Testing the aerial mapping performance of DJI Terra compared to the two main UAS mapping softwares

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Introduction

This pilot project was based on the collaboration between MyActionCam Magyarország Kft. and the University of Debrecen, Hungary.

The main goal of the analysis was to test the performance of the DJI Terra software in terms of processing UAS-based aerial imagery compared to the Agisoft Metashape and Pix4D Mapper softwares.

The case study had been performed at the main Campus of the University of Debrecen, Hungary. For the UAS mapping a DJI Matrice 210 RTK v2 drone was used (Fig.1). A Zenmuse X7 camera with a 24 mm lens was mounted to take high resolution aerial imagery. The survey was accompanied by the use of DJI D-RTK 2 base station in order to omit the necessity of using Ground Control Points (GCP).

Fig.1. The Matrice 210 RTK v2 UAV with Zenmuse X7 camera.

The area of interest was a 0.25 km^2 large polygonal area at the Campus (Fig. 2/B.). The area consisted of various educational buildings having lower and higher roofs, trees and plain surfaces as well in order to provide a complex photogrammetric mapping task.

The precise coordinates of the base station were measured by a survey-grade STONEX S9i RTK GPS having 32 cm horizontal and vertical accuracy. The WGS 84/UTM 34N (EPSG:32634) version of the coordinates and elevation were both registered in the DJI Pilot RTK settings before flight mission in order to use these coordinates as reference for the precise geotagging of the imagery. We carried out a 2D mapping using nadir camera angles. The flight mission captured 238 images with a resolution of 6016 x 3376 pixels by each.

At the processing phase our aim was to apply the same settings of the Structure-from-Motion algorithm in order to make the outputs comparable. Therefore, we applied half of image resolution used for the depth reconstruction and dense point cloud generation. We carried out a complete photogrammetric workflow as image matching, depth reconstruction, dense cloud generation, Digital Surface Model (DSM) interpolation and orthomosaic generation. The GPU-supported processing was enabled in each software. The geometric accuracy assessment was based on individual RTK GPS surveys of ground verification points around the Campus.

The aerial imagery of the case study was processed in the following software versions:

- DJI Terra v2.1.4
- Agisoft Metashape Professional v1.5.4
- Pix4D mapper v4.5.6

The processing computer settings were the following:

- Intel Xeon W-2265 3.5 GHz (12 cores/24 threads) CPU
- 64 GB RAM system memory
- 512 GB SSD hard disk
- nVidia Quadro P2000 5GB memory GPU

Results

The SfM processing of the aerial imagery resulted an orthomosaic having a ground resolution of 1.94 cm / pixel. According to the image overlap (Fig.2/A) the area of interest was covered by at least 8 images; therefore, a high accuracy model is expected. For the geometric accuracy analysis, the edges of the orthomosaic, where larger distortions and lower accuracy is expected, had been clipped out (Fig.2/B). The spatial resolution of the DSM was found to be 3.8 cm/pixel interpolated from a dense point cloud density of 667 points / m^2.

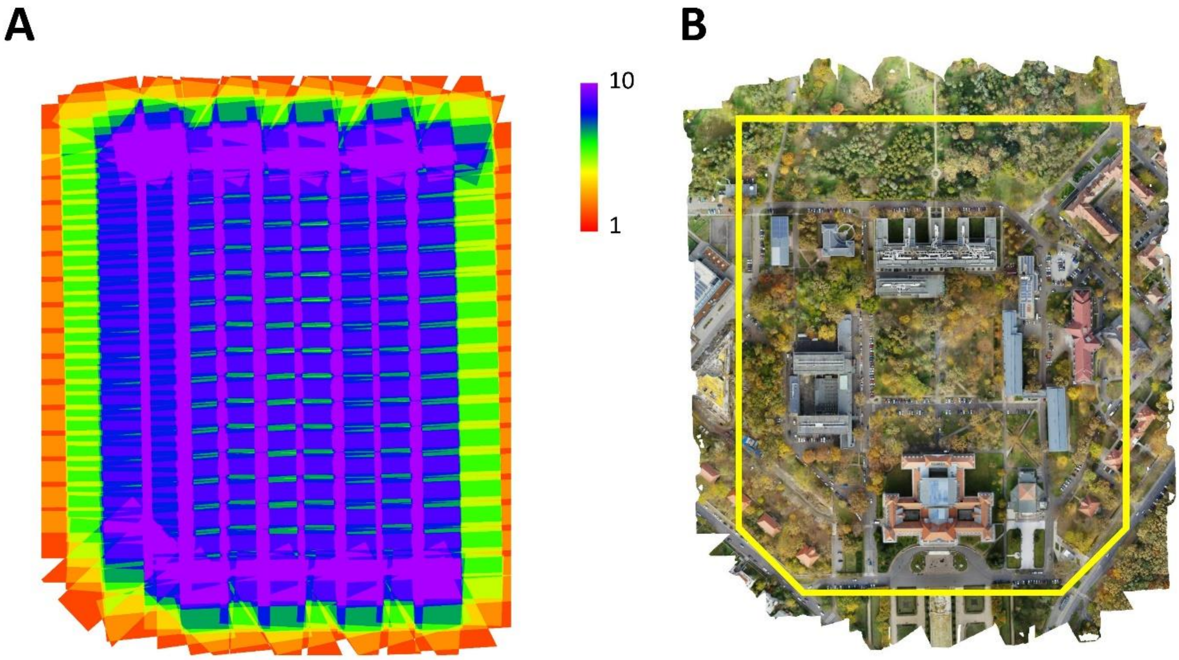

Fig. 2. The images taken by UAV (A), and the sample area at the University of Debrecen (B).

Examining the individual processing times among the three different software we found high differences (Fig.3). The DJI Terra was the fastest as it had finished the complete workflow around 10 minutes. This performance was found to be ~4 times better than the others. The processing speed between Agisoft Metashape and Pix4D was closer to each other since the difference between them was around ~20 minutes. The slowest processing time was provided by the Agisoft Metashape with a total workflow of 62 minutes.

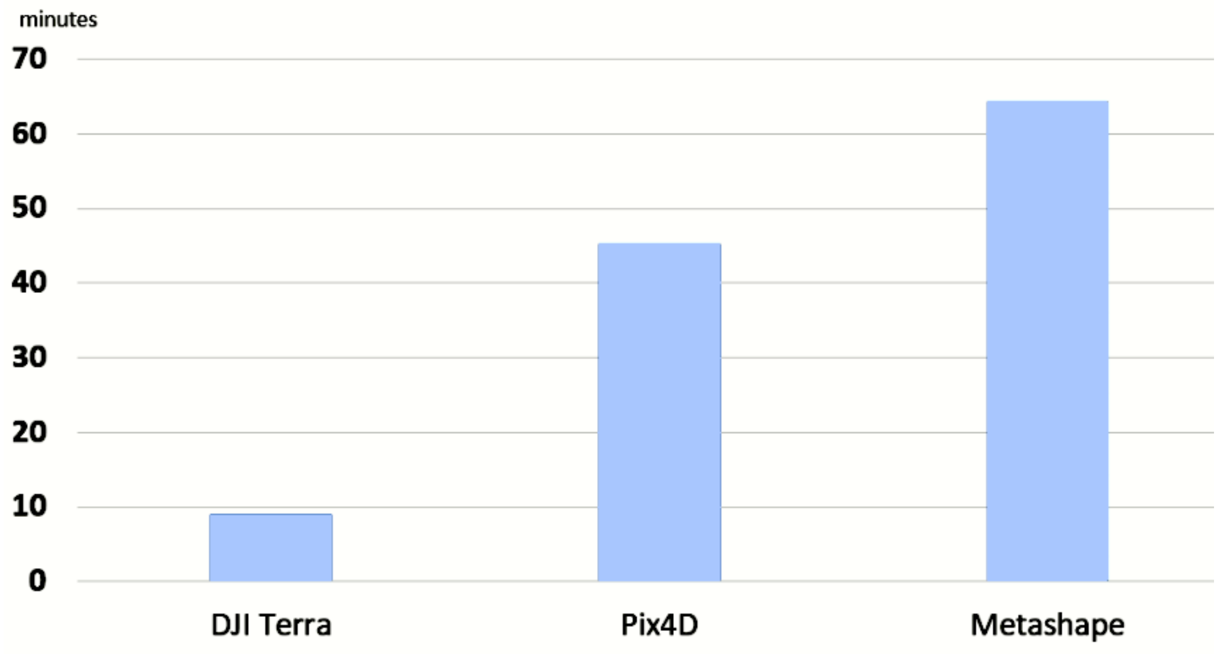

Fig. 3. Processing times of the three applied software.

As a test, the lower level of photogrammetric depth reconstruction in all software using only the 1/8 rate of image resolution for a brief processing was also applied. In this case, the fastest processing speed was also referring to DJI Terra followed by Metashape and Pix4D again but in an altered order.
The next step was the geometric accuracy assessment of all softwares.
According to the visual interpretation of the orthomosaics, similar results was found (Fig.4). The rooftop edges are continuous and significant gaps or breaks cannot be found on the lines on them or on the ground level. The plain surfaces are identified in their right position, and the geometry of the buildings are excellent. On the pavements the situation is the same, the road signs are situated at their original position and showing the favourable shape, at all of three software produced results.

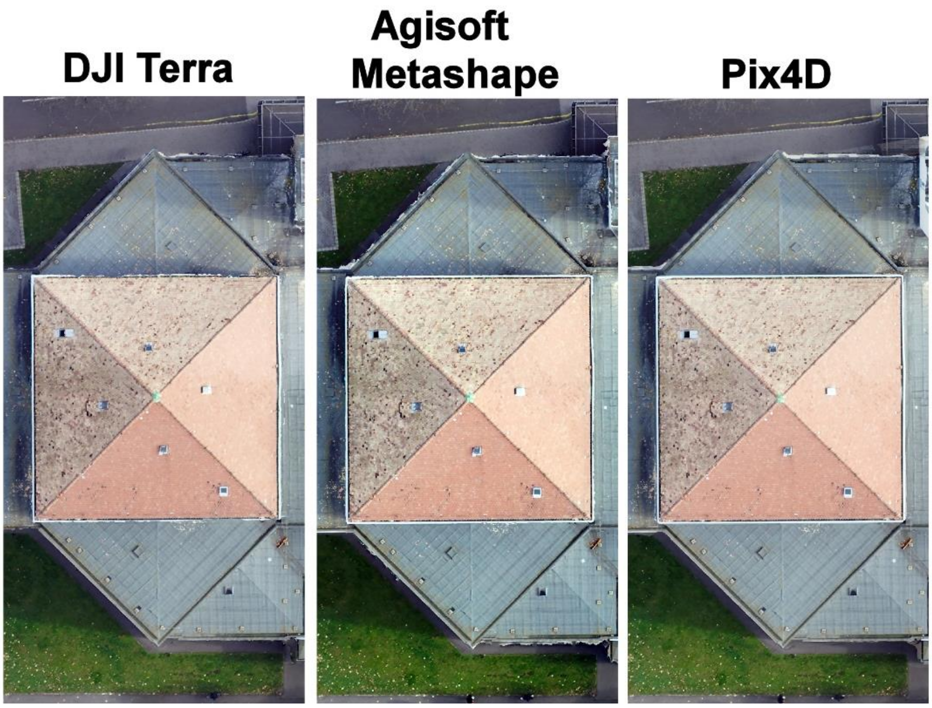

Fig.4. The same building in the three models.

However, the three softwares handle the moving objects in a different manner (Fig.5). The algorithm of DJI Terra tried to reconstruct the original plain surface of the road instead of plotting the car captured on the relevant imagery (left), while Agisoft Metashape applied a simple patching of the appropriate imagery (middle). Furthermore, Pix4D mapper just applied a slight opacity effect (right) between the moving object and the original road surface.

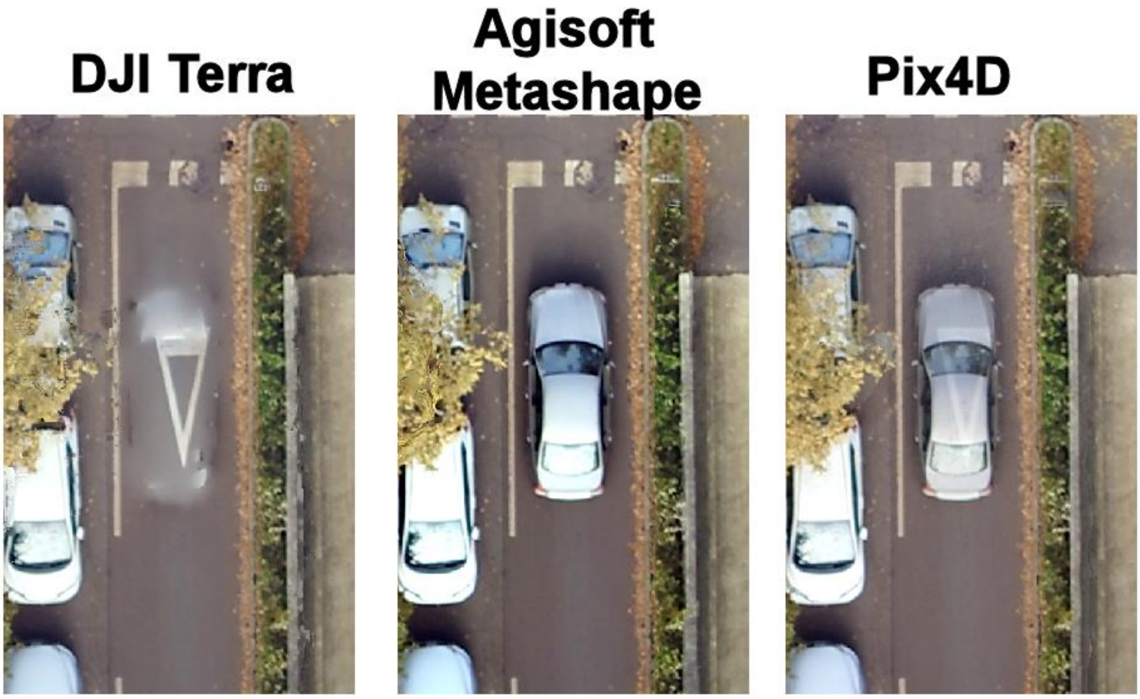

Fig.5. Different image patching techniques in the three models.

The geometric accuracy assessment of the ortophotos provided also very similar results in terms of the different software outputs (Table 1.). The horizontal error rates were almost the same for all three images.

Table 1. Mean absolute errors and standard deviations in the three databases.

	Mean absolute error (cm)	Standard deviation (cm)
DJI Terra	11.96	5.3
Agisoft Metashape	10.76	5.2
Pix4D	10.61	5.2

However, in total, the best result was given by Pix4D mapper, but its performance was only 1.3 cm better. These values can be seen in its original positions as well plotted on the orthophotographs (Fig.6). It is clearly visible, that the horizontal errors show quite similar rate of differences compared to the values of the individual validation points.

Fig.6. Horizontal biases at the validation points.

Examining the biases, it can be also noticed, the bias shows a slightly increasing rate towards the edges of the area of interest, even it is derived from an already clipped model.
In overall, the horizontal biases show about 10 cm shifts from the reference points. The differences among the three ortho images are quite similar, the mean differences are smaller than 2 cm (Fig. 7.).

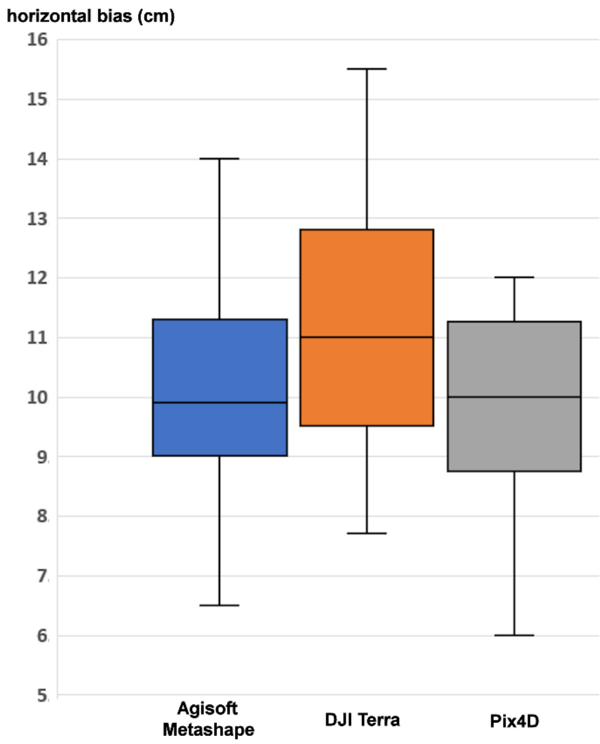

Fig. 7. The mean biases of the three DSMs.

Zooming on the DSMs generated by of the three software workflows the micro-relief of photogrammetric models can be examined. The results of the three software interpolations (with default settings) are shown on Fig.8.

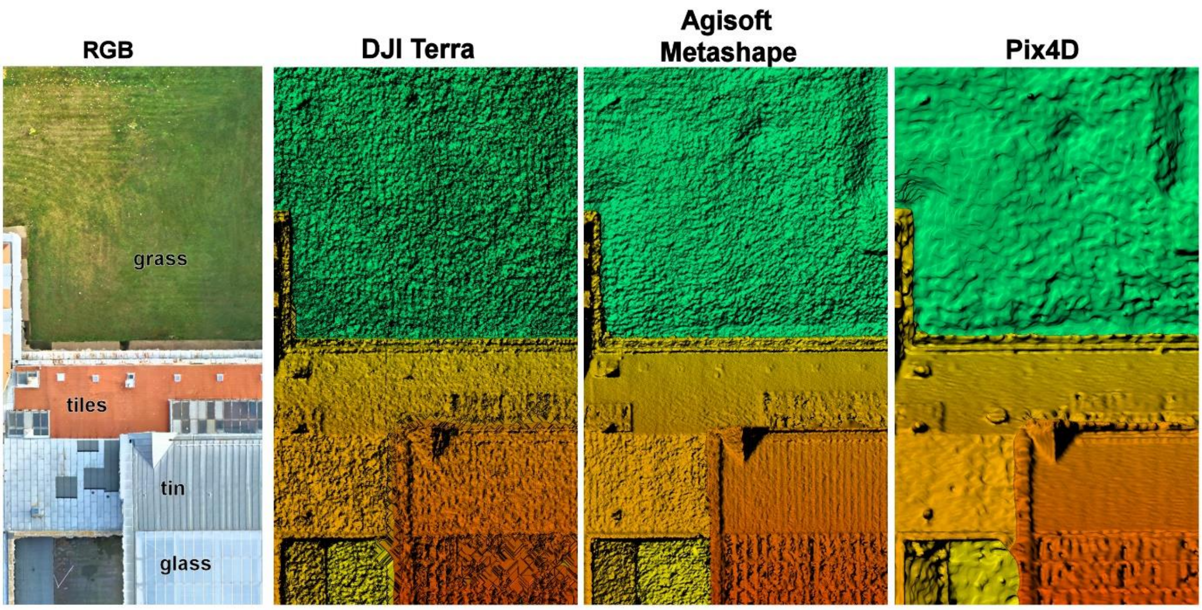

Fig. 8. The three DSMs and the same area on the orthophoto.

Since the GSD of the orthomosaics was ~2 cm, and on the figure, we highlighted a small area only, the differences in micro-relief are not significant (Fig. 9.).

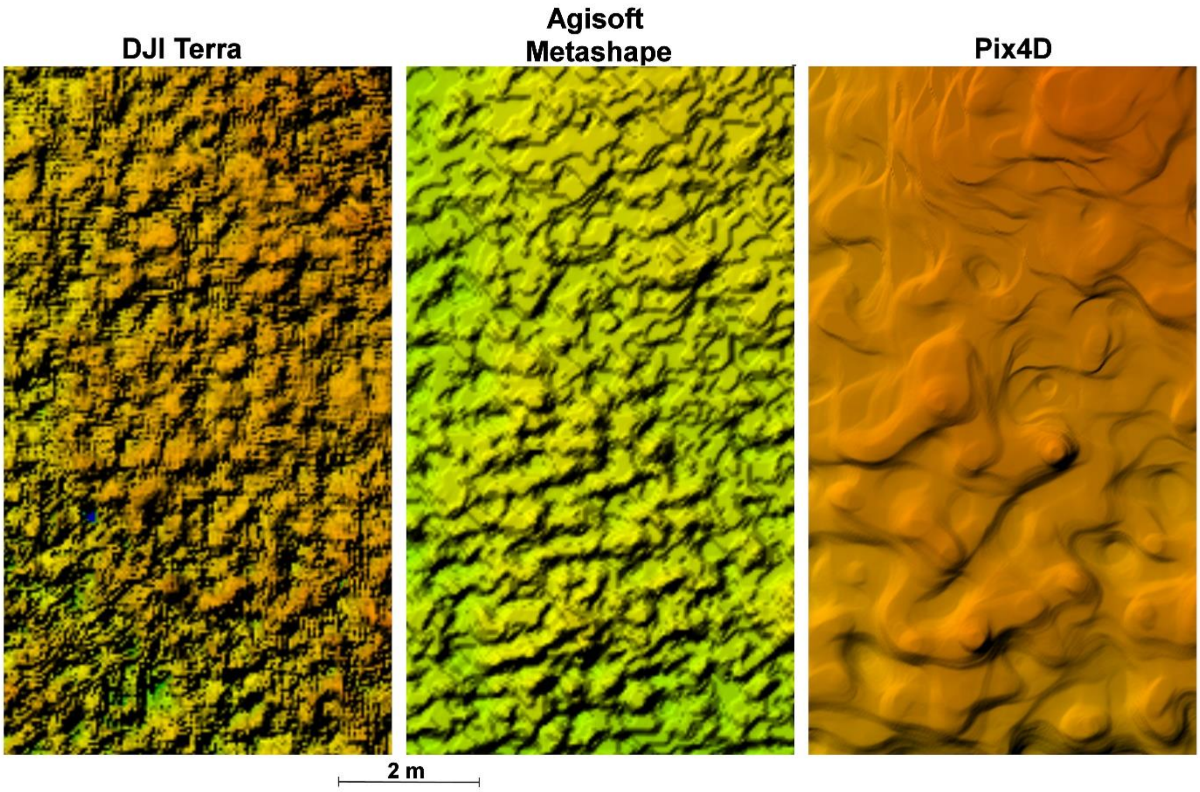

Fig.9. Different image patching techniques in the three models, near the “GRASS” text on Fig. 8.

Examining the micro-relief, we applied a transect line to plot the small local height differences along this direction. The base-distance was 40 m in a paved and asphalted area starting with concrete steps in front of the main building of the University (Fig. 10).

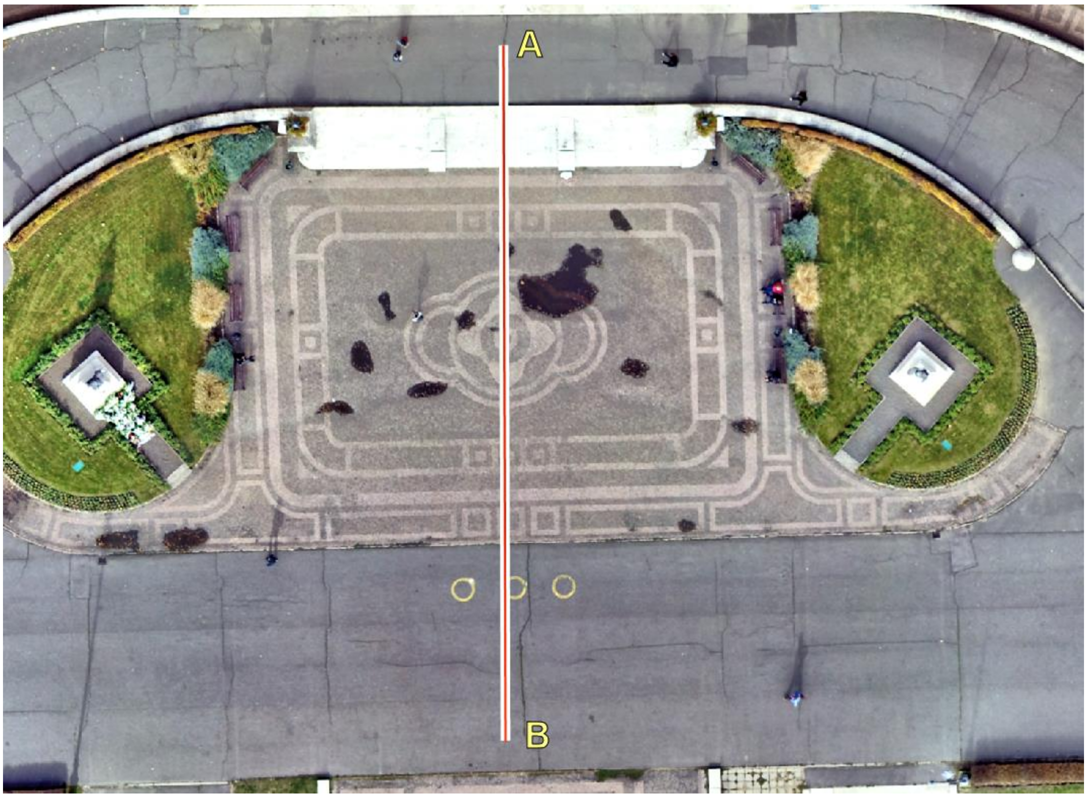

Fig. 10. The transect line ahead of the Main Building of the University of Debrecen.

On the transect we can see the result of strong smoothing effect of Pix4D (yellow line), the relatively high local differences on the Terra model (red line) and a down-shifted surface regarding to the Metashape (Fig.11).

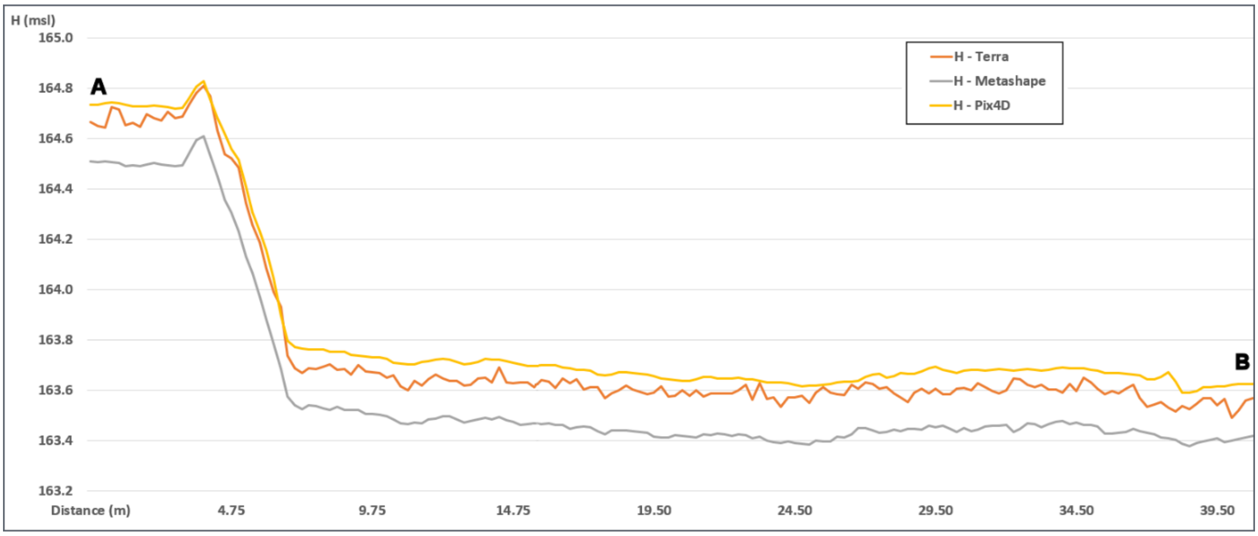

Fig. 11. Transect on the three models, next to the Main Building of University of Debrecen.

Regarding this height differences (Table 2.), on this transect we found a slight difference of mean height levels between DJI Terra and Pix4D (8 cm), and a larger shift of the surface of Agisoft Metashape model (20 cm). Since the same imagery with RTK-corrected geotags were the base of this processing, the reason of this shift is not clear. In overall, there are differences among the mean heights in relation of the three models, as well, but standard deviations are found to be the same.

Table 2. Differences among the DSMs.

	Mean height (m)	Standard deviation (m)
DJI Terra	162.32	0.91
Agisoft Metashape	162.16	0.91
Pix4D	162.40	0.91

Conclusions

Overall, all three software provided similar performance. This version of DJI Terra is impressively fast in terms of all parameterization cases. Examining the user interface, DJI Terra software seems to be the most simple, and requires the least amount of expertise from the user to operate. Agisoft Metashape and Pix4D software are more parameterizable and require deeper professional knowledge on photogrammetry from the user. An additional advantage of DJI Terra is that in the case of DJI drones, the flight plan can be prepared before the flight directly in the software.