Opportunities for the generation of high resolution digital elevation models based on small format aerial photography

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Introduction

High resolution digital elevation models can be generated based on field measurements or remote sensing data. High density field measurements are expensive and time consuming. Remote sensing data that can be used to derive high resolutions digital elevation models (or more exactly digital surface models) comes in the form of LiDAR data or stereo images. Both sources require considerable amount of planning and are costly as well. Using the small format aerial photography system recently developed at our department, we are trying to overcome these problems.
Originally, the small format aerial photography system was developed as a digital acquisition system to collect separate visible to near infrared images. To test if the system would also be usable for the generation of high resolution digital elevation models, it was decided to use data from an area where it would be relatively easy to find ground control points for the aerial triangulation.

Hardware

We developed a low cost, digital aerial imaging system, and have been using it for data collection since February 2008. The system, based on a Duncantech MS3100 CIR Multi-Spectral camera, can be deployed within an hour, and enhanced digital photos can be viewed in real time as they are collected or within minutes after landing. The camera is a 3CCD system with independent gain controls for each CCD which allows the use of different gains for each of the three bands. It has a resolution of 1392x1040 pixels per band and a 10-bits per band dynamic brightness range. For this project, about six images are being captured per second, while flying at an altitude of 1500 meter yielding a spatial resolution of 43 centimeter. A GPS was used to mark the approximate center point of each photo as it is taken. An inertial measuring unit (IMU) is not used, so no data is recorded about the plane's orientation. A National Instruments IMAQ 1428 frame grabber is used to capture the images from the camera.
In addition to the camera system, there is a second GPS system to aid the pilot navigating according to the flight plan during the flight. The flights are executed with a four seated, single engine Cessna 172 owned by our joint venture company. The airplane is stationed at the airport of Szeged.

Figure 1. The different components of the data acquisition system (from top left to bottom right): computer and camera, the cockpit and the navigational GPS, the airplane, an overview photo over the city, navigation laptop

Data collection and processing

The raw data does not come with any georeference because no inertial data is acquired during the flight. After the flight, a navigational GPS (Mobile Mapper CE) track which was recorded during the flight and the original plan are compared to determine possible errors. Based on the image acquisition time and the GPS track, the images are then time-synchronised and a first coarse georeference is created, resulting in a maximum positional error of about 100 meter. This georeference is good enough for Leica Photogrammetry Suite (LPS) to read the data.

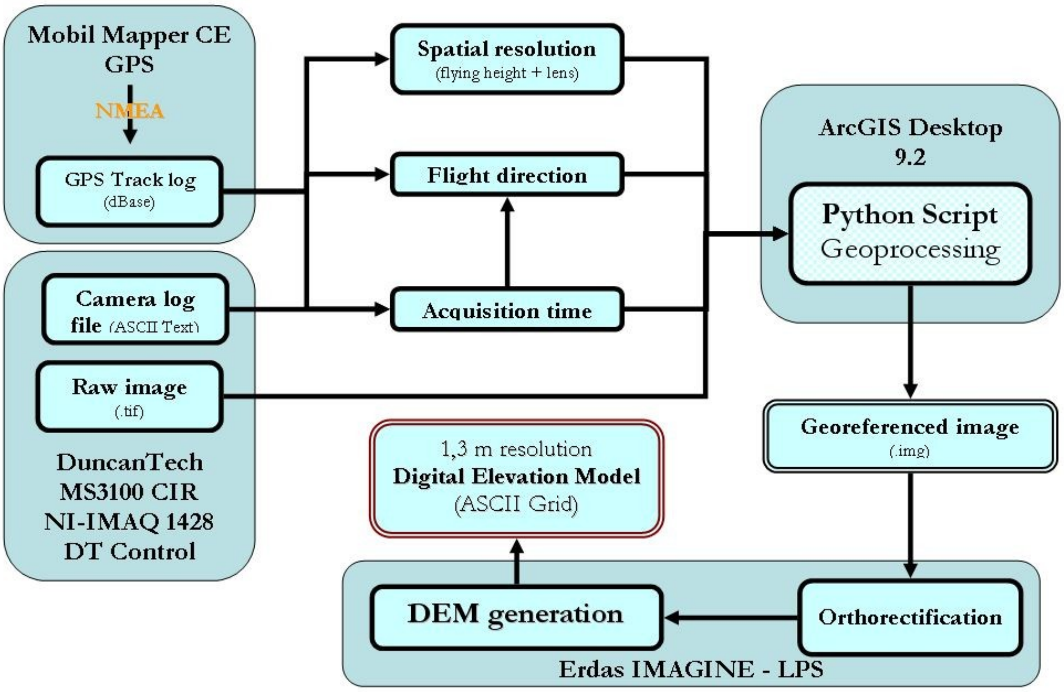

Figure 2. Image processing flowchart

Dem generation

To be able to generate digital elevation models of sufficient size, the overlap between stereo image pairs should be large (over 50%). To reduce the amount of images, the overlap was minimized during the original flight campaign, resulting in very few images suitable for testing the DEM (DSM) generation. As a first try, three images have been used that are on the same flight line. These images were read into LPS and four ground control points were identified on them. Accurate x, y coordinates were extracted from a 1 meter resolution orthophoto. The z coordinate was extracted by visual interpolation of contours on a scanned 1:10000 topographic map. The aerial triangulation resulted in an average RMS error of 6.7 meter and the output elevation model showed a strong tilt towards the southeast (see figure 3).

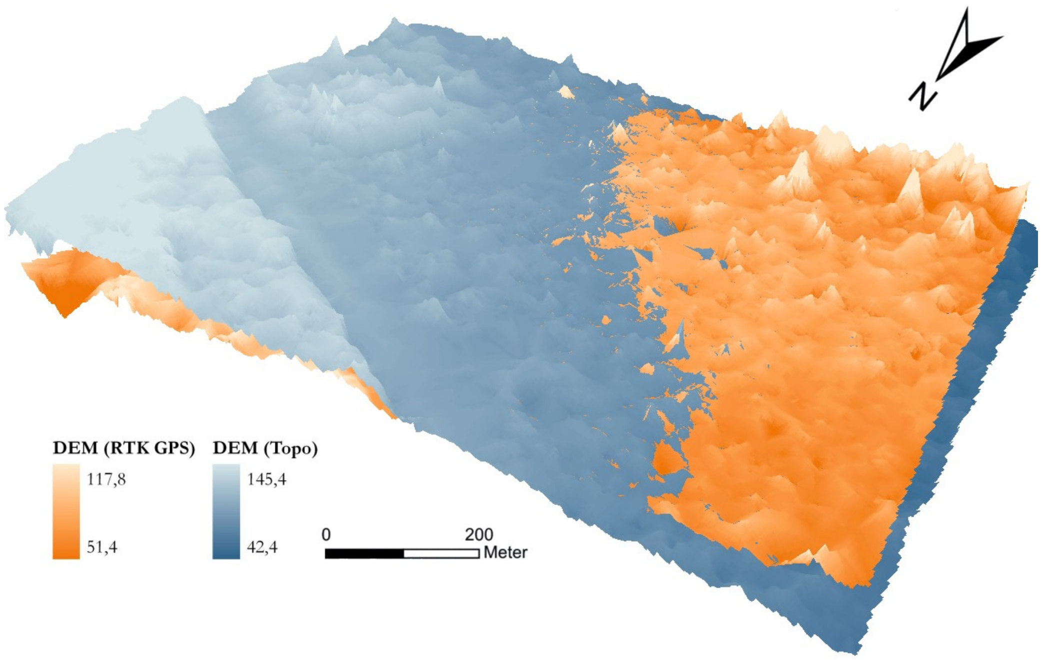

Figure 3. Visualization of the height differences between the DEMs. The DEM based on the topographic map shows a strong tilt towards the southeast.

To improve the aerial triangulation, ground control points were collected in the field with a RTK GPS, which has an intrinsic accuracy of 0-5 cm. The derived DEM (see figure 4) showed a much better result, although the average errors in X, Y and Z direction are still below our expectations (see table 1).

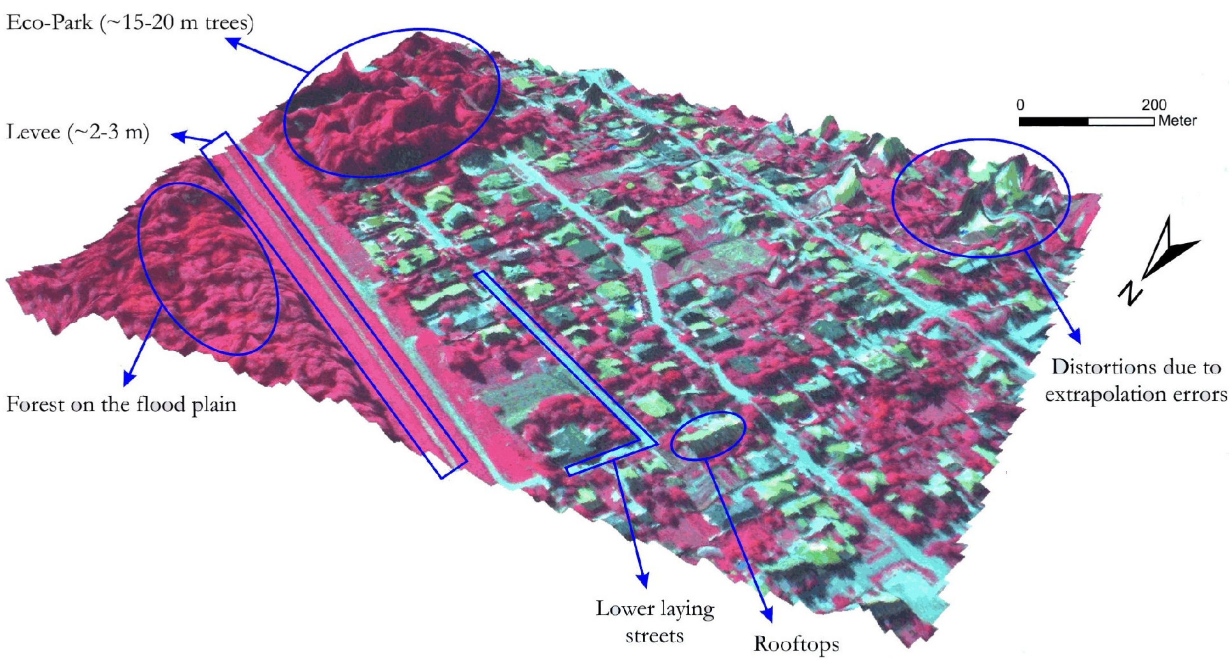

Figure 4. Final digital elevation model based on RTK GPS ground control points with a false color composite (NIR-Red-Green) raster drape.

Errors	RTK GPS GCP	Ortho + topo
Zmin	-10.02	-2.99
Zmax	7.41	3.16
Zrmse	6.72	1.99
Mass Point Quality		
Excellent %(1-0.85):	40.7269	40.1726
Good %(0.85-0.70)	39.1213	39.7617
Fair %(0.70-0.5)	0.0000	0.0000
Isolated %	0.0000	0.0000
Suspicious %	20.1518	20.0657

Table 1. Errors in the resulting digital elevation models

An important reason for the inaccuracy can be contributed to the camera model. The camera that was used to collect the images is not a frame camera, and has relatively large optical distortions towards the sides of the images. If these distortions are not corrected by control points, they cause large extrapolation errors in the mass points at the border of the images (see the upper right corner in figure 4). To visualize the spreading of the errors a point quality map was created (figure 5). The map shows that especially the forested area in the floodplain shows large errors.

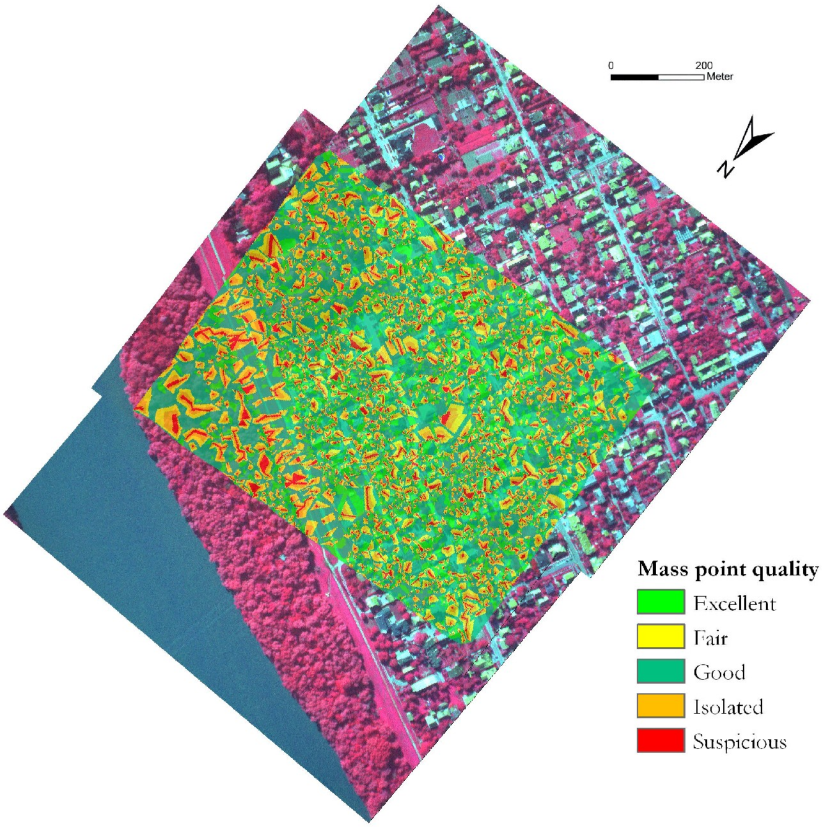

Figure 5. Original false color composite overlayed with the aerial triangulation quality image

Possibilities for further development

High precision GPS ground control points collected in the field at the borders of the images would reduce the errors due to the extrapolation. Furthermore, taking the distortions values of the camera into account will improve the interior orientation. Finally, the initial coarse georeference that is created for the raw images could be improved considerably by adding an inertial measurement unit (IMU) to the data acquisition system.

Conclusions

Our original aim to create a digital elevation model based on a digital non-frame camera with decimeter vertical accuracy does not seems to be realistic. However, the system did show to be capable of creating digital elevation models with meter accuracy for a relatively low price and without the lengthy planning that is common for traditional flight campaigns.