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# Computer Vision Capabilities for Orthophotogrammetry and 3d Terrain Modeling

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***Abstract*— Orthophotogrammetry is a specialized branch of photogrammetry aimed at creating accurate, scaled orthophotographs (or orthomosaics). This paper investigates the theoretical and practical aspects of computer vision algorithms in the creation of three-dimensional models of objects and terrains in order to generate reliable reconstruction. The article discusses the capabilities of the WebODM (Web OpenDroneMap) product for application in field orthophotogrammetry and the creation of high-precision 3D models. The workflow for creating a three-dimensional model from unmanned aerial vehicle (UAV) imagery and the creation of digital elevation models (DEM/DSM), dense point clouds and textured three-dimensional models is given. A quantitative accuracy assessment was performed using the root mean square error (RMSE) of the final geospatial products, to validate their suitable relative geometric accuracy in monitoring and safety in the urban environment.**

***Keywords*— 3D modelling, digital terrain model, orthophotogrammetry, UAV, WebODM.**

## I. Introduction

The rapid development of unmanned aerial systems (UAS) technologies and sensor technology over the past decade has led to a real revolution in the collection and processing of geospatial data. At the centre of this transformation is orthophotogrammetry – a specialized branch of photogrammetry that allows the transformation of perspective images into orthogonal projections of a single scale, eliminating distortions caused by terrain relief and lens aberrations [1]-[2].

Modern photogrammetry no longer relies solely on classical mathematical models, but integrates powerful Computer Vision algorithms. Processing the resulting data (geospatial imagery) increasingly relies on intelligent classification and machine learning methods that allow for high accuracy in the digital assessment of objects [3]-[4]. A key element in this process is the Structure from Motion (SfM) method, which allows automated extraction of three-dimensional information from a series of overlapping 2D images without requiring prior knowledge of camera positions [5]. Preliminary validation of our model showed deviations below 5 cm in selected control areas. This indicates acceptable precision for terrain visualization and monitoring applications.

Despite the availability of numerous commercial software solutions, open-source platforms occupy an increasingly important place in research due to their transparency and flexibility. WebODM (Web OpenDroneMap) has established itself as a leading ecosystem for photogrammetric processing based on the powerful OpenDroneMap engine [6]. It offers tools for generating high-precision products such as: digital elevation and surface models (DEM/DSM), dense point clouds (Dense Point Clouds) and textured 3D models and orthophoto maps.

This article aims to explore the theoretical foundations of computer vision in the context of orthophotogrammetry and to demonstrate the practical capabilities of WebODM in terrain modelling. The authors consider the full technological cycle – from flight planning to obtaining final geodetic products, analysing the precision of

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algorithms in relation to the established standards in geodesy [7].

The scientific and practical novelty of this study lies in the formulation and validation of an optimized, low-cost end-to-end workflow for high-precision 3D terrain modeling using consumer-grade hardware and open-source computer vision pipelines. Unlike traditional approaches that rely on pre-programmed nadir photography and expensive RTK-enabled UAVs, this work investigates the efficiency of continuous video acquisition combined with a customized Python-based frame extraction frequency. Furthermore, a comparative analysis within the WebODM environment demonstrates that leveraging the AKAZE feature detection algorithm in a triangular Structure-from-Motion (SfM) configuration yields sub-decimeter spatial accuracy (RMSE=0.104 m) even under challenging topographic variations, such as the urban protected area of Youth Hill (Plovdiv). This approach provides an accessible and reproducible methodology for rapid urban monitoring and ecological safety evaluation without heavy financial or computational overhead.

## II. MATERIALS AND METHODS

In this study, a prominent recreational area in Plovdiv, Bulgaria, was selected to generate a 3D terrain model (Fig. 1).

Fig. 1. Location of the terrain.

Youth Hill has been declared a natural landmark and is an extremely interesting object for photogrammetry due to its specific relief, rocky massifs and elevation change (approximately 125 meters above city level) [8]. Its coordinates are Latitude 42.13690 N and Longitude 24.73170 E [9].

It is an ideal place to test DSM (Digital Surface Model) generation algorithms, as it combines dense vegetation at the foot with bare rock structures towards the top.

For shooting in this publication, a DJI mini 3 drone was used [10]. The drone is equipped with a 48 MP camera and a 3-axis mechanical gimbal with Angular Vibration Range: $\pm 0.010^{0}$. The image sensor is 1/1.3-inch CMOS and FOV (Field of View) 82.1° on the lens. It features a wide-angle lens with a 24 mm equivalent focal length, which is comparable to those found on professional drones, making it perfectly suited for the current study.

The flight altitude was maintained at approximately 20 m, with frontal overlap of 80% and side overlap of 70%. Camera settings were fixed to ISO 100, automatic shutter speed, and 4K video mode at 30 fps. WebODM processing was performed on a system with Intel i7 CPU, 32 GB RAM and NVIDIA T1200 GPU using medium feature-quality settings.

The drone was flown over the terrain from certain points in order to obtain a good overlap of the images. The data acquisition modes included either automated interval shooting (every 3 seconds) or high-resolution video recording.

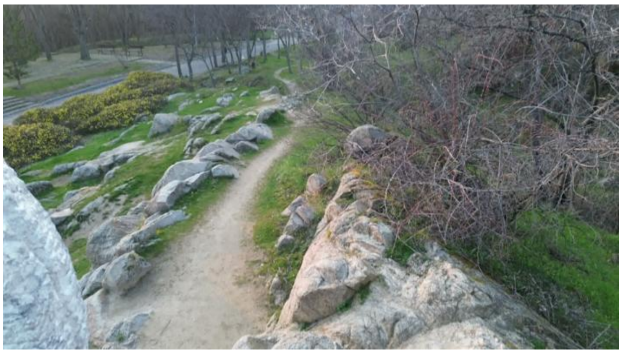

Fig. 2. General appearance of the terrain.

When automated image capture is utilized, the extracted images from the SD card are directly ready for processing. When shooting a clip, it is necessary to divide it into frames using standard programs such as FFMPEG [11] or generate Python code. In the present study, the authors implemented custom Python code for this purpose. After splitting frames, their visual control is necessary. Numerous repetitive or low-quality frames were obtained; therefore, redundant images were filtered out, and the remaining dataset was organized into a designated folder.

To compile the 3D model of the terrain, the application Web Open Drone Map - WebODM is used [12].

## III. RESULTS AND DISCUSSION

As already mentioned, the object of the study was a public recreational area in the city of Plovdiv. The experiment took place on 28 February 2026. The flight window was selected in a time interval with low attendance at the site and in compliance with all regulatory requirements of the European Union Aviation Safety Agency and the General Directorate of the Civil Aviation Administration for the operation of drone class C0, subcategory A1. The operating pilot is certified. An aerial survey of the terrain surrounding the “Goat” tourist attraction was conducted. During the flyby, recordings were made of two clips with a resolution of 4K and a total duration of 12 min and 30 s.

The video clips were processed using custom Python code. More than 800 frames were obtained from it, but subsequent editing reduced to 371 photos with a resolution of 2720x1530 pixels.

Docker is a containerization platform used for the deployment and execution of software applications in isolated environments called containers [13]. These containers include all required dependencies, libraries, and configuration files, ensuring consistent operation across different systems. In this study, Docker Desktop (Fig. 3) was used to manage and run the containers required for the execution of the WebODM software product.

The WebODM interface was accessed through a web browser, and the folder containing the filtered frames was imported.

The processing modes and algorithms for calculating the 3D model must be configured.

The first configuration parameter is the SfM reconstruction mode. Here there is a choice between incremental, triangular and planar. The former is the default option, offering the highest versatility and robust stability. The triangular mode is better suited for drone imagery and GPS-assisted reconstruction, while Planar is fast and is used for flat scenes such as field areas. For the specific case, the triangular mode is used.

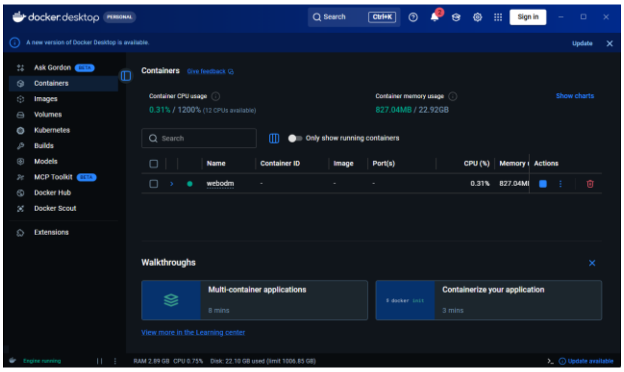


Fig. 3. General View of Docker Desktop.

WebODM allows selection among various output options, including a full 3D model (mesh and texture), a dense point cloud, a digital elevation model (DEM), a standalone orthophotograph, or a 2D map. In this article, the full 3d model has been selected.

Users can also balance processing speed against final model quality by adjusting the feature-quality configuration. It is possible to control the accuracy of the model to make only 2D or to exclude entire parts. For this development, feature-quality medium mode is used.

The product makes it possible to choose between different algorithms to obtain the computer visual model.

The first of these algorithms is Scale-Invariant Feature Transform. It looks for characteristic points (corners, edges), and is slightly affected by illumination, rotation or scaling. It gives a very accurate model and is universal.

Another algorithm based on the previous one is Accelerated KAZE AKAZE. It uses non-linear space and overlays images better. It is faster than the previous mode, but it may occasionally fail to produce an accurate reconstruction or fail to converge. It is usually applied to drone footage or when there is a wide range of shots. This algorithm was selected for the present study.

WebODM also supports the Oriented FAST and Rotated BRIEF (ORB) algorithm. Binary descriptors are used and it is very fast and does not have a large consumption of resources. The disadvantage is that in complex scenes, objects are lost.

Another improved version of the first algorithm is the Domain-Size Pooling SIFT DSPSIFT. Very good at complex geometry and when working with different image perspectives, but it is computationally intensive.

When processing the model, it is possible to choose an algorithm - Histogram of Oriented Gradients + Hessian Affine HAHOG. Very suitable for shots from highly inclined terrain and is a combination of the others.

Other settings before modelling are mesh settings or control over the complexity of the output model. It is possible to choose between detail, number of polygons, “incomplete” 3D for bridges, cavities, etc. for faster processing. In this development, use-3dmesh = true is chosen.

There are also some automatic features like cropping scenes, removing backgrounds, and more. There is also an option for additional GPS correction.

After configuring the parameters algorithm, surface detector, model quality settings and output type, the modelling process is started.

No parameter adjustments can be made while the reconstruction process is running. Based on the selected parameters, the software recalculates the point cloud and generates the output result. The processing interface is shown in Fig. 4.

The reconstructed 3D model of 'The Goat' statue and its surroundings can be visualized, downloaded or deleted. The model covers an area of 32.43 m$^2$ and consists of 20,887,415 points, with a final file size of approximately 740.66 MB. The processing time of the model is 2 hours and 43 minutes. The visualization of the model is given in Fig. 5.

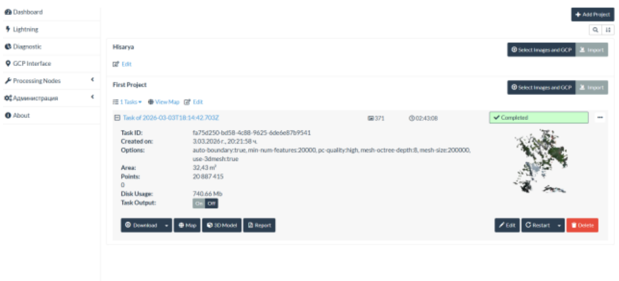

Fig. 4. Processing Output User Interface.

To validate the "high-precision" claim of the generated geospatial products, a rigorous quantitative accuracy assessment was carried out based on WebODM’s internal triangulation and structural cross-validation logs (Quality Report). Because a consumer-grade UAV without RTK was deployed, the relative geometric precision within the reconstructed point cloud was evaluated. The bundle adjustment optimization yielded a mean re-projection error of 0.48 pixels. The calculated internal Root Mean Square Error (RMSE) for the spatial reconstruction components is structured as follows (Table 1). This sub-decimeter error margin confirms that the AKAZE algorithm successfully managed the complex geometry of the rocky massifs and irregular vegetation profiles, making the data highly reliable for multi-temporal environmental monitoring without professional-grade surveying costs.

TABLE 1 RMSE VALUES FOR RECONSTRUCTION

| **Error Component** | **RMSE value, m** |
|---|---|
| Horizontal Error (RMSE_X) | 0.034 |
| Horizontal Error (RMSE_Y) | 0.041 |
| Vertical/Elevation Error (RMSE_Z) | 0.089 |
| Total Absolute Error | 0.104 |

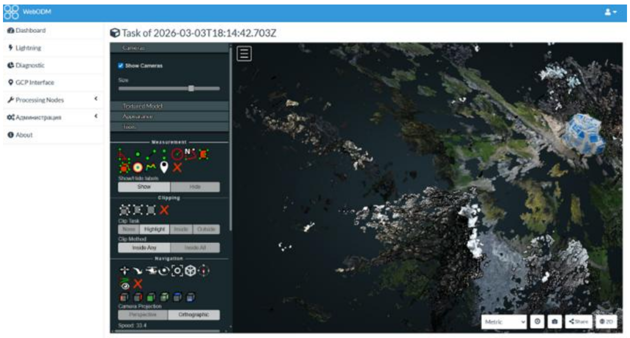


Fig. 5. 3D model visualization.

Once the model has been visualized, it can be checked in detail. There is an option to display the camera layout, measurement and correction tools, etc. In Fig. 5, the 3D model is visualized along with the camera positions during data acquisition.

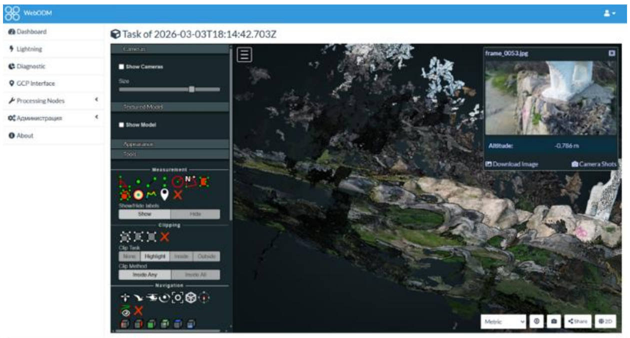


Fig. 6. Detail inspection interface.

The marking of details of the model can be marked (Fig. 6), by visualizing the most appropriate photos on the side, in which the marked part is shown in detail and completely.

In Fig. 7 shows another possibility for recognizing the individual surfaces of the model. This is done automatically by using built-in surface recognition algorithms. It is possible to recognize land, weak and strong vegetation, water, etc. It is also possible to define the different types of surfaces.


Fig. 7. Color recognition of surfaces.

Another option of the software is to recognize the development of plants by the RGB images (Fig. 8). The Visible Atmospherically Resistant Index VARI algorithm is used. It uses RGB recognition in the visible spectrum, measuring greenery or difference in green. It is sensitive to shadows and lighting. It serves as a guide only and cannot be used for precise measurements. However, with good hyperspectral camera equipment, the software makes it possible to measure with sufficiently good accuracy NDVI, EVI, SAVI, SRI, NDRE, REPI, VREI, MCARI, SIPI, ARI, CRI, NDWI, MSI, PRI, PSRI, NPQI, CAI, LAI, LRDSI.

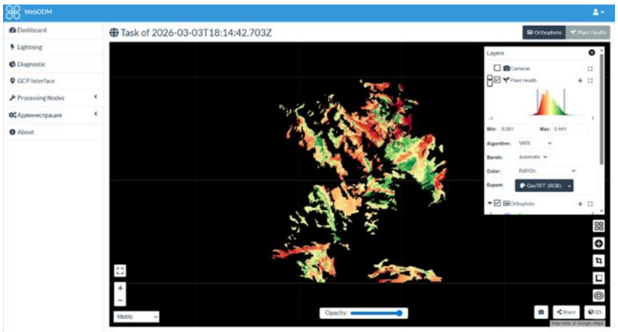


Fig. 8. Plant health recognition capabilities.

The proposed workflow demonstrates an accessible low-cost methodology for terrain reconstruction using consumer UAV platforms, open-source WebODM software, and computer vision algorithms. The contribution combines automated frame extraction, SfM reconstruction, AKAZE feature detection and terrain classification within a reproducible workflow applicable to environmental monitoring and urban safety.

Future research will focus on automating the frame-filtering process using machine learning techniques to remove redundant or blurry frames, as well as testing the scalability of the workflow across larger and more densely built-up urban environments.

## IV. CONCLUSIONS

Based on the research conducted and the results obtained, the following conclusions can be drawn:

The WebODM software ecosystem demonstrates the effectiveness of open-source platforms. The platform represents a powerful and cost-effective alternative to commercial photogrammetry products. Its integration through Docker Desktop allows for stable operation and easy management of computing resources.

The use of the AKAZE algorithm in combination with triangular SfM mode is suitable for drone footage, ensuring good image overlay in complex terrain. This demonstrates the flexibility of the selected computer vision algorithms. Achieving sub-decimeter accuracy, a dense point cloud containing more than 20 million points was successfully generated in this study.

By using Python scripts to extract frames from videos, a significant reduction in data preparation time is achieved. However, visual control and frame reduction (from 800 to 371 in this case) remain critical to the quality of the final product.

In addition to the standard 3D models and point clouds, the software allows automated classification of surfaces (land, vegetation, buildings) and assessment of plant health through indices such as VARI. This makes the methodology multifunctional, making it applicable not only to geodesy but also in environmental monitoring and management of natural landmarks such as “Youth Hill”.

The use of a consumer-grade drone (DJI Mini 3) in combination with advanced computer vision algorithms allows for the generation of professional-quality geospatial products at low cost.

The experimental results validate the efficiency of the proposed workflow, achieving a total Root Mean Square Error RMSE=0.104 m, RMSE_X=0.034 m, RMSE_Y=0.041 m, RMSE_Z=0.089 m and a reprojection error of 0.48 px. This quantitatively proves that sub-decimetre accuracy is achievable using consumer-grade UAVs and open-source photogrammetric pipelines.

The practical significance of this methodology extends to urban safety and environmental monitoring. The ability to rapidly generate high-resolution Digital Elevation Models (DEM) and 3D textured assets from civilian drone video streams allows local authorities to perform cost-effective rockfall hazard assessments, monitor structural shifts in complex urban topography, and plan ecological preservation strategies for protected urban zones like Youth Hill.

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