

This section contains the scripts for the photogrammetric workflow (Figure S1) with MicMac [1].

For information on the tool usage we recommend the reading of the official documentation [2].

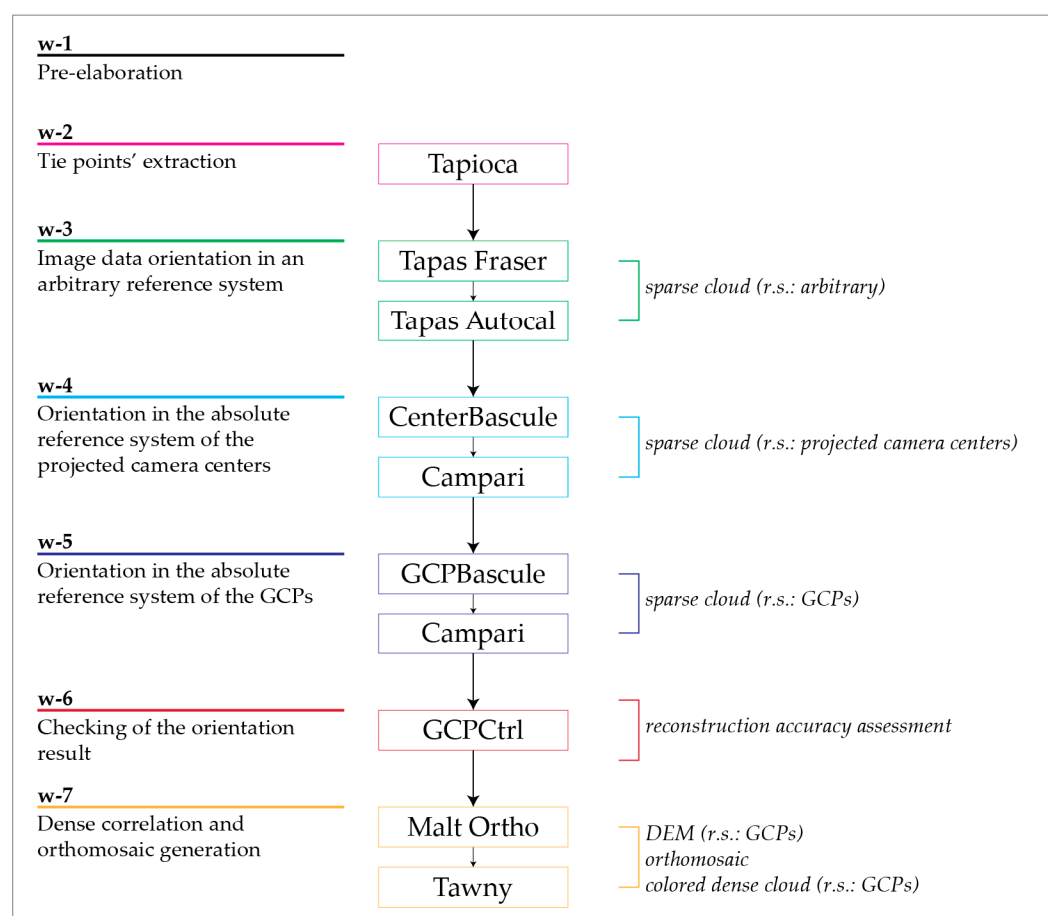


Figure S1. The MicMac pipeline for the photogrammetric reconstruction of the image data collected by the UAV system (r.s. for the reference system).

w-1 Pre-elaboration.

w-1.1 Removal of the last flight strip, because it has captured only water features: the dataset is reduced from 1253 to 1138 aerial pictures.

w-1.2 Export and elaboration of the EXIF metadata linked to the pictures: creation of the file "GPSExif.txt" containing the GNSS coordinates of the captures during the flight:

```
#F=N X Y Z K W P
#FileName GPSLongitude GPSLatitude GPSAltitude Yaw Pitch Roll
```

w-1.3 Creation of a local tangent plane with the origin in the center of the images. This plane allows the projection of the geographic coordinates into a Euclidean system.

```
mm3d XifGps2Xml *.JPG GPS_Raw
mm3d XifGps2Xml image-pattern output-orientation-directory
```

w-1.4 Conversion of the GNSS pictures data from TXT into the XML format, needed for the elaboration with MicMac; projection of the geographic coordinates into the local system defined at [w-1.3]; generation of a file containing the image pairs; generation of a sub-pattern of 50 pictures near to a central image.

```
mm3d OriConvert OriTxtInFile GPSExif.txt GPS_Raw_RTL
ChSys=DegreeWGS84@RTLFromExif.xml NameCple=FileImagePairs.xml MTD1=1 DN=50
OkNoIm=1 ImC=DJI_20231109142404_0325.JPG NbImC=50
mm3d OriConvert format-specification file-GNSS-coordinates output-orientation-directory
transformation-WGS84toRTL output-file-image-pairs compute-metadata-only-first-image
distance-from-object ok-if-image-not-present central-image-for-pattern number-images-for-pattern
```

w-2 Tie points' extraction.

w-2.1 Tie points extraction at half resolution, using the file containing the image pairs.

```
mm3d Tapioca File FileImagePairs.xml 4100
mm3d Tapioca File file-images-pairs image-resolution
```

w-2.2 Optional tie points' filtering. In this context the command is only used for an evaluation on the coverage of the images.

```
mm3d Schnaps *.JPG ShowStats=1 HomolOut=_filtered MoveBadImgs=1
mm3d Schnaps image-pattern show-filtering-process output-homol-directory move-image-bad-coverage
```

w-3 Image orientation in an arbitrary reference system.

w-3.1 Pre-calibration, using the sub-pattern of 47 pictures (3 pictures are excluded from the computation).

```
mm3d Tapas Fraser
"DJI_20231109142404_0325.JPG|DJI_20231109142405_0326.JPG|DJI_20231109142405_0327.JPG|
DJI_20231109142403_0324.JPG|DJI_20231109142406_0328.JPG|DJI_20231109142401_0323.JPG|
DJI_20231109142407_0329.JPG|DJI_20231109142409_0330.JPG|DJI_20231109142400_0322.JPG|
DJI_20231109142410_0331.JPG|DJI_20231109142359_0321.JPG|DJI_20231109142411_0332.JPG|
DJI_20231109142358_0320.JPG|DJI_20231109142747_0521.JPG|DJI_20231109142412_0333.JPG|
DJI_20231109142750_0524.JPG|DJI_20231109142746_0520.JPG|DJI_20231109142357_0319.JPG|
DJI_20231109142752_0525.JPG|DJI_20231109142413_0334.JPG|DJI_20231109142356_0318.JPG|
DJI_20231109142749_0523.JPG|DJI_20231109142414_0335.JPG|DJI_20231109142748_0522.JPG|
DJI_20231109142753_0526.JPG|DJI_20231109142355_0317.JPG|DJI_20231109142754_0527.JPG|
DJI_20231109142415_0336.JPG|DJI_20231109142354_0316.JPG|DJI_20231109142755_0528.JPG|
DJI_20231109142756_0529.JPG|DJI_20231109142741_0516.JPG|DJI_20231109142757_0530.JPG|
DJI_20231109142759_0531.JPG|DJI_20231109142417_0337.JPG|DJI_20231109142352_0315.JPG|
DJI_20231109142745_0519.JPG|DJI_20231109142418_0338.JPG|DJI_20231109142800_0532.JPG|
DJI_20231109142739_0514.JPG|DJI_20231109142351_0314.JPG|DJI_20231109142744_0518.JPG|
DJI_20231109142802_0533.JPG|DJI_20231109142419_0339.JPG|DJI_20231109142350_0313.JPG|
DJI_20231109142742_0517.JPG|DJI_20231109142803_0534.JPG|DJI_20231109143224_0714.JPG|
DJI_20231109143225_0715.JPG|DJI_20231109143223_0713.JPG" Out=Calib
mm3d Tapas calibration-model image-pattern output-orientation-directory
```

w-3.2 Bundle-block-adjustment, using the pre-calibration parameters of [w-3.1].

```
mm3d Tapas AutoCal *.JPG Out=Arbitrary InCal=Calib
```

```
mm3d Tapas calibration-model image-pattern output-orientation-directory input-calibration-directory
```

w-3.3 Sparse Cloud generation in the arbitrary reference system.

```
mm3d AperiCloud *.JPG Arbitrary Out=Bevano_Arbitrary_SparseCloud.ply  
mm3d AperiCloud image-pattern input-orientation-directory output-file-name
```

w-4 Orientation in the absolute reference system of the projected camera centers.

w-4.1 Model transformation (roto-translation with a scale factor) into the absolute reference system of the projected camera centers.

```
mm3d CenterBascule *.JPG Arbitrary GPS_Raw_RTL Terrain_GPS_RTL  
mm3d CenterBascule image-pattern input-orientation-directory input-images-centers-directory  
output-orientation-directory
```

w-4.2 Creation of a copy of the folder “GPS_Raw_RTL”, called “GPS_Raw_RTL-2”, in which the wrong camera orientation XML files are moved into the subfolder “reject”.

w-4.3 Compensation of heterogeneous measures (tie points and projected camera centers).

```
mm3d Campari *.JPG Terrain_GPS_RTL Ground_GPS_RTL EmGPS=[GPS_Raw_RTL-2,0.05]  
AllFree=1  
mm3d Campari image-pattern input-orientation-directory output-orientation-directory  
input-centers-coordinates,coordinates-accuracy free-all-calibration-parameters
```

w-4.4 Sparse Cloud generation in the absolute reference system of the projected camera centers.

```
mm3d AperiCloud *.JPG Ground_GPS_RTL Out=Bevano_Ground_GPS_RTL_SparseCloud.ply  
mm3d AperiCloud image-pattern input-orientation-directory output-file-name
```

w-5 Orientation in the absolute reference system of the GCPs.

w-5.1 Creation of the file “GCPs.txt” containing the coordinates of the Ground Control Points in the reference system RDN2008/UTM33N:

```
#F=N X Y Z  
# GCPs coordinates, reference system: RDN2008/UTM33  
#  
#Name Est Nord h_ellipsoidal  
di003 286428.862 4916728.837 39.898  
di005 286619.712 4916734.956 41.614  
di012 286653.269 4916545.369 40.454  
di004 286669.041 4916440.83 40.386  
di001 286608.286 4916930.657 40.311  
di006 286588.729 4917042.108 40.272  
di007 286442.661 4917013.374 39.717  
di013 286413.132 4916439.918 39.873  
di011 286435.121 4916902.492 39.685
```

w-5.2 Creation of the file “ID_GCPs.txt”, containing only the GCP name.

```
di003  
di005  
di012  
di004  
di001  
di006  
di007  
di013  
di011
```

w-5.3 Conversion of the GCP data from TXT into the XML format, needed for the elaboration with MicMac.

```
mm3d GCPConvert AppInFile GCPs.txt  
mm3d GCPConvert format-specification input-coordinates-file
```

w-5.4 Collimation of 4 points (di013, di007, di006, di004) in 3 images.

```
mm3d SaisieAppuisInitQT
"DJI_20231109141801_0005.JPG|DJI_20231109141803_0007.JPG|DJI_20231109141805_0009.JPG|
DJI_20231109142403_0324.JPG|DJI_20231109142405_0326.JPG|DJI_20231109142406_0328.JPG|
DJI_20231109143838_0043.JPG|DJI_20231109143835_0040.JPG|DJI_20231109143821_0028.JPG|
DJI_20231109144027_0138.JPG|DJI_20231109143629_0929.JPG|DJI_20231109143630_0930.JPG"
Ground_GPS_RTL ID_GCPs.txt MeasuresInit.xml
mm3d SaisieAppuisInitQT image-pattern input-orientation-directory input-ID-GCPs-file output-
measurement-file
```

w-5.5 Model transformation (roto-translation with a scale factor) into the absolute reference system of the points di013, di007, di006, and di004.

```
mm3d GCPBascule *.JPG Ground_GPS_RTL TerrainInit GCPs.xml MeasuresInit-S2D.xml
mm3d GCPBascule image-pattern input-orientation-directory output-orientation-directory
input-GCPs-coordinates-file input-measurement-file
```

w-5.6 Collimation of all the GCPs on the images.

```
mm3d SaisieAppuisPredicQT ".*(0[0-2][0-9][0-9]|03[0-2][0-9]|07[2-9][0-9]|0[8-9][0-9][0-
9]).JPG" TerrainInit GCPs.xml MeasuresFinal.xml
mm3d SaisieAppuisPredicQT image-pattern input-orientation-directory input-GCPs-coordinates-file
output-measurement-file
```

w-5.7 Model transformation (roto-translation with a scale factor) into the absolute reference system of the ground control points.

```
mm3d GCPBascule *.JPG TerrainInit TerrainFinal GCPs.xml MeasuresFinal-S2D.xml
mm3d GCPBascule image-pattern input-orientation-directory output-orientation-directory
input-GCPs-coordinates-file input-measurement-file
```

w-5.8 Compensation of heterogeneous measures (tie points and GCP coordinates).

```
mm3d Campari *.JPG TerrainFinal Ground GCP=[GCPs.xml,0.03,MeasuresFinal-S2D.xml,0.5]
AllFree=1
mm3d Campari image-pattern input-orientation-directory output-orientation-directory
input-GCPs-coordinates,coordinates-accuracy,image-measurement,collimation-accuracy
free-all-calibration-parameters
```

w-5.9 Sparse Cloud generation in the absolute reference system of the GCPs.

```
mm3d AperiCloud *.JPG Ground Out=Bevano_Ground_SparseCloud.ply
mm3d AperiCloud image-pattern input-orientation-directory output-file-name
```

w-6 Checking of the orientation result.

w-6.1 Creation of the file "Check.txt" containing the GCP coordinates in the reference system RDN2008/UTM33N.

```
#F=N X Y Z
# GCPs coordinates, reference system: RDN2008/UTM33
#
#Name Est Nord h_ellipsoidal
q001 286423.147 4916628.889 40.07
q002 286607.347 4916660.444 42.524
q003 286597.317 4916802.961 42.416
cs01 286427.895 4916728.628 39.954
cs02 286414.099 4916436.895 40.221
```

w-6.2 Conversion of the check point data from TXT into the XML format, needed for the elaboration with MicMac.

```
mm3d GCPConvert AppInFile Check.txt
mm3d GCPConvert format-specification input-coordinates-file
```

w-6.3 Collimation of all check points on the images.

```
mm3d SaisieAppuisPredicQT ".*(0[0-2][0-9][0-9]|03[0-2][0-9]|07[2-9][0-9]|0[8-9][0-9][0-
9]).JPG" Ground Check.xml MeasuresControl.xml
mm3d SaisieAppuisPredicQT image-pattern input-orientation-directory input-GCPs-coordinates-file
output-measurement-file
```

w-6.4 Checking of residual values.

```
mm3d GCPCtrl ".*JPG" Ground Check.xml MeasuresControl-S2D.xml  
mm3d GCPCtrl image-pattern input-orientation-directory input-GCPs-coordinates-file  
input-2Dmeasurement-file
```

w-7 Dense correlation and orthomosaic generation.

w-7.1 Creation of an approximate orthomosaic.

```
mm3d Tarama *.JPG Ground  
mm3d Tarama image-pattern input-orientation-directory
```

w-7.2 Creation of a masque on the approximate orthomosaic, in order to limit the area for the dense correlation.

```
mm3d SaisieMasqQT TA/TA_LeChantier.tif  
mm3d SaisieMasqQT input-orthomosaic
```

w-7.3 Dense correlation with the traditional pipeline (nadiral acquisition and approximation of the scene as 2.5D object), with a final resolution of 1/4 the original pictures (ZoomF=2 by default setting).

```
mm3d Malt Ortho *.JPG Ground EZA=1 DirMEC=Malt_Z2W1C0 SzW=1 DefCor=0  
mm3d Malt Ortho image-pattern input-orientation-directory absolute-value-for-Z output-correlation-  
directory window-size correlation-coefficient
```

w-7.4 Creation of the orthomosaic (Figure S2)

```
mm3d Tawny Ortho-Malt_Z2W1C0 Out=ortomosaico_1.tif  
mm3d Tawny input-orthophoto-directory output-orthomosaic-name
```

w-7.5 Dense Cloud generation in the absolute system of the GCPs, colored by the orthomosaic radiometric values.

```
mm3d Nuage2Ply Malt_Z2W1C0/NuageImProf_STD-MALT_Etape_10.xml Attr=Ortho-  
Malt_Z2W1C0/ortomosaico_1.tif Out=Bevano_Ground_DenseCloud.ply  
mm3d Nuage2Ply input-last-correlation-XML-file file-for-colored-cloud output-file-name
```

References

1. MicMac, (v1.1.1) Available online: <https://github.com/micmacIGN/micmac/releases> (accessed on 21 October 2024).
2. Pierrot-Deseilligny, M. MicMac, Aperio, Pastis and Other Beverages in a Nutshell! Available online: <https://github.com/micmacIGN/Documentation/blob/master/DocMicMac.pdf> (accessed on 9 January 2025).



Figure S2. The orthomosaic of the scene, map coordinate reference system RDN2008/UTM33, meter unit. Output with a GSD (Ground Sampling Distance) of 6 mm and subsampled at a resolution of 10 cm.