Principles of airborne laser scanning

Karl Kraus
Editor
Institute of Photogrammetry and Remote Sensing, Technical University of Vienna
Austria
kk@ipf.tuwien.ac.at

Preliminary remarks

This paper is the framework of a lecture presented on 17.4.2002 in Sweden on the occasion of the retirement of Prof. Dr. Torlegard. It is designed as an extended abstract with respective literature references from the Institute of Photogrammetry and Remote Sensing at the Technical University of Vienna (I.P.F.).

1 Introduction

Figure 1 represents the paradigm of laser scanning. A paradigm as generally known focuses on the basics and ignores minor matters. The paradigm of laser scanning can be characterised in the following way:

- A bundle of 3D-vectors, positioned by GPS and oriented by IMU
- Active sensors

Figure 2 illustrates the paradigm of Stereo-Photogrammetry and can be characterized by:

- 2 directed bundles, which intersect in object space
- Passive sensors
- GPS and IMU only optional

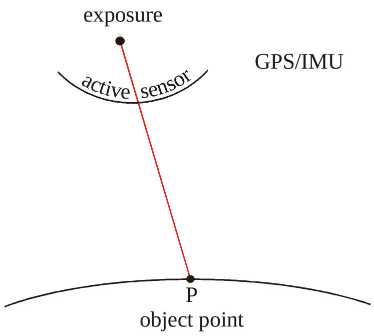

Figure 1: Paradigm of laser scanning

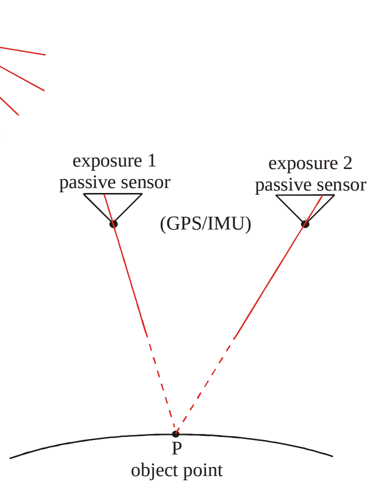

Figure 2: Paradigm of Stereo-Photogrammetry

The assets and drawbacks of both data capturing systems have been reported several times (e.g. Kraus, Pfeifer, 1998). In the following, a few principles established during the work with laser scanner data at the I.P.F. are summarised.

2 Simultaneous fitting of laser scanner strips

The principle of this method is the photogrammetric block adjustment with strips as independent units. We and also others like (Maas, 2001) have located deficiencies in the measurement system regarding the positioning by GPS and the IMU orientation. These differences are modelled by additional parameters. The required tie elements in the overlapping regions of the laser scanner strips are extracted automatically. For an increase in quality of laser scanner data we recommend a high overlap of the laser scanner strips and a few cross strips. Details to this method can be found in Kager and Kraus (2001).

3 Filtering of laser scanner data and interpolation

of a terrain model with robust linear prediction in a hierarchical approach. The keywords of this principle are:

- Filtering and interpolation take place in one process.
- The weight function is asymmetric and excentric. The weight function is derived from the data by statistical analysis.
- The different levels of the data pyramids are created with the original x, y and z-co-ordinates and in the form of a (regular) raster image.

More details on this method are available in the publications (Pfeifer et al., 2001, Kraus, Pfeifer, 2001). The current status of this method is summarized in the paper (Briese et al., 2002) submitted for the mid term symposium of ISPRS commission III.

4 Derivation of structure line elements

Laser scanning provides a point cloud without structure elements. On the other hand a high quality digital terrain model excels in the consideration of topographic structure elements.

The first method developed in structure line detection at the I.P.F. is based on a water flow analysis applied to a digital terrain model (Rieger, 1992). This approach is limited to fluvial dominated areas where the surface is formed by the process of water transport. With this algorithm it is possible to extract 3D river lines which show the highest amount of water transport. This line information can be used to get a digital terrain model with a high geomorphologic quality (Gajski, 2000). This method shows reasonable results in certain areas, but has its problems in flat regions were the water flow cannot be determined well.

The second method concentrates on the derivation of break lines, in particular to the upper edges on embankments. It operates in the object space on the original points with their x, y and z-co-ordinates. In an iterative process the original points are classified to the regions “left” and “right” with respect to the break line. These regions are approximated by a pair of moving planes. Details to this method and the first results are presented in the publication (Kraus, Pfeifer, 2001). Currently we work on refinements and further developments of this method.

5 Derivation of building models

The biggest challenge is the automated derivation of building models from laser scanner data. At the I.P.F. we recently started the first activities in this research area. The aim of F. Rottensteiner (Rottensteiner, Jansa, 2002, Rottensteiner, Briese, 2002) is to present intermediate results at the mid term symposia from ISPRS commission III and IV. This method abuts on the publications from Baillard et al. (1999), Brenner (2000), Ameri (2000) and Vosselmann (2001). The principles of this method are:

- Extraction of building outlines with original laser scanner data, which get a z-value in respect to their offsets to the digital terrain model,
- Detection of planar regions in 3D space,
- Extraction of the planar regions within the connected roof region,
- Grouping of neighbouring planar regions by merging co-planar regions,
- Intersecting non-co-planar regions and introducing vertical planes at step edges
- Finally the intersection of the roof model and the DTM with vertical walls dropped on the building outline completes the building model.

6 Conclusions

Until now we have only used laser scanner data at the I.P.F. which follow the paradigm presented in figure 1. The used data only consists of x, y and z-co-ordinates in object space. In the meantime laser scanner sensors were developed which allow to record multiple (distance-)echos and the intensity of the reflected radiation in the near infrared. Furthermore laser scanners are linked more frequently with optical remote sensing systems. In this field the term LIDAR is used more often than "laser scanning". In the figure 3 the paradigm of Stereo-LIDAR is sketched. It results by merging the paradigms of figure 1 and 2. The combined paradigm puts the electromagnetic radiation as information source into the centre. (Therefore the (linear) vectors and directions are replaced by electromagnetic waves.) The geometric view of the paradigms in figure 1 and 2 is linked with the physical.

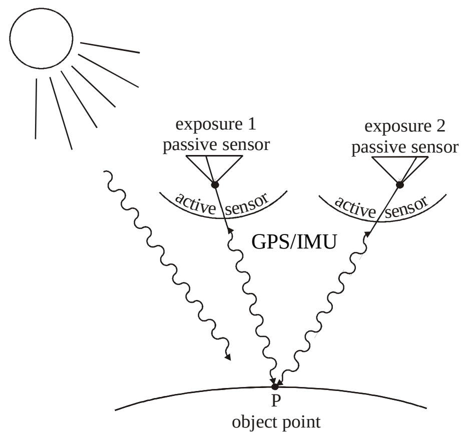

Figure 3: Paradigm of Stereo-LIDAR

The Stereo-LIDAR paradigm can be characterised like the following:

- To every radiometric pixel exists a spectrum of distances, which at least consists of the first or the last impulse
- To every geometric pixel exists a spectrum of electromagnetic radiation, which is - dependent on the used sensor – stamped by natural/artificial radiation
- To every pixel exists a second pixel with the same radiometric and geometric information, but observed from another direction
- The Stereo-coverage, which should be achieved by a very high amount of overlap, increases the reliability of the LIDAR data to a very high degree (e.g.

within the scope of the simultaneous fitting of the laser scanner strips, section 2).

The development of methods for data analysis, which match to the paradigm of Stereo-LIDAR or which are able to partly fulfil certain components, will be a big challenge for the next years.

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