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Application of Photogrammetry in Agriculture with an Emphasis on Close-Range

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Abstract: In contemporary agricultural practices and technological advancements, the paramount focus is on enhancing productivity and operational efficiency. This entails the effective management of digital resources like obtained from photos while minimizing costs. Through the application of close-range photogrammetry and various specialized software (Agisoft Metashape, CloudCompare, MicMac, Pix4Dmapper and OpenDroneMap), farmers can effectively and accurately monitor vegetation indices and generate three-dimensional models, thereby enhancing the optimization of their agricultural practices. Photogrammetric softwares enable creating 3D models, their interaction with the processing procedure, production of point clouds, image mergin from drone photos and an automatic extraction of DEMs. The emphasis of the paper is on the great potential of photogrammetry with the main goal to improve modern agriculture such as cost reduction, precision and accuracy, data collection and similar to. Paper is based on examples of practice and field work in the agricultural sector around the world.

Keywords: Agisoft Metashape; agriculture; close-range photogrammetry; CloudCompare; MicMac

1 INTRODUCTION

The non-contact acquisition of data on the characteristics of studied surfaces and objects and their interpretation can be done using photogrammetry [1] and, in general, the technique of measuring the shape, size or position of a selected object through the interpretation of a series of photographs [2]. According to [3, 4], photogrammetry can be described as an art, science and technology to obtain good quantitative information about various objects and the surrounding environment through the process of measuring, recording and deciphering photographic images. The most economical and fastest way to collect geospatial data is by using digital photogrammetry methods [5]. In the discussed field, remote sensing generally offers two functional options, namely, satellite imagery and unmanned aerial vehicle photogrammetry [6, 7]. According to [8] the monitoring of a selected corn hybrid within pre-defined growth intervals is possible with photogrammetry images. Authors [9] used digital photogrammetry to quantify erosion on agricultural land. Photogrammetry is divided into two main types, namely aerial photogrammetry and terrestrial photogrammetry [10]. At the same time, there are two further subdivisions in relation to the position of the camera, namely horizontal and extra-terrestrial photogrammetry [11]. In close-range photogrammetry, the objects studied are examined using photographs or digital images taken with a camera at close range. The model in close-range photogrammetry is created on the basis of the central perspective projection [12]. It is mainly based on digital technology to store and manipulate data (images) in the applied area to create digital models that correspond to the real captured objects. This opens up the possibility of modeling standard concepts such as length, area and size as well as spatial coordinates [13]. The authors [14] note that with the increasing resolution of digital cameras and advances in calibration, close-range photogrammetry is increasingly being used to create three-dimensional models of objects with high precision. Model construction with close-range photogrammetry consists of a series of steps that begin with taking photographs and orienting them relative to the object [15].

2 PHOTOGRAMMETRIC SOFTWARES

2.1 Agisoft Metashape

Agisoft Metashape is used for 3D modeling, which creates high-quality 3D spatial data by processing digital photos [16]. On figure 1 is presented the process of importing and aligning photos from plough share. Agisoft Metashape is a program that performs photogrammetric processing of digital photos and generates three-dimensional spatial information used in geographic information systems and visual effects production, as well as for indirect measurements of various objects. The authors [17] claim that it is an improved photo-based three-dimensional modeling that can be used to generate professional-quality three-dimensional content from still photographs. This program is one of the best photogrammetry tools. Author [2] states that the mentioned application is used to process 3D data on the wear and tear of parts of agricultural machinery. The program also makes it possible to work with laser scanning and combine data from LiDAR (Light Detection and Ranging) and cameras in the same project. LiDAR is a widely used method for reconstructing three-dimensional images for various applications and points to reconstruct three-dimensional maps of the investigated environment [18].

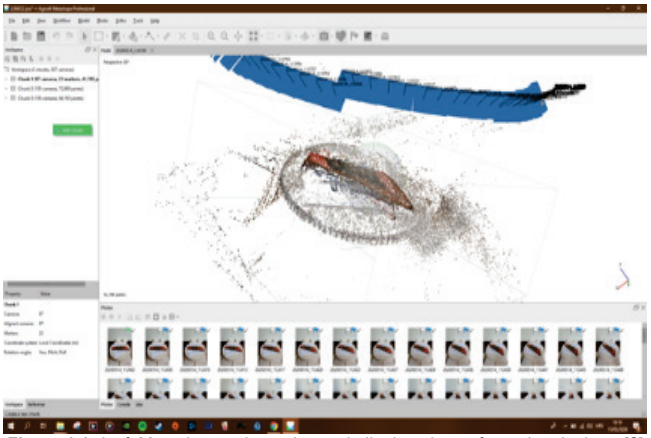

Figure 1 Agisoft Metashape – importing and aligning photos from plough share [2]

2.2 MicMac

MicMac (Fig. 2) is a freeware program for photogrammetry [19]. It is used by the French National Geographic Institute for its research, which includes algorithms for three-dimensional image processing for a wider audience, universities, public institutions and companies [20]. The MicMac processing method is fully customizable by the user, allowing for fine-tuning [21]. As a photogrammetric program, it is characterized by precision and reliability and offers capabilities not available in most alternative programs [14]. For example, according to the authors [20], the program allows access to intermediate results in open data formats, which enables interaction with the processing procedure at each stage as well as qualitative evaluation of the results via quality indicators. In addition, different models for camera calibration are available, e.g. models configured for cameras with basic functionality, large-format aerial cameras, cameras with very long focal lengths, fisheye cameras and cameras that can capture a 360-degree panorama [20]. Authors [22] state that the MicMac was successfully used for the purposes of determining key agricultural strategic factors.

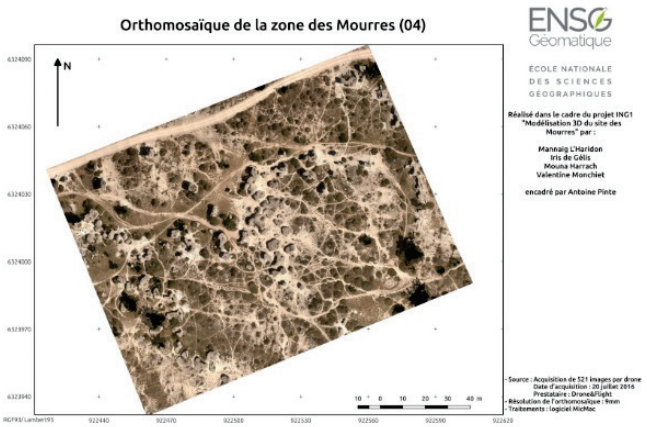

Figure 2 MicMac ortho-mosaic [23]

2.3 Pix4Dmapper

Pix4D (Fig. 3) is an advanced program for creating geocoded maps and models from aerial imagery. Sophisticated photogrammetry software is used to create professional orthomosaics, point clouds and models from images captured by drones [24]. According to the official manufacturer Pix4D, the main process consists of 7 steps: Capture, Digitize, Control, Measure, Review, Collaborate and Share. With the mentioned program, different performances of final products can be obtained, such as point clouds in full color, orthomosaics, three-dimensional textured meshes, a series of maps of general interest and temperature mapping with corresponding data processing that includes a report on the credibility of the data [25]. According to [26] the aforementioned application was used for software for processing photogrammetric data, more precisely for creating maps for precision fertilization.

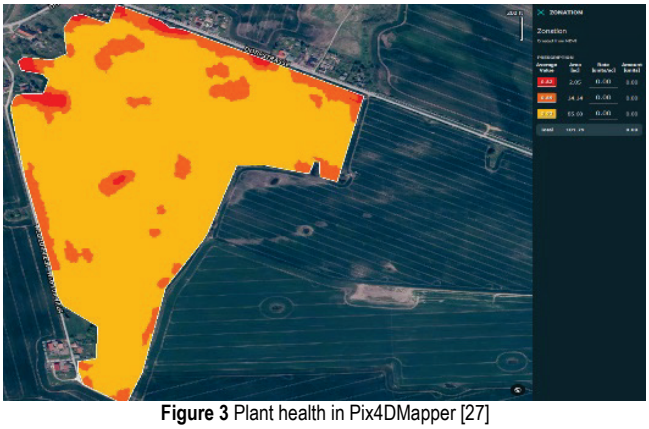

Figure 3 Plant health in Pix4DMapper [27]

2.4 OpenDroneMap

OpenDroneMap (Fig. 4) contains a set of open source software packages that provide a complete photogrammetric solution for small drones [28]. The software works as an application for processing non-referenced images with a high degree of overlap, including color point clouds, digital surface models, textured digital surface models, and orthophotos [29]. After the process of image merging, the software has a visualization option that uses Meshlab, Python, and the WebOdm web application to integrate features such as user authentication, map visualization, and three-dimensional displays [30]. According to [31] it was possible to create a weed spread map with the help of OpenDroneMap.

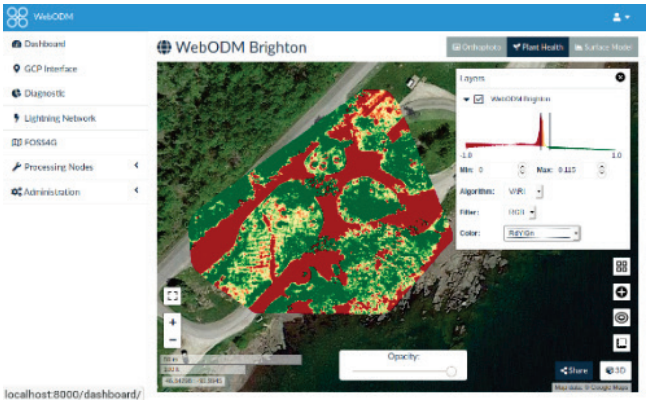

Figure 4 Plant health in OpenDroneMap [32]

Figure 5 Laser Scanner PlantEye builds 3D point clouds [34]

Laser scanners are often used for non-contact measurement (Fig. 5) of roughness and provide information on accuracy in the range of 0.1 – 0.5 mm and 0.1 – 2 mm for vertical and horizontal measurements respectively.

Numerous studies of this type have been carried out under controlled indoor conditions, as certain devices must be used in field research due to their complexity, which has a direct impact on variable costs, technical maintenance and ultimately low resistance to meteorological conditions and dust, as well as processing time [33].

3 APPLICATION OF PHOTOGRAMMETRY IN AGRICULTURE

3.1 Vegetation Indices

Vegetation indices (Tab. 1) provide a wealth of data for various practical applications in precision agriculture and offer quantitative information on plant growth and health [35]. Vegetation indices (VARI, NGRDI, GLI and ExG) are the result of very simple and effective algorithms for quantitative and qualitative prediction of vegetation cover, lushness and growth rate, which are used in environmental monitoring, biodiversity conservation, agriculture, forestry and other similar fields [36]. Vegetation indices are information obtained by calculating from numerous channels of multispectral images based on the absorption, transmission and reflectance of plants in different spectral channels. Vegetation indices are used to graphically predict vegetation activity on the production area under investigation. Vegetation indices in production areas with vegetation have higher pixel values than in areas without vegetation [3].

4 CLOSE-RANGE PHOTOGRAMMETRY IN AGRICULTURE

Close-range photogrammetry usually captures an object within a few metres from different angles. Used in agriculture, it can generate 3D models using various algorithms.

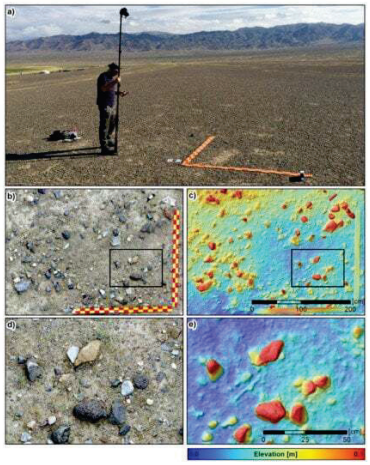

Figure 6 Measurement of soil surface roughness by close-range photogrammetry method processed by Agisoft Photoscan [41]

4.1 Improving the Accuracy of Soil Roughness Measurements

The quantification of soil roughness is actually the extent of irregularity of the production surface due to soil texture, aggregates, rock fragments and the way the production surface is worked. It has a significant impact on surface water storage, infiltration, overland flow and ultimately sediment deposition and erosion [37]. The roughness of the production surface can be determined by contact techniques such as roller chain calculations [38], profile measuring devices or using a needle [39] and automated relief measuring devices [27]. Automated close-range photogrammetry is increasingly used today (Fig. 6) [40]. Stereophotogrammetry, which enables very fast information acquisition and automatic extraction of DEMs, is used to obtain micro-reliefs of the production surface with acceptable accuracy (vertical 0.2–6 mm, horizontal 1–5 mm).

4.2 3D Surface Modeling of a Tomato Plant and Tractor Tire Footprints

The creation of a 3D model is considered a complete process, the first step of which is the collection of information, while the last step is the creation of a virtual 3D model that can be displayed on a computer multimedia [42]. Close-range photogrammetry enables very high-resolution point clouds (Fig. 7). Efficient methods for 3D reconstruction from images are widely available on web-based online processing services and allow the export of high-quality textured 3D models (Fig. 8) [43].

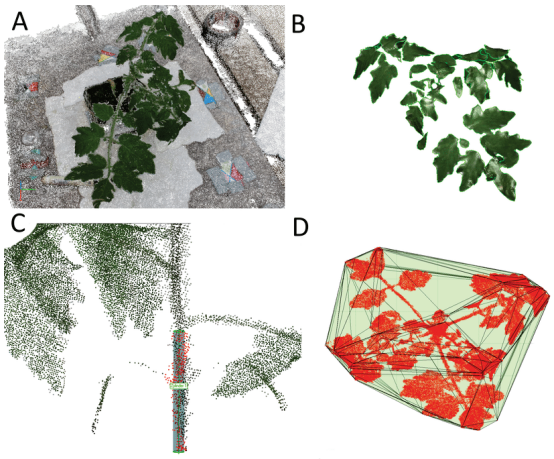

Figure 7 Three-dimensional mesh cloud of a tomato vegetable [5]

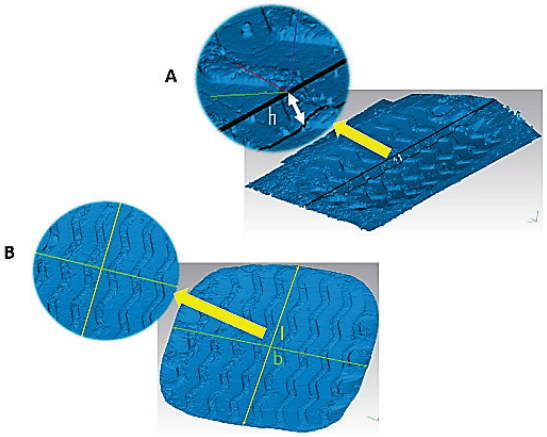

Figure 8 3D mesh of triangles of the tire imprint on the ground: A - with intact ground (h - depth of the imprint); B - determined imprint (l - length of the imprint and b - width of the imprint) in Smarttech3Dmeasure [44]

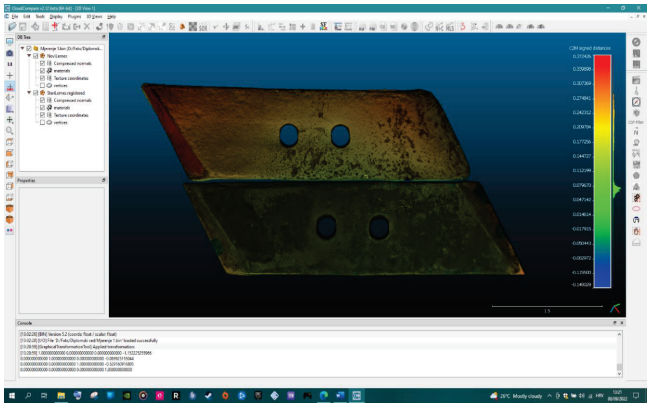

Figure 9 CloudCompare Surface differences on plough share's [2]

5 CLOUDCOMPARE

CloudCompare (Fig. 9) is a software for processing 3D point clouds and triangle meshes. Also, CloudCompare can show differences in surfaces, measure surface and measure volume. Very important for this kind of application is that it can shown and export differences by diagrams. In addition, it includes advanced data processing algorithms to perform actions such as displaying images in multiple projections (rectangular, cylindrical, conical), registering point clouds, calculating distances (between two point clouds, between a cloud and a triangle mesh, between two individual points), test statistics, and evaluating geometric properties [45]. It can be easily used for the visualization of large data sets.

6 CONCLUSIONS

Tribology is the science that studies phenomena on the surfaces of two bodies in contact or relative motion (triboelements), primarily friction, material wear, and the effects of lubrication. At the beginning tribology was based on measuring the mass of objects before and after using. in this way, an insight was gained into the state of the materials, i.e. today's 3D models, which can be created much faster thanks to the mentioned programs. The use of photogrammetry in agriculture represents a significant and promising approach for the further development of the agricultural sector. This paper has also emphasized the potential of photogrammetry, i.e., short-range photogrammetry, in various segments or aspects of agriculture, ranging from crop monitoring using vegetation indices to the accuracy of soil surface roughness measurements and the creation of 3D plant models through short-range photogrammetry. The use of photogrammetric technologies and the processing of images with photogrammetric software enable farmers and experts to optimize the use of resources and improve productivity and work efficiency. Close-range photogrammetry in agriculture offers great opportunities for precision agriculture. Agisoft Metashape is one of the best known photogrammetry programs and is characterized by its ability to create very high quality 3D models. It is mainly intended for professionals. MicMac and OpenDroneMap are open source programs that provide tools for image processing and 3D model creation. Their best feature is their cost-effectiveness. Pix4DMapper is a program, which uses photos to create high quality orthomosaics and is often used in agriculture. CloudCompare, while not photogrammetry software, is used for processing and analyzing 3D point cloud data.

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