HIGH RESOLUTION OPTICAL AND SAR IMAGE FUSION FOR ROAD DATABASE UPDATING

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1. INTRODUCTION

With the recent (or in the very next future) availability of high resolution (HR) optical and radar satellite sensors (such as in the ORFEO program), the need of multi-sensor image processing chains that are able to assist a human expert in scene interpretation is increasing. We focus on the problem of cartographic databases creation/update in urban environment. More precisely, the generic processing chain presented in [1] to update and create building databases is modified for road processing. Input images are HR optical (in the range 70cm up to 2.5m) and/or radar (1m) satellite images. Several scenarios are considered depending on the available images and data.

Most existing road extraction strategies are specific to one sensor in single mode. For instance, many methods have been proposed to extract roads from a single optical image [2–5]. Some significant works have also been proposed for extracting a road network from synthetic aperture radar (SAR) images [6–10]. Multi-sensor algorithms for extracting roads have received less attention in the literature [11, 12]. For road extraction, the integration of exogenous data such as an outdated database can be very useful. Indeed, as roads are organized as a network, it is interesting to use prior knowledge [13–17] for their extraction. This paper studies a processing chain for road extraction integrating features coming from various sensors and exogenous data. The goal is to exploit all the available information on a scene (without including a wide temporal series of images).

2. PROCESSING CHAIN

The road extraction chain studied in this paper is depicted in Fig. 1. This chain has been inspired from the works conducted in [1] for creating and updating building databases. The road database updating is performed in two steps. First, we check whether roads coming from the database are present in the images. To do so, we identify features that characterize roads in input images. These features (extracted from images) are then fused to obtain for each object the likelihood of being a road. The second step of the proposed road extraction chain consists of detecting roads outside the database. This step is performed using automatic or semi-automatic road extraction algorithms from multispectral images [3] and SAR images [7]. A score computed as for road database verification is assigned to each detected road section. Detected roads are then included to the database according to their score and their proximity with the verified road network.

3. FEATURE EXTRACTION

The goal of feature extraction is to find clues in images about the presence of roads. As our approach must be generic, we have to find features common to most kinds of roads. Road characterization in optical and SAR images is illustrated in Fig. 2. A typical road has the following properties: it contains linear and parallel boundaries, does not project a shadow (contrary to buildings), contains no vegetation, appears as a strip of homogeneous radiometry in optical images, and as a strip of low intensity in SAR images. Once primitives have been extracted from input images, appropriate features are computed providing a score associated to the presence of roads. The computed features depend on the images available for road extraction. The features considered in this paper have been chosen from the existing literature on road extraction and from a previous study conducted in [1] for building extraction. The considered features are summarized below:

1. **Line segments:** We compute the percentage of road pixels that contain an extracted segment parallel to the road centerline in their neighborhood.

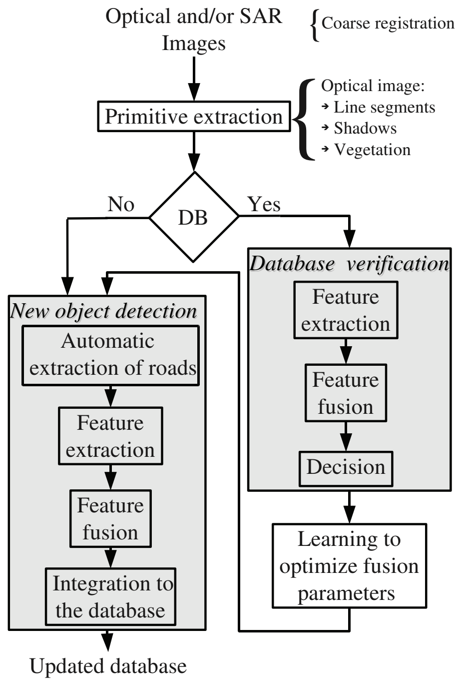

Fig. 1. Processing chain

2. **Shadow:** As we know the direction of the sun, we compute the percentage of road pixel that project a shadow (a shadow mask is obtained thanks to a thresholding of the optical image).
3. **No vegetation:** We determine the percentage of non vegetated pixels located along the road centerline (a vegetation mask is obtained thanks to a thresholding of the NDVI [18] of the multispectral image).
4. **Homogeneous strip:** A central region (region 1) is defined around each road section. Two other regions (denoted as regions 2 and 3) are defined on both sides of this region. We use an image representing the spectral angle with respect to an asphalt reference pixel in multispectral images. The corresponding score is the ratio of means defined as $\text{score} = \log\left(\frac{m_1}{m_{2,3}}\right)$, where m_1 and $m_{2,3}$ are the means of the spectral angle image computed for region 1 and regions 2 and 3 respectively.
5. **SAR low intensity strip:** Considering the same regions as for the homogeneous strip, a score is defined as the ratio of means $\text{score} = \log\left(\frac{m_1}{m_{2,3}}\right)$, where m_1 and $m_{2,3}$ are the means of the SAR image in region 1 and regions 2 and 3 respectively.
6. **Building processing chain:** The processing chain for building database creation/update [1] can be used to provide a likelihood of being a building for each region of the image. Roads can be close to buildings but cannot cross them. Consequently a low score will be attributed to a road crossing a building.

This list of features is far from being exhaustive. However it will appear to be sufficiently efficient for our application. Moreover, once the strategy of how to include new features has been set up, new features can be easily integrated to our generic processing chain. The score indicating the likelihood of being a road is computed from a fusion procedure described in the next section.

4. FEATURE FUSION

The feature fusion gathers all the available knowledge to obtain a score for each object. Based on this score, a decision can be taken to include or not a road section in the database. As explained in [1], the Dempster-Shafer evidence theory has interesting properties for data fusion. It can be considered as a generalization of Bayesian theory allowing one to handle imprecise information. However, it requires less prior information than Bayesian theory, facilitating the integration of new features in the chain. More details about the proposed Dempster-Shafer strategy for data fusion will be provided in the final version of this paper.

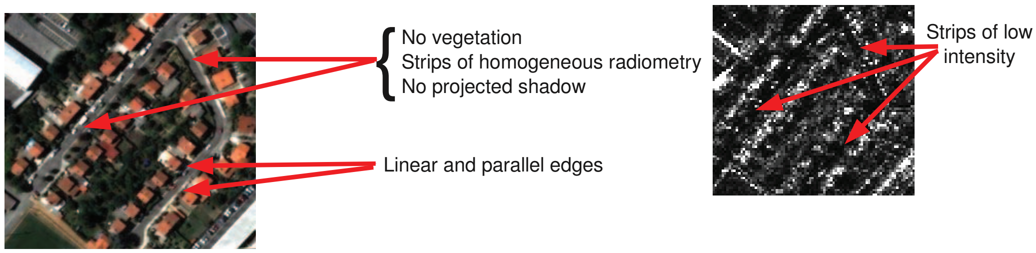

Fig. 2. Characterization of roads in optical and SAR images

5. RESULTS

Many experiments have been performed to evaluate both the road database verification and the detection of new roads. The images considered in this paper have been acquired over Toulouse, France, in an urban environment. More precisely, we used a Pleiades simulated image (coming from the airborne sensor PELICAN downsampled to 70cm and to 2.5m) and a TerraSAR-X satellite image at 1m resolution associated to the same area. Road databases contain vector data representing the 2-D coordinates of road centerlines. Results are evaluated using measures of correctness, completeness, and quality defined in [19]. Table 1 shows the results of the database verification step for various scenarios. The input images include optical panchromatic (P), optical multispectral (XS) and SAR images. Note that the results shown in Table 1 have been obtained without using the building processing chain. To evaluate the method, a database containing a ground truth for roads has been considered. False roads have also been included in the database. The proposed results illustrate the capacity of the processing chain to remove false roads and to keep true roads in the database. Table 1 shows that the first four cases lead to similar results. A 70cm panchromatic image is sufficient for the road verification. In this case a 1m SAR image or a multispectral 70cm image do not improve results. However if only a 2.5m panchromatic image is available (Case 8), a lot of roads are rejected. In this case the presence of an SAR image (Case 7) and/or a multispectral image (Case 6) improves the results. Fig 3 shows some detailed results projected on the optical and on the SAR image for Case 1. Results concerning the detection of roads outside the database will be presented in the final paper.

Table 1. Database verification results.

Case	Data	Correctness	Completeness	Quality
1	XS 70cm + SAR 1m	93.4	84.6	0.798
2	XS 70cm	90.7	88.1	0.808
3	P 70cm + SAR 1m	90.4	89.5	0.817
4	P 70cm	90.3	89.4	0.816
5	XS 2.5m + SAR 1m	83.9	76.1	0.664
6	XS 2.5m	83.6	79.2	0.686
7	P 2.5m + SAR 1m	80.5	66.9	0.576
8	P 2.5m	95.2	39.0	0.383
9	SAR 1m	82.5	35.3	0.328

6. CONCLUSION

This abstract presented a generic processing chain to create/update road databases. The road database verification was tested for various scenarios including optical panchromatic, optical multispectral and SAR images. Note that this processing chain was implemented using CNES ORFEO Toolbox free software `http://www.orfeo-toolbox.org` and that it can be used jointly with a similar building processing chain to improve the scene interpretation.

7. REFERENCES

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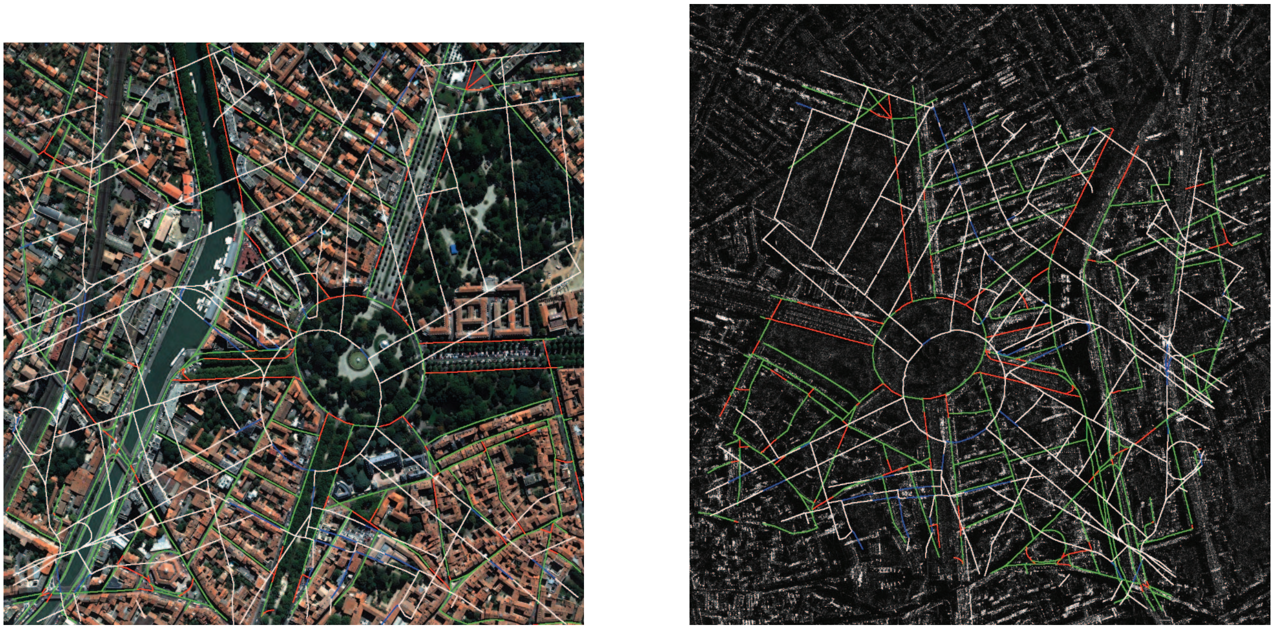

(a) Results projected on the multispectral image

(b) Results projected on the SAR image

Fig. 3. Results of database verification for Case 1 with the following colors: true roads correctly detected, true roads not detected, false alarms, and, in white, false roads correctly rejected.

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