EVALUATION OF OPEN DRONE MAP TOOLKIT FOR GEODETIC GRADE AERIAL DRONE MAPPING – CASE STUDY.

Dr. Pawel Burdziakowski[1]

[1] Faculty of Civil and Environmental Engineering, Gdansk University of Technology - **Poland**

ABSTRACT

An open source tool's popularity has increased considerably, as well as micro aerial vehicles (MAV) technologies based on open source hardware. An open source software and hardware delivers a wide variety of applications and technology. The world's most successful open source projects have their roots in the academy, and now its participation includes a wide variety of academic programs and research. Based on open source technology, a case study has been designed and performed, in order to prove this technology meets geodetic requirements. The study has been performed within tested area, using MAV with construction and design based only on open hardware technology. All image data gathered have been post processed using recently developed open source toolkit for aerial drone mapping – Open Drone Map. The presented open source approach for digital surface model delivery has been compared with pure commercial approach. The commercial approach, for the same case and area, has been performed by a state of art commercial MAV technology and software. Results show differences between both approaches in data processing, accuracy and digital surface modeling. The paper concludes both process usability and ability to perform a geodetic grade surface modeling within presented case, and foreseen its usability of Open Drone Map toolkit for academic education purposes and researches.

Keywords: aerial, mapping, photogrammetry, UAV, MAV

INTRODUCTION

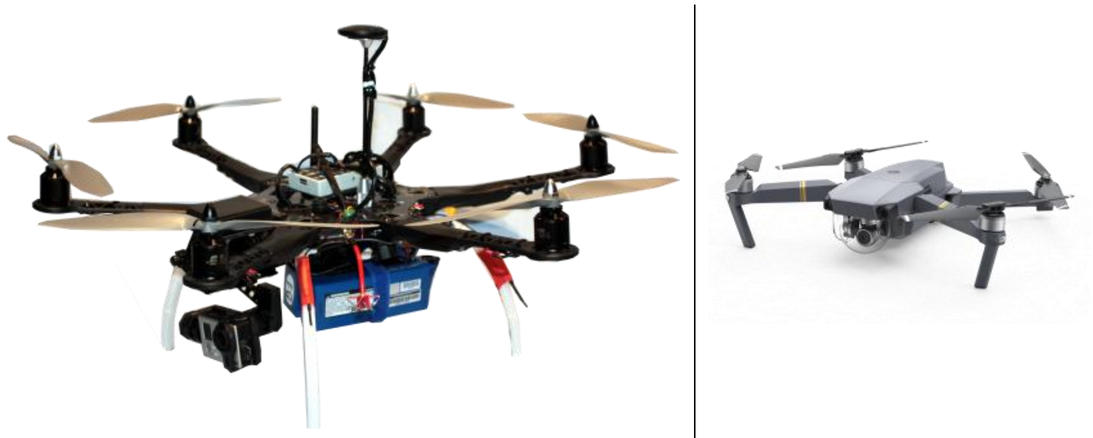
Micro aerial vehicles (MAV) are becoming very popular and widely used for photogrammetry and remote sensing applications. MAV is a class of unmanned aerial vehicle (UAV) with maximum takeoff weight (MTOW) of 5 kg, with endurance around 1 hour and an operative range around 10 km. A possibility a use of MAVs for the photogrammetry tasks introduces low-cost alternatives for a classical aerial photogrammetry. The MAV's market offers basically two main ideas of construction. The first idea is based on open source hardware (OSH) and open source software (OSS). MAVs based on OSH and OSS are mainly made by hobbyists and researchers. The world's most successful open source projects have their roots in the academy, and now its participation includes a wide variety of academic programs and research. The open source projects have some cons and pros, which will be highlighted in the paper. Second idea is based on pure commercial solution and offer. In this idea, the software and hardware is developed, provided and maintained by a commercial company.

Todays, commercial MAVs for amateur and professional use are widely offered and present quality and accuracy not available in past few years.

Based on these two ideas, the case study has been considered and performed. The study has been performed within tested area. The tested area was placed on the typical agriculture field. Using MAV with construction and design based only on open hardware technology an image data was gathered. All images have been post processed using recently developed open source software for aerial drone mapping – Open Drone Map (ODM) [6]. It presents pure open source approach for digital surface model (DSM) production. The opposite approach, the same area has been modelled using commercial MAV and commercial software for data processing.

MICRO AIR VEHICLES

The open source MAV is represent by OSH hexacopter (Fig. 1a) [5]. This platform's project is based on open source hardware and software. System basic components are: aerial platform - 550 mm hexacopter frame, the Pixhawk flight controller (FC) with integrated orientation and navigation modules, external navigation sensors – two GNSS receivers based on U-Blox Neo M8N chip and compass module, data acquisition module – camera GoPro Hero 3 Black and 3 axis brushless gimbal for its stabilization. Ground Controls Station (GCS) consists of PC commuter with open source Mission Planer Software linked with hexacopter via radio modem. A detailed navigation accuracy for OSH Hexacopter is presented in [4].



a) b)

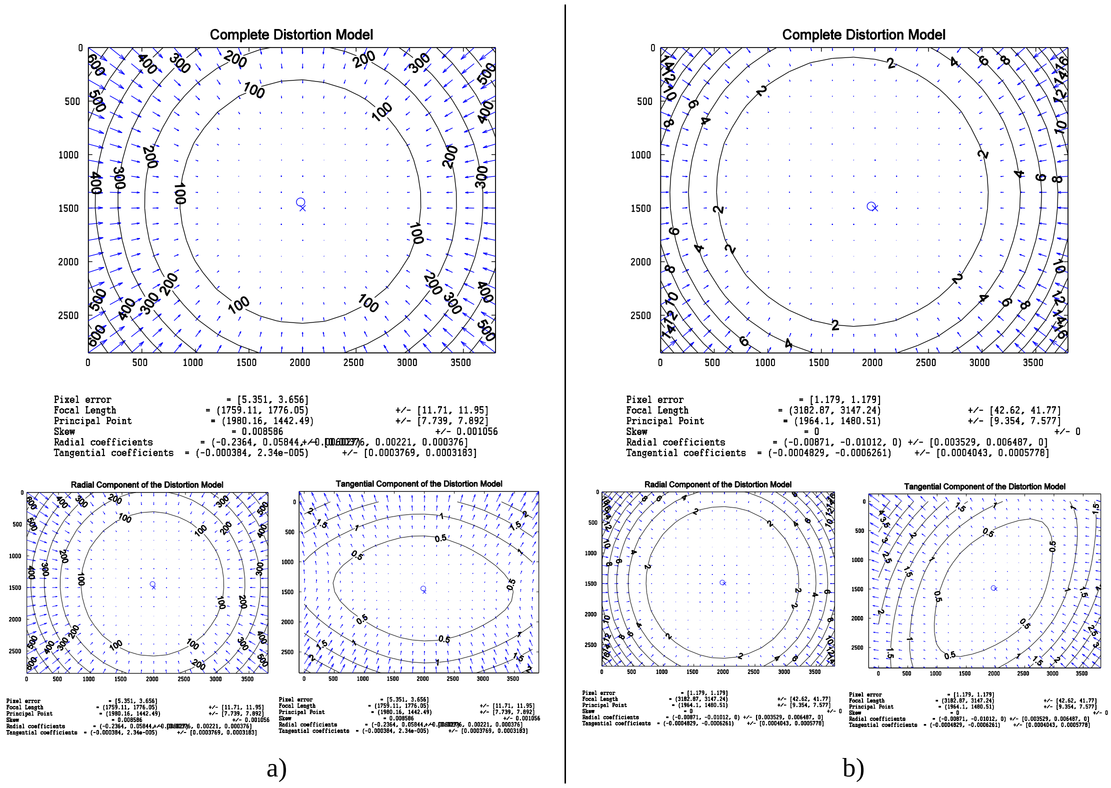
Fig. 1 a) OSH hexacopter b) DJI Mavic Pro

The commercial MAV is represented by DJI Mavic Pro (Fig. 1b). At the moment, this product is the smallest flying and stabilized camera on the commercial market (weight only 734 g). The platform utilizes for navigation one GPS and GLONASS module, two Inertial Measurement Unit (IMU) modules, Forward and Downward Vision System to automatically stabilize itself and navigate between obstacles and track moving objects. This product is prepared for filmmakers and hobbyists. A standard controlling application (DJI GO4 App) does not support mission planning for mapping tasks. The software functions are optimized for film making applications. In order to plan and execute a mapping mission it is needed to use third party application, not provided by a DJI company for this MAV. A comparison of both platform technical specifications is presented in Tab. 1.

Tab. 1 OSH Hexacopter and DJI Mavic Pro technical specification

Technical data	DJI Mavic PRO	OSH Hexacopter
Dimensions (height, width, length)	83mm x 275 mm x 198mm	350mm x 570mm x 570mm
Diagonal Size (Propellers Excluded)	335 mm	550 mm
Weight (Battery & Propellers Included)	734 g	2670g
Max Ascent Speed	5 m/s	10 m/s
Max Descent Speed	3 m/s	10 m/s
Max Speed	65 km/h	60 km/h
Max Service Ceiling Above Sea Level	5000 m	not tested
Max Flight Time	27 minutes	21 minutes
Max Hovering Time	24 minutes	15 minutes
Overall Flight Time	21 minutes	17 minutes
Max Flight Distance	13 km	7 km
Operating Temperature Range	0° to 40° C	0° to 40° C
Satellite Positioning Systems	GPS / GLONASS	2 x GPS / GLONASS

Presented MAVs are using non-metric cameras with the same size sensor (1/2.3`` - 6.17x4.55 mm) with the same pixel size (1.55 µm) (Tab. 2). OSH hexacopter is equipped with standalone camera Gopro Hero3 Black. This type of camera is state of art sports cameras, originally designed for action sports filming. The lens of the Gopro is highly distorted, characteristic fish-eye type, with wide field of view (FOV) up to 170°, what induces high radial distortion. Due to that reason its potential for photogrammetry tasks is rather small, however this low-cost solution has been pointed in few publication, as for the photogrammetry tasks [7], [11]. The Mavic's camera is designed and integrated with the desired platform. As the producer declares, it has very low distortions. For the purpose of this research distortions coefficients of both cameras was checked in accordance with paper [3], and detailed results are presented on Fig. 1.



a) b)

Fig. 2 a) Gopro Hero 3 Black Distortion details b) Mavic Pro Camera Distortion details

Tab. 2 Cameras technical specifications

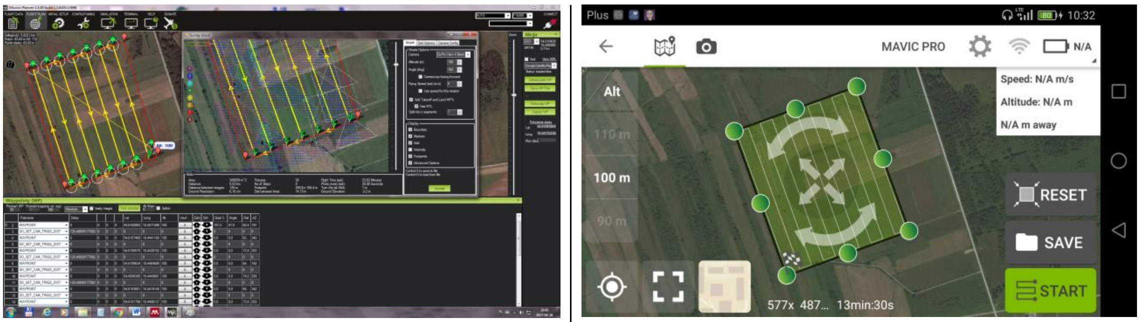
Technical data	DJI Mavic PRO camera	GoPro Hero 3 Black camera
Sensor	1/2.3”, 12 MP	1/2.3”, 12 MP
Pixel Size (in µm)	1.55	1.55
Lens (field of view - FOV)	FOV 78.8° (28 mm*) f/2.2	FOV 170° (12 mm*), 120° (17mm*) 85° (24mm*) f/2.8
Distortion	< 1.5%	Fish eye
Focus	from 0.5 m to ∞, auto/manual focus	from 0.05 m to ∞, fixed focus
ISO Range	100-3200 (video), 100-1600 (photo)	100-6400
Electronic Shutter Speed	8s -1/8000s	0.5s -1/8192s
Image Size (pixels)	4000×3000	4000×3000
Still Photography Modes	Single shot, Burst shooting: 3/5/7 frames, Auto Exposure Bracketing (AEB): 3/5 bracketed frames at 0.7 EV, Interval	Single, Burst Mode: up to 30 frames, Exposure Bracketing (AEB) -2 to +2, in 0.5 EV, Interval
Video Recording Modes	C4K: 4096×2160, 24fps 4K: 3840×2160, 24/25/30fps 2.7K: 2720x1530, 24/25/30fps FHD: 1920×1080, 24/25/30/48/ 50/60/96fps HD: 1280×720, 24/25/30/48/ 50/60/120fps	4K: 3840 x 2160, 15/12.5 fps 2.7K: 2720x1530, 30/25 fps 1440: 1920x1440, 48/30/25/24 fps FHD: 1920×1080, 60/50/48/ 30/25/24 fps HD: 1280×720, 120/100/60/50 fps 480: 848x480 240 fps
Photo file format	JPEG, DNG	JPEG, RAW
Video file format	MP4, MOV (MPEG-4 AVC/H.264)	MP4 (H.264)

** 35 mm format equivalent*

FLIGHT PLANNING SOFTWARE

The Mission Planer (MP) (Fig. 3a) is the open source software for OSH hexacopter. The OSH platform is based on Pixhawk FC and MP software is a main configuration tool for this FC, as well as mission planning and execution software. The Mission Planner main functions covers: loading the firmware (the software) into the autopilot that controls specific vehicle, setup, configure, and tuning the vehicle for optimum performance, planning, saving and loading autonomous missions into the autopilot with simple point-and-click way-point entry on Google or other supported maps, downloading and analyzing mission logs, interfacing with a PC flight simulator in order to create a full hardware-in-the-loop UAV simulator. On board the OSH hexacopter additional hardware is installed and this feature allows: monitor the vehicle’s status while in operation, recording telemetry logs which contain much more information the on-board autopilot logs, operating the vehicle in first person view mode (FPV). The Mission Planner supports all functions for the autopilot, as well as provides full mission planning capabilities. Every aspect of autonomous mission may be programed and controlled via this application. Summarize, full photogrammetry mission may be planned and executed by MP software.

The standard application for a DJI Mavic Pro does not support mission planning on the maps. The DJI application covers only waypoint re-flying function. In this mode MAV firstly is directed by operator to the desired points and then it is able to refly via already visited points. In order to execute mapping mission along projected track, third party application has to be used. In this research a Pix4D Capture (Fig. 3b) commercial application was used. Pix4D Capture application features includes planning of: grid mission for general mapping, double grid mission for 3D model reconstruction, circular mission for point-of-interest 3D model reconstruction and free flight mission for vertical object mapping with manual flight control. Application adjusts: flight speed, camera angle, front overlap, flight altitude, facing direction of the camera and distance-based camera trigger.



a) b)

Fig. 3 a) Mission Planer's survey planning screen, b) PIX4DCapture survey planning.

PROCESSING SOFTWARE

The evaluated software, named Open Drone Map (ODM), is an open source toolkit for processing aerial drone imagery. It has to be emphasized that, the current ODM version number is 0.3 beta, means that this community project is at the early stage of developing. This software is designed for processing non-metric MAV imagery, and at the moment delivers point clouds, digital surface models, textured digital surface models and orthorectified imagery [6]. ODM do not provide graphical user interface (GUI) to interact with user, what imposes basic knowledge as for the Linux operating system terminal commands. The input images are to be prepared and placed in specified folder. Commands used in the terminal start processing the images. The results are placed in desired folders structure. ODM do not provide any additional viewing result interface. An supplementary software for viewing, editing or evaluating results is required. All processes are computed using central processing unit (CPU), graphical processing unit (GPU) is not supported. While using GPU for processing images with NVIDIA CUDA technology [1] computation speed can be accelerated up to 8 times, with compare to CPU computation.

The initial process starts with acquire images Exchangeable Image File Format (EXIF) data with camera details and image georeferencing location. The camera parameters extracted form EXIF are compared with the cameras database, in which all calibration parameters can be found. Unfortunately, used Gopro Hero 3 Black is not fully supported, and distortions coefficients do not meet photogrammetric quality. After undistortion process radial distortion remained. After getting deeper into ODM code, it turned out that software process undistortion algorithm based only on two radial distortion coefficients (k_1, k_2) and tangential (p_1, p_2) are assumed zero. This is a potential field for improving ODM toolkit.

The commercial software Pix4D Mapper, is a state of art UAV photogrammetry processing software on the market. The software accuracy was evaluated [13], and generated 3D photogrammetric models from images of different cameras and lenses were compared with the results of a laser scanner. As it was proven, the accuracy of image derived 3D models was comparable to that of a laser scanner. In this experiment [13], there was concluded that fisheye lenses can reach accuracies that are substantially below 10 cm for an approximate object distance of 15m. The worst result was obtained from a full 180-degree lens (GoPro Hero 4 Black Edition). The accuracy results of a full 180-degree fisheye is not as good as that of a perspective lens. The smaller angle fisheye lenses on good cameras gave comparable results to perspective lenses. The software Pix4D software supports both standard perspective camera models and equidistant fisheye camera models [10] [12] [8], what results in a relatively respectable grades models for fisheye camera. The accuracy of the Pix4D mapping software was proved, and model generated with this tool was used as a referenced for ODM evaluation.

EVALUATION

The ODM evaluation was conducted using data gathered by OSH hexacopter with Gopro camera. The image data were processed without any initial calibration. Due to the fact that, the camera is not writing GPS location to the EXIF file, for direct georeferencing Gopro images a GeoSetter software was used. The GeoSetter is a freeware tool for Windows, for showing and changing geo data and other metadata of image files. The tested area (a typical agriculture field) was mapped using survey grid planned and executed in Mission Planner. For the reference data, the same area was mapped used DJI Mavic Pro, Pix4D Capture for executing survey mission and Pix4D Mapper for data processing. The Mavic's image data were processed without any initial calibration. The DJI's MAV writes direct GPS images location to EXIF file, therefore no additional process was required, opposite to Gopro case.

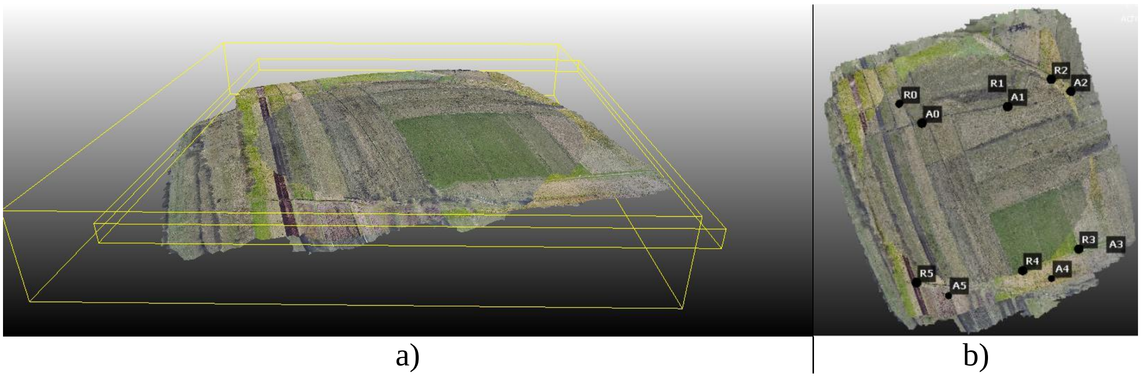
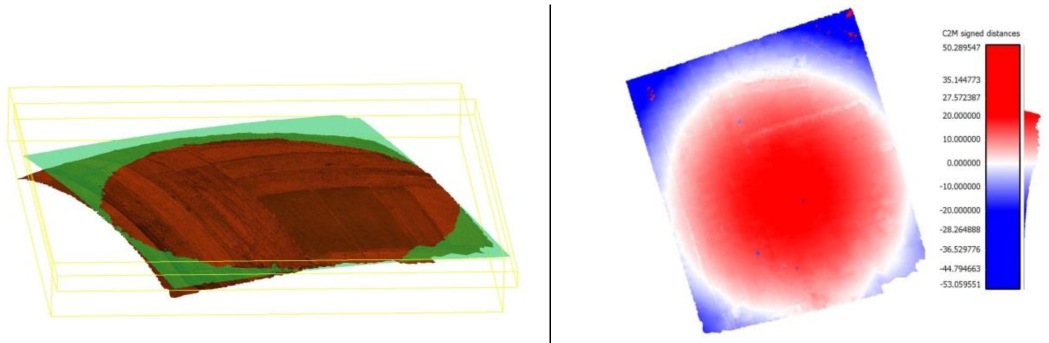


Fig. 4 Differences between two orthophotomaps

Two generated orthophotomaps are visualized on Fig. 4 Differences between two orthophotomapsFig. 4a. The characteristic points for referenced model (*R0-R6*) and their homogenous point on ODM orthophoto (*A0-A6*) are marked on Fig. 4b. ODM model is translated, and presents spherical distortion. The reason that ODM map is spherically is recognized in the bad camera model used in ODM toolkit. The distortion model used for Gopro in ODM (perspective camera model) is not sufficient for fisheye camera. A deeper evaluation the ODMs files generated during processing and analysis of the source code revealed that ODM uses a simple perspective camera model only up to two radial coefficients for images undistortion process. The tangential coefficient are assumed zero and are not taken into calculation. This is the area where this software needs a significant improvement. The highly distorted images should be undistorted before processing in this tool. The transformation matrix between two models has been calculated, and ODM was transformed using calculated matrix. Having applied transformation matrix, the spherical distortion is much more visible (Fig. 5 a), with calculated distances presented on Fig. 5 b.



a) b)

Fig. 5 a) Differences between orthophotomaps after transformation b) distances between two models.

CONCLUSION

The mapped area image data has been processed using recently started open source project for aerial drone mapping – Open Drone Map. The presented open source approach for digital surface model delivery has been compared with pure commercial, the state of art commercial MAVs technology and software. The results show main differences between both approaches in data processing, accuracy and digital surface modeling. At the present stage of developing, ODM do not provide GUI to interact with user, what imposes basic knowledge as for the Linux operating system terminal commands. The ODM undistortion algorithm is based only on two radial distortion coefficients, and camera database do not provide reliable camera data. This is a young project (ver. 0.3) and its development is not supported by commercial founds. There is no deadlines assigned for each phase of developing, and its rhythm is dependent on community contributions. The most valuable attribute of this project, as for student's education, is the free and open source code. It can be analyzed, supported and developed for overall project progress, and changed for specific research projects. The research papers are implemented in programing language code. On the opposite side, commercial products provides only results, no strict implementation is available.

At the moment, ODMs geodetic grade models are possible to achieve, however it requires some programming knowledge, low distortion camera or additional calibration process. ODM toolkit is not optimized for simple interaction with user, however sister project called WebODM already provides Python based web interface. The presented project roadmap is very optimistic, and allows contributors to develop each needed part. At the moment Open Done Map offers tremendous possibility for tweaking by photogrammetry students and Geodesy Departments researchers on Faculty of Civil and Environmental Engineering University of Technology in Gdansk. It is foreseen to engage ODM in Geodesy Departments future researches in order to support projects [2], [9], [14], [15].

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