An attempt to derive a DEM and ortho-photo map from hyperspectral data in the high resolution mode (Casi/SWIR)

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ABSTRACT: Future Remote Sensing data will include hyperspectral data more and more. This study frames the preliminary studies to investigate the possibilities of these types of data. In this framework experimental flights were organised by VITO (Flemish Institute for Technological Research) and OSTC (Federal Office for Scientific, Technical and Cultural Affairs) on 13th of September 2002 with a Dornier 228 aircraft carrying the CASI/SWIR sensor, over different test sites in Belgium. The flights were done by NERC and VITO and framed in the STEREO-program of OSTC.

This paper deals with the “Ghent test site” over a peri-urban area, and focuses on the 3D-geometry of these data. These hyperspectral data are characterised by relief-displacement and differences in relief. These displacements occur in a direction away from the centre of the image. For remotely sensed images this is the direction away from the flight-line. In the monoscopic analysis of such images, these displacements will disturb the interpretation, the classification and the mapping of the image information.

These distortions can be compensated for with a DEM. Very often this DEM has to come from an external data source such as laser scanning or aerial photography. However, when hyperspectral data is taken stereoscopically, it is possible to derive a DEM from these stereoscopic hyperspectral images, and so avoiding the cost to purchase an external DEM.

To obtain stereoscopic imagery, two images were taken with an overlap of 80% in the so called “metrical mode” i.e. with a high spatial resolution (0.5m) and a lower spectral resolution. A third image was taken in “spectral mode”, for interpretation issues. A DEM and orthophoto were generated from the hyperspectral data by means of digital photogrammetry. A number of Ground Control Points were collected for absolute orientation, by means of DGPS. The geometric precision of the DEM and orthophoto derived from these data are evaluated using DEM and orthophoto derived from aerial pictures on different scales.

1 INTRODUCTION

How can hyperspectral data contribute to the extraction of 3D geometric and thematic information over urban and suburban areas? An attempt was made to answer this question using the hyperspectral data that were collected in a flight campaign on September 13 2002. This campaign framed in the OSTC APEX exploitation programme and provided seven Belgian research teams with hyperspectral data spread over several test sites. Research teams from Universities of Ghent (UGent), Brussels (VUB, ULB) and Liège (Ulg) dealt with the data over the urban and suburban area. This frames in the larger SPIDER-project (improving Spatial Information extraction for local and regional DEcision makers using Remotely sensed data) by the aforementioned teams.

The role of the UGent and Ulg research groups was to derive a Digital Surface Model (DSM) and an orthophoto from the hyperspectral images. A DSM is needed to correct the images for the image displacements caused by the terrain relief and building height. A DSM can be obtained from external sources e.g. aerial photography, laserscanning, but this can be very expensive, since it requires an extra flight and other instruments. Thus, if a DSM can be obtained with the same flight and the same sensor as for the hyperspectral data, this reduces the cost.

2 FLIGHT PLANNING AND STUDY AREA

The study area is located in the southern part of the city of Ghent (Belgium), and measures approximately 200 m by 1000 m. The reason for the small
size of the study area is the low flight height of the platform. This was necessary to obtain the highest possible spatial resolution with the hyperspectral sensor. As shown on Fig. 1 there are three flight strips.

![Figure 1. Overview of the three flight strips](image)

Each flightline corresponds with one hyperspectral image. Two images were made in, what was called, the “metrical mode”, at a spatial resolution of 0.52 m, with 10 spectral bands. Another image was made in the “hyperspectral” mode with a spatial resolution of 1.21 m, with 48 spectral bands. The altitude of the platform was 370 m and 970 m.

The two metric images were taken with a cross-track overlap of 80% to obtain a stereoscopic effect that eventually allows to derive a DSM from the images.

The flight planning was developed in cooperation with VITO (Flemish Institute for technological research) who coordinated the whole of the mission, and the flight was done by NERC (Natural Environment Research Council, UK)

3 FLIGHT CAMPAIGN

3.1 Platform and sensor

The CASI sensor (Compact Airborne Spectrographic Imager) was mounted on a Dornier 228. The plane was equipped with INS/GPS instruments for the geometrical calibration of the images.

3.2 Ground measurements

Simultaneously with the flight, there were three types of ground measurements. A sunphotometer and a spectroradiometer were used for measurements needed for the radiometric calibration of the images. This was done by VITO. A differential GPS system on the ground recorded data during the flight.

The GPS antenna was installed on a point for which the coordinates are known both in the WGS84 system as in the Belgian Lambert 72 system. Two backup systems were also recording at the same time.

3.3 Ground Control Points (GCP)

A total number of nine GCP were measured over the site, using real time differential GPS. The accuracy of the measured points is 0.05 m.

4 DATA PREPROCESSING

The radiometric, geometric and atmospheric corrections of the hyperspectral data was carried out by VITO and will not be further explained in this context. A more extended documentation on this topic can be found in “Operational Airborne Imaging Spectroscopy in Belgium” (W. Debruyne et. al. 2003)

However, it has to be mentioned that this geometric correction does not concern the image displacements due to terrain relief and building height. It only corrects for the attitude of the platform at the moment of capture, using the data from the onboard GPS and the fixed GPS antenna on the site.

![Figure 2. Comparison of the uncorrected (left) and the corrected image (right)](image)

5 PHOTOGRAMMETRICAL PROCESSING

The photogrammetrical processing of the hyperspectral data and the GCP was done with the VirtuoZo 3.2 softcopy photogrammetric software.

5.1 Band reduction

The first step is to reduce the ten bands of the two metric images to three bands, because the software only allows 3-band tiffs. Two methods were tested for band reduction. In the first method, all the bands were grouped, meaning that all the bands in the green spectrum were used for green etc. In this way, a true color composite was obtained.
The second method was to select the three bands that react the best to the matching algorithm. Each corresponding band of the images was tested iteratively with the matching algorithm that is used for the relative orientation. The number of homologous points that was found varies from 60 to 106, with a maximum of four iterations before convergence was achieved. The RMS is approximately 0.2 pixel for each of the separate bands. These results are shown in Table 1.

## Table 1. The number of points that was found with the matching algorithm.

<table>
<thead>
<tr>
<th>band</th>
<th>interval</th>
<th>number of points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>467.4nm+-17.9nm</td>
<td>74</td>
</tr>
<tr>
<td>2</td>
<td>502.9nm+-16.1nm</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td>540.5nm+-19.9nm</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>581.1nm+-19.1nm</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>639.0nm+-10.6nm</td>
<td>49</td>
</tr>
<tr>
<td>6</td>
<td>670.4nm+-19.2nm</td>
<td>68</td>
</tr>
<tr>
<td>7</td>
<td>725.9nm+-34.6nm</td>
<td>86</td>
</tr>
<tr>
<td>8</td>
<td>795.9nm+-33.8nm</td>
<td>101</td>
</tr>
<tr>
<td>9</td>
<td>866.2nm+-34.8nm</td>
<td>96</td>
</tr>
<tr>
<td>10</td>
<td>926.0nm+-23.3nm</td>
<td>106</td>
</tr>
</tbody>
</table>

This table shows that bands 8, 9 and 10 respond best to the matching algorithm, and those bands were used to make a false color composite. The bands 8, 9 and 10 were respectively coloured in the red, green and blue band.

## Figure 3. The result of the false colour composite with bands 8, 9 and 10

### 5.2 Orientation

#### 5.2.1 Relative orientation
In this phase about 100 homologous points are automatically found on the images. A manual check of the result showed that many points were on the edge of shadow areas. The time gap between the moment of capture of both the images is fifteen minutes. This means that the shadow of a 20 m high building has moved 1.3 m in this time, which is more than twice the pixel size. This error does not become clear in the RMS that is returned.

To avoid the influence of shadow displacement the relative orientation has to be done manually. 70 homologous points were selected like this before the RMS converged.

#### 5.2.2 Absolute orientation
When absolute orientation was performed with the nine GCP that were measured with GPS, no height information could be derived from the stereo model. The reason for this is the low B/H ratio. With the base being 20% of 200 m, and the flight height of 370 m the B/H ratio is 0.11. This probably explains the poor quality of the stereo model.

Since all the GCP measured with GPS are at ground level, and the terrain is relatively flat, the height of all the objects on the terrain has to be extrapolated. Therefore four points were measured at the rooftop level, based on a stereo model of 1/12,000 aerial photography with a resolution of 0.14m. In this way GCP are available as well for the lower parts (ground level) as for the higher parts (rooftop level) in the area.

### Figure 4. Interface for the relative and absolute orientation
5.3 Automatic parallax matching in the stereomodel

Once the orientation of the stereo model is known, the parallaxes can be calculated automatically, and the DSM and orthophoto are generated. The results from the automatic DSM generation are not satisfactory and the automatic process needs to be manually redirected at certain points. This is done in 2 steps of editing. Figure 5 shows the concept of these editing steps.

![Initial DSM to final DSM](image)

Figure 5. Scheme of the stereo model editing process showing the example of a single house.

In a first editing step breaklines are manually added to the stereo model. In general these breaklines are roof boundaries. Next to line features, also point (top of belltower) and area features (flat roofs) can be added. The absolute condition for a feature to be selected as breakline is that it must be clearly visible in both photographs of the stereo model. These breaklines act as a restriction for the matching algorithm. After the breaklines and the automatic parallax calculations, the stereo model still needs to be edited. In this step we ensure that the height contour lines fit close to the buildings. From a methodological point of view we can say that in the first step a rooftop level DSM is created, and in the second step a DSM at ground level is made. In the literature this concept of DSM generation is referred to as the Merging Method (Skarlatos, 1999).

6 CONCLUSION

As a conclusion of this series of experiments we can state that cross-track stereo overlap with two nadir images is not a good situation to obtain a good stereo model, and thus a good DSM and orthophoto. But as spatial resolution will probably improve in the future, better results will be possible. Future test sites should be larger and extend over a wider urban area.

![Final DSM](image)

Figure 6. The resulting orthophoto after the editing of the stereomodel.
Figure 7. The DSM after the stereo model editing. It is clear that there are some errors, caused by the low B/H ratio.

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