Experimental aerial photogrammetry with professional non metric camera Canon EOS 5D

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1. Introduction

With this project we wanted to test professional non metric digital camera Canon EOS 5D in aerophotogrammetry purposes. For this purpose we used this equipment: digital non metric camera, wide angle lens, airplane, camera box, camera carrier. Project was made to see how will digital non metric camera work as an aerial photogrammetry camera.

The full featured digital aerial photogrammetry system is very expensive and with this project we can see what can be done with much less expenses.

Camera specification:

Canon EOS 5D (Fig.1)

Sensor type
- 35.8 x 23.9 mm CMOS
- 12.8 million effective pixels

Records RAW/JPEG images

Image sizes:
- 4368 x 2912
- 3168 x 2112
- 2496 x 1664

Dimensions:
- 152 x 113 x 75 mm (6.0 x 4.4 x 2.9 in)

Weight
- No battery: 810 g (1.8 lb)
- With battery: 895 g (2.0 lb)

Fig.1 Canon EOS 5D with 50mm lens

Lens type used in project:

Canon lens EF 24mm 1:1.4 (Fig.2)

Fig.2 Canon lens EF 24mm 1:1.4

This is wide angle lens that has spherical aberration in the corners of the photograph. In optics, spherical aberration is an image imperfection that occurs due to the increased refraction of light rays that occurs when rays strike a lens or mirror near its edge, in comparison with those that strike nearer the center. Because of spherical aberration we had problems with parallax and correlation on the edges of the photograph.

Camera box and carrier:

Camera carrier is made of light and strong material and adopted for loading the camera box and other devices that were needed for the project. Camera carrier with the box was set into horizontal position during the flight manually.

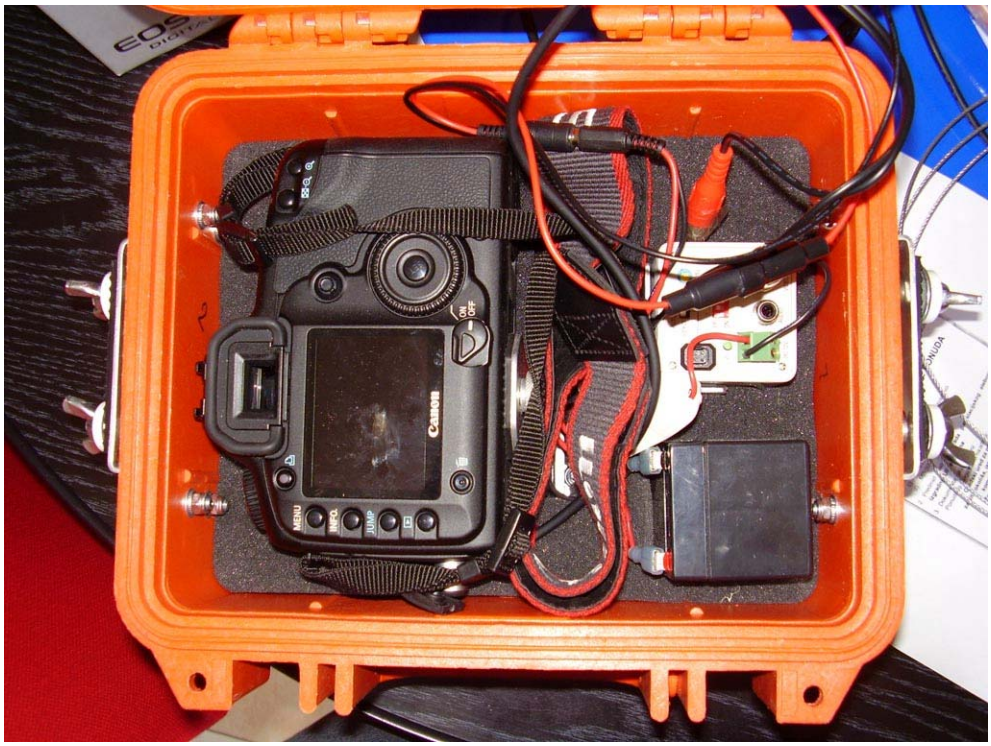

Fig.3 Picture of the devices in the box

Fig.4 Picture of the airplane, carrier and the box.

Airplane Cessna 172 Rocket:

Cessna 172 Rocket is a four-seat, single-engine, high-wing airplane. It is likely the most popular flight training aircraft in the world.

Specifications:

- Crew: One
- Capacity: 3 passengers
- Length: 27 ft 2 in (8.28 m)
- Wingspan: 36 ft 1 in (11.0 m)
- Height: 8 ft 11 in (2.72 m)
- Wing area: 174 ft² (16.2 m²)
- Empty weight: 1,620 lb (743 kg)
- Useful load: 881 lb (400.5 kg)
- Max takeoff weight: 2,450 lb (1,111 kg)
- Powerplant: 1× Lycoming IO-360-L2A piston engine, 160 hp at 2,400 rpm (119 kW)

Performance:

- Never exceed speed: 185 mph (300 km/h)
- Maximum speed: 142 mph at sea level; (228 km/h)
- Stall speed: 49 mph (79 km/h)
- Range: 790 mi at 60% power at 10,000 ft (3,040 m) (1,270 km)
- Service ceiling: 13,500 ft (4,115 m)
- Rate of climb: 720 ft/min (3.7 m/s)
- Wing loading: 14.1 lb/ft² (68.8 kg/m²)
- Power/mass: 15.3 lb/hp (6.9 kg/hp)

Fig.5 Picture of the aeroplane

Flight plan and flight specification:

- Focal length: 23.811862 mm
- Flight height above ground is: 300m
- Flight speed: 140 km/h
- Aperture value: automatic
- Exposure: 1/1000
- Scale 1:12500
- Images overlapping: 60 %
- Strips overlapping: 30%
- Resolution of images: 4368pix x 2912pix
- Type of images: JPG
- Size of images: ~ 6.5MB
- Ground sampling distance: 0.10 m

2. Project work flow

For this project work flow was by this order:

- camera calibration
- making flight plan
- flying and taking images of selected area
- loading images in PHOTOMOD, aerotriangulation
- creation of DEM and digital orthophoto

3. Camera calibration

Camera Calibration is the process of determining the characteristics of a camera such as focal length and lens distortion so it can be used as a measurement device.

Calibration was made with software PhotoModeler pro 5.0. Determining camera interior orientation parameters was done using 2D dimensions calibration grid that goes with software PhotoModeler Pro 5.0.

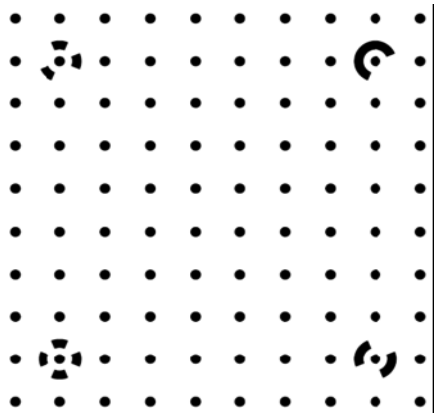

Fig.6 Calibration grid

Results of camera calibration:

Focal Length
Value: 23.811862 mm
Deviation: Focal: 0.002 mm
Xp - principal point x
Value: 17.311063 mm
Deviation: Xp: 0.003 mm
Yp - principal point y
Value: 11.615114 mm
Deviation: Yp: 0.003 mm
Correlations over 90.0%: P2:91.5%
Fw - format width
Value: 34.686014 mm
Deviation: Fw: 7.5e-004 mm
K1 - radial distortion 1
Value: 1.376e-004
Deviation: K1: 6.5e-007

K2 - radial distortion 2
Value: -2.251e-007
Deviation: K2: 3.6e-009
K3 - radial distortion 3
Value: 0.000e+000
P1 - decentering distortion 1
Value: 9.774e-006
Deviation: P1: 1.5e-006
P2 - decentering distortion 2
Value: 8.374e-006
Deviation: P2: 1.4e-006
Correlations over 90.0%: Yp:91.5%

4. Flight plan

Area for the project is 2.2 km long area of the highway near city Zagreb. The area will be taken in two strips end every strip will have ~ 25 images. Base of the images is 120 m, distance between strips is 310 m.

Garmin hand GPS is used for navigation of the airplane. The flight plan was made on 1:25000 scale map.

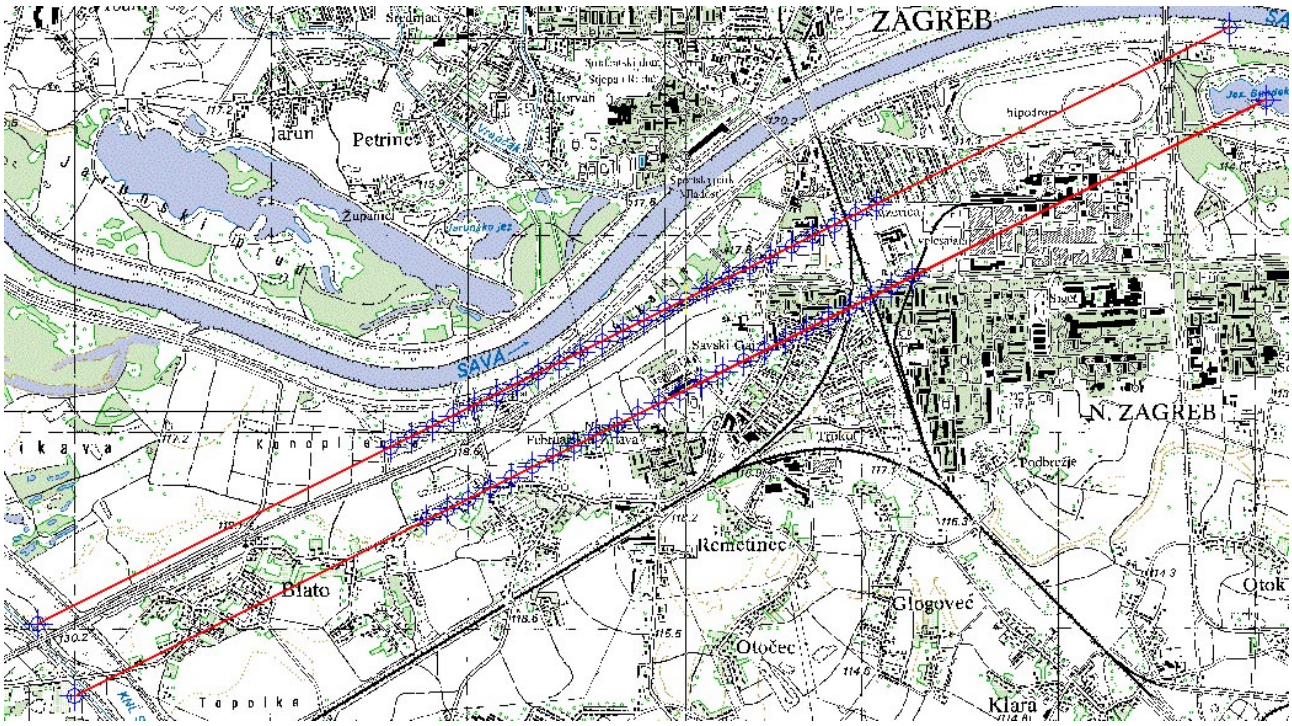

Fig.7 Flight plan

5. Aerotriangulation

Whole process from loading images into project to crating digital orthophoto was made in Photomod 4.0. Normal configuration of Photomod was used in this project.

For aerotriangulation we used correlation not less then 0.94 and parallax not greater then 0.010mm.

We used 10 ground control points, 4 at the beginning and the end of the strips and 2 in the middle of the strips. Ground control points were measured by RTK with accuracy of 2-3 cm.

Fig.8 Positions of GCP

Results of aerotraingulation:

Ground control point residuals

N	Xm-Xg	Ym-Yg	Zm-Zg	Exy (meter)
limit:	0.200	0.200	0.200	0.200
OR1	-0.049	-0.046	0.119	0.068
OR2	0.036	0.020	-0.187	0.042
OR2A	0.006	0.018	0.084	0.019
OR3A	0.016	-0.019	0.093	0.025
OR4	-0.011	0.062	-0.254*	0.063
OR5	0.042	0.020	-0.269*	0.046
OR6	-0.043	-0.017	0.016	0.047
OR7	-0.077	-0.073	0.171	0.106
OR7A	0.087	0.102	-0.089	0.134
OR8	-0.006	-0.067	0.316*	0.068
mean absolute:	**0.038**	**0.045**	**0.160**	**0.062**
RMS:	**0.046**	**0.053**	**0.184**	**0.070**
maximum:	**0.087**	**0.102**	**0.316***	**0.134**

Tie point residuals (between stereopairs)

N	X1-X2	Y1-Y2	Z1-Z2	Exy (meter)
limit:	0.200	0.200	0.200	0.200
mean absolute:	**0.073**	**0.075**	**0.142**	**0.114**
RMS:	**0.102**	**0.111**	**0.180**	**0.151**

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            maximum:          0.449*          0.584*          0.629*          0.640*
  number of points (differences):
                933 (           1272            1272            1272            1272)

between stereopairs

                  N           X1-X2           Y1-Y2           Z1-Z2             Exy (meter)

              limit:          0.200           0.200           0.200           0.200
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      mean absolute:          0.059           0.055           0.134           0.089
                RMS:          0.082           0.086           0.167           0.119
            maximum:          0.352*          0.514*          0.629*          0.565*
  number of points (differences):
                764 (           779             779             779             779)
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between strips

                  N           X1-X2           Y1-Y2           Z1-Z2             Exy (meter)

              limit:          0.200           0.200           0.200           0.200


      mean absolute:          0.090           0.096           0.152           0.143
                RMS:          0.121           0.130           0.196           0.177
            maximum:          0.440*          0.469*          0.621*          0.586*
  number of points (differences):
                316 (           316             316             316             316)

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In the result of the aerotriangulation you can see that the accuracy of ground control points is:

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                  N           Xm-Xg           Ym-Yg           Zm-Zg             Exy (meter)

      mean absolute:          0.038           0.045           0.160           0.062
                RMS:          0.046           0.053           0.184           0.070
            maximum:          0.087           0.102           0.316*          0.134
```

7. Creation DEM and digital orthophoto

The DEM (1m) for project was created using vectors and breaklines vectorized manually in Photomod StereoDraw. Digital elevation model was used for creating digital orthophoto. Ground sampling distance of orthophoto image is 0.10 m in tiff format.

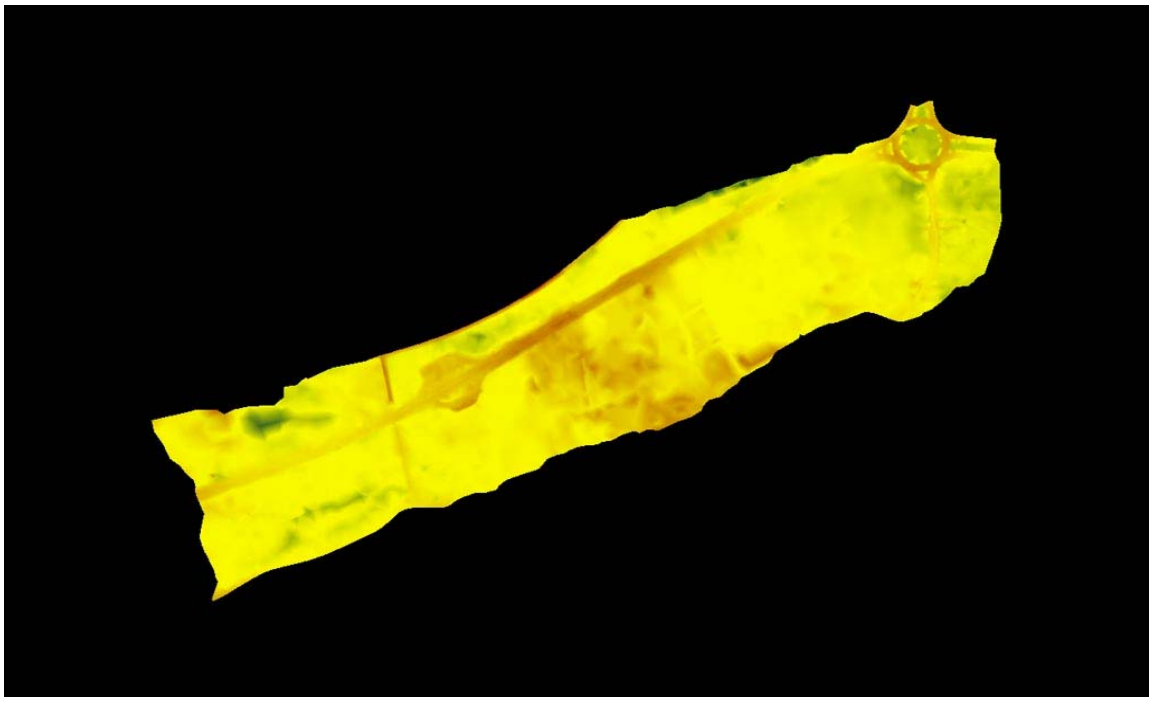

Fig.9 DEM of the project area

After creating digital orthophoto we used some existing data of project area to see does orthophoto overlap with that data. The results were very good - max overlap error was 0.3m.

8. Conclusions

Despite some problem during project creation the accuracy of the data is satisfying. Because small size of image made by Canon EOS 5D camera this type of creating orthophoto images is not good for projects that involve taking images of large areas. The number of images would be much larger then normal aerial photogrammetry camera creates.

We can see that digital non metric camera are getting better and better. In near future there will be larger sensors of digital cameras (16 Mpix, 32 Mpix ...). This kind of non metric camera will bring better accuracy's of images and with good calibration they could be used for projects involving aerial photogrammetry.