Building detection from disparity of edges

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ABSTRACT: The availability of metric or sub-metric satellite images like Ikonos or Quickbird has enabled the fast and automatic detection of man-made structures for applications such as risk or damage assessment and change detection. In particular, the use of stereo pairs reveals the third dimension so distinctive for buildings and responsible for artefacts like shadow and occlusions complicating traditional 2D approaches. Unfortunately, areas to be studied are quite large and algorithms for height estimation are computationally demanding. We propose a simple and fast approach for building detection which computes the disparity at pixels of sufficient gradient and highlights linear segments so representative of building outlines. We have applied it to an Ikonos pair aiming at detecting large buildings in the context of security within the GMOSS Network of Excellence.

1 INTRODUCTION

The currently available images from very high resolution (VHR) satellite like Ikonos or Quickbird has enabled the remote detection of man-made structures. See for instance the work of Fraser et al. (2001) who present their evaluation of Ikonos imagery for geoposioning accuracy and radiometric quality as well as building reconstruction from stereo Ikonos images. Based on the processing of satellite image data, the solution can be automatic and fast. The Ikonos or Quickbird satellites offer for each capture a quite comfortable area of more than 100 km^2 with a *revisit time* of a few days allowing frequent update. All these properties make VHR satellite images suited for applications such as risk assessment, damage assessment or change detection.

Many studies have been reported on the use of Ikonos or Quickbird images for building detection as referred to and exemplified in Jin & Davis (2005). In particular, the availability of stereo pairs of satellite images has been used (Fraser et al. 2001, Vozikis 2004) to exploit the third dimension so distinctive for elevated man-made structures like buildings.

In risk or damage assessment for security applications, areas to be studied are likely to be large. Fast response with even partial information is welcome. We propose a simple and fast approach for building detection which computes the disparity between two Ikonos or Quickbird images of a stereo pair. To focus on man-made structure and speed up processing, only segments of sufficient gradient are considered for disparity estimation. Segments with sufficient disparity highlight elevated lines so representative of building outlines.

2 APPROACH

We aim at detecting buildings in satellite images for risk assessment (e. g. the localization of industrial areas) or change detection. When considering monocular images, buildings appear thanks to linear edges related to roof borders and possibly shadow cast. However, linear segments are also present due to roads, parking lots or field separation. To better highlight buildings from these other linear candidates, their elevation can be estimated thanks to the disparity of matching segments in the left and right images of a stereo pair.

Figure 1. Part of the left and right images of the Ikonos stereo pair.

For disparity estimation, many approaches are possible, as surveyed by Brown et al. (2003). Observing the instability of the intensity of roof areas depending on sun elevation and sensor inclination, we adopted a feature matching approach, matching the edges of homogeneous areas like roof ridges and roof limits. Matching edges also result in much less points to be compared for pairing.

The algorithm is divided into three parts. First, each image is processed to detect edge candidates linked into thin segments, storing gradient magnitude and orientation information. Secondly, edge candidates of the left and right images are paired according to gradient magnitude and orientation in order to derive disparity values. Finally building candidates are highlighted by segments of high disparity. These can be further filtered based on segment length or straightness.

2.1 *Edge detection*

At each pixel (x,y), we measure the horizontal and vertical derivatives of image intensity I:

$$Gx = I(x+1,y) - I(x-1,y) \quad \text{and} \quad Gy = I(x,y+1) - I(x,y-1) \tag{1}$$

to derive the gradient vector whose amplitude G and orientation θ are:

$$G^2 = Gx^2 + Gy^2 \quad \text{and} \quad \tan(\theta) = Gy/Gx. \tag{2}$$

As most buildings exhibit lines with clear contrast, we look for connected pixels with sufficient gradient magnitude thanks to a linking procedure. This consists in connecting neighbouring pixels with sufficient gradient and consistent orientation. In our implementation, scanning the image from top to bottom and left to right, each pixel of sufficient gradient is retained as segment seed. Then pixels are added to growing segments as long as the strongest pixel (maximal gradient) of the three 8-neighbors 'perpendicular' to the seed orientation has enough gradient and consistent orientation (absolute difference with seed pixel less than 22 °). Segments which are too short are abandoned.

The result of the linking procedure is a set of 1-pixel thick segments, more appropriate for matching than initial gradient pixels thanks to their better localization and reduced number of pixels. Fig. 2 shows the results of extracting thin segments of images of Fig. 1. Segments are displayed with a hue related to their orientation and intensity related to the edge strength.

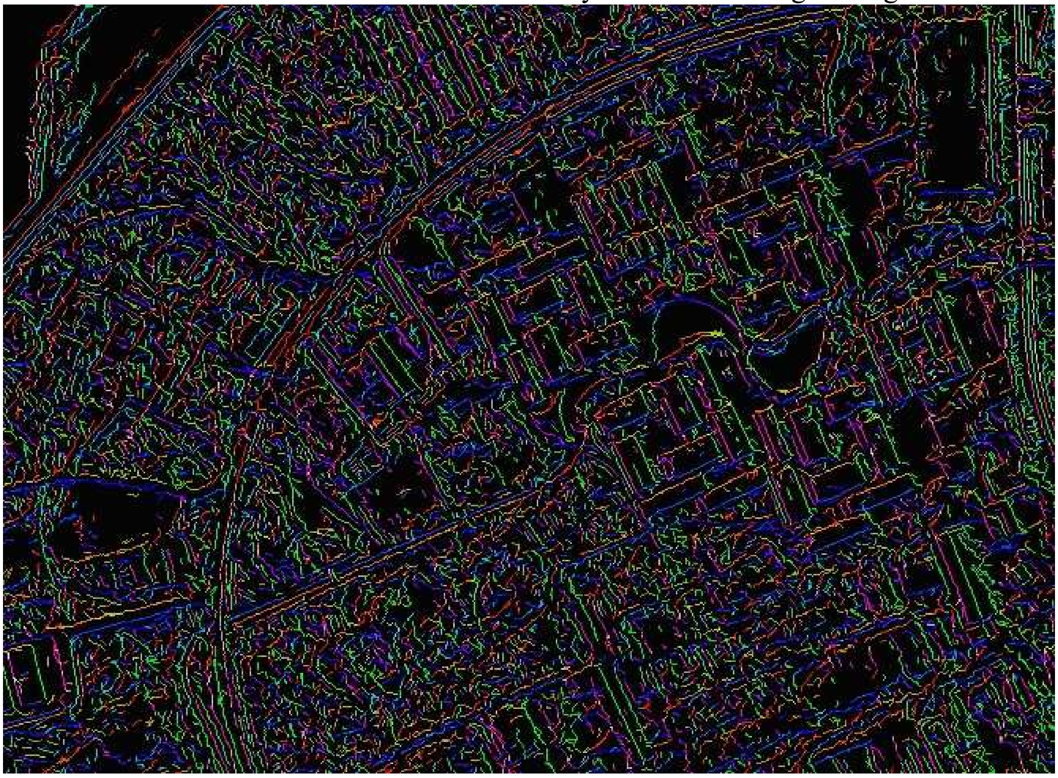

Figure 2. Thin edge segments obtained from the left image of Fig. 1.

2.2 *Disparity*

Disparity estimation consists in trying to pair corresponding edges from the left and right images. Fortunately, in the case of Ikonos images, stereo pairs can be acquired with epipolar resampled images, meaning that left and right projections of an object point are horizontally displaced with amplitude depending on the object elevation. This property simplifies the matching to a 1-dimensional search problem.

For each pixel of the left image, a range (*min_disp* up to *max_disp*) of pixels of the right image with the same vertical coordinate is considered. The right image pixel with sufficient gradient magnitude and maximal similarity in gradient orientation with the left pixel is kept as corresponding point so that the disparity is the difference between the right and left horizontal coordinates.

Disparity estimation typically suffers from ambiguity, meaning that several candidates are present and difficult to correctly rank. In the present implementation, the sought buildings are quite large (more than 20 pixel/20 m long); the expected disparity range is roughly known (available terrain model – SRTM, usual building height, known capture geometry with Baseline / Height ratio stored with image); and the number of edges with correct direction is limited. These factors favour small ambiguity.

However, edge features can be quite different in the two images due to the difference in viewpoint possibly modifying border orientation, intensity levels, occlusion and shadow cast. Better results are expected from lower B/H ratios, leading to more similar left and right images, arguing that the implied lower elevation precision is not critical for our application.

2.3 *Building detection*

The detection of buildings is based on the localization of edge segments whose elevation is beyond some threshold value relative to neighbouring elevation.

In security applications, an accurate elevation value is often not necessary. A rough height measure relative to the neighbourhood suffices. In that case, disparity values in pixel may be directly interpreted when looking for elevated objects.

Due to the variety of building shapes and appearances (contrast, occlusion), complete building outlines are unlikely to be detected. Each elevated linear segment is a possible building candidate. To reduce false alarms and increase robustness, geometrical constraints help to filter candidates (segment length and straightness, closeness of parallel or perpendicular segments).

3 APPLICATION

The approach has been applied in the context of GMOSS to the case of building detection in a stereo pair of Ikonos images around Bagdad, Iraq. GMOSS (Global Monitoring for Stability and Security) is a network of excellence in the Aeronautics and Space priority of the 6th Framework of the European Union lasting from 2004 to 2008. Part of the GMES program, GMOSS aims at integrating civil security research to acquire and maintain expertise for global monitoring using satellite earth observation. One of the GMOSS objectives is to establish links between researchers and organizations. This was for instance achieved with several test cases related to real situations through which partners could contribute depending on their expertise.

Thanks to GMOSS, we obtained Bagdad data in the form of a pair of Ikonos images. We intended to apply detection of medium or large buildings thanks to disparity estimation for risk assessment. Industrial areas, mainly consisting of large buildings, are indeed sensitive regions in crisis situations, either as a potential target or due to dangerous products.

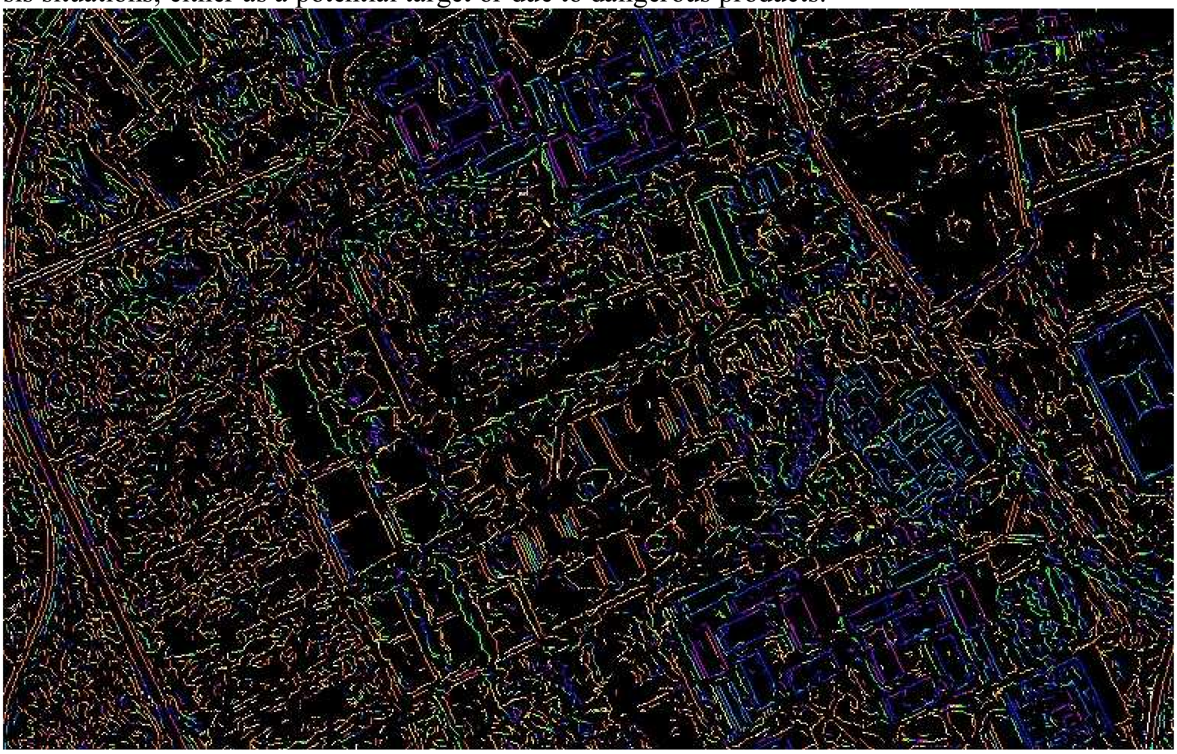

Figure 3. Disparity from a stereo pair of images near Bagdad using the rainbow false colouring. Ground objects are red or orange while elevated buildings are in green, blue or violet.

Results of disparities estimated from thin segment edges by our approach are shown in Fig. 3 in rainbow false colours (red and orange are low disparities; yellow and green are middle disparities; blue and violet are high disparities). The disparity map of an area of 1Mpixel (1 km^2) was processed in about three seconds on a 2Ghz PC, showing the rapidity of the approach. Most of the time is devoted to gradient computation. Building segments are clearly highlighted (in green, blue and violet) and distinguished from other linear objects thanks to their height attribute. For instance, mention the fields characterized by a rather uniform intensity and a rectangular shape with similar size as large buildings. Their outline mostly appears in red or orange corresponding to a low elevation, and sometimes in green, but with low intensity, when bordered by trees. Roads are also clearly out of focus when considering elevation. Close to buildings, many shadow casts are depicted in red or orange, as they are projected on the ground. Fig. 4 confirms these results (without edge thinning for better legibility) for a larger area of the Ikonos image.

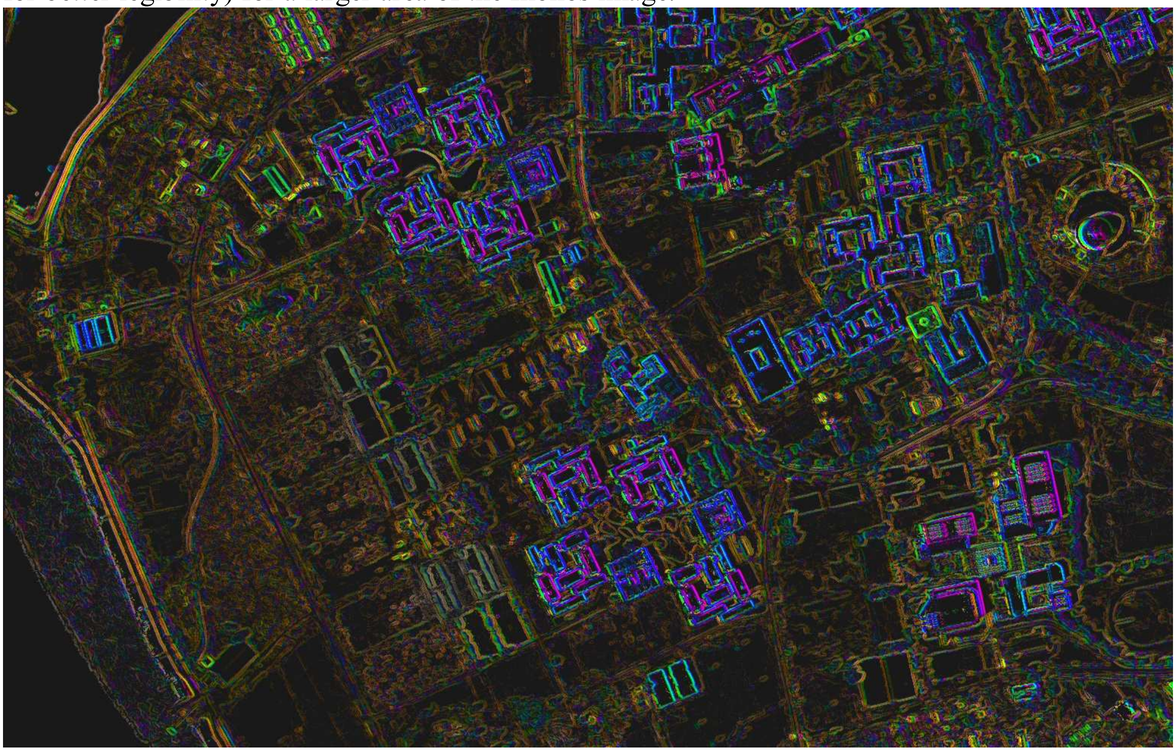

Figure 4. Chromo-disparity without thinning edges (for better legibility) for a larger part of the Ikonos image.

These qualitative results are very encouraging. Quantitative results are to be obtained thanks to a shape database of buildings in the area serving as ground truth, which will also allow us to demonstrate the change detection and damage assessment potentials.

Although well adapted to detect large or medium size buildings (> 20m), smaller structures need more accuracy and special care when detecting edge. The addition of a straightness constraint (Beumier 2006) when detecting edge segments to focus on human structures earlier in the process will prevent from matching many useless segments and will allow for more precision in disparity thanks to sub-pixel estimation. In particular, the disparity of nearly horizontal segments will be correctly estimated although individual pixel matching is ambiguous in that case.

Comparing edge features for disparity estimation is successful for images sufficiently similar, what normally happens for limited values of the B/H ratio. Otherwise the difference in sensor direction may lead to large change in intensities, occlusions or shadows, also depending on the sun elevation and azimuth.

4 CONCLUSIONS

We have presented the rapid detection of elevated buildings from VHR satellite images based on the disparity estimation from edge segments with sufficient contrast and coherent orientation. Qualitative results are promising regarding the simplicity of the approach.

The limitation of the current technique is due to large changes in radiometric or geometrical appearance of buildings as it may happen when the points of view of the left and right images are very different.

In the future, we intend to introduce a straightness constraint during segment detection so that disparity can be evaluated directly to matching segment pairs. This will reduce the computation load and will allow for sub-pixel localisation.

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