Airborne Laser Scanning

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In recent years, airborne laser scanning has become a dynamic branch of the applied sciences, of research and development, and of technology, with users in diverse disciplines as the main driving force. Our Institute of Photogrammetry and Remote Sensing at the Vienna University of Technology (I.P.F.) is active in this field for 8 years. Methods, algorithms and corresponding computer programs are developed for extracting information of laser scanner data, and pilot projects are performed for governmental institutions and private companies. Based on this experience, I am dealing here with some aspects of interest – as I hope – to members of EuroSDR. In this sense, the main concern will be deriving digital terrain models (DTMs).

Geo-referencing

In their overlapping regions, adjacent laser scanner strips carry differences often up to half a meter and more. Isolines in these areas oscillate then. These effects have to be corrected by improved geo-referencing. At I.P.F., block adjustment of strips as independent units has been suggested and realized. The required tie elements in the overlapping regions of the laser scanner strips are extracted automatically. In the corners of the block, control planes are introduced so to provide for proper fitting into the geodetic frame.

But more recently, this specialized height adjustment of such blocks has been replaced by a three dimensional solution. Unknowns in this process are corrections to the six orientation parameters, i.e. to three co-ordinates on the flying trajectory, and three attitudes of the laser scanner.

Hierarchical Robust Linear Prediction

We derive the DTM with linear prediction in a hierarchical approach. The keywords of this principle are:

- Filtering and interpolation take place in one and the same process.
- The weight function is asymmetric and eccentric; it is derived by statistical data 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.

The current status of this method is summarized in the paper (Briese et al., 2002).

Quality Overlays

The large gaps in data distribution, resulting from eliminating points on large buildings or areas covered by dense vegetation prompted us to complement the DTM software SCOP (see both homepages cited in the *Literature* section) with overlays to represent the quality of the DTM. At this point, we are developing the following three quality overlays:

a) To visualize distances between grid points of the DTM as interpolated, and the point of the original data set next to them.

b) To visualize quality measures as derived from the differences between the elevations of the original points and the elevations of the DTM surface at the same locations; the quality measures will be analyzed for minute area cells according to user request.
c) To visualize elevation accuracy in grid points of the DTM, computed on the basis of the minimal distances (a), of the empirical accuracy measures (b), and of the curvature in the grid point in question.

Data Reduction

The very high density of points as delivered by laser scanning is of great advantage for improving quality – but it confronts data management with severe difficulties. The method for data reduction as proposed and implemented at the I.P.F. reminds the step-wise data acquisition by progressive sampling. Over a dense DTM derived from the original data set, radii of curvature R and slope values are derived, local to the individual grid point to be eliminated ("reduced"). This information allows for defining the maximal allowable distance to the next neighbor so to remain within a threshold of dZ_{max} for approximation accuracy. Figure 1 shows results for a small example. In a case with 4 millions of grid points and with a user defined threshold of dZ_{max} = 25cm, the reduced grid carried 1.3 million points. This reduction, including output of the reduced set in ASCII, took 4.75 minutes on a 2 GHz computer.

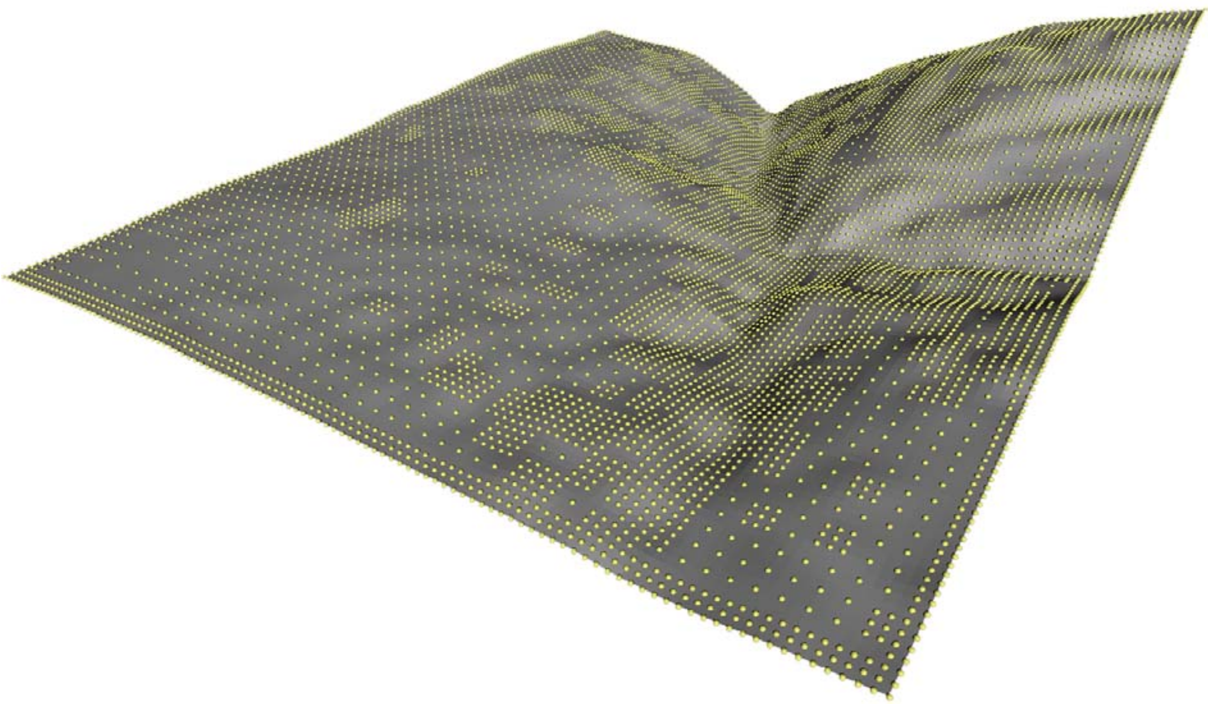

Figure 1: DTM grid past its reduction.

Fusion of (Stereo-)Photogrammetry and Airborne Laser Scanning

In a recent publication (Kraus, 2002) I have formulated the paradigms of (stereo-)photogrammetry as opposed to that of airborne laser scanning. They are schematically represented in the figure 2. The paradigm of (stereo-)photogrammetry can be characterized as:

- Two perspective bundles intersecting in the object space.
- Passive sensors.
- GPS and IMU only optional.

The same for the paradigm of airborne laser scanning:

- A field of 3D-vectors positioned by GPS and oriented by IMU.
- Active sensors.

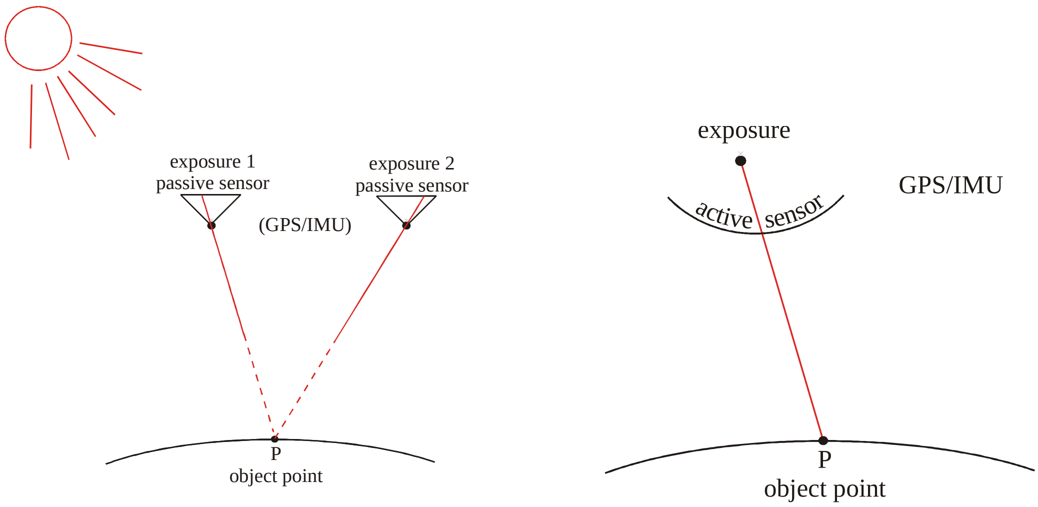

Figure 2: Two paradigms

I do not intend to deal here in detail with the commonalities and differences of these competing techniques; details concerning these can be found in the publication mentioned. One point is however of major interest in the reasoning to follow: it is the currently wide difference in the resolution as provided by both techniques. The resolution of airborne laser scanner data is currently in the range of about 0.5 to 3 m. At corresponding flying heights of 1 to 2 km, the resolution of digitized aerial photographs – i.e. of the data carriers in photogrammetry – is about 0.1 m. Therefore, fusion of both techniques is beyond doubt inevitable. Accuracy potentials yield a further ground for such consolidation: of both techniques,

- Airborne laser scanning is more accurate concerning elevations, and
- (Stereo-)photogrammetry provides better horizontal accuracy.

The fusion of both technologies can be implemented in several different ways. Here is a list of some alternatives, started with the simpler ones:

- Overlaying the DTM derived of laser scanner data, and the corresponding digital ortho-photo. (Austria is covered by digital color ortho-photos with a pixel size of 25 cm).
- Using the DTM as derived of laser scanner data for monoplotting.
- Applying laser scanner data for improving elevations of structure lines – especially of break lines – as gained by stereo-photogrammetric compilation. (In Austria, a hydrologic pilot project – financed by the government of Upper Austria – is underway, with the aim to improve elevations of a country wide set of digitized structure lines, in applying laser scanner data).

- Recording of the intensity of the laser rays as reflected, resulting in a black-and-white infrared image – although with the low resolution of the laser scanner.
- Equipping the airplane carrying the laser scanner with a digital photogrammetric camera, without any synchronization with the laser scanner.
- Installing the laser scanner and a digital photogrammetric line-camera on the same gyroscopically stabilized platform, for synchronous operation.

The last alternative mentioned is but a future perspective, especially if aiming at the level of photographic resolution. Equipment manufacturers, theoreticians, software developers, and users will be meet great challenges in the coming years.

Literature

Briese, C., Pfeifer, N., Dorninger, P. (2002): Applications of the Robust Interpolation for DTM Determination. Symposium der ISPRS-Comm. III in Graz, 9.-13. September International Archives of Photogrammetry and Remote Sensing, Vol.XXXIV/3A, pp. 55 – 61.

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