Precision agricultural and game damage analysis application for unmanned aerial vehicles

András Molnár, Dániel Stojcsics, István Lovas

***Abstract*—**In modern agriculture the game damage is a real problem. Analyzation of the affected areas can be measured usually from the ground or with human piloted airplanes. With unmanned aerial vehicles (UAV) the survey can be made easily for a 1 km^2 area from a single flight, while the operating costs are significantly lower. During the flight (depending on the camera and the UAV airspeed) around 1-2000 pictures were taken. The photogrammetric reconstruction and the orthomosaic analysis needs a significant computation power. The paper presents the scientific basis of the analysis and the possible applications for the UAVs in modern agriculture including game damage made by rodents and deer in corn and sunflower filed, using aerial time line series.

***Keywords*—**GPGPU, precision agriculture, game damage assessment, UAV, photogrammetry, orthomosaic reconstrucion

I. The basis of aerial surveys

THE basis of taking orthophotos is the automatized fitting of the typical points of certain images. In the aerial survey the camera on the aircraft makes it possible to map the area (Fig. 1). The camera is placed at the bottom of the aircraft looking downwards. It takes several pictures of the area one after each but from a slightly different angle. The images significantly overlap. Typically it is 50% both horizontally and vertically (Fig. 2).

To this end, such a flight plan is necessary (Fig. 1, image on the left) that surveys the area to be detected in parallel with the routes of the same distance. The average altitude is 100-150 m depending on the camera, aircraft and area.

This procedure is not sensitive to slewing the picture and the camera's position on a stabilized platform is not a criterion, either. That is, the camera should not exactly look downwards vertically at all times. After the flight the interface software looks for typical point pairs on the images (they can even amount to several thousand per picture), which are matched afterwards. The widely used processes - SIFT [1][2][3], SURF [4][5], RANSAC [6], ICP [7] - are then optimized on modern video cards (GPGPU) so these devices help accelerate the process which is then ten times faster than with a traditional processor (CPU) [8][9].

After the software finished matching the point pairs, a colorful point cloud is created (Fig. 3). There is still an opportunity for deleting faulty or not appropriate images and point pairs [10]. Afterwards, a properly filtered 3D surface is created from the point cloud on which a low resolution texture is made by montaging the original pictures. Georeferencing is possible on both on the generated surface and the original pictures on the basis of the typical objects on the site or the surveyed points. A punctuality of 1-2 m is realistic on an area of 0.5-0.6 km2 in general.

Greater punctuality can be achieved by locating exact positions and with the application of D-GPS. High resolution GeoTIFF and/or Google Earth KMZ maps can be exported of the georeferenced are, which can be used both for defining distances and areas (Fig. 4).

II. Agricultural experiments

High resolution orthophotos were made from series in each experiment by a camera with a not stabilized platform. The aircraft robotic system ensures the proper flying route of the electric UAV with rigid wings that carries the camera. The method is suitable for the cost-effective survey of smaller areas (0.3-0.6 km2) rapidly (15-20 minutes) but it can also be applied on an area of 1-1.5 km^2 easily. In case of using a cheap, 10-14 megapixel camera orthophotos of 3-3.5 cm/pixel can be made in general by using the pictures. Furthermore, the resolution of the orthophoto depends on the height from where the photos were made, which is basically determined by the speed of the aircraft used and the shooting speed of the camera. The prerequisite of taking photos is the minimum overlapping of 40% among the pictures. In the experiments we tried to achieve the 60% overlapping [11].

The images make it possible to survey the current situation of an area. Due to the tiny size of the equipment, making a picture does not require any special infrastructure. The UAV can even be launched manually and it can land on a clearing or a lane.

A. Molnar is with the Faculty of Economy, J. Selye University 3322 Bratislavská cesta, 945 01, Komárno, SLOVAKIA (e-mail: molnara@selyeuni.sk).

D. Stojcsics is with the Faculty of Economy, J. Selye University 3322 Bratislavská cesta, 945 01, Komárno, SLOVAKIA (e-mail: stojcsicsd@selyeuni.sk).

I. Lovas is with the J. von Neumann Faculty of Informatics, Óbuda University, HUNGARY (e-mail: lovas.istvan@nik.uni-obuda.hu)

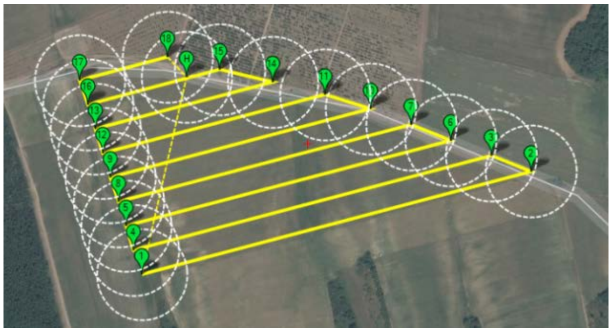

Fig. 1: The route of the UAV

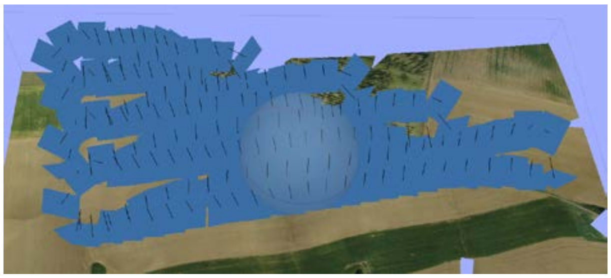

Fig. 2: The position of the photos

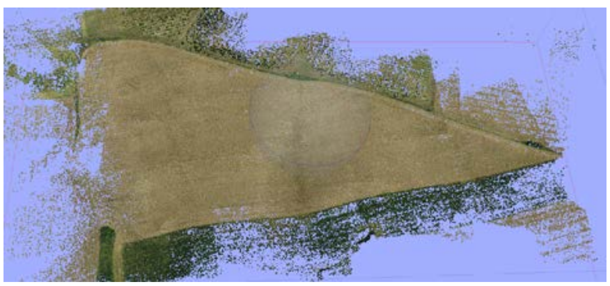

Fig. 3. The point cloud generated from the area

By means of our methods exact figures and data can be gained in surveying game damage or by making series of pictures the development of agricultural cultures can be monitored. By analyzing data the usage of fertilizers and herbicides can be optimized and reduced [12][13].

III. Game damage done by rodents

Processing aerial pictures make it possible to carry out precise measuring and analyses. An experiment was carried out on a young wheat field where the size was determined together with the area that does not yield.

By analyzing the latter one we separated damages due to cultivation and those done by gophers proliferating the area. The preciseness of the pictures did not even result in determining the damaged area by the gophers but also the number of their ’nests’.

In Hungary there is a regulation on protection against gophers *(Par. 2(1) of the Ministry of Agriculture and Rural Development 43/2010. (23 April) on plant protection orders protective measures taken against gophers by farmers and other land users).* On the basis of it, protection is not only the option but also an obligation for the farmers.

At the same time, the rues of chemical protection are quite strict. Except for special cases protection means placing chemical agents into the holes of the gophers. It means that protection is possible by surveying the agricultural area. Typically, systematic walking is necessary to find the nests of the gophers, which is time consuming and labor intensive. With the help of our aerial pictures made by UAVs such orthophotos were taken that can serve as the basis for both quantitative and qualitative analyses (Fig. 5) [14][15][16]. The

Fig. 4: Georeferenced orthophoto on Google Earth satellite image and one of its magnified parts

analyses assisted us in determining the extent of the infection (number of nests in the given area) and its current effect on the growth of wheat (non-yielding area). A 'map' can also be made of the given area in addition to determining the number of nests.

By using this map, protection took place by the direct approach of the detected nests instead of the systematic wandering of the area. After some weeks new series of pictures were made (Fig. 6, 7) whose analysis provided us with quantitative information on the effectiveness of protection and also the extent of regeneration on the damaged area.

The figure illustrates that after protective measures were taken the damaged area did not increase. On the contrary, the green plants started to grow, which resulted in the apparent decrease of the size of the damaged field.

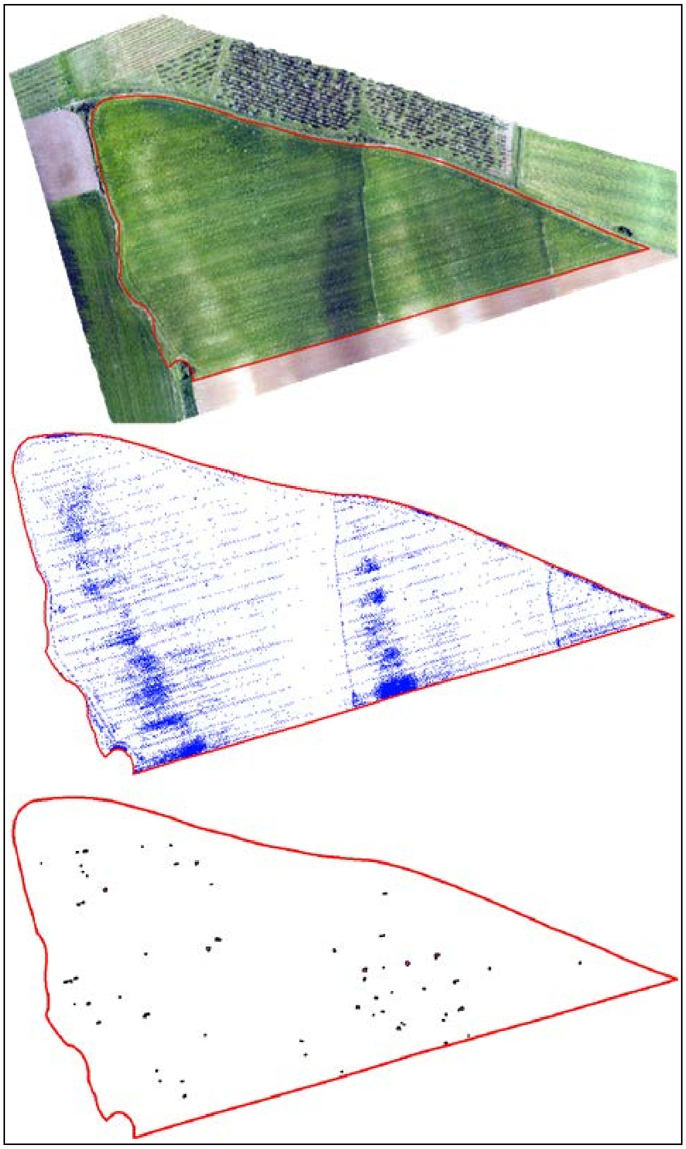

Fig. 5. Determining the expected yield loss of wheat fields and the extent of the damage done by gophers. (24.04.2015); Top: the total area (0.2 km^2); Middle: the area of not yielding or germinating wheat (cultivation traces, improper sowing, soil erosion, rodent damages - 0.0166 km^2); Bottom: damage done by the gophers (196 m^2, 61 nests).

IV. Game Damage Done by Large Wild Animals

Game damage can always be traced down in plant cultures during vegetation whose impact on the final yield depends on the time of the impact as well as the nature of the concrete damage. In the case of trampling if it takes place during vegetation, partial or even total regeneration is possible provided that no other trampling occurs.

When the plant, especially its shoot tips or productive parts are chewed, the damage is usually irreversible. Of course, in this case protection means stopping further damage. It is very difficult and often imprecise to assess the damage and express it numerically as the height of the plant culture does not make the observation of the area possible [17].

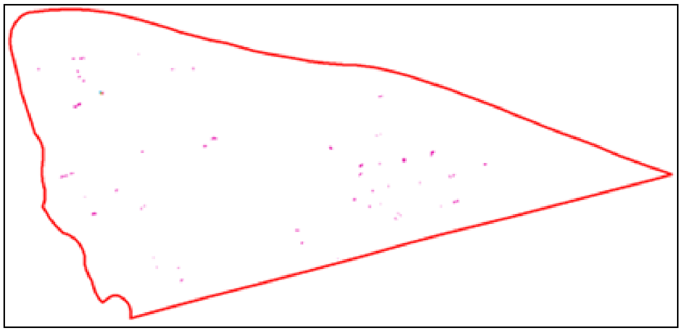

Fig. 6: Gopher nests after protection

Fig. 7: Before and after protection – no damaged area growth

Typically, only the borders of the damaged area can be discerned and the extent of the real damage, which is not visible from the land, can empirically be concluded.

Fig. 8 presents the assessment of a sunflower field. Pictures were taken in several stages of growth. Assessment took place on the basis of the picture taken at blooming but, of course, the time series make it possible to follow the entire process of growth and changes in the damage. The high resolution serves as the basis for detailed and exact analysis.

Paying attention to details necessitates adjusting the barren area with spaces between the lines as the analysis regards them as damaged areas. When magnifying the figure part of the examined area free from damages can be seen well. The yellow color marks the area not covered by plants (Fig 9.).

Accordingly, had the area not been damaged, the uncovered part would amount to 15.6%, which is the consequence of natural cultivation, i.e. covering 84.4% can be regarded as 100% utilization. By adjusting this figure we managed to assess the extent of damage made by deer. The image shows that the sunflower filed basically suffered damage from the bordering forest, which justifies the experience that the wild herbivorous game damage the open cultures by coming out of the forest.

Fig. 8. Game damage in the sunflower field
(Area: 0.263 m^2, Coverage ratio of healthy area: 84.4%, Vegetation: 0.153 m^2, Barren: 0.11 m^2, Adjusted barren ratio: 26.2%

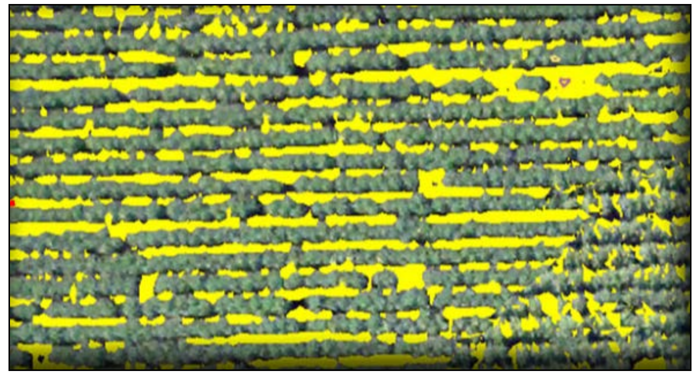

Fig. 9. Corrected vegetation ratio. Yellow marks non computable areas.

When having a closer look at the photo it can be seen that the deer bit the middle of the growing plant. This observation justified the determination of the areas declared to be damaged on the basis of the aerial pictures.

Regularly taking pictures of the examined areas is useful from a lot of aspects. On the one hand, the temporary stage of development can be seen and in some cases this information can assist decision making to determine the time and the extent of the necessary interventions. On the other hand, at the different stages of the plant's development, different types of information can be obtained while assessing the pictures, e.g. the damage done to sunflowers can best be assessed at blooming.

Fig. 10 presents the photograph of sunflower on the seventh day after desiccation. The healthy and the damaged area are not so well discernible in the picture so at this stage the assessment of the damage is uncertain.

Figure 10: Blooming (top) and dried (bottom) sunflower

Figure 11: Monitoring the development of agricultural cultures by UAV (The bottom left corners show a magnified part of the area.)

V. Monitoring plant development

Due to the relative simplicity of shooting the pictures and its cost-effectiveness (when compared with traditional pictures from manned aircrafts or satellite ones of the same resolution) even smaller areas can serve as the subject of the temporal series.

The pictures taken of the same area at the single key stages of plant development or in the period after spreading the insecticides and fertilizers can help determine the exact time of chemical distribution and also obtain more exact feedback on the efficiency of the treatment.

Fig. 11 presents the temporal series of pictures taken of a wheat field. The first picture was made when the plant had only two leaves. We also managed to locate the gopher nests at that time exactly, which was the basis for protection. The picture in July reflects the situation before harvesting while the one in September shows the green condition. It can be seen well that the eroded parts of the area made a significant impact on the plant in spite of the fact that the wheat obtained enough nitrogen in the vegetation period.

Another way to monitor plant development is usage of a multispectral camera. Low resolution (1 MPixel) versions are available for UAV applications (e.g. Tetracam ADC Micro). These sensors are usually lightweight (1-200g) but they are slower and have significantly lower resolution compared to their full sized versions. Usually the resolution of final multispectral ortophoto (Fig. 12, 13) is around 0.15-0.30 m/pixel, while Landsat 7/8 satellite provides (free of charge) 30-60 m/pixel resolution images which can used to verify UAV surveys and calculate e.g. NDVI maps (Fig. 14, 15).

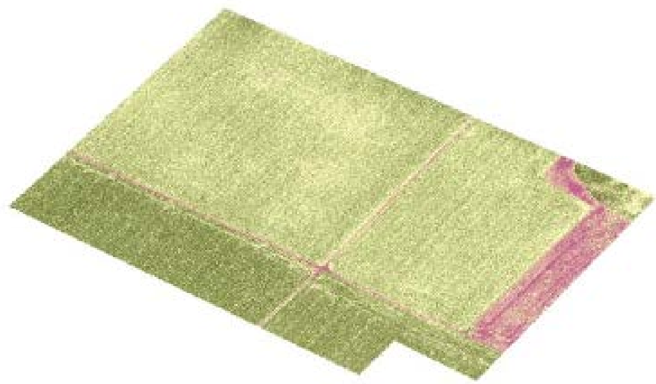

Fig. 12: NDVI map from ADC micro

Fig. 13: NDVI map from Landsat 8 (from the same area as Fig. 12)

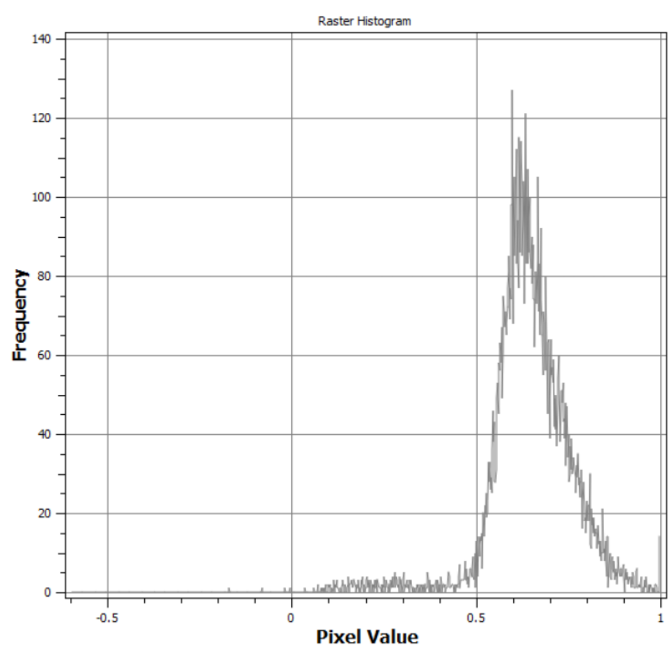

Fig. 14: NDVI histogram from ADC micro data

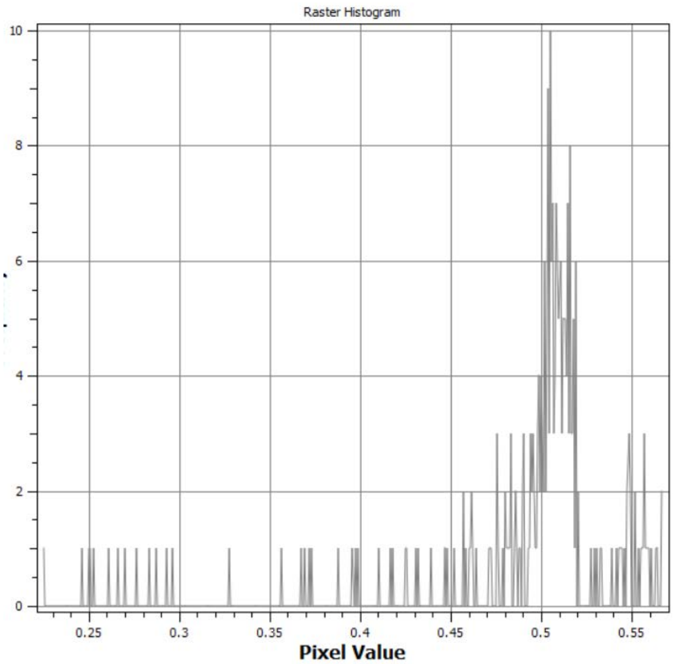

Fig. 15: NDVI histogram from Landsat 8 (from the same area as Fig. 14)

VI. Conclusion

The use of UAV in agriculture provides several opportunities. The applications presented can result in significant savings or minimizing losses and also can serve as the basis for assessing game damages. Due to high resolution and georeferencing, the precise results can be used for monitoring and controlling works on the field. We intended to the cost-effectiveness and efficiency of applying these instruments in agriculture so that farms would not be required to build special infrastructure for UAV so it can be applied on any agricultural area depending on the weather conditions. They grant cheaper survey compared to a human piloted aircraft and has even around 100 times better resolution compared to a multispectral Landsat 7-8 satellite image.

References

[1] T. Moranduzzo et al: Multiclass Coarse Analysis for UAV Imagery, (2015) IEEE Transactions on Geoscience and Remote Sensing, 53 (12), art. no. 7152884, pp. 6394-6406.

[2] C. Wu, R. Zhang, B. Liu, Z. Fang: An optimization algorithm for stitching of aerial images taken by UAV, (2015) Shenyang Jianzhu Daxue Xuebao (Ziran Kexue Ban)/Journal of Shenyang Jianzhu University (Natural Science), 31 (1), pp. 182-192.

[3] M. Zheng, C. Wu, D. Chen, Z. Meng: Rotation and affine-invariant SIFT descriptor for matching UAV images with satellite images, (2015) 2014 IEEE Chinese Guidance, Navigation and Control Conference, CGNCC 2014, art. no. 7007582, pp. 2624-2628.

[4] Y. Zhang, G. Jiang, Y. Di: Speed-up matching method with navigation data for UAV remote sensing images of coastal region, (2015) Proceedings of SPIE - The International Society for Optical Engineering, 9669, art. no. 966908,

[5] S. Yahyanejad, B. Rinner: A fast and mobile system for registration of low-altitude visual and thermal aerial images using multiple small-scale UAVs, (2015) ISPRS Journal of Photogrammetry and Remote Sensing, 104, pp. 189-202.

[6] Z. Tong et al: Integration of UAV-based photogrammetry and terrestrial laser scanning for the three-dimensional mapping and monitoring of open-pit mine areas, (2015) Remote Sensing, 7 (6), pp. 6635-6662.

[7] K. Han et al: UAV vision: Feature based accurate ground target localization through propagated initializations and interframe homographies, (2012) Proceedings - IEEE International Conference on Robotics and Automation, art. no. 6225073, pp. 944-950.

[8] S. Szénási, Z. Vámossy: Evolutionary algorithm for optimizing parameters of GPGPU-based image segmentation, (2013) Acta Polytechnica Hungarica, 10 (5), pp. 7-28.

[9] G. Kertész, S. Szénási, Z. Vámossy: Parallelization Methods of the Template Matching Method on Graphics Accelerators, (2015) 16th IEEE International Symposium on Computational Intelligence and Informatics – CINTI, pp. 161-164. ISBN:978-1-4673-8520-6

[10] L. Somlyai, Z. Vámossy: Map Building with RGB-D Camera for Mobil Robot, IEEE 16th International Conference on Intelligent Engineering Systems 2012 (INES 2012), pp. 489-493, ISBN: 978-1-4673-2695-7, Lisbon, Portugal, 2012

[11] D. Turner, A. Lucieer, L. Wallace: Direct georeferencing of ultrahigh-resolution UAV imagery, (2014) IEEE Transactions on Geoscience and Remote Sensing, 52 (5), art. no. 6553130, pp. 2738-2745.

[12] B.S. Faiça et al: The use of unmanned aerial vehicles and wireless sensor networks for spraying pesticides, (2014) Journal of Systems Architecture, 60 (4), pp. 393-404.

[13] Y.B. Huang et al: Development and prospect of unmanned aerial vehicle technologies for agricultural production management, (2013) International Journal of Agricultural and Biological Engineering, 6 (3), pp. 1-10.

[14] F. Rinaudo, F. Chiabrando, A. Lingua, A. Spanò: Archaeological site monitoring: UAV photogrammetry can be an answer, (2012) International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives, 39, pp. 583-588.

[15] H. Eisenbeiss, M. Sauerbier: Investigation of UAV systems and flight modes for photogrammetric applications, (2011) Photogrammetric Record, 26 (136), pp. 400-421.

[16] A. Lucieer, D. Turner, D.H. King, S.A. Robinson: Using an unmanned aerial vehicle (UAV) to capture micro-topography of antarctic moss beds, (2014) International Journal of Applied Earth Observation and Geoinformation, 27 (PARTA), pp. 53-62.

[17] J.P. Dandois, E.C. Ellis: High spatial resolution three-dimensional mapping of vegetation spectral dynamics using computer vision, (2013) Remote Sensing of Environment, 136, pp. 259-276.

A. Molnar was born in Moscow, USSR on 5 May 1967, and received his MSc degree at University of Szeged Faculty of Science and Informatics, Hungary in 2001. He received his PhD degree in 2006 at the Zrinyi Miklos National Defence University, Hungary. He is an Associate Professor at J. Selye University, Slovakia. His main research areas are autonomous control of Unmanned Aerial Vehicles and related applications.

D. Stojcsics was born in Budapest, Hungary on 21 February 1984, and received his MSc degree at Obuda University John von Neumann Faculty of Informatics, Budapest, Hungary in 2010. He received his PhD degree in 2012 at the Obuda University, Doctoral School of Applied Informatics. He is a Lecturer at J. Selye University, Slovakia. His main research area is guidance methods of fixed wing Unmanned Aerial Vehicles.

I. Lovas was born in Budapest, Hungary on 04. September 1990, and received his BSc degree at Obuda University John von Neumann Faculty of Informatics, Budapest, Hungary in 2015. Now he is an MSc student and co-researcher at Obuda University. He is a professional fixed and rotary wing drone pilot and his main research area is multicopter indoor navigation..