POSITIONING IN TIME & SPACE

Cost-effective exterior orientation for airborne archaeological photographs (FWF-P24116-N23)

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VIENNA UNIVERSITY OF TECHNOLOGY
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RESEARCH GROUPS PHOTOGRAMMETRY & REMOTE SENSING

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AERIAL ARCHAEOLOGY

└ OVERVIEW

- Imagery acquired from a certain altitude
  - RADAR and ALS (LiDAR) data
  - airborne multi/hyperspectral scanning
  - vertical (high-altitude) photography
  - oblique (low-altitude) photography
    - relatively low-cost and straightforward
    - low-flying small aircraft
    - (digital) still camera

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AERIAL ARCHAEOLOGY

└ OVERVIEW

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AERIAL ARCHAEOLOGY

└ OBLIQUE RECONNAISSANCE AND GEOCODING

- Random
- Fast workflow
- 2 options
  - log flight path – synchronise

→ Image location

  - physical connection (external or built-in)

↓

Geocoded image

(geotagging – location stamping)

AERIAL ARCHAEOLOGY

└ GEOCODING

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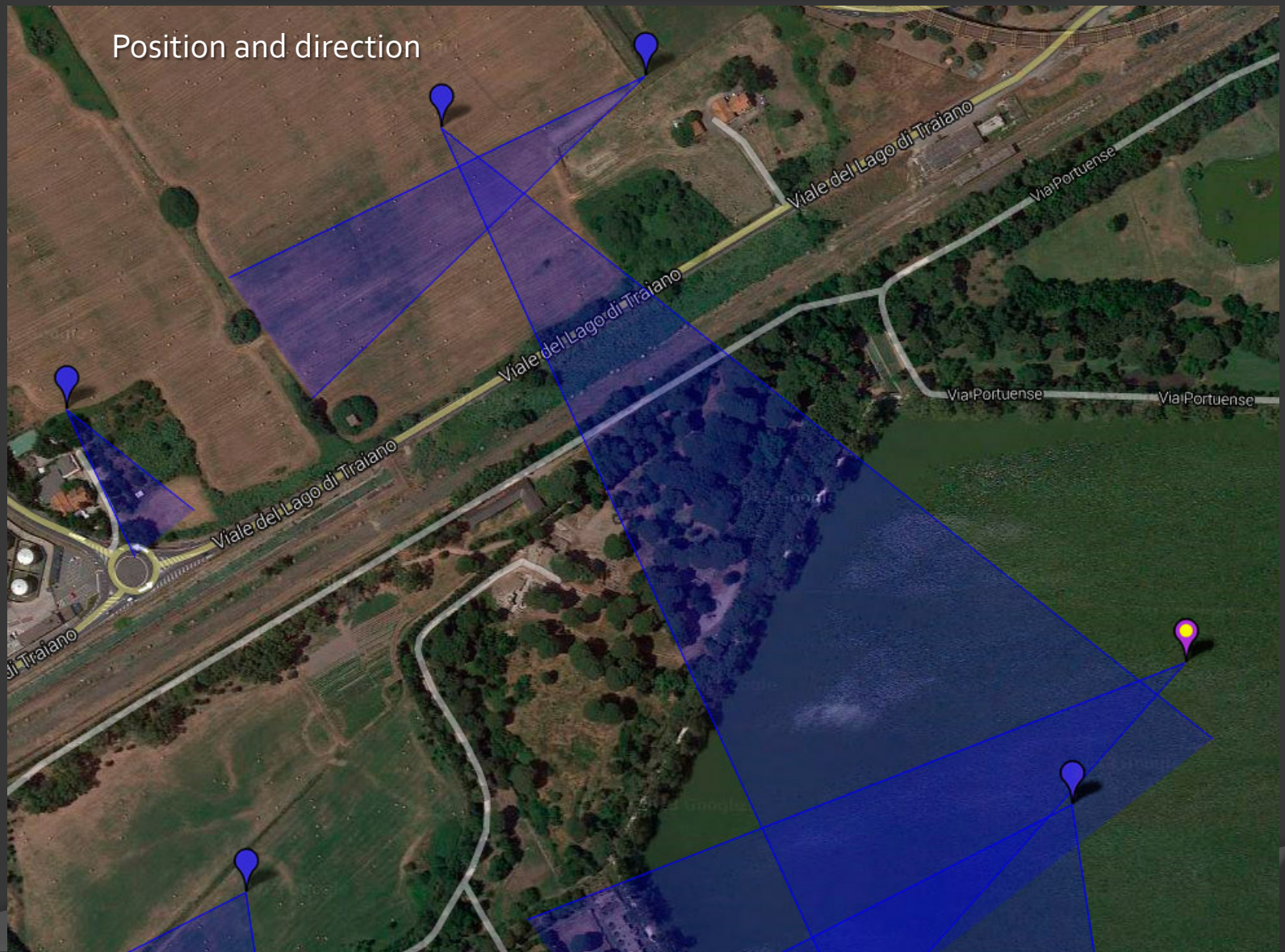
AERIAL ARCHAEOLOGY

└ GEOCODING



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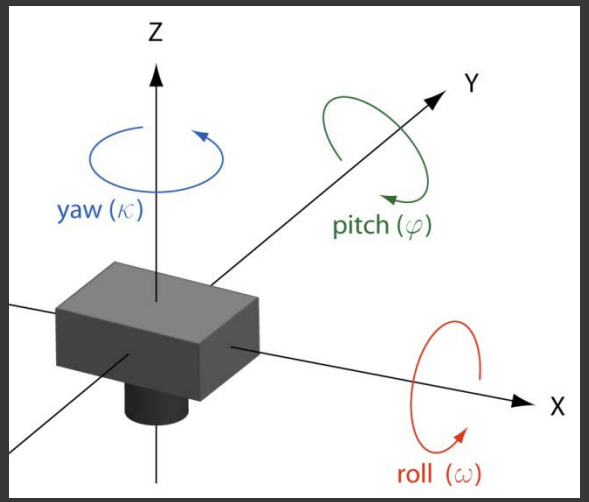
AERIAL ARCHAEOLOGY

└ EXTERIOR ORIENTATION

- Problems
  - camera location
  - only postion (sometimes heading/yaw)
  - inaccurate heading
- Needed
  - accurate description of area photographed

- exterior orientation
  - 3 coordinates X_O, Y_O, Z_O
  - 3 angles roll (ω), pitch (φ) and yaw (κ)



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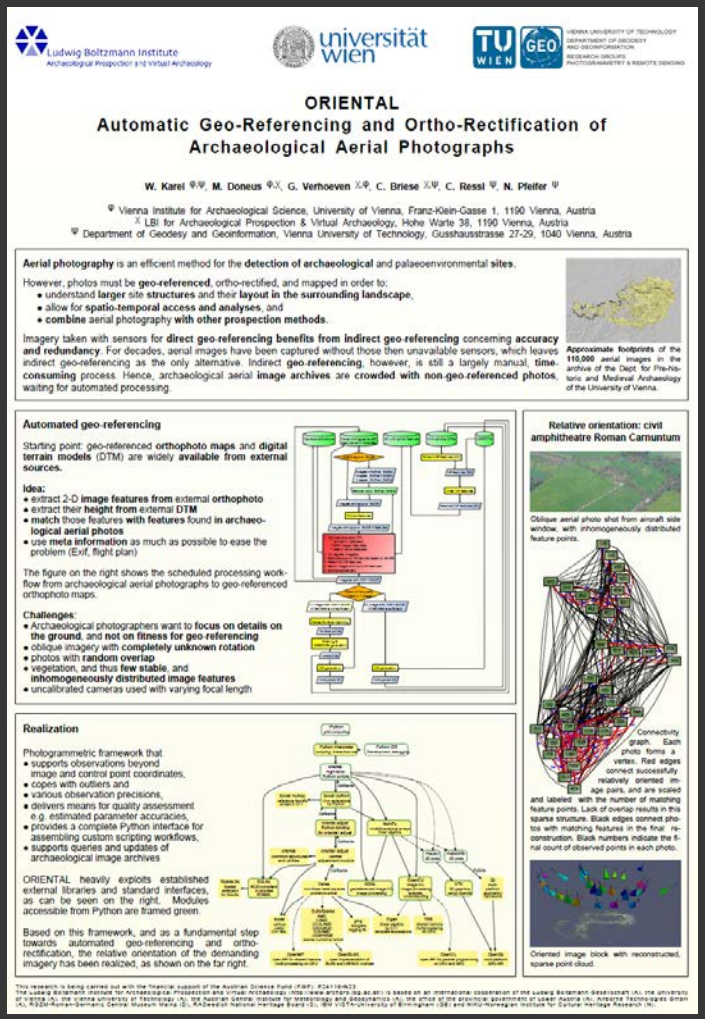
AERIAL ARCHAEOLOGY

└ PROJECT AIMS

- Low-cost solution
- Sufficiently accurate
- Exterior orientation in Exif
- Software for 3D display
- Initial parameters for auto-orthorectification
  - ORIENTAL
  - P28 - CIPA2013-205



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TU WIEN GEO

ORIENTAL
Automatic Geo-Referencing and Ortho-Rectification of Archaeological Aerial Photographs

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Aerial photography is an efficient method for the **detection of archaeological** and palaeoenvironmental **sites**.

However, photos must be **geo-referenced**, ortho-rectified, and mapped in order to:
- understand **larger** site **structures** and their **layout in the surrounding landscape**,
- allow for **spatio-temporal access and analyses**, and
- **combine** aerial photography **with other prospection methods**.

Imagery taken with sensors for **direct geo-referencing benefits from indirect geo-referencing** concerning **accuracy and redundancy**. For decades, aerial images have been captured without those then unavailable sensors, which leaves indirect geo-referencing as the only alternative. Indirect **geo-referencing**, however, is still a largely manual, **time-consuming** process. Hence, archaeological aerial **image archives** are **crowded with non-geo-referenced photos**, waiting for automated processing.

Approximate footprints of the **110,000** aerial images in the archive of the Dept. for Pre-historic and Medieval Archaeology of the University of Vienna.

Automated geo-referencing

Starting point: geo-referenced **orthophoto maps** and **digital terrain models** (DTM) are widely **available from external sources.**

Idea:
- extract 2-D **image features from** external **orthophoto**
- extract their **height from** external **DTM**
- **match** those features **with features** found **in archaeological aerial photos**
- use **meta information** as much as possible to ease the problem (Exif, flight plan)

The figure on the right shows the scheduled processing workflow from archaeological aerial photographs to geo-referenced orthophoto maps.

Challenges:
- Archaeological photographers want to **focus on details on the ground**, and **not on fitness for geo-referencing**
- oblique imagery with **completely unknown rotation**
- photos with **random overlap**
- vegetation, and thus **few stable**, and **inhomogeneously distributed image features**
- uncalibrated cameras used with varying focal length

Relative orientation: civil amphitheatre Roman Carnuntum

Oblique aerial photo shot from aircraft side window, with inhomogeneously distributed feature points.

Connectivity graph. Each photo forms a vertex. Red edges connect successfully relatively oriented image pairs, and are scaled and labeled with the number of matching feature points. Lack of overlap results in this sparse structure. Black edges connect photos with matching features in the final reconstruction. Black numbers indicate the final count of observed points in each photo.

Oriented image block with reconstructed, sparse point cloud.

Realization

Photogrammetric framework that
- supports observations beyond image and control point coordinates,
- copes with outliers and
- various observation precisions,
- delivers means for quality assessment e.g. estimated parameter accuracies,
- provides a complete Python interface for assembling custom scripting workflows,
- supports queries and updates of archaeological image archives

ORIENTAL heavily exploits established external libraries and standard interfaces, as can be seen on the right. Modules accessible from Python are framed green.

Based on this framework, and as a fundamental step towards automated geo-referencing and ortho-rectification, the relative orientation of the demanding imagery has been realized, as shown on the far right.

This research is being carried out with the financial support of the Austrian Science Fund (FWF): P24116-N23

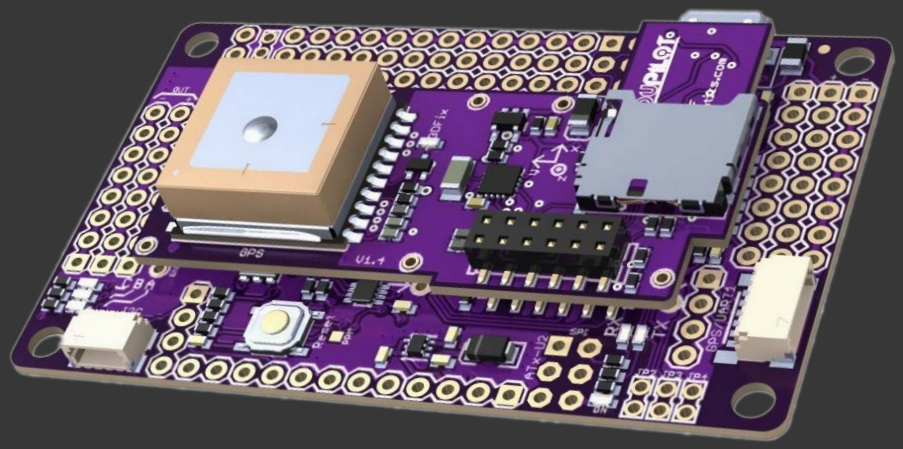
HARDWARE SOLUTION

└ APM 2.0

APM 2.0

GNSS | IMU | MAG

- APM 2.0:
  - ArduPilot Mega
  - integrated GNSS, IMU & magnetometer
  - € 200



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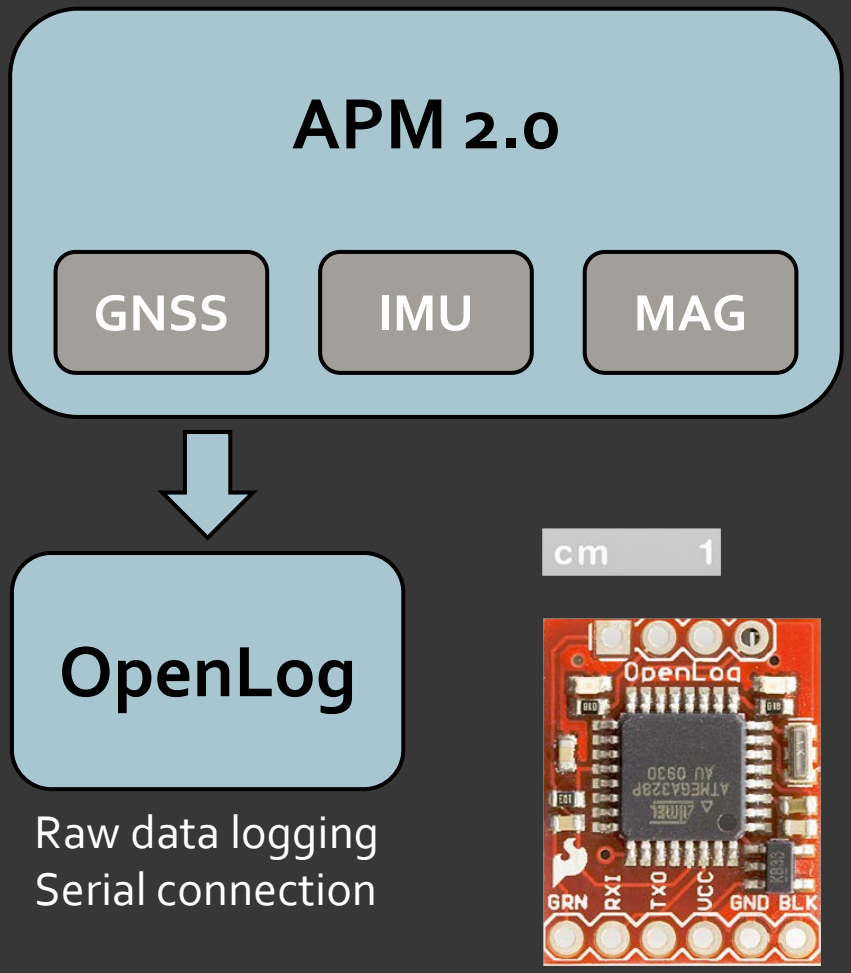
HARDWARE SOLUTION

└ APM 2.0 + OPENLOG



- APM 2.0:
  - ArduPilot Mega
  - integrated GNSS, IMU & magnetometer
  - € 200
- OpenLog
  - IMU: 200 Hz
  - Magnetometer: 80 Hz
  - GNSS: 5 Hz
  - € 30

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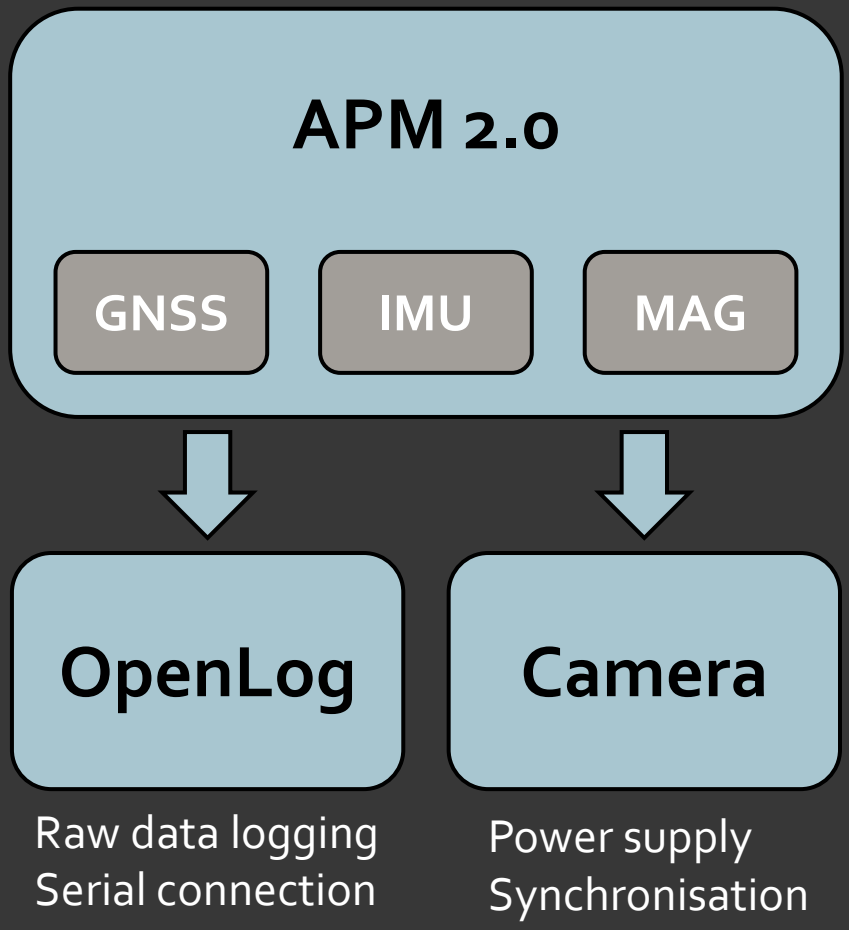
HARDWARE SOLUTION

└ APM 2.0 + OPENLOG + D300



- APM 2.0:
  - ArduPilot Mega
  - integrated GNSS, IMU & magnetometer
  - € 200
- OpenLog
  - IMU: 200 Hz
  - Magnetometer: 80 Hz
  - GNSS: 5 Hz
  - € 30
- Camera
  - Nikon D300

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HARDWARE SOLUTION

└ APM 2.0 + OPENLOG + D300

Hardware: € 300

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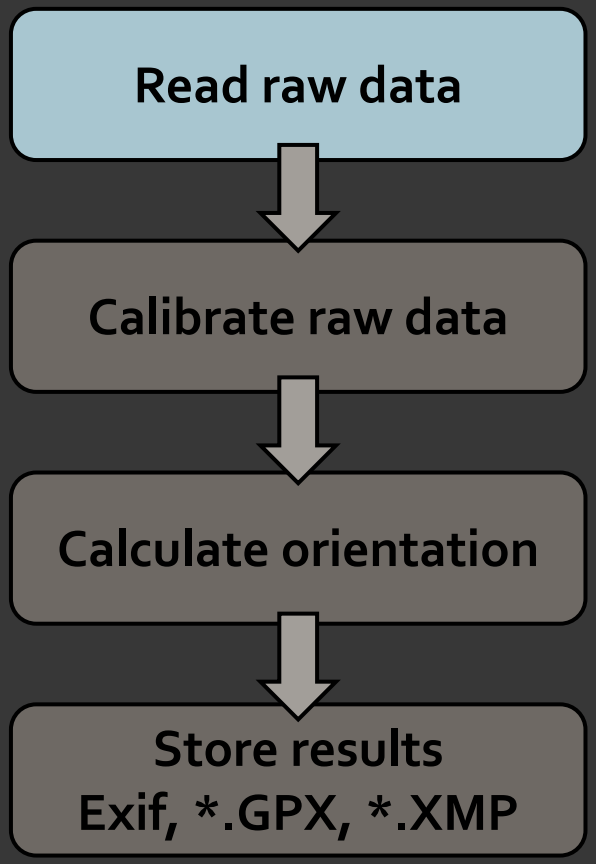
SOFTWARE SOLUTION

└ GNSS/IMU POST-PROCESSING

MATLAB




```
i 696518028 -1979   237 -3488    -60    39     9 -5054
i 696522788 -1975   231 -3471    -60    37    13 -5059
e 696527864   456  -144   552
f 696527864 99067.234000 217.906450 0.142034 -0.441468 16
i 696527548 -2004   238 -3494    -60    32    16 -5054
i 696540044 -2051   239 -3504    -56    29    15 -5060
i 696544804 -2084   224 -3507    -51    30    13 -5054
i 696549564 -2089   232 -3482    -49    33    12 -5057
i 696554324 -2102   224 -3526    -47    36     8 -5062
i 696559084 -2105   222 -3473    -47    41     4 -5062
i 696563844 -2117   229 -3500    -45    44     1 -5059
g 696568780 48.1967450  16.3700910  64.989998 0.320000 94.489998 5 3 100407000 280313
i 696568604 -2102   235 -3516    -43    52    -3 -5063
i 696580756 -2086   232 -3481    -40    62    -7 -5066
i 696585516 -2068   216 -3482    -37    69   -13 -5068
i 696590276 -2056   222 -3512    -38    74   -16 -5067
```

i = IMU
e = magnetometer
g = GNSS
~~f = barometer~~

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SOFTWARE SOLUTION

└ GNSS/IMU POST-PROCESSING

MATLAB

Read raw data

↓

Calibrate raw data

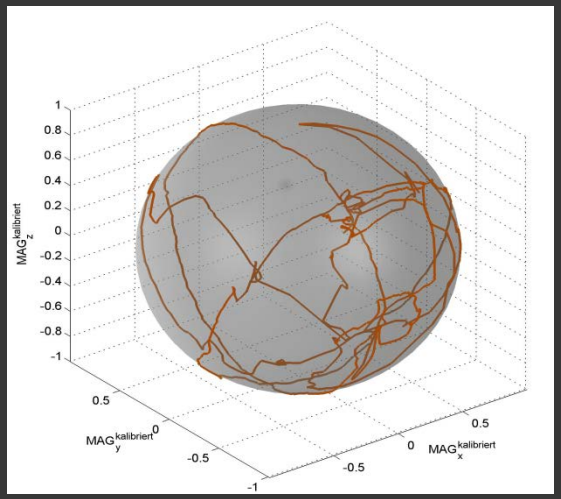
↓

Calculate orientation

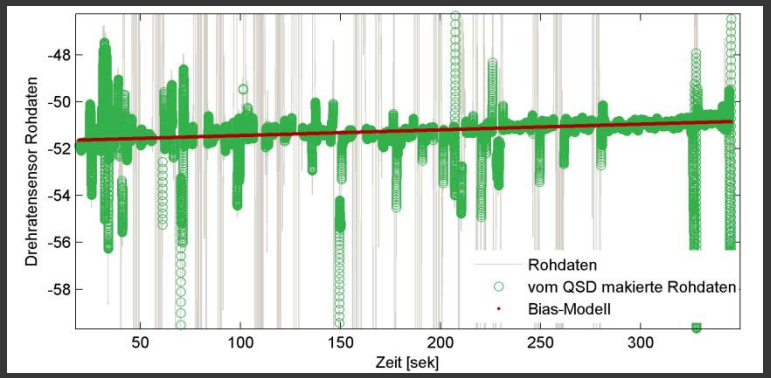
↓

Store results
Exif, *.GPX, *.XMP

Magnetometer calibration



Gyro bias and bias drift estimation



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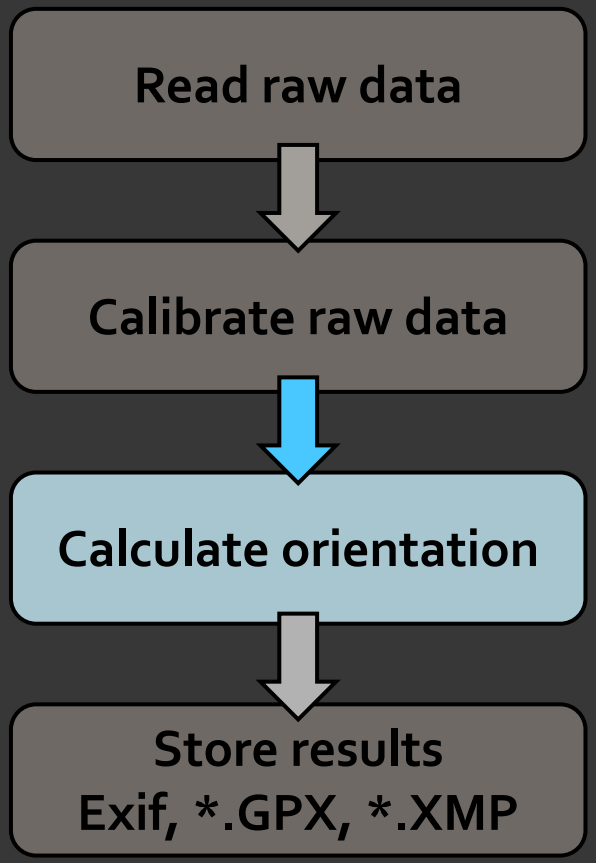
SOFTWARE SOLUTION

└ GNSS/IMU POST-PROCESSING

MATLAB



- strap down algorithm with sensor fusion
- mounting calibration

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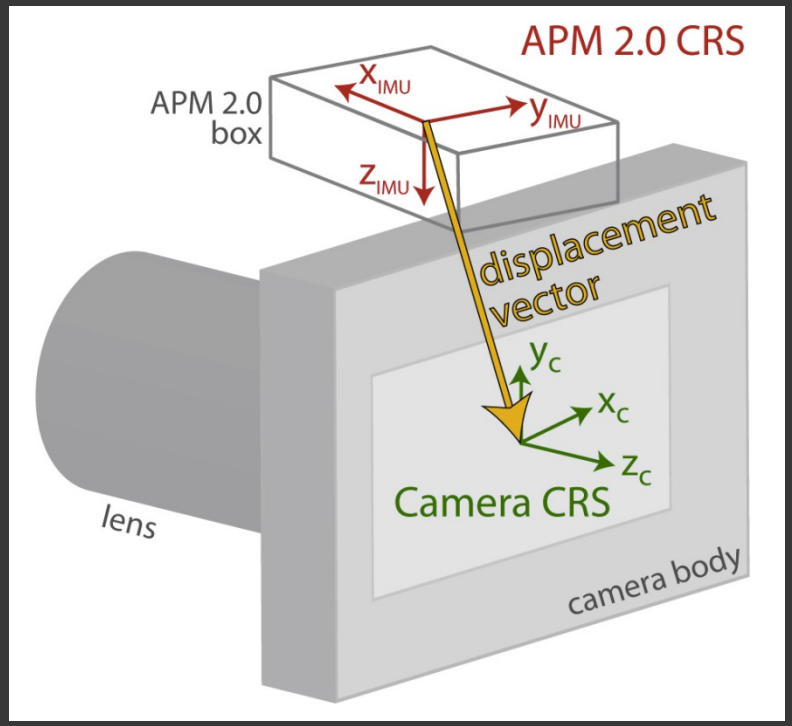
SOFTWARE SOLUTION

└ MOUNTING/BORESIGHT CALIBRATION

- Coordinate reference system camera vs. APM 2.0
  - translation + rotation
- Coordinate transformation: APM 2.0 → image



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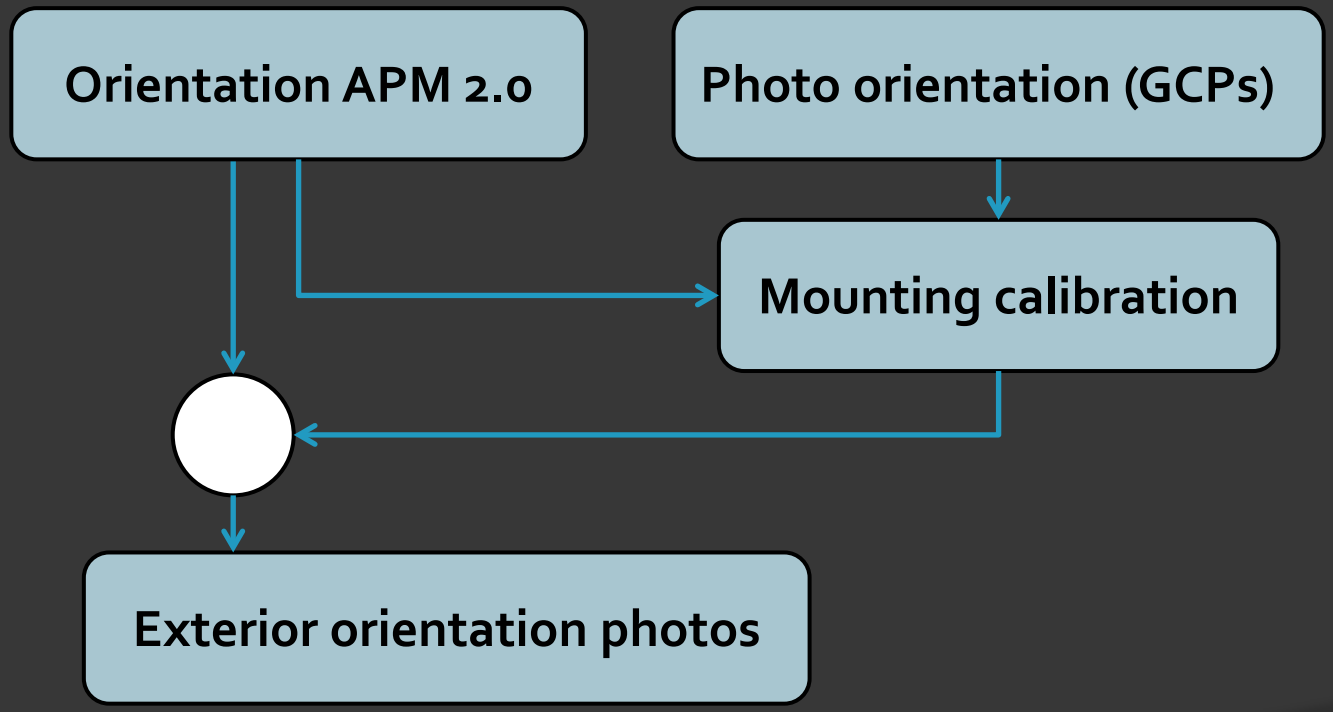

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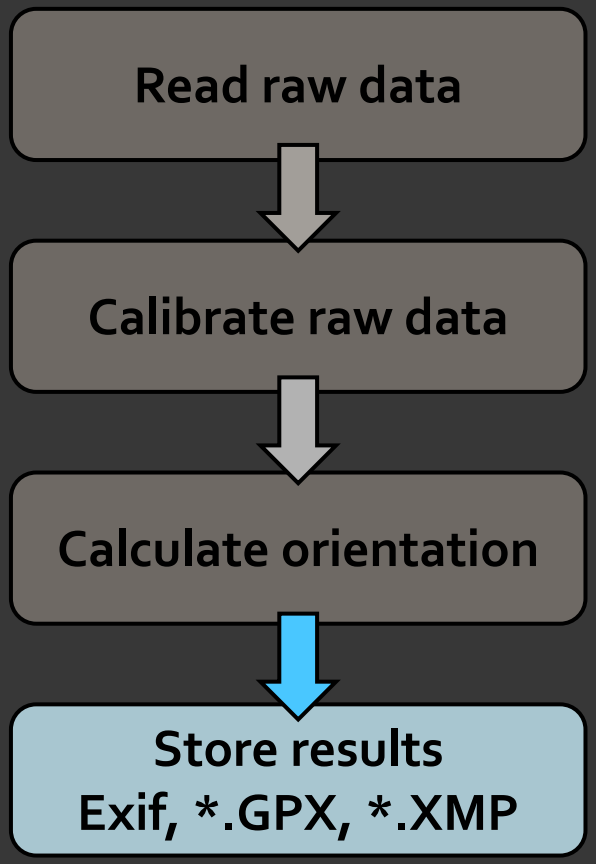
SOFTWARE SOLUTION

└ GNSS/IMU POST-PROCESSING

MATLAB



- use ExifTool
- define new tags pitch and roll

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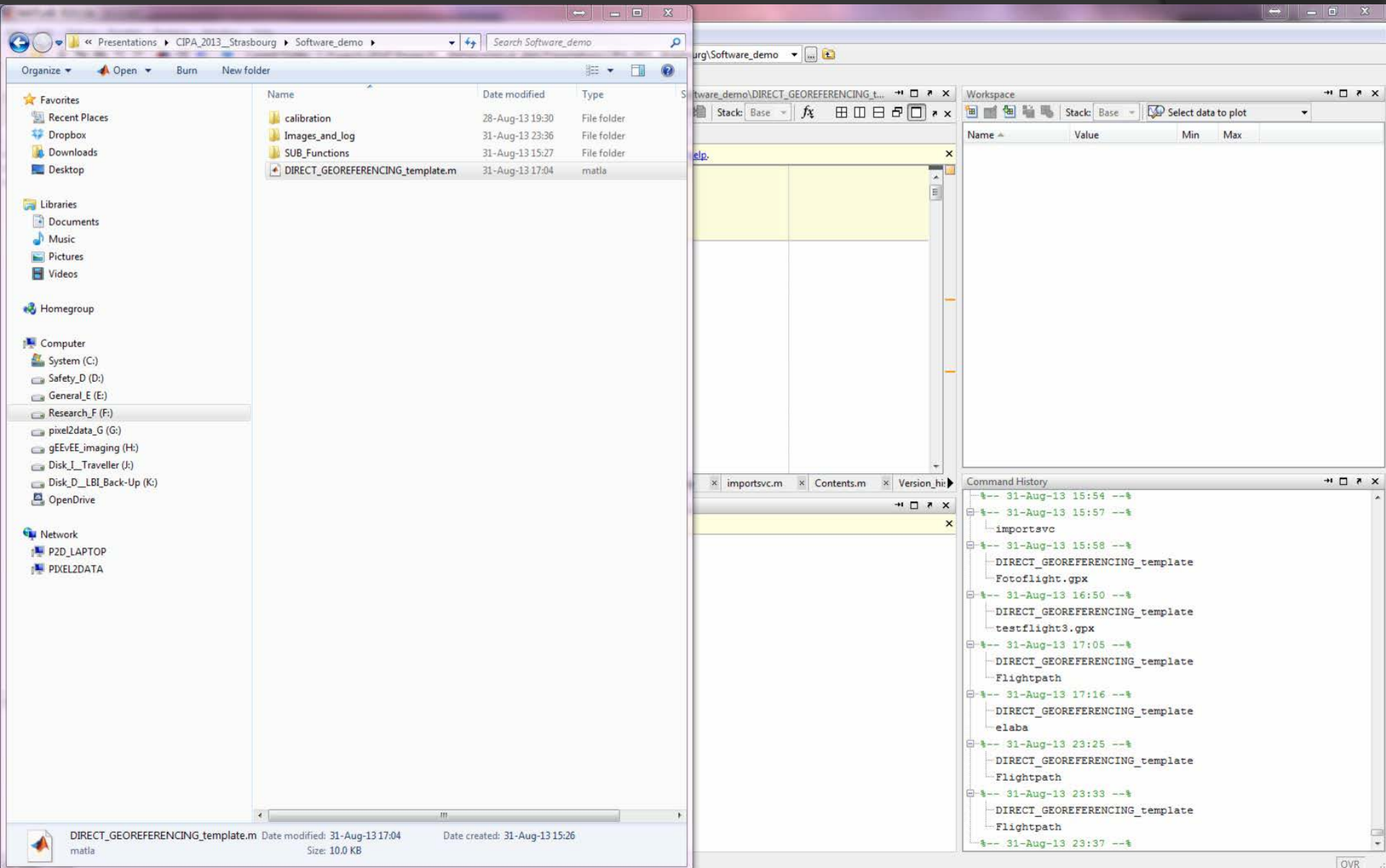
EXAMPLE

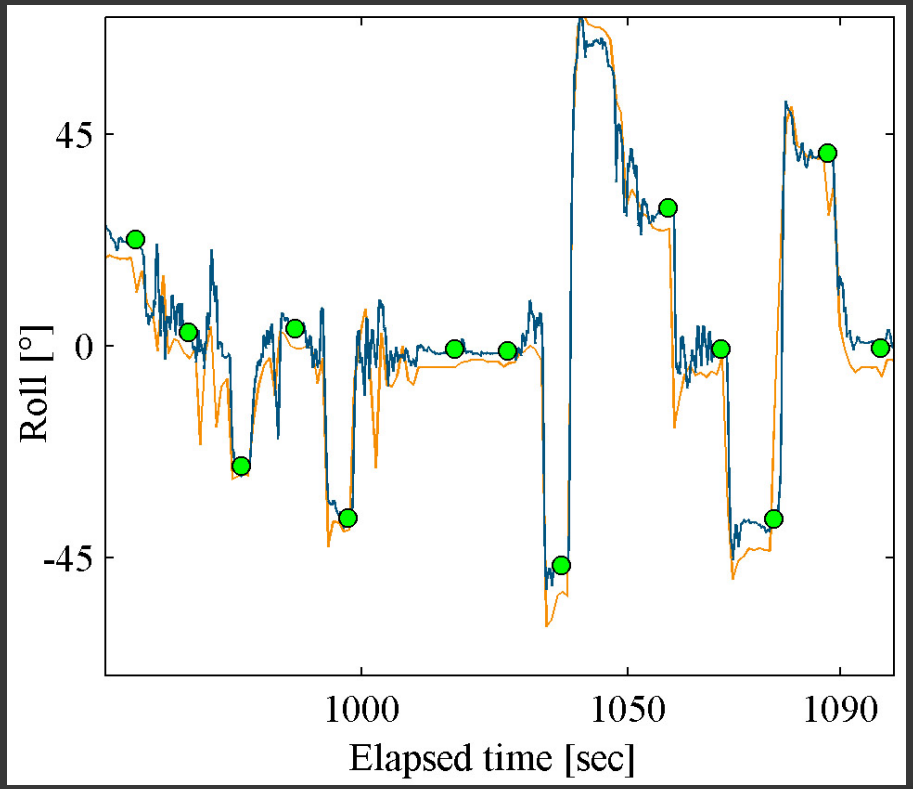
└ WORKFLOW



EXAMPLE

└ COMPARISON

- APM 2.0 vs. Solmeta Geotagger Pro 2
  - Solmeta is less accurate
  - no post-processing
  - logs only at 1 Hz



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ROUND-UP

└ PROS, CONS AND FUTURE

- Low-cost solution
- Sufficiently accurate
- Improvements
  - airborne tests
  - post-processing with Kalman filter
  - Xsens MT-G-700 GPS/INS
  - 3D visualisation software

Thank you for your attention

! Poster P28 - CIPA2013-205 !

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