 155 444 |
| German Aerospace Center The Remote Sensing Technology Institute Photogrammetry and Image Analysis Department Image Analysis Team | DLR  DLR | Prof. Mihai Datcu German Aerospace Center The Remote Sensing Technology Institute Oberpfaffenhofen, D-82234 Wessling, Germany Email: mihai.datcu@dlr.de Tel: +49 8153 28 1388, Fax: +49 8153 28 1444 |
| Stichting Centrum voor Wiskunde en Informatica Database Architecture Group | CWI  CWI | Prof. Martin Kersten Stichting Centrum voor Wiskunde en Informatica P.O. Box 94097, NL-1090 GB Amsterdam, Netherlands Email: martin.kersten@cw.nl Tel: +31 20 5924066, Fax: +31 20 5924199 |
| National Observatory of Athens Institute for Space Applications and Remote Sensing | NOA  INSTITUTE FOR SPACE APPLICATIONS AND REMOTE SENSING | Dr. Charalambos Kontoes National Observatory of Athens Institute for Space Applications and Remote Sensing Vas. Pavlou & I. Metaxa, Penteli, GR 152 36 Athens, Greece Email: kontoes@space.noa.gr Tel: +30 210 8109186, Fax: +30 210 6138343 |
| Advanced Computer Systems A.C.S S.p.A | ACS  ADVANCED COMPUTER SYSTEMS | Mr. Ugo Di Giammatteo Advanced Computer Systems A.C.S S.p.A Via Della Bufalotta 378, RM-00139 Rome, Italy Email: udig@acsys.it Tel: +39 06 87090944, Fax: +39 06 87201502 |

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1. Introduction

One of the goals of the TELEIOS project is to analyze a lot of image data (e.g., TerraSAR-X data) and to extract semantic characteristics from the data. In order to define semantic categories, we need to process the data and this is an on-going process which will continue during the entire project period. For this, we need ontologies (taxonomies) which are strongly connected to the resolution, scale, and the estimated parameters of the data. The ontologies will be enriched step by step every time when new data have been processed.

Why we need this? Because for TerraSAR-X there is no annotated database or software to do this automatically like in multimedia¹².

The main purpose of this document is to specify the first version of the ontology for the Virtual Observatory for TerraSAR-X data developed by DLR and other partners of TELEIOS. This ontology will help us to annotate TerraSAR-X data and enable users to ask queries that are not possible with existing DLR systems, such as the EOWEB portal and the EO data management system DIMS.

The ontology covers:

- The semantics of the content of the products that were generated by the knowledge discovery algorithms developed in WP3.
- The TerraSAR-X XML metadata that currently exists in each product managed by the EOWEB portal (e.g., mission, image mode, look direction, polarisation, product variant, latitude, longitude, incidence angle).

The ontology is given in RDFS and we also give examples of stRDF triples that are derived from TerraSAR-X data and are used to annotate them. We also give examples of stSPARQL queries that can be used to illustrate the advantages of TELEIOS technologies for querying TerraSAR-X data in a semantic way.

This deliverable belongs to Task 6.2 of work package WP6. Task 6.2 has two deliverables, the present one (D6.2.1) and D6.2.2, with the delivery in month 30.

¹ ImageCLEF - The CLEF Cross Language Image Retrieval Track: <http://www.imageclef.org/>

² LabelMe the open annotation tool: <http://labelme.csail.mit.edu/>

The organization of this deliverable is as follows:

Chapter 2 of this document contains a description of the TerraSAR-X data set and few details about image tiling and feature extraction. The full description is presented in Deliverable D3.1.

Chapter 3 gives an idea about semantic categories that can be generated for available TerraSAR-X image data set. We start with a general annotation of the patches using the primitive features and we continue with an example how the multiple annotations can be applied for the available data set. In the second part of the chapter, the issues of multi-resolution and scale are analysed in terms of their influence in the annotation.

Chapter 4 provides a complete description of a TerraSAR-X image and its generation steps using the XML annotation file (metadata). The elements extracted from the XML file as metadata can be used for query.

Chapter 5 presents an RDFS ontology which captures the contents of the TerraSAR-X datasets to be used in the DLR use case.

Chapter 6 is dedicated to a classification of queries on TerraSAR-X data that are possible using the TELEIOS technologies. These examples of queries can be realized using the data model stRDF, the query language stSPARQL and the Strabon system.

Chapter 7 presents the conclusion of this deliverable.

Appendix and Bibliography ends this deliverable, D6.2.1.

2. A TerraSAR-X test data set

In this chapter, we present a TerraSAR-X data set that was first introduced in Deliverable D3.1 and was used to experiment with the knowledge discovery techniques presented there. This data set is used as a basis for several examples throughout this deliverable. Relevant metadata, extracted feature vectors and related semantic classes are later on captured by stRDF triples to further enhance the reader's conceptual understanding of the RDF data modelling.

In D3.1, the test dataset consists of two TerraSAR-X products. Each TerraSAR-X product comprises a TSX xml file, which defines in detail the data types, valid entries, supported product attributes and a TSX quick-look image³ annotated with latitude/longitude coordinates⁴, which gives a preview of the product in GeoTIFF⁵ format. GeoTIFF is an extension of the TIFF (Tagged Image File Format) standard which defines additional tags concerning map projection information. Large files which would exceed the 4GB limit are compressed using the standard TIFF packbits algorithm.

The XML files which are included in the delivered product packages have the following structure:

```

<productInfo>
  <missionInfo>
    <mission>TSX-1</mission>
    ...
  </missionInfo>
  <acquisitionInfo>
    ...
  </acquisitionInfo>
  ...
</productInfo>
<platform>
  <orbit>
    ...
    <stateVec num="95" qualInd="1" maneuver="NO">
      ...
    </stateVec>
    <stateVec ...>
      ...
    </stateVec>
    ...
  </orbit>
</platform>
etc
  
```

³ The spatial extent is specified using WGS84 annotations

⁴ Given the position in grids coordinates for MGD (or in easier way in pixels/lines) and UTM/UPS for GEC/EEC (easting/northing in meters). More details are available in (*TSX, 2007*).

⁵ <http://trac.osgeo.org/geotiff/>

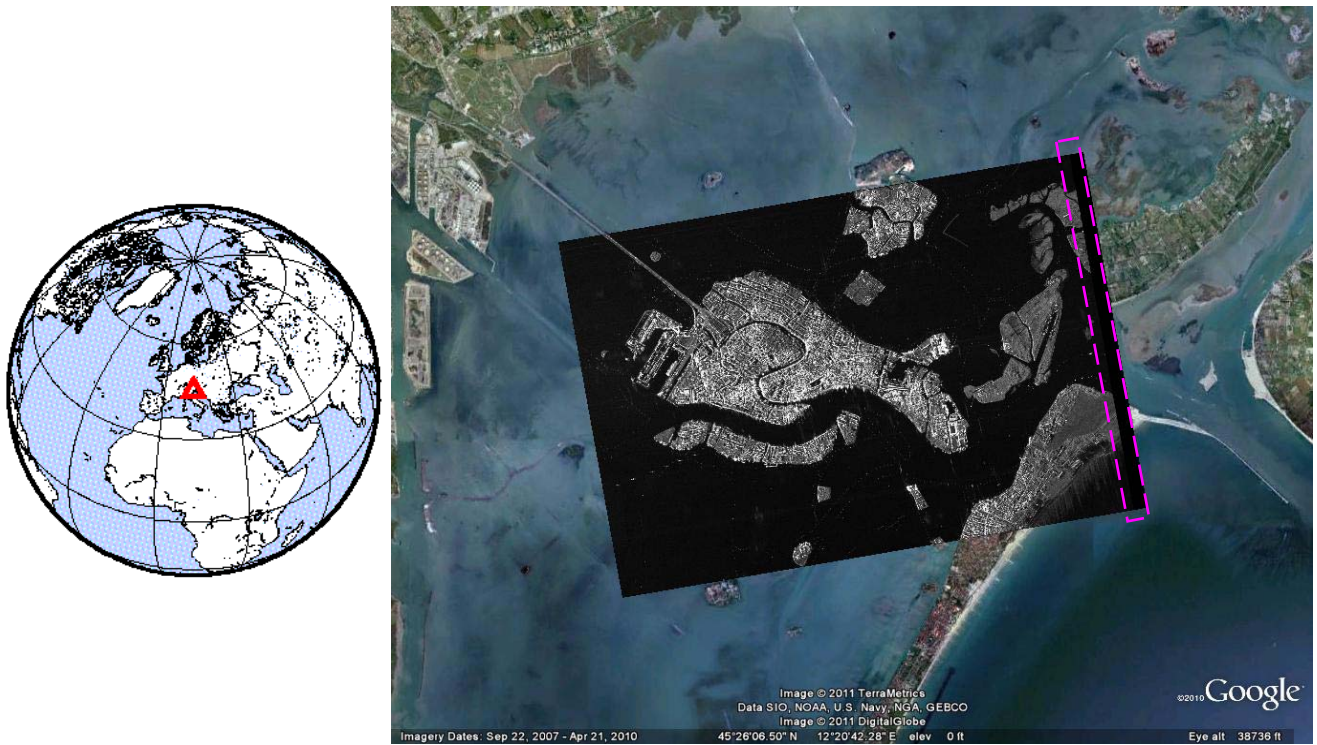


Figure 1: Overlay on Google Earth and location of the Venice test site.

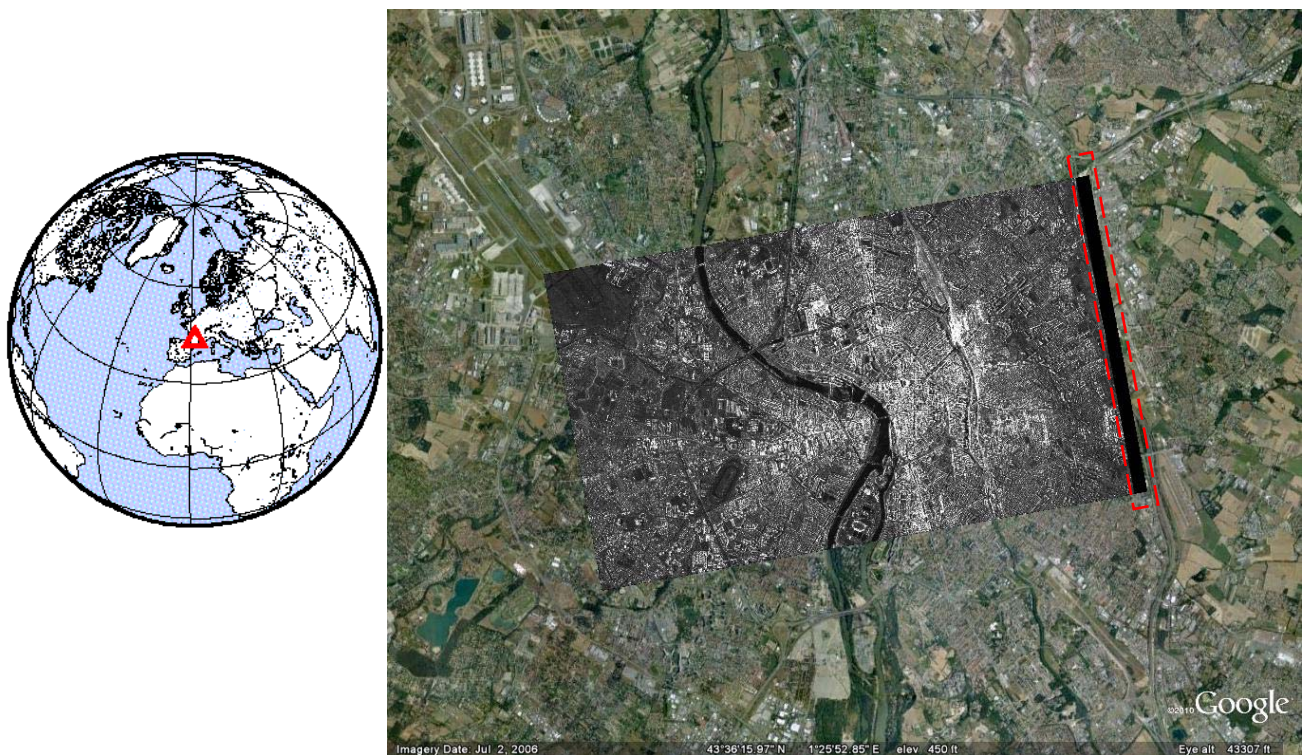


Figure 2: Overlay on Google Earth and location of the Toulouse test site.

Figure 1 and Figure 2 show the projection our Venice and Toulouse test images on Google Earth and the position of these two sites on the globe; the images are also available in Deliverable D3.1.

For each TSX product, the image is tiled into patches (1026 for Venice / Italy and 1144 for Toulouse / France) using the patch tiling algorithm presented in Deliverable D3.1. The size of the generated patches depends on the resolution of the image and its pixel spacing.

When the patch tiling algorithm is applied to MGD type products, we need to consider only the “real” number of columns which are given in the XML file, via *refRow* and *refColumn*. The number of rows (*numberOfRow*) of the image is identical to the *refRow* entry, the only difference for these two images is in their *refColumn* entry (see Figure 3 and details in Deliverable D3.1). An example how to tile these images into patches is presented in Figure 3.

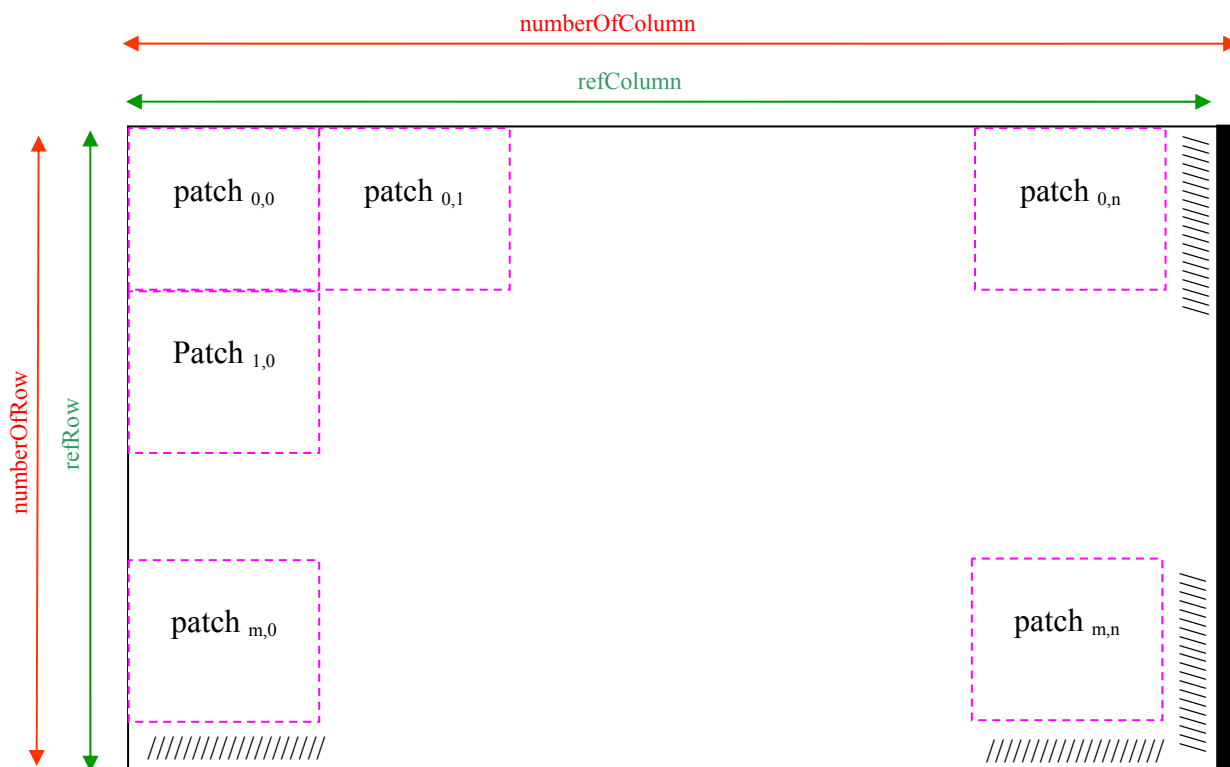


Figure 3: Tiling the product image into patches considering only the reference number of columns and rows of the image (North up, East to the right).

Tile patches are basically a form of image segmentation, as can be seen in Figure 3. In this case, the patch size is 200 x 200 pixels for a 1 meter resolution image. An example of a patch for Venice is shown in Figure 4.

A multi-resolution and scale analysis was performed (see the Deliverable D3.1) using TerraSAR-X detected data. This analysis performs a pyramid of different resolutions of each sub-scene to ensure whether the various textures are identified at the related scale. For this analysis each product is tiled at different patch sizes and to each of these patches the feature extraction methods (presented in detail in Deliverable D3.1) were applied. A synthesis of these methods is presented in next table, Table 1.

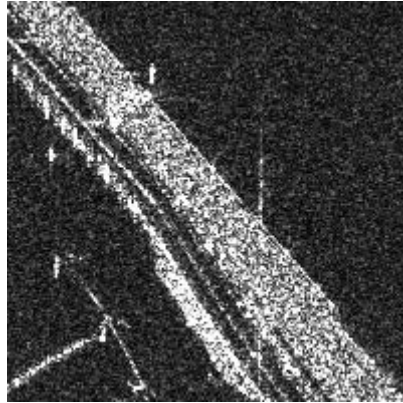


Figure 4: Example of a 1 meter resolution, 200 x 200 pixels patch from the Venice image.

| Feature extraction method | Number of features (parameters) |
|--|--|
| GAFS - Gabor Filters (2 scales and 2 orientations) | 48 |
| GAFS - Gabor Filters (4 scales and 6 orientations) | 8 |
| GLCM – Gray Level Co-occurrence Matrix | 48 |
| NSFT – Nonlinear Short Time Fourier Transform | 6 |
| QMFS - Quadrature Mirror Filters (number of wavelet decompositions equal to 1) | 8 |
| QMFS - Quadrature Mirror Filters (number of wavelet decompositions equal to 2) | 14 |

Table 1: Our feature extraction methods.

An identification code for each patch and feature vector has been proposed by DLR in Deliverable D3.1 for a simple recognition of the original product/image of these patches/features. Finally, every tile patch with their associated feature vector has been annotated with a semantic label. Next chapter provides the first idea about the annotation of the TerraSAR-X data set.

3. Semantic categories

In this chapter, we present the semantic categories that can be generated from the TerraSAR-X image data set. In the first part, we start with a general annotation of the patches and we continue with an example how the multiple annotations can work. In the second part a multi-resolution and scale analysis is done in terms of their influence on annotation.

In our image information mining system, we try to implement techniques from statistical/spectral and machine learning to provide users with innovative tools to explore and explain the image data in the archive: a user can select several features that are most suitable for him, train a specific cover-type of his interest by giving examples (positive and negative ones) and insert the cover-type semantics in the data base management system. The idea is to build intelligent visual interfaces which explain image data and high-level user concepts in order to achieve a compromise for a common understanding. In this way we expect to achieve knowledge sharing which be realized using techniques from ontologies. In this context we understand ontology as it is now used by Semantic Web researchers: as a description of the categories and associations that could be established between the components of the set of hierarchical representation of information and for a given user conjuncture (see Figure 8).

Users of the mining system have different domain specific background knowledge and therefore can taxonomically be assigned to several ontology domains (*Daschiel, 2004*).

3.1. Patches and annotation

The evaluation methodology is detailed in Deliverable D3.1 and consists of establishing the TSX data base, selecting a patch footprint area on ground (typically 200 x 200 m) and after that definition of patch size in pixels, extraction of primitive features for each patch and organizing them in a separate data bases per feature algorithm, and performing an iterative annotation of the TSX data patches using the Support Vector Machine with a Relevance Feedback and the human expertise.

Note that before using the Search Engine based on the Support Vector Machine (SVM) classifier, the features need to be normalised. We applied the Z-score normalisation (*Karthikeyani and Thangavel, 2009*) for our primitive features.

After the tiling and feature extraction procedures are finished, each patch is characterized by a feature vector and a semantic annotation. An example of this is presented in the next figure (Figure 5) where only one level of annotation per patch was considered.

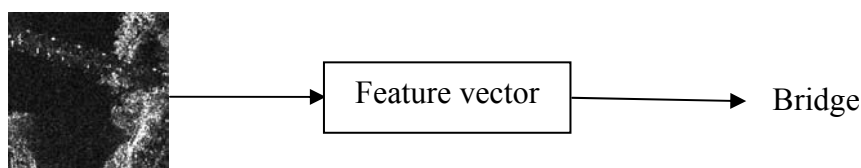


Figure 5: Example of patch annotation.

Typical semantic categories extracted from our TSX MGD product High Resolution Spotlight mode images are presented in Figure 6 for the Venice and Toulouse site. The first column corresponds to the centre of the class/category followed by the remaining patches in this class/category. The full list of identified categories with their number of patches per category and the “actual” associated semantic meaning is shown in Figure 7 for Venice and in Figure 8 for Toulouse. Only the categories that appear in more than 10 patches are marked in bold; the performance metric (e.g., precision/recall) was calculated as described in Deliverable D3.1.

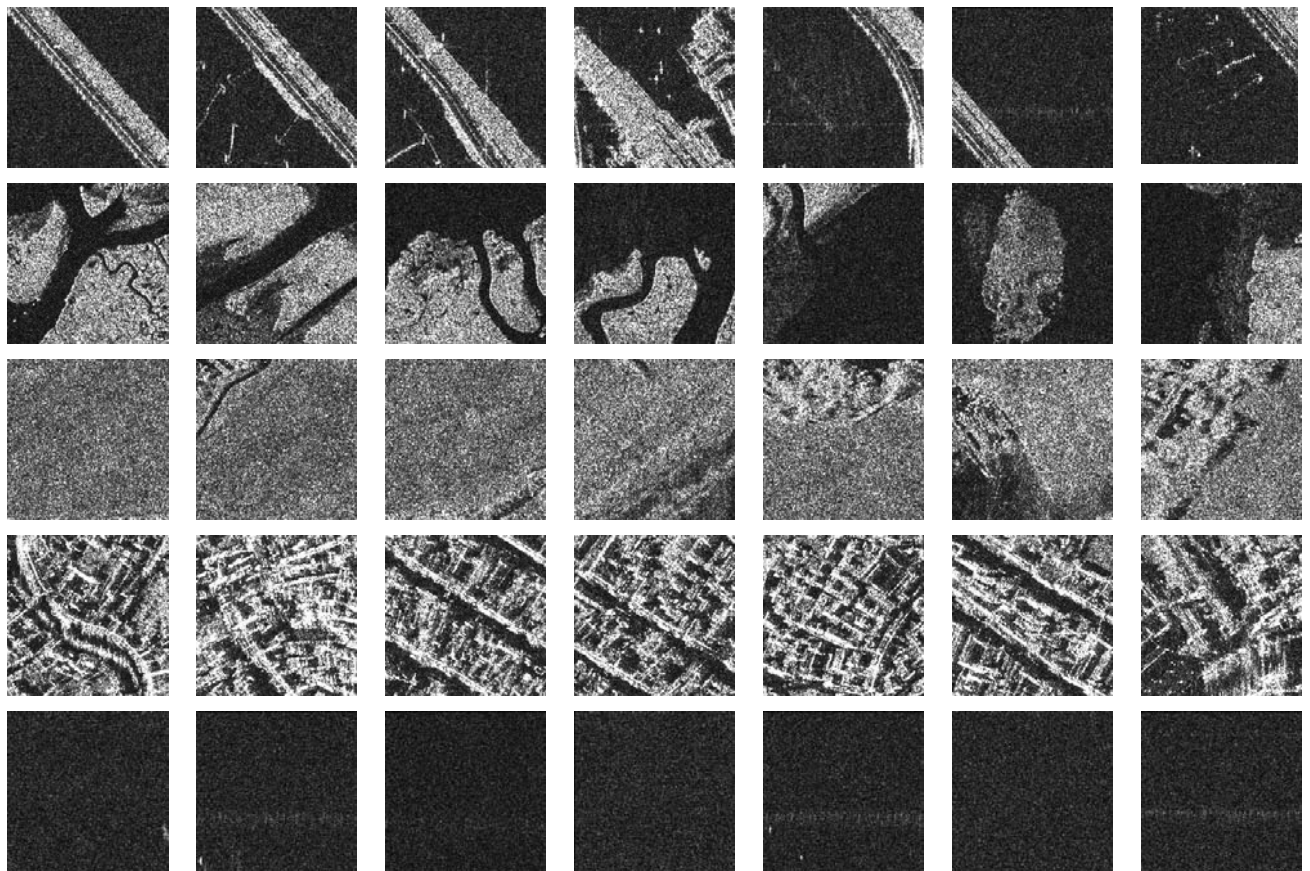
We can observe in these last two figures a big diversity in the number of patches retrieved for each category/class. This number varies from 2-3 patches/category for railway tracks, cemetery (Venice), parking, and a park with streets (Toulouse) up to 367 for water (in Venice) and 279 for urban type 2 (Toulouse).

During this evaluation, a number of 35 classes/ categories were identified for the Venice and Toulouse area. From a total of 2170 patches, 2085 were annotated with their appropriated semantics and the remaining of patches were considered as not annotated.

At the moment, only some generic semantics were assigned to these categories (e.g., bridge, port, water, etc). The full list of these semantics for all 35 categories is shown in Figure 7 and Figure 8.

From the total number of categories, we selected 30 categories (categories with more than 10 patches with the same semantic meaning) that can be retrieved with a very good factor of the precision/recall factor. For precision this level of confidence is more than 80% and for recall is between 30% and 36%. The results for each product are shown separately for precision in Table 2 and for recall in Table 3. The full precision/recall evaluation is presented in Deliverable D3.1.

A set of patches from the Venice image



A set of patches from the Toulouse image

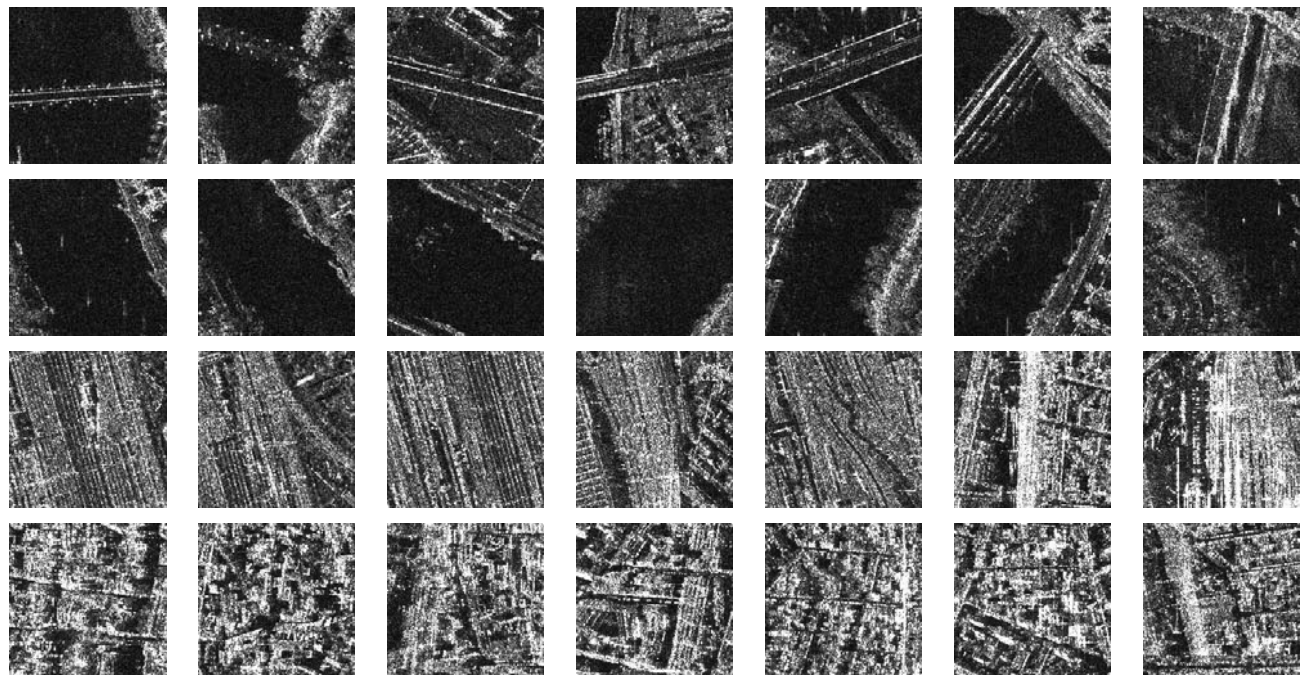


Figure 6: Typical examples of patches for Venice and Toulouse.

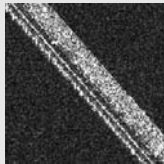
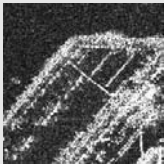
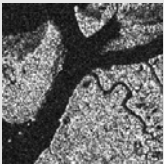
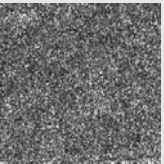
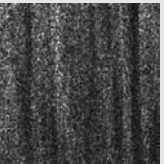
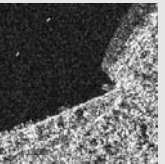
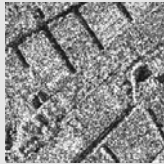

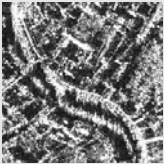
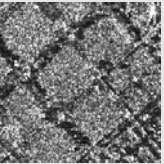
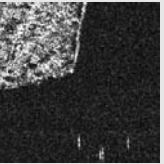
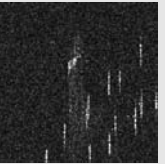
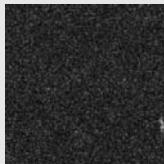
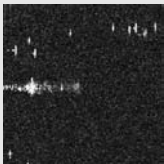


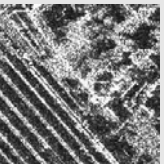
| Venice image categories | | | | | | |
|-------------------------------------|---|---|---|---|---|--|
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Bridge type 1 | Port | River deposits | Agriculture | Breaking waves | Mixed Vegetation and Water |
| Number of patches for each category | 11 | 39 | 24 | 16 | 14 | 30 |
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Vegetation | Urban and Water | Urban | Cemetery | Water and Vegetation | Water and Ambiguities |
| Number of patches for each category | 17 | 84 | 142 | 3 | 34 | 202 |
| Patch quick-look |  |  |  |  |  | |
| Semantics | Water | Water and Boats | Vegetation and Buildings | Beach area | Railway tracks | |
| Number of patches for each category | 367 | 18 | 17 | 5 | 3 | |

Figure 7: Example of typical categories with their semantic annotation identified for Venice.

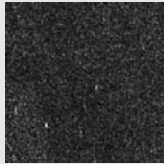
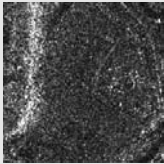
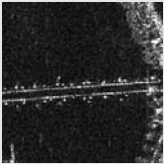
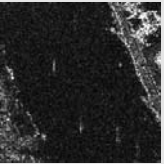

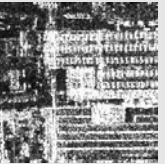
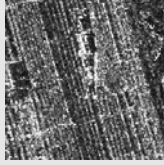




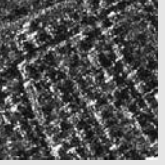





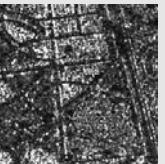
| Toulouse image categories | | | | | | |
|-------------------------------------|---|---|---|---|---|---|
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Grassland | Forest | Bridge type 2 | Water and Urban or Vegetation | Roads and Vegetation | Roof structure |
| Number of patches for each category | 33 | 31 | 18 | 50 | 55 | 16 |
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Railway tracks | Urban type 1 | Grassland with rectangular bounds | Grassland with objects | Buildings with different shape | Urban type 2 |
| Number of patches for each category | 23 | 54 | 11 | 23 | 91 | 279 |
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Building reflections | Vegetation and Urban | Roads and Buildings | Trees and Buildings | Parking | Park with streets |
| Number of patches for each category | 31 | 135 | 195 | 11 | 3 | 2 |

Figure 8: Example of typical categories with their semantic annotation identified for Toulouse.

| Semantics | Standard MGD-SE | MGD-SE 1m resolution | MGD-SE 2 m resolution | Standard MGD-RE | MGD-SE 4 m resolution |
|---|-----------------|----------------------|-----------------------|-----------------|-----------------------|
| Venice image | | | | | |
| Bridge type 1 | 92.26% | 98.15% | 100.00% | 94.10% | 97.22% |
| Port | 83.67% | 95.60% | 98.49% | 96.55% | 92.04% |
| River deposits | 89.02% | 93.16% | 85.66% | 89.17% | 83.60% |
| Agriculture | 94.18% | 95.89% | 70.90% | 94.45% | 93.95% |
| Breaking waves | 97.05% | 97.92% | 89.32% | 90.02% | 95.39% |
| Mixed Vegetation and Water | 99.24% | 90.07% | 88.62% | 82.72% | 93.04% |
| Vegetation | 97.41% | 95.00% | 91.67% | 84.25% | 93.61% |
| Urban and Water | 83.70% | 84.52% | 77.12% | 82.98% | 93.58% |
| Urban | 68.54% | 94.77% | 90.53% | 94.79% | 63.74% |
| Water and Vegetation | 82.43% | 97.44% | 83.00% | 87.96% | 99.09% |
| Water and Vegetation | 65.26% | 70.44% | 74.00% | 65.46% | 75.46% |
| Water | 79.71% | 79.50% | 80.15% | 82.41% | 74.21% |
| Water and Boats | 88.31% | 85.00% | 64.24% | 96.97% | 74.98% |
| Vegetation and Buildings | 91.80% | 95.83% | 100.00% | 93.33% | 96.00% |
| Toulouse image | | | | | |
| Grassland | 92.86% | 94.84% | 80.78% | 95.83% | 100.00% |
| Forest | 96.43% | 95.65% | 83.39% | 92.11% | 96.63% |
| Bridge type 2 | 95.43% | 93.39% | 98.33% | 100.00% | 100.00% |
| Water and Urban or Vegetation | 92.46% | 95.33% | 88.43% | 80.03% | 99.09% |
| Roads and Vegetation | 76.12% | 87.51% | 76.61% | 79.55% | 94.10% |
| Roof structure | 94.44% | 95.95% | 100.00% | 100.00% | 98.00% |
| Railway tracks | 95.04% | 97.41% | 100.00% | 100.00% | 100.00% |
| Urban type 2 | 56.26% | 62.80% | 44.49% | 48.76% | 90.23% |
| Grassland with rectangular bounds | 100.00% | 88.37% | 100.00% | 100.00% | 100.00% |
| Grassland with objects | 88.39% | 97.92% | 91.48% | 81.98% | 96.25% |
| Buildings with different shape | 45.49% | 46.17% | 45.62% | 43.51% | 74.89% |
| Urban type 2 | 44.84% | 60.63% | 73.60% | 59.62% | 74.84% |
| Building reflections | 52.32% | 58.78% | 78.34% | 68.92% | 97.14% |
| Vegetation and Urban | 37.51% | 47.56% | 40.27% | 30.96% | 78.95% |
| Roads and Buildings | 41.33% | 47.69% | 53.52% | 59.96% | 62.91% |
| Trees and Buildings | 100.00% | 95.00% | 89.39% | 91.67% | 95.00% |
| Average of all algorithms and categories | 80.72% | 84.61% | 81.26% | 82.27% | 89.46% |

Table 2: Computed precision metrics for 30 out of 35 categories identified for these two sites.

| Semantics | Standard MGD-SE | MGD-SE 1m resolution | MGD-SE 2 m resolution | Standard MGD-RE | MGD-SE 4 m resolution |
|---|-----------------|----------------------|-----------------------|-----------------|-----------------------|
| Venice image | | | | | |
| Bridge type 1 | 60.02% | 63.15% | 66.06% | 63.52% | 66.36% |
| Port | 37.33% | 35.48% | 36.33% | 38.89% | 38.47% |
| River deposits | 39.58% | 36.78% | 49.31% | 23.67% | 25.00% |
| Agriculture | 56.54% | 41.67% | 47.92% | 37.35% | 45.63% |
| Breaking waves | 66.07% | 59.53% | 54.76% | 57.14% | 47.86% |
| Mixed Vegetation and Water | 33.33% | 28.33% | 33.89% | 33.34% | 30.00% |
| Vegetation | 45.09% | 37.99% | 36.27% | 56.76% | 41.18% |
| Urban and Water | 35.12% | 23.84% | 26.99% | 31.94% | 24.76% |
| Urban type 1 | 46.77% | 31.90% | 38.85% | 42.14% | 36.55% |
| Water and Vegetation | 31.38% | 31.10% | 30.32% | 37.26% | 24.12% |
| Water and Vegetation | 62.33% | 42.12% | 39.61% | 40.68% | 33.86% |
| Water | 48.11% | 57.63% | 48.16% | 47.23% | 30.68% |
| Water and Boats | 39.35% | 42.58% | 36.38% | 37.97% | 20.00% |
| Vegetation and Buildings | 34.90% | 27.64% | 31.37% | 32.00% | 26.47% |
| Toulouse image | | | | | |
| Grassland | 29.29% | 36.87% | 36.15% | 37.88% | 27.58% |
| Forest | 18.80% | 33.33% | 35.49% | 33.87% | 25.81% |
| Bridge type 2 | 26.85% | 33.80% | 25.93% | 31.48% | 23.89% |
| Water and Urban or Vegetation | 24.85% | 30.33% | 39.78% | 32.00% | 24.40% |
| Roads and Vegetation | 28.33% | 39.11% | 28.18% | 36.37% | 18.38% |
| Roof structure | 25.00% | 28.65% | 32.29% | 30.39% | 27.03% |
| Railway tracks | 26.09% | 35.50% | 45.70% | 32.61% | 31.74% |
| Urban type 2 | 22.37% | 20.65% | 21.49% | 33.20% | 30.67% |
| Grassland with rectangular bounds | 19.70% | 23.43% | 22.73% | 27.27% | 22.73% |
| Grassland with objects | 21.74% | 37.24% | 36.56% | 37.68% | 23.48% |
| Buildings with different shape | 22.83% | 29.08% | 24.47% | 29.22% | 27.69% |
| Urban type 2 | 27.27% | 19.95% | 22.89% | 27.43% | 27.74% |
| Building reflections | 24.73% | 32.12% | 27.96% | 24.73% | 19.68% |
| Vegetation and Urban | 21.74% | 18.59% | 20.91% | 23.71% | 34.00% |
| Roads and Buildings | 22.77% | 22.01% | 20.43% | 17.66% | 32.95% |
| Trees and Buildings | 26.51% | 30.30% | 34.85% | 33.33% | 25.45% |
| Average of all algorithms and categories | 34.16% | 34.36% | 35.07% | 35.62% | 30.47% |

Table 3: Computed recall for 30 out of the 35 categories identified for these two sites.

Trying to expand the generic semantics that have been used so far, we intend to have an annotation scheme of patches like the first one presented below (the first draft). More details about this annotation scheme are presented in Appendix.

| L1 Code | | L2 Code | | Class code |
|----------|---|-----------------------|--|-----------------------|
| 0 | Not classified yet | 0 | Not specified further | 00 |
| 1 | Urban built-up | 0 | Not specified further | 10 |
| | <i>Relevance of built-up to emergency applications ("this is where the people are") justifies many classes</i> | 1 | High-density residential and CBD | 11 |
| | | 2 | Medium-density residential (row buildings, 'Blockrandbebauung', other) | 12 |
| | | 3 | Low-density residential (single family, treed) | 13 |
| | | 4 | Informal settlements - solid ('favelas', Kibera) and transitional (no refugee camps) | 14 |
| | | 5 | Refugee camps (transitional housing, structured) | 15 |
| | | 6 | Commercial | 16 |
| | | 7 | Industrial | 17 |
| 2 | | Transportation | 0 | Not specified further |
| | <i>Relevant to SAFER⁶⁷ → own L1 class</i> | 1 | Roads (straight, curved, forked, intersection) | 21 |
| | | 2 | Railroads (single, double, forked) | 22 |
| | | 3 | Bridges (road, railroad) | 23 |
| | | 4 | Ports | 24 |
| | | 5 | Airports | 25 |
| 3 | | Agriculture | 0 | Not specified further |
| | | 1 | Cropland (all types) | 31 |
| | | 2 | Pasture | 32 |
| | | 3 | Stubble / bare agricultural land | 33 |
| 4 | | Forest | 0 | Not specified further |
| | <i>An alternative to forest type could be percentage of contiguous forest coverage (relevance depending on application)</i> | 1 | Forest coniferous | 41 |
| | | 2 | Forest broadleaf | 42 |
| | | 3 | Forest mixed | 43 |
| | | 4 | Regrowth | 44 |
| | | 5 | Clearcut | 45 |
| 5 | | Bare ground | 0 | Not specified further |
| | <i>Not too well structured; alternative to this L2 division</i> | 1 | Brush / Rangeland (dense, scattered) | 51 |
| | | 2 | Barren, soil or sand (no agriculture / clearcut) | 52 |
| | | 3 | Barren, rock | 53 |

⁶ <http://www.emergencyresponse.eu/gmes/en/ref/home.html>

⁷ <http://www.zki.dlr.de/project/162>

| | | | | |
|---|-------|---|----------------------------|----|
| | | 4 | Snow / ice covered | 54 |
| 6 | Water | 0 | Not specified further | 60 |
| | | 1 | River / Channel | 61 |
| | | 2 | Lake (natural, artificial) | 62 |
| | | 3 | Ocean | 63 |

Table 4: Two level classification scheme (Draft 1).

For this, we start from simple examples to more complicated ones (see Figure 9) and try to annotate them using the proposed multi-level scheme.

For all three examples given below, the first value in the identification code corresponds to the level L1 which has a general meaning (e.g., transportation, water, etc) and the second one to the level L2 which is more detailed (e.g., bridge, roads, river, channel, etc). For example:

- code 63 – this means level L1 = 6 corresponds to water and level L2 = 3 corresponds to ocean;
- code 24 – this means level L1 = 2 corresponds to transportation and level L2 = 4 corresponds to ports.

In the first example (Figure 9(a)), the selected patch contains only one object and can be annotated as river allocating the code 61 (L1-water plus L2-river). In the next figure, Figure 9(b), we select another example in which the patch contains two objects and the annotation of this patch can be river (code 61) and bridge (code 23, L1-transportation plus L2-bridge). In this second case, a double semantic annotation is generated. In the last example, Figure 9(c), the patch contains three objects: channel (code 61, L1-water and L2-channel), bridge (code 23, L1-transportation plus L2-bridge), and forest (code 40, L1-forest plus L2-unspecified type of forest). In this case, we have multiple semantic annotations.

Selecting from our dataset (TSX MGD products with in High Resolution Spotlight mode with 1 m resolution) a set of patches, we can use concepts such as “sea”, “channel”, “port”, “train lines”, “roads”, “railroads”, “bridges”, “airports”, “commercial”, “industrial”, etc (as a level L2 of annotations). As a more generic concept (as a level L1 annotations), such as “urban built-up”, “transportation”, “agriculture”, “forest”, “bare ground”, and “water” are much more general and there are not so user-specific like level L2, which may correspond to different visual realities depending on the user expertise. Notice, however, that a detailed concept in level L2 can map to multiple generic concepts in the upper level L1. This does not apply to the current annotation scheme being used, but may be the case as the annotation scheme is being enriched.

In Figure 10, we show an example of how this two-level annotation concept can be used for annotating our TerraSAR-X data set.

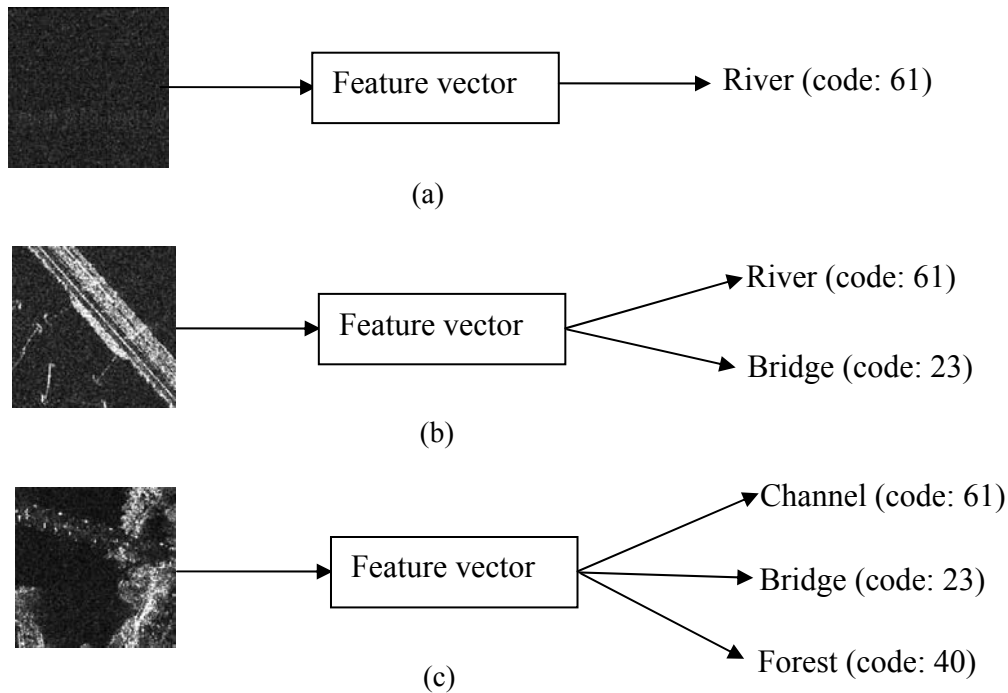


Figure 9: Example of generating: (a) one category, (b) two categories, (c) three categories starting from the input patch. The generated two-level classification code for each category is chosen based on the scheme presented in the Table 4.

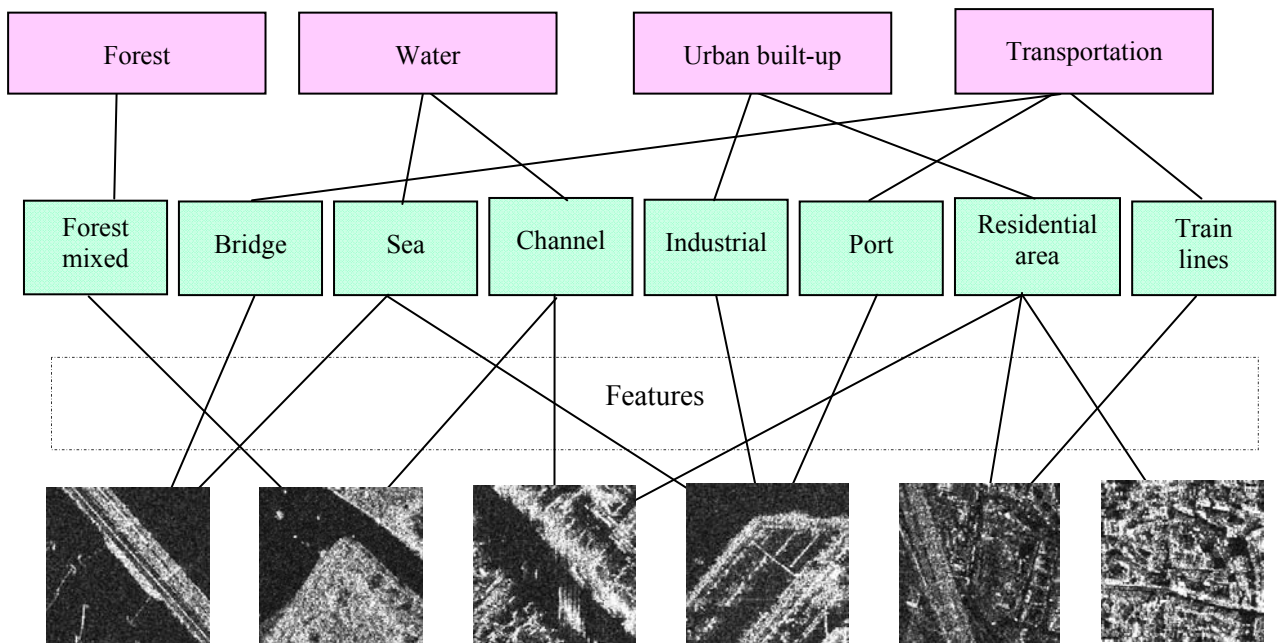


Figure 10: Example of the concept of multi-semantic annotation. The first level (from bottom to top) corresponds to patches of the image, the second one to the features and the last two to annotations. The first one for annotation is connected to the image/patch content and is the lowest level (L2) and corresponds to a detailed concept and the second one is the higher level in hierarchy and corresponds to a more generic concept (L1)

In Deliverable D3.1, during the evaluation of the number of retrievable categories / classes we found 17 categories for Venice (Italy) and 18 categories for Toulouse (France). From this number of categories, we selected 14 for Venice and 16 for Toulouse, categories with more than 10 patches having the same semantics.

Another evaluation using the same procedure was done for Berlin (Germany) and Ottawa (Canada). The number of retrieved categories is 11 for Berlin and 6 for Ottawa. The TSX data of these two last sites are also detected data and the characteristics are: High Resolution Spotlight mode, Radiometrically Enhanced with about 2.9m resolution. After tiling, a total of 1380 patches were generated.

The semantic annotation of 2170 patches for Venice and Toulouse and 1380 for Berlin and Ottawa was done using a generic annotation and all these categories have been retrieved with a good confidence factor (see Table 2 and 3 for Venice and Toulouse and Table 5 and 6 for Berlin and Ottawa).

| Semantics | High Resolution Spotlight mode Radiometrically Enhanced | |
|---|---|---------------|
| | Precision | Recall |
| Berlin image | | |
| Forest | 90.63% | 82.15% |
| Forest with objects | 82.16% | 71.97% |
| Channel | 81.58% | 58.11% |
| Railway tracks type 1 | 100.00% | 58.33% |
| Urban type 1 | 77.67% | 65.00% |
| Railway tracks type 2 | 100.00% | 45.46% |
| Building reflections | 70.68% | 68.06% |
| Urban type 2 | 82.61% | 38.24% |
| Streets with buildings | 56.67% | 18.75% |
| Urban type 3 | 85.91% | 32.15% |
| Sport and different fields | 100.00% | 55.56% |
| Average of all algorithms and categories | 84.35% | 53.98% |

Table 5: Precision-recall computed for the categories identified in Berlin.

| Semantics | High Resolution Spotlight mode Radiometrically Enhanced | |
|---|---|---------------|
| | Precision | Recall |
| Ottawa image | | |
| Water | 92.19% | 79.04% |
| Channel | 89.58% | 67.19% |
| Building reflections | 79.79% | 80.96% |
| Urban type 1 | 96.24% | 76.07% |
| Urban type 2 | 68.00% | 62.50% |
| Fields | 85.16% | 66.67% |
| Average of all algorithms and categories | 85.16% | 72.07% |

Table 6: Precision-recall computed for the categories in Ottawa.

Figures 11 and 12 show the categories identified for Berlin and for Ottawa together with the most relevant patches in each class/category. The semantic annotation for these categories is a general annotation and is identical with the annotation generated for Venice and Toulouse.

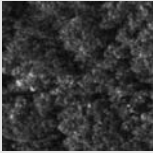


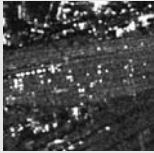

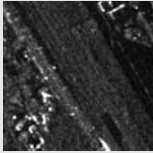
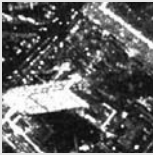


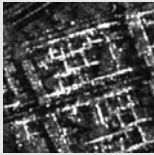

| Berlin image | | | | | | |
|-------------------------------------|--|--|--|---|--|---|
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Forest | Forest with objects | River | Railway tracks type 1 | Urban type 1 | Railway tracks type 2 |
| Number of patches for each category | 14 | 66 | 37 | 12 | 30 | 10 |
| Patch quick-look |  |  |  |  |  | |
| Semantics | Building reflections | Urban type 2 | Streets with buildings | Urban type 3 | Sport and different fields | |
| Number of patches for each category | 72 | 34 | 48 | 28 | 9 | |

Figure 11: Example of typical categories with their semantic annotation identified for Berlin.

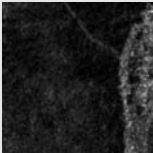
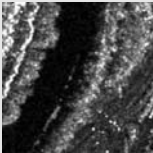

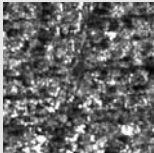
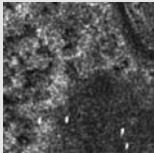
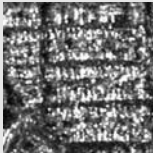
| Ottawa image | | | | | | |
|-------------------------------------|---|---|---|--|---|---|
| Patch quick-look |  |  |  |  |  |  |
| Semantics | Water | Channel | Building reflections | Urban type 1 | Fields | Urban type 2 |
| Number of patches for each category | 31 | 32 | 64 | 111 | 42 | 16 |

Figure 12: Example of typical categories with their semantic annotation identified for Ottawa.

In Figure 13, three patches containing bridges from Venice, Toulouse, and Ottawa are presented. From the semantic point of view all these three bridges should be grouped in the same category, but because of the feature diversity (see the example for Gabor filters with 4 scales and 6 orientations in Figure 14) this is not possible and for this reason, we have different categories and semantics for these bridges. When we compare the features in the case of normalised features, Figure 14 – (b), the Z-score normalisation method was used where the mean and standard deviation are computed on the entire set of patches/features of the considered image or images. This issue can be addressed by enriching the annotation scheme presented earlier and shown in Figure 10 with new concepts, either by the system during the evaluation and the semantic annotation of patches, as more data are handled and annotated, or by the user.

Another example is for houses (urban area) in Venice, Toulouse, and Berlin as can be seen in Figure 7, Figure 8, and Figure 11. For the urban area there are several categories that cannot be grouped together.

Based on the examples presented in Figure 13 and Figure 9 and discussed before, we can identify two situations:

- First, there are three patches which contain the same object (e.g., bridge – Figure 13) but they cannot be grouped together in the same category because of the feature diversity and for this reason different categories/semantics are generated for these patches.
- Second, there is a patch with three different objects inside (e.g., channel, bridge, and forest - Figure 9 (c)) for which multiple semantic annotation is needed.

For a more accurate annotation of the patches that takes into account the entire content of the patch, we proposed to have a multiple semantic annotation (see the last examples in Figure 9) considering for the moment a two-level annotation scheme concept. Before using this concept with a large amount of data, we need to evaluate the precision/recall metric of this multiple semantic annotation like the evaluation done for the generic annotation in D3.1. In future, such a confidence metric needs to be implemented to extract directly from the KDD.

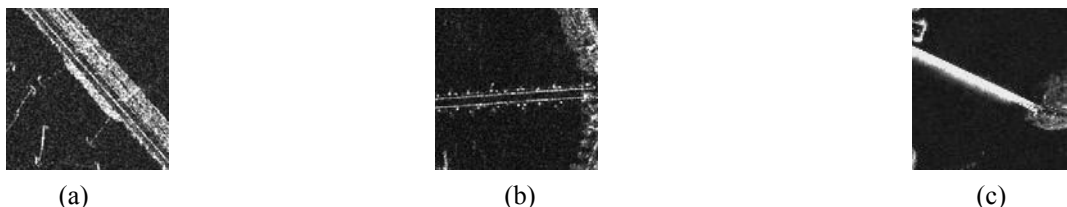
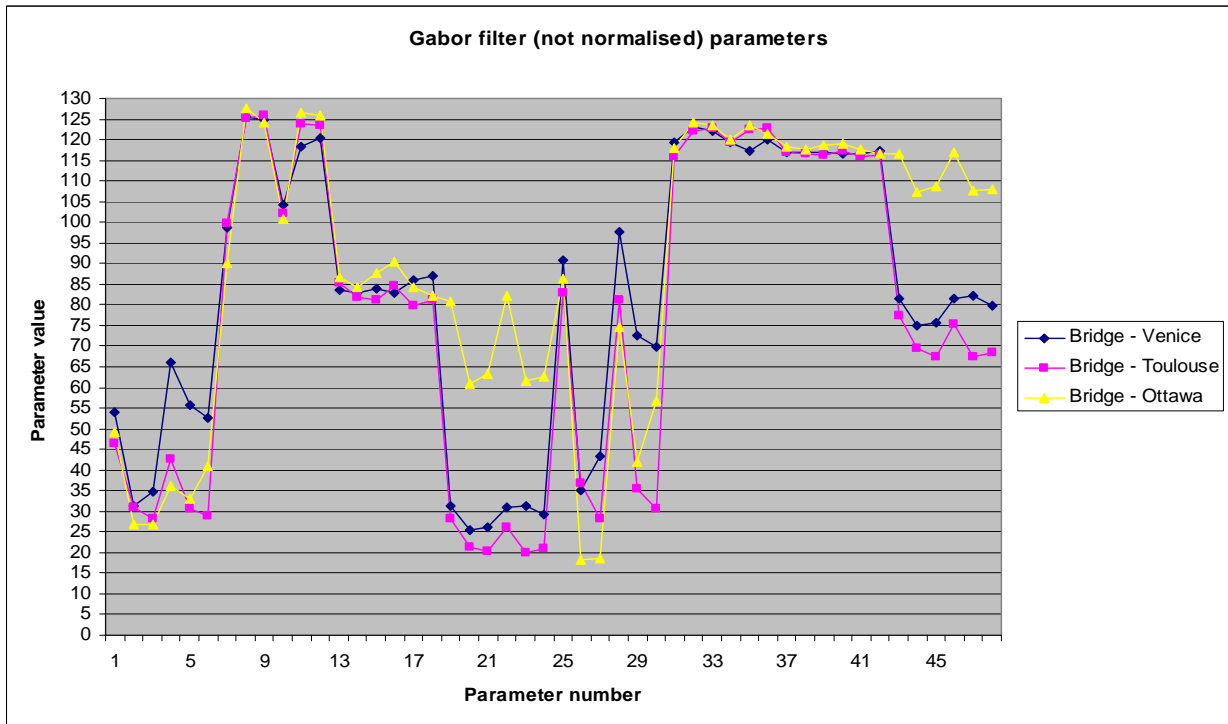
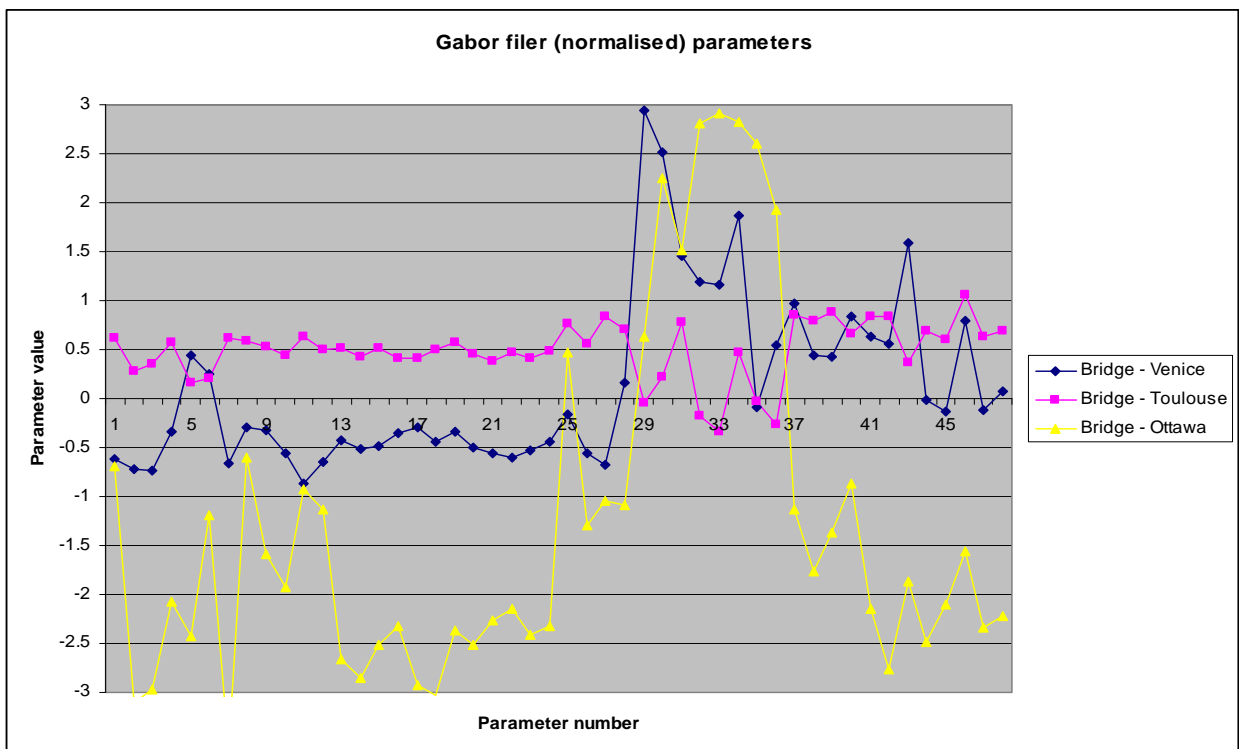


Figure 13: Example of bridges from: (a) Venice (Italy), (b) Toulouse (France), and (c) Ottawa (Canada).



(a)



(b)

Figure 14: The Gabor features extracted from the three types of bridges presented in previous figure (Figure13). In (a) the Gabor features are not normalised and in (b) the Gabor features normalised using the Z-score method.

3.2. Resolution and scale

In order to get a defined patch footprint area on ground, the patch size needs to be adapted to the resolution and the pixel spacing of each product. In Figure 15, a multi-resolution pyramid corresponding to the six (re-scaled) TerraSAR-X MGD products is presented.

An example of how the resolution and pixel spacing impacts the size of the patch (covering 200 x 200 meters on ground) is shown below:

| | | | |
|---------------------|-------------------|----------------------|---------------|
| (a) standard MGD-SE | resolution = 1m | pixel spacing = 0.5 | → patch = 400 |
| (b) special MGD-SE | resolution = 1m | pixel spacing = 1 | → patch = 200 |
| (c) special MGD-SE | resolution = 2m | pixel spacing = 2 | → patch = 100 |
| (d) standard MGD-RE | resolution ~ 2.9m | pixel spacing = 1.25 | → patch = 160 |
| (e) special MGD-SE | resolution = 4m | pixel spacing = 4 | → patch = 50 |
| (f) special MGD-SE | resolution = 8m | pixel spacing = 8 | → patch = 25 |

Note that the important characteristic of the *specialy processed MGD-SE products* is that the resolution of the image is equal to the pixel spacing.

Changing the resolution of the product/image, the objects from the image can disappear or are not visible anymore and the semantic meaning of this patch is changed partially or totally. A different semantic meaning of the same area (patch) can be obtained by changing its resolution.

In Figure 16 such an example is illustrated for a range of resolutions from 1 m to 8 m covering the same area on ground (e.g., port in Venice). Another example that shows the change of the content of different patches having a resolution of 1 m, 2 m, 4 m, and 10 m is presented in Figure 17.

An example of the influence of the resolution of the image for the urban area is presented in Figure 18. These three images were selected in order to have an idea how an urban area looks for different products: TerraSAR-X (1 meter), Sentinel-1 (about 8-9 meters), and ERS-1 (20 meters).

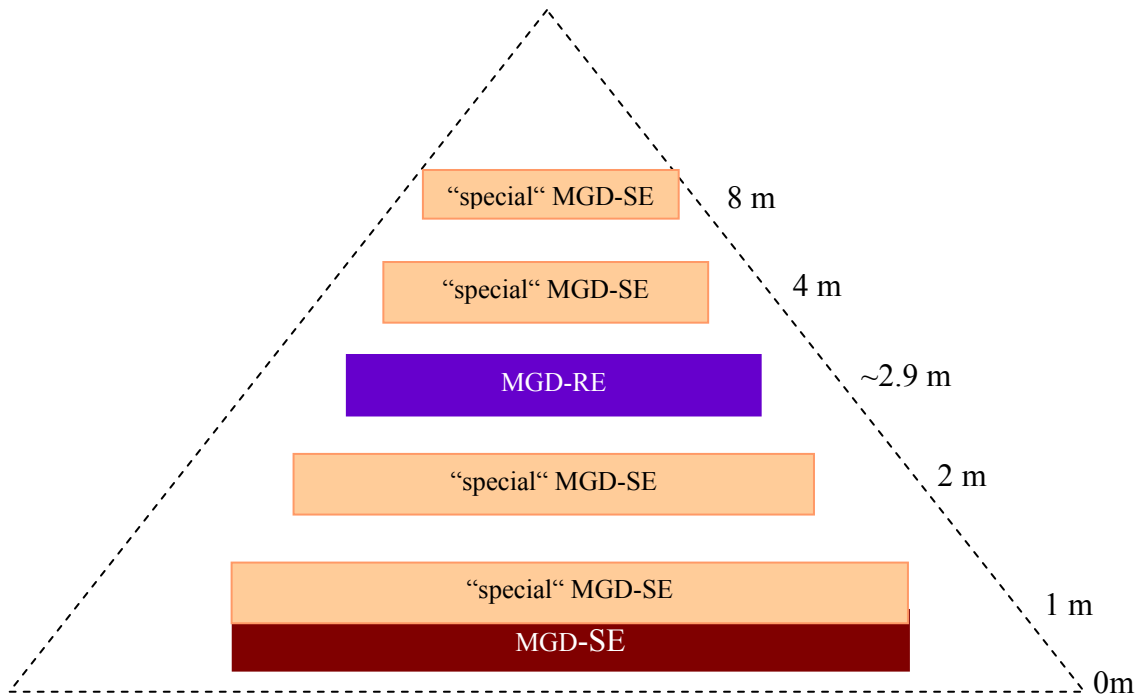


Figure 15: The multi resolution pyramid corresponding to each product. The TerraSAR-X MGD-SE standard product, marked in red, has 1m resolution. The TerraSAR-X MGD-RE, marked in lilac, has 2.9m resolution. The multi-resolution product marked in orange, has 1m, 2m, 4m, and 8 m of resolution.



Figure 16: Retrieved information for a set of five patches in the port having a resolution from 1 m to 8 m. Trying to identify an object from 1m to 8m, for example the ship, we can notice that for the last two resolutions this is not possible anymore.

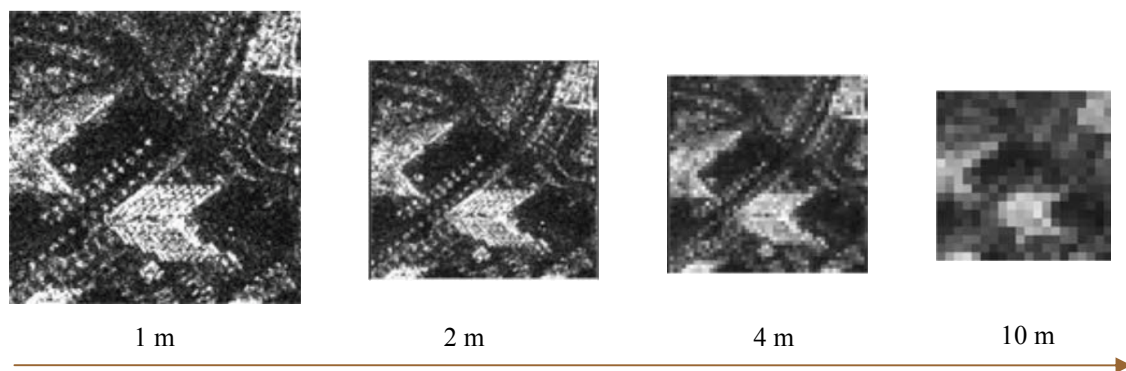


Figure 17: Another example showing the information that can be retrieved from patches with different resolutions. In this case we have skyscrapers in an urban area.

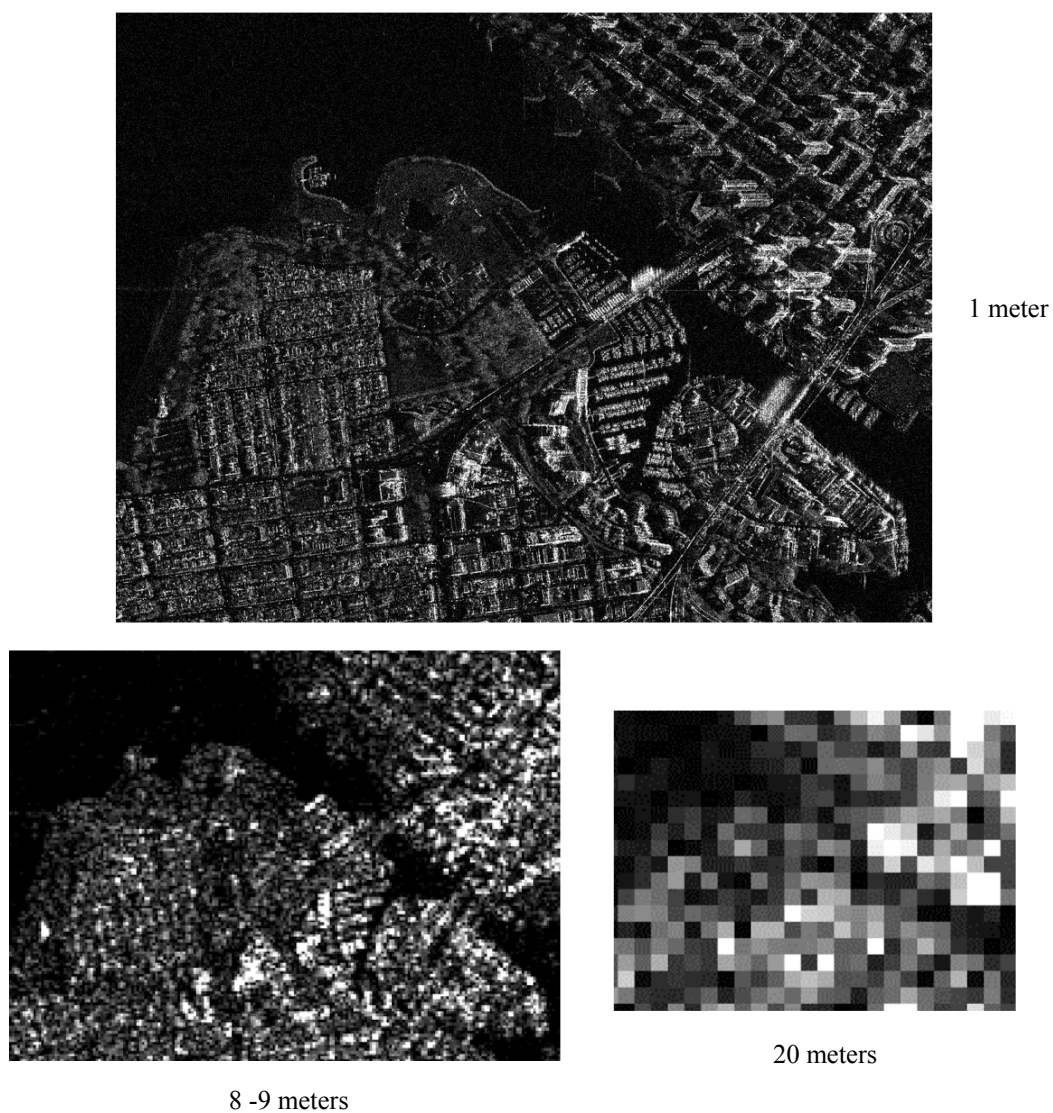


Figure 18: Understanding an urban area with different resolutions.

In the next figure, a scale analysis is done and for exemplification a patch “generally” annotated as port is used (see Figure 16). If a scale is applied to this patch, we’ll have different general annotations for the four resulting patches, as (see Figure 19 top right corner):

- patch I – cargo storage area (e.g., dock for import /export market),
- patch II – vegetation,
- patch III – industrial area plus vegetation,
- patch IV –water plus ship.

We continue our scale analysis and we divide (by scaling) the patch IV into another four small patches (see the Figure 19 bottom right corner). The annotation of these patches can be:

- patch IV-I – cargo storage area,
- patch IV-II –ship plus water,
- patch IV-III – marine terminal,
- patch IV-IV – water.

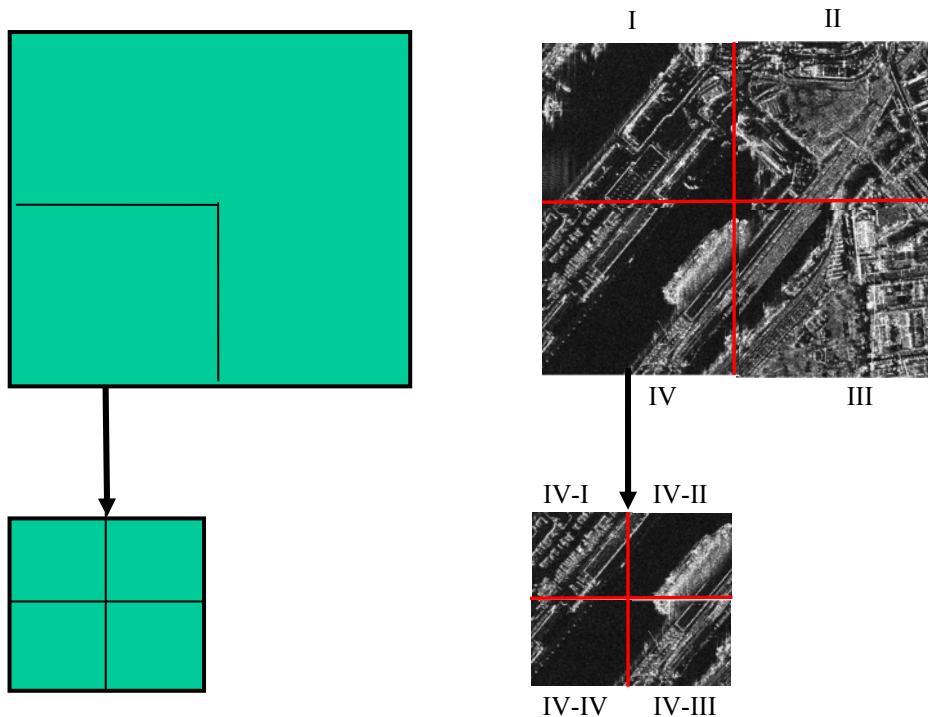


Figure 19: (a) Scale analysis principle. (b) An example of this principle applied to for a patch annotated initially as port.

The strategy adopted in (Barz *et al.*, 1998) is the definition of structural meta-features to be used in queries with progressive detail as information at large scales in comparison with information at small scales.

4. Image descriptors

In this chapter, we describe the main aspects of the xml file that can be used for queries of the metadata.

The TerraSAR-X xml file provides information used for querying the image metadata as well as information for tiling the image content. Further, the first list of most important descriptors of the xml file is presented. In the Appendix (Table 8) are presented the descriptors that are intended to be store for the moment in the database.

➤ **productComponents:**

1. **annotation:** Pointer to the annotation file (xml file).
 - **path:** Localisation of the xml file.
 - **filename:** Name of the xml file (i.e., TSX1_SAR_MGD_RE__HS_S_SRA_20080919T052516_20080919T052517.xml).
2. **imageData:** Information about the TerraSAR-X image
 - **path:** Localisation of the GeoTIFF file.
 - **filename:** Name of the file (i.e., IMAGE_HH_SRA_spot_042.tif).

➤ **productInfo**

1. **missionInfo:** Mission and orbit parameters at start of scene
 - **mission:** name of the mission.(i.e., TSX-1).
 - **orbitPhase:** Orbit phase. The possible values are: -1 prelaunch phase, 0 launch phase, 1 nominal Orbit.
 - **orbitCycle:** Cycle number (i.e., 15).
 - **absOrbit:** absolute orbit number at start of scene 2469.
 - **relOrbit:** relative orbit number 131.
 - **numOrbitsInCycle:** nominal number of orbits per cycle depends on phase currently 167.
 - **orbitDirection:** ascending / descending flag.
2. **acquisitionInfo:** SAR sensor configuration and instrument modes during acquisition
 - **sensor:** Identifier of the sensor (i.e., SAR).
 - **imagingMode:** From the many technical possibilities four imaging modes have been designed to support a variety of applications. The following imaging modes are defined for the generation of basic products: StripMap mode (SM) in single or dual polarization, High Resolution Spotlight mode (HS) in single or dual polarization, Spotlight mode (SL) in single or dual polarization, ScanSAR mode (SC) in single polarization.

- **lookDirection**: look direction of the satellite sensor, which can be left or right.
 - **antennaReceiveConfiguration**: single-receive antenna (SRA).
 - **polarisationMode**: Polarisation mode of the antenna. This can be single, dual, twin, quad.
 - **polLayer**: polarization layer list (i.e., HH, VV, HV, VH).
3. **productVariantInfo**: Product type and variant description
- **productType**: Refers to Product Identification Scheme, which is used to identify and classified the different basic products for TerraSAR by using a mnemonic scheme described in the following. The product identifier is split into 4 sub-identifiers and the global product name is composed as: <projection>_<resolution class>_<imaging mode>_<polarization mode> (e.g., MGD_SE_SM_S for a spatially enhanced single polarization StripMap product in multi look ground range projection).
 - **productVariant**: This specify the type of geometrical projection and data representation. The possible values are: Single Look Slant Range, Complex representation (SSC), Multi Look Ground Range, Detected representation (MGD), Geocoded Ellipsoid Corrected, detected representation (GEC) and Enhanced Ellipsoid Corrected, detected representation (EEC).
 - **projection**: Type of projection (i.e., slant range, ground range, map).
 - **resolutionVariant**: The TerraSAR-X products can be Spatially Enhanced Products (SE) or Radiometrically Enhanced Products (RE).
 - **radiometricCorrection**: Refers to the calibration of the image. It can be absolutely calibrated, relative calibrated, not calibrated.
4. **imageDataInfo**: Image layer format
- **pixelValueID**: complex amplitude and phase, radar brightness (beta nought), sigma nought, etc.
 - **imageDataType**: detected or complex.
 - **imageDataFormat**: GeoTIFF for geocoded images, COSAR for SSC products.
 - **numberOfLayers**: number of polarizations + DRA channels + elevation beams (ScanSAR).
 - **imageDataDepth**: bits per pixel (16bit for detected data or 2x16bit for complex data).
 - **imageRaster**: Main description about the image data:
 - **numberOfRows**: Total of rows in the image.
 - **numberOfColumns**: Total of columns in the image.
 - **rowSpacing**: Spacing of samples within a row from common raster [s or m].
 - **columnSpacing**: Spacing within a column (e.g. azimuth sampling).
 - **groundRangeResolution**: Resolution in range.

- **azimuthResolution**: Resolution in azimuth.
- **azimuthLooks**: effective number of looks (ENL).
- **rangeLooks**: number of looks taken in range

5. **sceneInfo**: Time and scene location information

- **sceneID**: Orbit and timing information. This field allows to uniquely identify the TerraSAR-X product (i.e., C43_N2_D_HS_spot_042_R_2008-09-19T05:25:16.874506Z).
- **scene Star TimeUTC**: time stamps of first image row (all processed azimuth times should be Doppler zero times (e.g., 2009-03-09T20:29:17.722418Z in CCSDS ASCII time format).
- **scene Stop TimeUTC**: time stamps of last image row.
- **sceneCenterCoord**: Information about the center of the scene expressed in geographic coordinates:
 - **refRow**: Position in image row. Range sample position for SSCs. Annotated image sample positions for complex products has only informative purposes. All localisation is based on timing information.
 - **refColumn**: Position in image column.
 - **lat**: Geographical latitude positive towards north.
 - **lon**: Geographical longitude positive towards east.
 - **azimuthTimeUTC**: geo coordinates are derived from this timing information using the corrections annotated in the geo reference annotation component.
 - **rangetime**: geo coordinates are derived from this timing information using the corrections annotated in the geo reference annotation component.
 - **incidenceAngle**: Incidence angle is the angle between the vertical to the terrain and the line going from the antenna to the object.

5. The DLR ontology

In this chapter we present an RDFS ontology which captures the contents of the TerraSAR-X datasets to be used in the DLR use case (WP6). From this point on, we will refer to this ontology as the DLR ontology.

In Table 7 we show the prefixes used for the various namespaces that are included in our ontology.

| Namespace name | Prefix |
|---|--------|
| http://www.earthobservatory.eu/ontologies/dlrOntology.owl | dlr |
| http://www.w3.org/2001/XMLSchema | xsd |
| http://www.w3.org/1999/02/22-rdf-syntax-ns | rdf |
| http://strdf.di.uoa.gr/ontology | strdf |
| http://www.w3.org/2000/01/rdf-schema | rdfs |

Table 7: Namespace names and their prefixes.

The DLR ontology comprises the following two major classification schemes:

- The *product classification scheme*, which consists of all the different product related concepts included in the dataset, specifically, the concept of an image, the concept of a patch, the concept of a label, the concept of a feature vector, and the concept for a product itself.

The product classification scheme is shown in Figure 20.

- The *land cover/use classification scheme* for annotating image patches. This scheme was constructed according to the classification scheme proposed by DLR, and was extended where needed. We made the decision not to employ a “full blown” land cover/use ontology (e.g., Europe CORINE⁸), because the annotation of image patches currently being carried out in WP3 returns simple labels. The classification scheme only provides the basic structure for annotating patches. It can be further enriched either by the system during the evaluation and the semantic annotation of patches, as more data are handled and annotated, or by the user.

Figure 21 shows our current land cover/use classification scheme for annotating image patches.

⁸ <http://harmonisa.uni-klu.ac.at/ontology/corine.owl>



Figure 20: Product classification.

In detail, the DLR ontology has the following classes:

- **dlr:Product**. This class corresponds to the Earth observation products available from the data set. Some sTRDF triples that are produced from an actual product of the provided data set are the following:

```

dlr:Product_1 rdf:type dlr:Product .
dlr:Product_1 dlr:hasImage dlr:Image_1.tif .
dlr:Product_1 dlr:hasName
    "TSX1_SAR_MGD_SE__HS_S_SRA_T1_T2"^^xsd:string .
dlr:Product_1 dlr:hasXMLfilename
    "TSX1_SAR_MGD_SE__HS_S_SRA_T1_T2.xml"^^xsd:string .
    
```

dlr:Product_1 is an individual which is of type dlr:Product. Property dlr:hasImage is an object property that connects images, instances of class dlr:Image, to their corresponding products, instances of class dlr:Product. Properties dlr:hasName and dlr:hasXMLfilename are data properties, that describe the product's name and the product's XML filename respectively.



Figure 21: Land cover classification.

- **dlr:Image.** This class corresponds to our TSX images available from the dataset. Some stRDF triples that are produced from an actual TSX image of the provided dataset are the following:

```

dlr:Image_1.tif rdf:type dlr:Image .
dlr:Image_1.tif dlr:hasName
    "IMAGE_HH_SRA_spot_047.tif"^^xsd:string .
dlr:Image_1.tif dlr:consistsOf dlr:Patch_1.jpg .
...
dlr:Image_1.tif dlr:consistsOf dlr:Patch_1026.jpg .
dlr:Image_1.tif dlr:hasGeometry "POLYGON (
    (12.26159381501743970 45.56299181348614270 ,
    12.35852960881112850 45.57488231984351050 ,
    12.37054237986822080 45.52667299525913340 ,
    12.27374715364156190 45.51479102744408320 ,
    12.26159381501743970 45.56299181348614270)
    )"^^strdf:WKT .
    
```

dlr:Image_1.tif is an individual which is of type dlr:Image. Property dlr:consistsOf is an object property, that connects tile patches, instances of class dlr:Patch, to their corresponding images, instances of class dlr:Image. Properties dlr:hasName and dlr:hasGeometry are data properties that describe the image's name and the image's geometry in polygon format projected to the WGS84 reference system. The geometry from an area is described in Well-Known Text (WKT⁹) format using the constructs available by stSPARQL as explained in Deliverable D2.1. Well-Known Text is a text mark-up language for representing vector geometry objects on a map, spatial reference systems of spatial objects and transformations between spatial reference systems.

- **dlr:Patch.** This class corresponds to the image tile patches available from the dataset. Some stRDF triples that are produced from an actual image tile patch of the available data set are the following:

```

dlr:Patch_1.jpg rdf:type dlr:Patch .
dlr:Patch_1.jpg dlr:hasName
    "Patch_200_0_0.jpg"^^xsd:string .
dlr:Patch_1.jpg dlr:hasSize "200"^^xsd:int .
dlr:Patch_1.jpg dlr:hasIndexI "0"^^xsd:int .
dlr:Patch_1.jpg dlr:hasIndexJ "0"^^xsd:int .
dlr:Patch_1.jpg dlr:hasGeometry "POLYGON (
    (12.2615938150174397 45.5629918134861427 ,
    12.2641171989506348 45.5633013411799438 ,
    12.2645639307508231 45.5615295791493590 ,
    12.2620405468176280 45.5612200514555579 ,
    12.2615938150174397 45.5629918134861427)
    )"^^strdf:WKT .
    
```

⁹ http://en.wikipedia.org/wiki/Well-known_text

```

dlr:Patch_1.jpg dlr:hasLabel dlr:Label_1 .
dlr:Patch_1.jpg dlr:hasGAFS_vector dlr:GAFS_2_2_1 .
dlr:Patch_1.jpg dlr:hasGAFS_vector dlr:GAFS_4_6_1 .
dlr:Patch_1.jpg dlr:hasGLCM_vector dlr:GLCM_1_2_3_4_1 .
dlr:Patch_1.jpg dlr:hasNSFT_vector dlr:NSFT_1 .
dlr:Patch_1.jpg dlr:hasQMFS_vector dlr:QMFS_1_1 .
dlr:Patch_1.jpg dlr:hasQMFS_vector dlr:QMFS_2_1 .
  
```

`dlr:Patch_1.jpg` is an individual which is of type `dlr:Patch`. Property `dlr:hasLabel` is an object property that connects semantic labels, instances of class `dlr:Label`, to their corresponding tile patches, instances of class `dlr:Patch`. Properties `dlr:hasIndexI` and `dlr:hasIndexJ` are data properties that describe the relative position of a patch inside the image it is part of. Property `dlr:hasSize` is a data property that describes the size of a patch in pixels. Properties `dlr:hasGAFSvector`, `dlr:hasGAFSvector`, `dlr:hasGLCMvector`, `dlr:hasNSFTvector`, `dlr:hasQMFSvector`, and `dlr:hasQMFSvector` are object properties that connect specific types of feature vectors, instances of subclasses of class `dlr:FeatureVector`, to their corresponding tile patches, instances of class `dlr:Patch`. Property `dlr:hasGeometry` is a data property, that describes the patch geometry¹⁰ in polygon format projected to the WGS84 reference system, as was the case with the image.

An individual of type `dlr:Patch` can use the `dlr:consistsOf` object property, to connect itself to smaller patches, that result from splitting the initial patch, as shown in Figure 19.

- **dlr:Label.** This class corresponds to the semantic label annotations available from the dataset. Some stRDF triples that are produced from an actual semantic label annotation for a tile patch of the provided dataset are the following:

```

dlr:Label_1 rdf:type dlr:Label .
dlr:Label_1 dlr:correspondsTo dlr:Bridge .
  
```

`dlr:Label_1` is an individual which is of type `dlr:Label`. Property `dlr:correspondsTo` is an object property that maps semantic classes of type `dlr:LandCover`, to their corresponding labels, instances of class `dlr:Label`. The label, then, is annotated to its corresponding patch, through object property `dlr:hasLabel`, as explained above.

- **dlr:FeatureVector.** This class corresponds to the values of feature vectors available from the dataset. Some stRDF triples that are produced from actual values of a feature vector of the provided dataset, are the following ones:

```

dlr:GAFS_2_2_1 rdf:type dlr:GAFS_Vector .
dlr:GAFS_2_2_1 dlr:hasFeatureVectorValues
    dlr:GAFS_2_2_1_values .
  
```

¹⁰ The geometry of a patch is stored, because it would be infeasible to derive it upon a SPARQL query with a variable binding. The geometry is needed, because we would also want to compare patches between different images, which demands taking global position of the patch into account.

```

dlr:GAFS_2_2_1 dlr:hasScales "2"^^xsd:int .
dlr:GAFS_2_2_1 dlr:hasOrientations "2"^^xsd:int .
dlr:GAFS_2_2_1_values rdf:type
                                dlr:FeatureVectorValues .
dlr:GAFS_2_2_1_values rdf:_1 "106.68505"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_2 "106.6875"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_3 "21.5155"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_4 "20.702925"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_5 "15.852302"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_6 "14.374722"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_7 "24.08146"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_8 "19.869558"^^xsd:double .
    
```

dlr:GAFS_2_2_1 is an individual which is of type dlr:GAFS_Vector. Property dlr:hasFeatureVectorValues is an object property, that connects feature vectors, instances of class dlr:FeatureVector, to their corresponding value containers, instances of the RDF sequence container¹¹ dlr:FeatureVectorValues. Every value container comprises the output values, based on different parameters, for a given patch and a given feature extraction algorithm. The parameters for the GAFS algorithm used in the example, are given by the data properties dlr:hasScales and dlr:hasOrientations. The data properties naturally differ between different algorithms.

- **dlr:LandCover.** This class builds upon the classification scheme proposed in Appendix. Instances of class dlr:Label become instances of class dlr:LandCover, through the object property dlr:correspondsTo. The dlr:LandCover class is illustrated in the land cover classification scheme shown in Figure 21.

Next follows an example of stRDF triples that describe an annotated patch and its respective product. The patch is shown in Figure 9(c) and is annotated with the following three semantic labels: Channel, Bridge, and Forest.

The stRDF triples are the following:

```

dlr:Product_1 rdf:type dlr:Product .
dlr:Product_1 dlr:hasImage dlr:Image_1.tif .
dlr:Product_1 dlr:hasName
                "TSX1_SAR_MGD_SE__HS_S_SRA_T1_T2"^^xsd:string .
dlr:Product_1 dlr:hasXMLfilename
                "TSX1_SAR_MGD_SE__HS_S_SRA_T1_T2.xml"^^xsd:string .
dlr:Image_1.tif rdf:type dlr:Image .
dlr:Image_1.tif dlr:hasName
                "IMAGE_HH_SRA_spot_047.tif"^^xsd:string .
dlr:Image_1.tif dlr:consistsOf dlr:Patch_1.jpg .
    
```

¹¹ http://www.w3.org/TR/rdf-schema/#ch_seq

```

dlr:Patch_1.jpg rdf:type dlr:Patch .
dlr:Patch_1.jpg dlr:hasName
    "Patch_200_0_0.jpg"^^xsd:string .
dlr:Patch_1.jpg dlr:hasSize "200"^^xsd:int .
dlr:Patch_1.jpg dlr:hasIndexI "0"^^xsd:int .
dlr:Patch_1.jpg dlr:hasIndexJ "0"^^xsd:int .
dlr:Patch_1.jpg dlr:hasGeometry "POLYGON (
    (12.2615938150174397 45.5629918134861427 ,
    12.2641171989506348 45.5633013411799438 ,
    12.2645639307508231 45.5615295791493590 ,
    12.2620405468176280 45.5612200514555579 ,
    12.2615938150174397 45.5629918134861427)
)"^^strdf:WKT .

dlr:Patch_1.jpg dlr:hasLabel dlr:Label_1 .
dlr:Label_1 rdf:type dlr:Label.
dlr:Label_1 dlr:correspondsTo dlr:Channel .
dlr:Patch_1.jpg dlr:hasLabel dlr:Label_2 .
dlr:Label_2 rdf:type dlr:Label.
dlr:Label_2 dlr:correspondsTo dlr:Bridge .
dlr:Patch_1.jpg dlr:hasLabel dlr:Label_3 .
dlr:Label_3 rdf:type dlr:Label.
dlr:Label_3 dlr:correspondsTo dlr:Forest .
dlr:Patch_1.jpg dlr:hasGAFS_vector dlr:GAFS_2_2_1 .
dlr:Patch_1.jpg dlr:hasGAFS_vector dlr:GAFS_4_6_1 .
dlr:Patch_1.jpg dlr:hasGLCM_vector dlr:GLCM_1_2_3_4_1.
dlr:Patch_1.jpg dlr:hasNSFT_vector dlr:NSFT_1 .
dlr:Patch_1.jpg dlr:hasQMFS_vector dlr:QMFS_1_1 .
dlr:Patch_1.jpg dlr:hasQMFS_vector dlr:QMFS_2_1 .
dlr:GAFS_2_2_1 rdf:type dlr:GAFS_Vector .
dlr:GAFS_2_2_1 dlr:hasFeatureVectorValues
    dlr:GAFS_2_2_1_values .
dlr:GAFS_2_2_1 dlr:hasScales "2"^^xsd:int .
dlr:GAFS_2_2_1 dlr:hasOrientations "2"^^xsd:int .
dlr:GAFS_2_2_1_values rdf:type
    dlr:FeatureVectorValues .
dlr:GAFS_2_2_1_values rdf:_1 "106.68505"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_2 "106.6875"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_3 "21.5155"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_4 "20.702925"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_5 "15.852302"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_6 "14.374722"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_7 "24.08146"^^xsd:double .
dlr:GAFS_2_2_1_values rdf:_8 "19.869558"^^xsd:double .

...
    
```


6. Queries in an extended EOWEB portal

The purpose of this chapter is to show that with the work carried out in WP6 we improve the state of the art in EO portals such as EOWEB that are aimed at end-user querying, but also data management systems available in EO data centers today, such as DIMS (Wolfmueller et al., 2009). We first present the categorization of queries that are possible in the TELEIOS system. Then we show how these queries can be realized using the data model stRDF, the query language stSPARQL++, and the Strabon system.

6.1. Types of queries

In this sub-section, we present some classes of queries that can be asked by EO users using the TELEIOS system. The categorization presented is not exhaustive, but serves to illustrate the expressive power of our annotation schemes and the query language stSPARQL.

1. **Query for a product and its metadata:** This type of query is based on the metadata extracted from the XML file of the TerraSAR-X products. A complete list of the metadata that can be used in a query is presented in Appendix, Tables 8 and 9.
2. **Query for an image and its metadata:** This type of query is based on the image and its attached metadata (e.g., geographic latitude/longitude). This can be useful for a fast query of a location knowing the latitude and longitude of the area (e.g., Venice: 12°17'21.50"E, 45°27'11.31"N or 12.34517226488142E, 45.4351575435622905N).
3. **Query for images of products that contain patches that have certain properties.** Queries of this type can be further categorized as follows:
 - a. **Query by the land cover/use class of a certain patch:** This type of query is based on the metadata annotated to the patches, according to the land cover/use classification scheme presented in Section 3.1 and in the Appendix.
 - b. **Query by the land cover/use class of a patch and the qualitative or quantitative spatial properties of a patch:** This type of query allows us to query for patches with some land cover/use class that are spatially related to other patches or to a user defined area. Here one can use various qualitative or quantitative spatial relations (Cohn, 1997) (Nebel et al., 1998) (e.g., topological, cardinal directions, orientation, distance)
 - c. **Query by correlating the land cover/use class of more than one patch that have various qualitative or quantitative spatial relations between them:** This type of query extends the previous query by allowing the correlation based on land cover/use class of multiple patches with various spatial relations between them.

- d. **Query that involves features of a patch but also other properties like the land cover/use class and spatial relations:** This type of query is based on the parameters of the feature extraction algorithms presented in D3.1. Using feature values in queries is very useful when we want to distinguish patches of the same semantic class that differ on specific properties.

Now by examining the above types of queries we see that existing EO portals such as EOWEB and DIMS offer partial or full support for asking queries of type 1 and 2, but cannot be used to answer any of the queries of type 3 and its subcategories. These are queries that can only be asked and answered if the knowledge discovery technologies of WP3 are applied to TerraSAR-X images and relevant knowledge is extracted and captured by semantic annotations expressed in stRDF. In other words these queries are made possible for users due to the advances of TELEIOS technologies.

Examples of these classes of queries are presented in sub-section 5.2. The structure of the examples that are presented in the next sub-section is: define the query class by choosing one of the four classes previously presented; transform this query into SPARQL, display the results of the query, and identify possible use cases /applications for this query. For each example, we try to identify use cases / applications that ZKI¹² has faced recently.

6.2. Examples of queries in stSPARQL++

In this section we show how the query language stSPARQL++ and the Strabon system developed in WP4 can be used to express the classes of queries discussed above. To do this we give examples of queries from the above classes.

For the given test data set we managed to express the data in RDF using appropriate Python scripts, and store them using the Strabon¹³ system. The following queries were written in SPARQL, as a proof of what the data can be used for. Results are presented in an informal manner, because they would occupy too much space in their full extent. However, the interested reader may find both the queries shown here, and their results, in the following location: <http://www.earthobservatory/misc/Queries.tar.bz2>

We now proceed with the queries:

1. **Query by the land cover/use class of a certain patch:** “Find all patches that correspond to a parking.”

```
SELECT ?p ?g
WHERE {
    ?x rdf:type dlr:Product .
    ?y rdf:type dlr:Image .
    ?x dlr:hasImage ?y .
```

¹² <http://www.zki.dlr.de/>

¹³ <http://strabon.di.uoa.gr/>

```

?y dlr:consistsOf ?p .
?p rdf:type dlr:Patch .
?p dlr:hasLabel ?l .
?p dlr:hasGeometry ?g .
?l rdf:type dlr:Label .
?l dlr:correspondsTo dlr:Parking .
    
```

}
Query results.

| ?p | ?g |
|--|---|
| dlr:QLK_TSX1_SAR_MGD_SE_HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_14_13.jpg | POLYGON ((1.407 43.599 , 1.410 43.600 , 1.410 43.598 , 1.408 43.598 , 1.407 43.599)) |
| dlr:QLK_TSX1_SAR_MGD_SE_HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_14_14.jpg | POLYGON ((1.410 43.600 , 1.412 43.600 , 1.412 43.598 , 1.410 43.598 , 1.410 43.600)) |
| dlr:QLK_TSX1_SAR_MGD_SE_HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_14_15.jpg | POLYGON ((1.412 43.600 , 1.414 43.600 , 1.415 43.599 , 1.412 43.598 , 1.412 43.600)) |

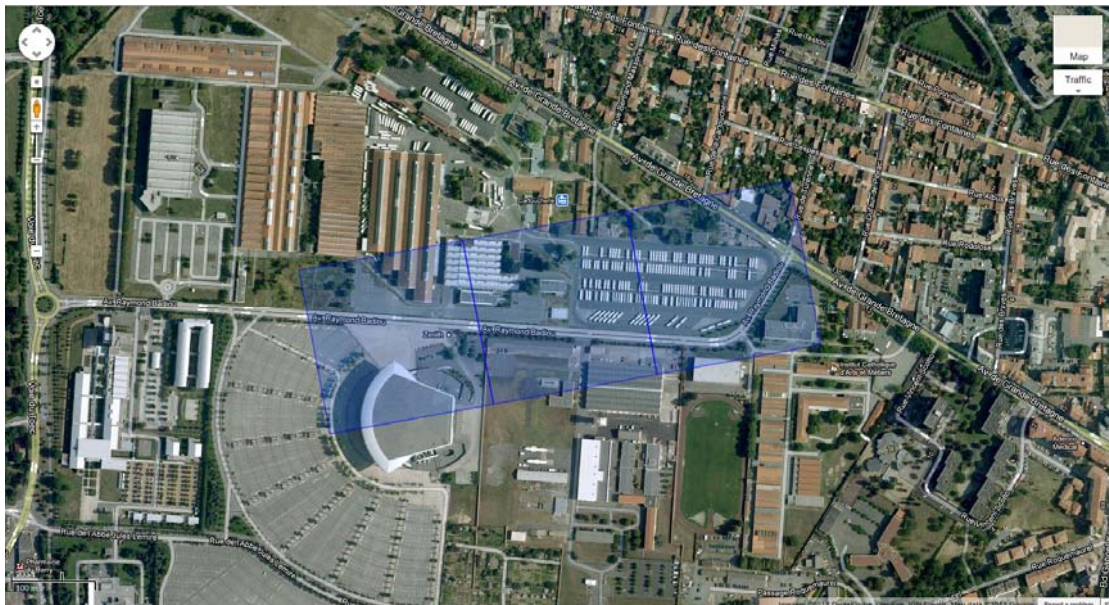


Figure 22: Query results projected on Google Maps.

In Figure 23 the results of the query containing parking areas are presented. Figure 22 also shows the results projected on Google Maps. This type of query can be useful for different applications like:

- Find parking in the case of a disaster (e.g., earthquake¹⁴) to build camps for those who lost their home or for the Red Cross.
- Analyse the parking occupancy and the relevant parking spaces available in the city or around for different events (a new ZKI scenario¹⁵) and for some special events (e.g., a concert or a football match).



QLK_TSX1_SAR_MGD_SE
 __HS_S_SRA_20071127T17
 4146_20071127T174147_IM
 AGE_HH_SRA_spot_038.tif_
 200_14_13.jpg

QLK_TSX1_SAR_MGD_SE
 __HS_S_SRA_20071127T1
 74146_20071127T174147_IM
 AGE_HH_SRA_spot_038.tif_
 200_14_15.jpg

QLK_TSX1_SAR_MGD_SE
 __HS_S_SRA_20071127T1
 74146_20071127T174147_IM
 AGE_HH_SRA_spot_038.tif_
 200_14_14.jpg

Figure 23: Query results of “Find all patches that correspond to a parking”.

2. **Query by the land cover/use class of a patch and the qualitative or quantitative spatial properties of a patch:** Find all the patches containing water limited in the north by the port.

```

SELECT  ?p1 ?g1
WHERE {
    ?x rdf:type dlr:Product .
    ?y rdf:type dlr:Image .
    ?y dlr:hasGeometry ?g .
    ?x dlr:hasImage ?y .
    ?y dlr:consistsOf ?p1 .
    ?p1 rdf:type dlr:Patch .
    ?y dlr:consistsOf ?p2 .
    ?p2 rdf:type dlr:Patch .
    ?p1 dlr:hasGeometry ?g1 .
    ?p1 dlr:hasLabel ?l1 .
    ?l1 rdf:type dlr:Label .
    ?l1 dlr:correspondsTo dlr:Water .
    ?p2 dlr:hasGeometry ?g2 .
    ?p2 dlr:hasLabel ?l2 .
    ?l2 dlr:correspondsTo dlr:Port .
    ?l2 rdf:type dlr:Label .
    
```

¹⁴ <http://www.zki.dlr.de/category/topic/10>

¹⁵ <http://www.zki.dlr.de/article/2114>

```

FILTER (strdf:above(?g1,?g2)) .
FILTER ( strdf:contains
        (strdf:buffer(?g2,0.005),?g1))
    }
    
```

Query results.

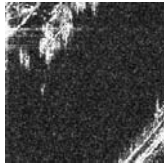
| ?p1 | ?g1 |
|---|---|
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _8_5.jpg | POLYGON ((12.305 45.440, 12.307 45.440, 12.308 45.439, 12.305 45.438, 12.305 45.440)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _10_6.jpg | POLYGON ((12.308 45.437, 12.311 45.437, 12.311 45.435, 12.309 45.435, 12.308 45.437)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _9_3.jpg | POLYGON ((12.300 45.438, 12.303 45.438, 12.303 45.436, 12.301 45.436, 12.300 45.438)) |
| ... | ... |



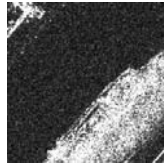
Figure 24: Query results projected on Google Maps.

The results of this type of query are presented in the next figure. Figure 24 also shows the results projected on Google Maps. Such a result can be useful for the port authority in order to monitor the port area.

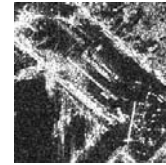
For other sites, this query can be extended in order to improve navigational safety in coastal regions near ports and other marine terminals that experience heavy traffic by large crude-oil carriers, towed barges, and other vessels of deep draught or restricted manoeuvrability.



QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T16
5907_20071124T165908_IM
AGE_HH_SRA_spot_047.tif_
200_8_5.jpg



QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T165
907_20071124T165908_IMA
GE_HH_SRA_spot_047.tif_20
0_10_6.jpg



QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T16
5907_20071124T165908_IM
AGE_HH_SRA_spot_047.tif_
200_9_3.jpg

Figure 25: Query results of “Find all patches containing water limited in the north by the port”.

3. **Query by correlating the land cover/use class of more than one patch that have various qualitative or quantitative spatial relations between them:** Find all patches that correspond to a road or railroad and are within 300 m distance of patches that correspond to an industrial area.

```

SELECT  ?p1 ?g1 ?p3 ?g3
WHERE {
    ?x rdf:type dlr:Product .
    ?y rdf:type dlr:Image .
    ?x dlr:hasImage ?y .
    ?y dlr:consistsOf ?p1 .
    ?y dlr:consistsOf ?p2 .
    ?y dlr:consistsOf ?p3 .
    ?p1 rdf:type dlr:Patch .
    ?p2 rdf:type dlr:Patch .
    ?p3 rdf:type dlr:Patch .
    ?p1 dlr:hasGeometry ?g1 .
    ?p1 dlr:hasLabel ?l1 .
    ?l1 rdf:type dlr:Label .
    ?l1 dlr:correspondsTo dlr:Road .
    ?p2 dlr:hasGeometry ?g2 .
    ?p2 dlr:hasLabel ?l2 .
    ?l2 dlr:correspondsTo dlr:Commercial .
    ?p3 dlr:hasGeometry ?g3 .
    ?p3 dlr:hasLabel ?l3 .
    ?l3 dlr:correspondsTo dlr:Railroad .
    ?p3 dlr:hasIndexI ?i3 .
    
```



```

FILTER(
  strdf:contains(strdf:buffer(?g2,0.007),?g1)
  ||strdf:contains(strdf:buffer(?g2,0.007),?g3)
)
}
    
```

Query results.

| ?p1 | ?g1 |
|---|--|
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_8_38.jpg | POLYGON ((1.465 43.618, 1.468 43.618, 1.468 43.617, 1.466 43.616, 1.465 43.618)) |
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_12_35.jpg | POLYGON ((1.460 43.610, 1.462 43.610, 1.463 43.608, 1.460 43.608, 1.460 43.610)) |
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_12_36.jpg | POLYGON ((1.462 43.610, 1.465 43.611, 1.465 43.609, 1.463 43.608, 1.462 43.610)) |
| ... | ... |
| ?p3 | ?g3 |
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_5_31.jpg | POLYGON ((1.447 43.621, 1.449 43.621, 1.450 43.620, 1.447 43.619, 1.447 43.621)) |
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_5_32.jpg | POLYGON ((1.449 43.621, 1.452 43.622, 1.452 43.620, 1.450 43.620, 1.449 43.621)) |
| dlr:QLK_TSX1_SAR_MGD_SE__HS_S_SRA_20071127T174146_20071127T174147_IMAGE_HH_SRA_spot_038.tif_200_6_32.jpg | POLYGON ((1.450 43.620, 1.452 43.620, 1.453 43.618, 1.450 43.618, 1.450 43.620)) |
| ... | ... |

This type of query “find patches that correspond to a road or railroad within 300 m distance of patches that correspond to industrial areas” can be useful for different applications like:

- Urbanism and environmental monitoring.

- Fast intervention of the civil protection authorities in case of explosions, fire or technical accidents in industrial areas¹⁶.

Figures 26 and 27 shows the results of this query projected on the Google Maps and three retrieved patches.

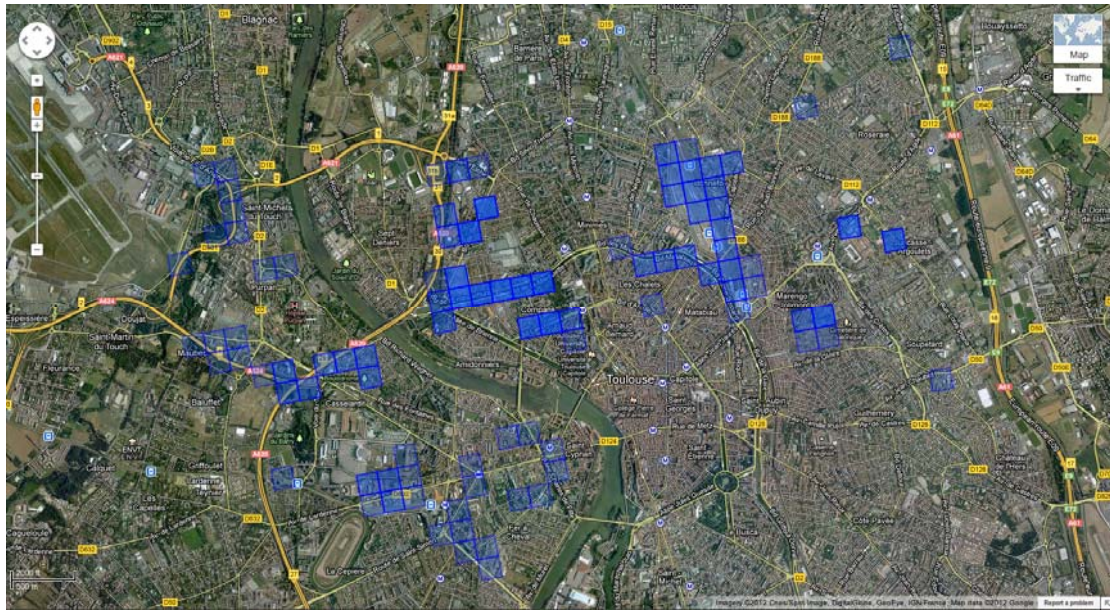
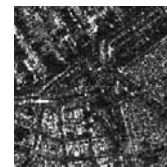
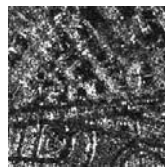


Figure 26: Query results projected on Google Maps.



QLK_TSX1_SAR_MGD_SE
 ___HS_S_SRA_20071127T1
 74146_20071127T174147_I
 MAGE_HH_SRA_spot_038.tif_
 _200_8_38.jpg

QLK_TSX1_SAR_MGD_SE
 ___HS_S_SRA_20071127T1
 74146_20071127T174147_IM
 AGE_HH_SRA_spot_038.tif_
 200_12_35.jpg

QLK_TSX1_SAR_MGD_SE
 ___HS_S_SRA_20071127T1
 74146_20071127T174147_IM
 AGE_HH_SRA_spot_038.tif_
 200_12_36.jpg

Figure 27: Query results of “Find all patches that correspond to a road / railroad (for Toulouse this is equivalent to the category roads and buildings) within 300 m distance of patches that correspond to industrial areas (for Toulouse this is equivalent to roof structures)”.

¹⁶ <http://www.zki.dlr.de/article/1655>

4. **Query by the land cover/use class of a patch and the qualitative or quantitative spatial properties of a patch:** Find all the patches that correspond to a port and are within a defined polygon.

```

SELECT  ?p ?g
WHERE {
    ?x rdf:type dlr:Product .
    ?y rdf:type dlr:Image .
    ?x dlr:hasImage ?y .
    ?y dlr:consistsOf ?p .
    ?p rdf:type dlr:Patch .
    ?p dlr:hasGeometry ?g .
    ?p dlr:hasLabel ?l .
    ?l rdf:type dlr:Label .
    ?l dlr:correspondsTo dlr:Port .
    FILTER ( strdf:contains(
        "POLYGON ((12.37112 45.446577,
        12.388287 45.447607, 12.389317
        45.434561, 12.371807 45.432158,
        12.37112 45.446577))",?g))
}
    
```

Query results.

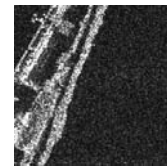
| ?p | ?g |
|--|---|
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _11_35.jpg | POLYGON ((12.382 45.444, 12.384 45.444, 12.385 45.443, 12.382 45.442, 12.38 45.444)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _12_34.jpg | POLYGON ((12.380 45.442, 12.382 45.442, 12.383 45.440, 12.380 45.440, 12.380 45.442)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _12_35.jpg | POLYGON ((12.382 45.442, 12.385 45.443, 12.385 45.441, 12.383 45.440, 12.382 45.442)) |
| ... | ... |

The results of the query are shown in Figure 29. Figure 28 also shows the results projected on Google Maps.

This query can be useful for monitoring coastal zones close to busy industrial ports (e.g., Rotterdam, Hamburg, Singapore, Shanghai, etc).



Figure 28: Query results projected on Google Maps.



QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T16
5907_20071124T165908_IM
AGE_HH_SRA_spot_047.tif_
200_11_35.jpg

QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T165
907_20071124T165908_IMA
GE_HH_SRA_spot_047.tif_20
0_12_34.jpg

QLK_TX1_SAR_MGD_SE_
_HS_S_SRA_20071124T165
907_20071124T165908_IMA
GE_HH_SRA_spot_047.tif_20
0_12_35.jpg

Figure 29: Query results of “Find all the patches that correspond to a port and are within in a defined polygon”.

5. **Query that involves features of a patch but also other properties like the land cover/use class and spatial relations:** Find the 1st feature value of the Gabor algorithm with 4 scales and 6 orientations, for a patch that corresponds to a bridge.

```
SELECT ?p ?g
WHERE {
    ?x rdf:type dlr:Product .
    ?y rdf:type dlr:Image .
    ?x dlr:hasImage ?y .
    ?y dlr:consistsOf ?p .
    ?p rdf:type dlr:Patch .
```



```

?p dlr:hasLabel ?l .
?p dlr:hasGeometry ?g .
?l rdf:type dlr:Label .
?l dlr:correspondsTo dlr:Bridge .
?p dlr:hasGAFSvector ?v .
?v rdf:type dlr:GAFS_Vector .
?v dlr:hasScales ?s .
FILTER (?s = "4"^^xsd:int ) .
?v dlr:hasOrientations ?o .
FILTER (?o = "6"^^xsd:int ) .
?v dlr:hasFeatureVectorValues ?fv .
?fv rdf:_1 ?fv1 .
FILTER (5 < ?fv1 && ?fv1 < 35.0)
    }
    
```

Query results.

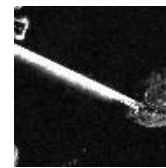
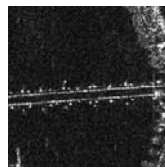
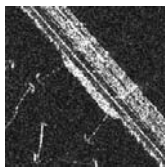
| ?p | ?g |
|--|--|
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _0_4.jpg | POLYGON ((12.299 45.454, 12.301 45.454, 12.302 45.452 , 12.299 45.452, 12.299 45.454)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _0_3.jpg | POLYGON ((12.296 45.454, 12.299 45.454, 12.299 45.452 , 12.297 45.452, 12.296 45.454)) |
| dlr:QLK_TX1_SAR_MGD_SE__HS_S_S RA_20071124T165907_20071124T1659 08_IMAGE_HH_SRA_spot_047.tif_200 _1_4.jpg | POLYGON ((12.299 45.452, 12.302 45.452, 12.302 45.451, 12.300 45.450, 12.299 45.452)) |
| ... | ... |

For illustration, the query patches are presented below in Figure 31. Figure 30 also shows the results projected on Google Maps.

This type of query can be extended from only one feature value to the full dimension of the feature vector (e.g., for all 48 feature values of the Gabor algorithm with 4 scales and 6 orientations) and it can be used for searching bridges that are grouped together semantically based on their feature vectors. Such an example was presented in Figure 13 for bridges collected from different cities (Venice, Toulouse and Ottawa) having different parameters.



Figure 30: Query results projected on Google Maps.



QLK_TX1_SAR_MGD_RE_
 __HS_S_SRA_20071124T16
 5907_20071124T165908_IM
 AGE_HH_SRA_spot_047.tif_
 200_3_6.jpg

QLK_TSX1_SAR_MGD_RE_
 __HS_S_SRA_20071127T174
 146_20071127T174147_IMA
 GE_HH_SRA_spot_038.tif_20
 0_20_24.jpg

QLK_TSX1_SAR_MGD_RE_
 __HS_S_SRA_20110802T1
 11219_20110802T111220_IM
 AGE_HH_SRA_spot_055.tif_
 200_0_7.jpg

Figure 31: Patches used for a bridge query.

6. **Query for a product and its metadata:** Find SAR scenes appropriate for permanent scatters with a given <dispersion> of the <elevation> of the permanent scatters as a function of the <number of data acquisitions> and of the <dispersion of the perpendicular baselines>.

```
SELECT ?x
WHERE {
    ?x rdf:type dlr:Product .
    ?x dlr:hasNominalSNR ?s .
    ?x dlr:hasCenterFrequency ?f .
    ?x dlr:hasBandwidth ?b .
    ?x dlr:hasSarAntennaPosition ?p .
    ?p dlr:hasPositionVectors ?pv .
```

```

?pv rdf:type rdf:List .
?pv rdf:x ?pvx .
?pv rdf:y ?pvy .
?pv rdf:w ?pvz .
FILTER (?s = " 2.81E+1"^^xsd:double) .
FILTER (?f = "9.65E+9"^^xsd:double) .
FILTER (?b = "3.00E+8"^^xsd:double) .
FILTER (?pvx = " 1.89E-1"^^xsd:double) .
FILTER (?pvy = "1.42E-9"^^xsd:double) .
FILTER (?pvz = "8.34E-8"^^xsd:double) .
}
    
```

Query results.

| ?p |
|---|
| dlr:TSX1_SAR_MGD_SE__HS_S_SRA_20071124T165907_20071124T165908 |

This is in the frame of query for a product with expected performance for permanent scatters InSAR measurement precision (*Rocca, 2004*). The metadata descriptors that need to be extracted from the xml file (an extension of the initial list is presented in Table 10 – Appendix) are: position vectors (*numstatevectors*), central frequency, bandwidth, signal to noise ratio, and Doppler.

Details regarding how to determine the Doppler are presented in the TerraSAR-X product description, Annex B pages 256-257 (*TSX, 2007*).

The atmospheric time jitter is assumed to be the noise source. A large baselines diversity involves an enhanced estimate of the elevations.

7. Conclusion

In this deliverable we discussed the ontologies for the Virtual Observatory in the case of TerraSAR-X data. The document is structured in three parts.

In the first part, we presented the two data sources: the TerraSAR-X image data and the XML file (the TerraSAR-X metadata) that has been proposed in Deliverable D3.1. In particular, we selected two other sites, namely Berlin and Ottawa in addition to those already studied Venice and Toulouse.

In the second part, these two types of data sources are analysed.

For the image, we provided an idea about the semantic categories that can be generated for available TerraSAR-X image data set. We start this with a general annotation of the patches (before the images were tiled and the feature extraction methods were applied to these patches) and we continue with an example how the multiple annotations can be applied for the available data set. For a more accurate annotation of the patches that takes into account the entire content of the patch, we proposed to have for the multiple semantic annotation a two-level annotation scheme concept, but before using this concept for a large amount of data, we need to evaluate the precision/recall metric of this multiple semantic annotation like the evaluation done for the generic annotation in D3.1. In future, we propose that such a confidence metric to be implemented directly in the system.

After that, we performed an analysis of the multi-resolution and scale influence in the annotation of the patches. The general idea is that the semantic annotation of the patch shall consider the resolution and the scale because sometimes the content of the patch can change.

For the metadata, we proposed a first list of elements extracted from the TerraSAR-X XML file that can be used for query.

In the last part, an RDFS ontology which captures the contents of the TerraSAR-X data sets to be used in the DLR use case was implemented and planned to be used further. The deliverable ends with a list of queries that are possible in an extended EOWEB portal. These examples of queries are realized using the data model stRDF, the query language stSPARQL++ and the Strabon system.

Almost each example has four parts:

- define the query,
- give the pseudo-code used for query,
- display the results,

and

- find some use cases/applications related with the ZKI topics.

8. Appendix

8.1. Annotation scheme details

In Table 4 a two-level classification scheme for annotating the patches is presented based on the initial scheme of Anderson (*Anderson et al., 1976*).

General remarks:

- Limit to few classes for this test, knowing some relevant ones will not yet be covered
- Hierarchical scheme is proposed; flat hierarchy, 2 levels - 2 digit number to identify classes, an adapted Anderson scheme
- Hierarchy can be by map scale / spatial resolution (e.g., Anderson: Level 1 = Landsat, >1:80,000; Level 2= 1:80,000; Level 4 < 1:20,000) with levels depicting more and more spatial detail
- Classification schemes (relevant classes, subdivisions and semantics) are application dependent! Application favoured here: SAFER context → Emergency response, preparedness
- Classification of land cover different from land use → final scheme will probably be mixed
- Classes might also reflect structural differences. Feature extraction from patches divides into structural classes. Structural differences (road, intersection, forked road) could still mean same semantic class (roads), depending on application.
- Classes may also consider detectability in SAR (e.g., corn versus other crops)
- Some L2 classes can possibly be further subdivided into structurally different classes (e.g., medium-density residential includes row buildings, and 'Blockrandbebauung'), or semantically / functionally different categories (High-density residential versus CBD - both might be structurally similar)
- Intact / destroyed could be a separate class, or as an added digit (0 not known, 1 intact, 2 damaged, 3 destroyed) → would be relevant to SAFER
- Classes to use could also be selected from e.g., different levels of the Anderson scheme, selecting only those considered relevant for the time being
- Not all available digits are used on either level → this leaves room for expansion of the scheme

8.2. TerraSAR-X metadata

In the next table, Table 8 the TerraSAR-X metadata extracted from the xml file with their corresponding type and description are presented (see also Deliverable D3.1).

| TerraSAR-X metadata | Type | Description |
|-----------------------|--------------|---|
| mission | VARCHAR(20) | Name of the mission |
| orbitphase | INT | Orbit phase |
| orbitcycle | INT | Cycle number |
| absorbit | INT | Absolute orbit number at start of scene |
| relorbit | INT | Relative orbit number |
| numorbitsincycle | INT | Nominal number of orbits per cycle |
| orbitdirection | VARCHAR(15) | Ascending or descending flag |
| sensor | VARCHAR(20) | Identifier of the sensor |
| imagingmode | VARCHAR(5) | Imaging mode: SM, HS, SL, SC |
| lookdirection | VARCHAR(5) | Look direction of the satellite sensor. |
| polarisationmode | VARCHAR(2) | Polarization mode of the antenna. Dual, single, Twin or quad |
| pollayer | VARCHAR(2) | Layer list HH, VV, e |
| producttype | VARCHAR(12) | Product identification scheme |
| productvariant | VARCHAR(3) | Type of geometrical projection and data representation |
| projection | VARCHAR(15) | Type of projection |
| resolutionvariant | VARCHAR(2) | Spatially (SE) or radiometrically enhanced (RE) |
| radiometriccorrection | VARCHAR(15) | Calibration of the image |
| pixelvalueid | VARCHAR(20) | complex amplitude and phase, radar brightness (beta nought), sigma nought, etc. |
| imagename | VARCHAR(500) | Name of the image file |
| imagedatatype | VARCHAR(8) | Image data type can be detect or complex |
| imagedataformat | VARCHAR(7) | Format of the image, tiff, geotiff, etc. |
| numberoflayers | INT | Number of image layers |
| imagedatadepth | INT | Image data depth refers to bits per pixel. |
| numberofrows | INT | Total of rows in the image |
| numberofcolumns | INT | Total of column in the image |
| groundrangeresolution | DOUBLE(53,0) | Resolution in range |

| | | |
|----------------------------|---------------|--|
| azimuthresolution | DOUBLE(53,0) | Resolution in azimuth |
| azimuthlooks | DOUBLE(53,0) | Effective number of looks |
| rangelooks | DOUBLE(53,0) | Number of looks in range |
| sceneid | VARCHAR(70) | Orbit and timing information |
| scenestartimeutc | VARCHAR(30) | Scene start time UTC refers time stamps of first image row |
| scenestoptimeutc | VARCHAR(30) | Scene stop time UTC time stamps of last image row |
| scenecentercoord_refrow | DOUBLE(53,0) | Reference row of the scene center |
| scenecentercoord_refcolumn | DOUBLE(53,0) | Reference column of the scene center |
| scenecentercoord_lat | DOUBLE(53,0) | Geographical latitude of the center of the scene |
| scenecentercoord_lon | DOUBLE(53,0) | Geographical longitude of the center of the scene |
| center_azimuthtimeutc | VARCHAR(30) | Time stamps of center image in azimuth |
| center_rangetime | DOUBLE(53,0) | Time stamps of center image in range |
| center_incidenceangle | DOUBLE(53,0) | Incidence angle in the center of the image |
| filename | VARCHAR(1000) | File name of EO product |
| productpath | VARCHAR(500) | Physical path of the product |
| scenecornercoord_lon | DOUBLE(53,0) | Geographical longitude of the corner of the scene (for all four corners) |
| scenecornercoord_lat | DOUBLE(53,0) | Geographical latitude of the corner of the scene (for all four corners) |
| scenecornercoord_refrow | DOUBLE(53,0) | Reference row of the corner of the scene (for all four corners) |
| scenecornercoord_refcolumn | DOUBLE(53,0) | Column of the corner of the scene (for all four corners) |
| referenceprojection | VARCHAR(128) | System of geographic reference |
| rowspacingunit | VARCHAR(1) | Units of row spacing (i.e m) |
| columnspacingunits | VARCHAR(1) | Unit of column spacing (i.e m) |
| rowspacing | DOUBLE(53,0) | Spacing of samples within a row |
| columnspacing | DOUBLE(53,0) | Spacing within a column |
| refcolumn | INT | Reference column of the image |
| refrow | INT | Reference row of the image |

Table 8: The metadata of the TerraSAR-X that can be extracted from the xml file.

The extended list of metadata needed for the permanent scatters query is presented in Table 9.

| TerraSAR-X metadata | Type | Description |
|--|--|--|
| numstatevectors | INT | The state vectors of the platform used for the processing. |
| centerfrequency | DOUBLE(53,0) | The center frequency |
| rangelookbandwidth azimuthlookbandwidth totalprocessedrangebandwidth | DOUBLE(53,0) DOUBLE(53,0) DOUBLE(53,0) | Total target bandwidth in acquisition is azimuthlookbandwidth * azimuthlooks or rangelookbandwidth * rangelooks |
| totalprocessedazimuthbandwidth | DOUBLE(53,0) | |
| snr | DOUBLE(53,0) | The nominal signal to noise ratio |
| validityrangemin validityrangemax referencepoint polynomialdegree coefficient_exponent_0 coefficient_exponent_1 numberofdopplerrecords | DOUBLE(53,0) DOUBLE(53,0) DOUBLE(53,0) INT DOUBLE(53,0) DOUBLE(53,0) INT | Doppler centroid estimates and derived parameters extracted from the xml file. coefficient = "0" coefficient = "1" |

Table 9: The extended metadata of the TerraSAR-X needed for permanent scatters query.

9. Bibliography

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