Usability of IKONOS images as a basis of data capture for the NascaGIS

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ABSTRACT: The primary requirements of any GIS application are the data, which can be obtained e.g. by field measurements, photogrammetric techniques or very high resolution (VHR) satellite images. The potential of the VHR satellite images allows the extraction of accurate spatial information for a multiplicity of GIS applications. In general, VHR images can be used for data capture; it only depends on the accuracy to be achieved. Because of the special astronomical investigations in the Nasca Project Dresden, sub-meter accuracy is needed. The two major questions to be answered are the influence of the DTM (Digital Terrain Model) accuracy on the orthorectification of the satellite data and the accuracy of the data capture itself. Besides of the existing DTM’s, worked out by digitizing contour lines, especially the SRTM data were analyzed regarding to their usability for the orthorectification of the IKONOS data. The orthorectification with SRTM-1 (X-Band) as well as with SRTM-3 (C-Band) has brought very good results in the plain of the Pampa of Nasca, where sub-pixel accuracy was achieved for the vector data capture. More problematic are the mountainous areas, because the partially large height discrepancies affect significantly the orthorectification especially of the off-nadir satellite images, which result in less accuracy of the vector data. Nevertheless, because most of the lines and figures at the Pampa of Nasca are situated in the flat area, the orthorectified satellite images can be used for the GIS data capture in an adequate accuracy.

1 INTRODUCTION

One of the most fascinating mysteries of the world are the famous Lines and Figures at the Pampa of Nasca and Palpa in the south of Peru, which have their seeds in the pre-Columbian Nasca culture (approx. 200 BC – 650 AC). Several hundred square kilometers of rock strewn desert are covered with thousands of lines, large biomorph figures and various geometric shapes. Because of the dry and stable climate, the light-colored traces have remained nearly unchanged during the last 2000 years. But today this world cultural heritage is threatened with destructions. The Dresden born researcher Dr. Maria Reiche was the first one who fought against the destruction of the Nasca Lines. It’s not possible to enumerate all her efforts and activities. Not least because of her engagement the lines where added to the UNESCO World Heritage List in February 1995. In memomir of Maria Reiche and in order to help to protect and preserve the cultural heritage of Nasca and Palpa a scientific project was originated by members of the association “Dr. Maria Reiche” e.V. in Dresden, Germany. One of the main objectives of the Nasca Project Dresden is the digital conservation of the lines and figures of Nasca and Palpa. The basis of this Nasca project is a Geographical Information System (NascaGIS), which shall preserve this cultural heritage at least in digital form and provide an easy digital access to the public at large. (RICHTER 2007a)

The primary requirements of any GIS application are the data, which can be obtained e.g. by field measurements or photogrammetric techniques. The most practical solution to capture the geometrical information of this huge area to an adequate accuracy is the photogrammetric approach. Unfortunately the available aerial photos cover only the main area of the Pampa of Nasca (Fig. 1). For this reason the usability of very high resolution satellite images as a basis for the data capture in the remaining region had to be investigated.

2 AVAILABLE DATA IN THE INVESTIGATION AREA

The study area (approximately 580 sq km) is located in the south of Peru between the Pacific Ocean and the foothills of the Andes north of the little town Nasca (see Fig. 1). It includes the whole Pampa of Nasca, a nearly flat terrain with bare ground, delimited by the mountains in the west and the Ingenio valley in the north.
To cover the whole investigation area five IKONOS scenes in eleven tiles from 2000 and 2001 were used. The IKONOS sensor generates approx. 1 m panchromatic and 4 m multispectral images depending on the viewing angle. The scenes 0, 1 and 2 were provided as pansharpened data with 1 m resolution and scenes 3 and 4 as panchromatic plus multispectral data. All the scenes were available as Carterra Geo Ortho Kit Product consisting of the high-resolution Geo images and auxiliary Rational Polynomial Coefficient (RPC) files, which provide the sensor geometry. The acquisition parameters are summarized in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scene 0</th>
<th>Scene 1</th>
<th>Scene 2</th>
<th>Scene 3</th>
<th>Scene 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>nominal collection azimuth</td>
<td>19.8731°</td>
<td>46.4443°</td>
<td>264.0727°</td>
<td>295.8129°</td>
<td>170.4125°</td>
</tr>
<tr>
<td>nominal collection elevation</td>
<td>72.04422°</td>
<td>87.24905°</td>
<td>56.06464°</td>
<td>58.20786°</td>
<td>72.89145°</td>
</tr>
<tr>
<td>sun angle azimuth</td>
<td>34.7991°</td>
<td>34.6010°</td>
<td>40.0705°</td>
<td>40.4531°</td>
<td>106.9303°</td>
</tr>
<tr>
<td>sun angle elevation</td>
<td>43.91391°</td>
<td>44.02104°</td>
<td>48.11153°</td>
<td>47.88911°</td>
<td>60.83793°</td>
</tr>
<tr>
<td>nadir angle</td>
<td>17.95578°</td>
<td>2.75095°</td>
<td>33.93536°</td>
<td>31.79214°</td>
<td>17.10855°</td>
</tr>
</tbody>
</table>

Since the RPC-file expresses the complete and accurate sensor geometry, the accuracy of the orthorectification of the IKONOS data is defined by the accuracy of the Ground Control Points (GCP) and the Digital Terrain Model (DTM).

During our GPS campaign in 2004 more than 2000 contour points where measured in the Pampa of Nasca, whereas approx. 80 points are appropriate as GCP’s for the orthorectification of the IKONOS data. The measuring accuracy of these GCP’s is better than 5 cm, while the identifiability inside the Pampa is about 10 - 30 cm.

The other important data for the orthorectification is the DTM. During the last years different DTM’s were developed within the Nasca Project Dresden. A high-precision DTM was generated from the photogrammetric aerial photos by using the software LPS, but it covers only a small part of the Pampa of Nasca. Therefore years ago a regional DTM was worked out by digitizing contour lines and single points from existing topographical maps. At the end of the 90th there were only maps in the scale 1:100.000 available (DTM100).
Later we've got cadastral maps of the main part of the Pampa in the scale 1:25,000 (DTM25). The DTM100 spans over the entire study area whereas the DTM25 covers only the main part of the Pampa of Nasca (see Fig. 1).

Today it’s possible to use the results of the Shuttle Radar Topography Mission (SRTM), which obtained elevation data of the earth surface with data points spaced every 1 arc second (≈ 30 m) of latitude and longitude (SRTM-1). During the mission two antenna pairs operating in C-band and X-band were used. The C-band interferometer, with its swath width of 225 km, covers 119 million km² of the entire landmass between 60°N and 54°S. The X-band provides only half of this area due to its swath width of 45 km. (RABUS et al. 2003)

The C-band data with a spatial resolution of 3 arc seconds (SRTM-3) are available for free on the Internet (LP DAAC 2005). These C-band data covers the entire investigation area, whereas the X-band data are available only for the eastern part (see Fig. 1).

3 ANALYSIS OF THE DTM ACCURACY

To analyze the accuracy, 1116 common points, measured with GPS, had been used. The rough results are given in Table 2.

Table 2. Differences between the 1116 GPS points and the DTM’s

<table>
<thead>
<tr>
<th>DGM</th>
<th>Minimum [m]</th>
<th>Maximum [m]</th>
<th>Mean [m]</th>
<th>Standard deviation [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRTM-1</td>
<td>- 6.85</td>
<td>16.60</td>
<td>- 0.47</td>
<td>2.44</td>
</tr>
<tr>
<td>SRTM-3</td>
<td>- 10.06</td>
<td>32.34</td>
<td>0.79</td>
<td>2.90</td>
</tr>
<tr>
<td>DGM25</td>
<td>- 28.89</td>
<td>62.67</td>
<td>2.62</td>
<td>6.79</td>
</tr>
<tr>
<td>DGM100</td>
<td>- 34.52</td>
<td>76.14</td>
<td>- 6.46</td>
<td>14.77</td>
</tr>
</tbody>
</table>

As expected the SRTM-1 data has shown the highest accuracy, but this DTM does not cover the whole investigation area. Since the comparison of the GPS points with SRTM-3 has yield also good results, this DTM is appropriate for further research. The accuracy of DTM25 and DTM100 is considerably lower and after extensive investigation rough errors were detected. Hence these DTM’s are not recommendable for further use.

In addition to those results two other comparisons had been evaluated, the differences of SRTM-1 and SRTM-3 and the comparison of SRTM-3 with the photogrammetric DTM. The differences between SRTM-1 and SRTM-3 are less than 5 m in flat terrain and between ± 60 m in mountainous regions with maximum differences of ± 350 m. The comparison of SRTM-3 with the photogrammetric DTM has brought very good results with differences less than ± 3 m in the flat terrain of the Pampa of Nasca. At the edge of the Ingenio valley in the north of the Pampa the differences between the two DTM’s are in the range of ± 40 m. It results from the precipitous area with slopes of 62° and the spatial resolution of the SRTM-3 data (see Fig. 2). In the nearly flat terrain of the Pampa of Nasca the SRTM-3 data is very much appropriate for the orthorectification. (RICHTER 2007b)

Figure 2. Comparison of the slopes between SRTM-3 (left) and photogrammetrical DTM (right)
4 ORTHORECTIFICATION AND VECTOR DATA CAPTURE

The accuracy of the orthorectification of satellite images depends on the accuracy of the DTM and the GCP’s. Of minor importance for the orthorectification of IKONOS images is the number of GCP’s. One or two GCP’s are really sufficient when RPC-data is available; more GCP’s will not improve the result (JACOBSEN 2005). The DTM accuracy has much more influence on the result of the orthorectification of satellite images (see e.g. TOUTIN, CHENG 2001). The accuracy of the orthorectified image becomes worse in mountainous regions, especially if the images were acquired with off-nadir viewing angles, which is quite common for IKONOS imagery. The tangent of the nadir angle determines the influence of the height difference in the DTM. That means, e.g. in scene 2 (tan 34° = 0,67) the horizontal displacement equates approx. 2/3 of the height error. Very detailed investigations confirmed this dependency (RICHTER 2007b). By using only GCP’s in the flat area an overall RMSE less than one meter was achieved, although in scene 2 a maximum horizontal displacement in the mountainous area of approx. 40 m can be expected. For the triangulation of all IKONOS tiles 49 GCP’s in the flat area, several tie points, SRTM-3 and RPC-data were used. In the mainly flat terrain of the Pampa a sub-meter accuracy within the scenes 0, 1 and 4 (nadir angle < 18°) and a maximum horizontal displacement of 3 m within the scenes 2 and 3 (nadir angle > 31°) were achieved.

Because of the special astronomical investigations in the Nasca Project Dresden, sub-meter accuracy is needed (TEICHERT 2007). To achieve this high accuracy for the NascaGIS two points of interest had to be considered; on the one hand the accuracy of the orthorectification and on the other hand the accuracy of the vector data capture. Thereby the recognisability of points in the images is a crucial factor. The following results are related to points which could be very good identified. Independent and multiple measurements within the orthorectified image resulted in a relative horizontal accuracy between 10 cm and 30 cm. The comparison of these measurements with the available GPS-coordinates has shown an absolute accuracy of less than one meter for points inside the flat Pampa, where most of the lines and figures of Nasca are situated. In the scenes with a nadir-angle of about 33° a horizontal shift of 3 m could possibly occur based on the accuracy of the SRTM data. (RICHTER 2007b)

5 RESULTS

The orthorectification with SRTM-1 (X-Band) as well as with SRTM-3 (C-Band) has brought very good results in the plain of the Pampa of Nasca. Sub-meter accuracy was achieved for the vector data capture. More problematic are the mountainous areas, because the partially large height discrepancies of the DTM affect significantly the orthorectification, especially the off-nadir satellite images, which result in less accuracy of the vector data. Nevertheless, since most of the lines and figures at the Pampa of Nasca are situated in the flat area, the orthorectified satellite images can be used for the GIS data capture in an adequate accuracy.

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6 REFERENCES


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