Fachhochschule Graubünden
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SWISS PHOTONICS

PHOTONICS INNOVATION BOOSTER

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Smart sensing - the key to successful use of robotics in agriculture

Sensing in unforgiving environments

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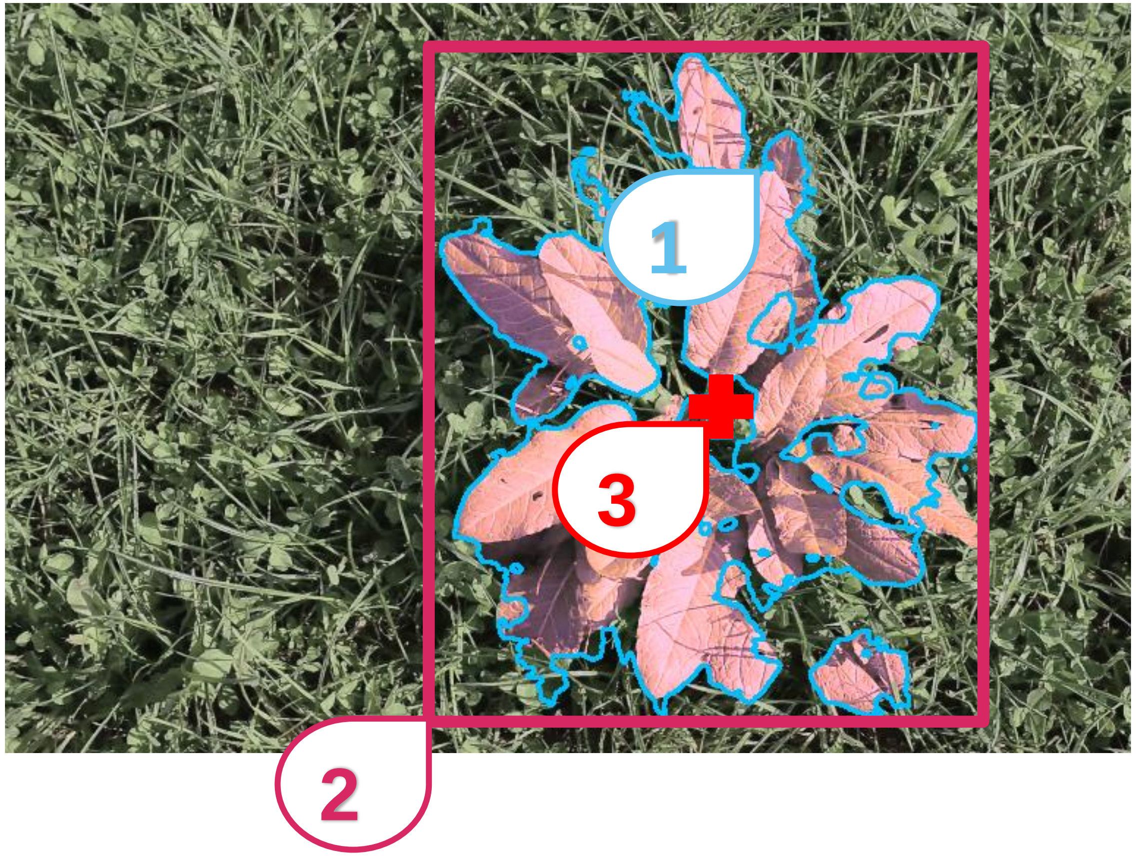
Our problem:



Challenge 1:

Fly autonomously over a meadow and map it in the highest resolution possible. UAV should fly as high as possible

Challenge 2:

Detect and localise weed in the meadow in 5 mm accuracy.

Challenge 3:

Detect the root position of a weed for treatment.

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“I sense something; a presence I have not felt since…”

- Sensing in an outdoor environment is as challenging as it can be:
  - The exposure of the robot(s) and sensor(s) to the elements is inevitable
  - Everything “disturbs” observations and suppresses the use of straightforward algorithms. Environment changes during the season and session and affects sensors in many ways
  - The farming environment is highly dynamic and in many ways chaotic: Robots and sensors are moving, and objects are dynamic too (flora and fauna)
- Three major problems must be solved:
  - Weed detection, precisely data annotation problem (20 – 30 kImages should be annotated and verified)
  - Localise detected plants in 1-3 cm accuracy
  - Extract root location for hot water treatment
- … and, all data must be processed in real-time.

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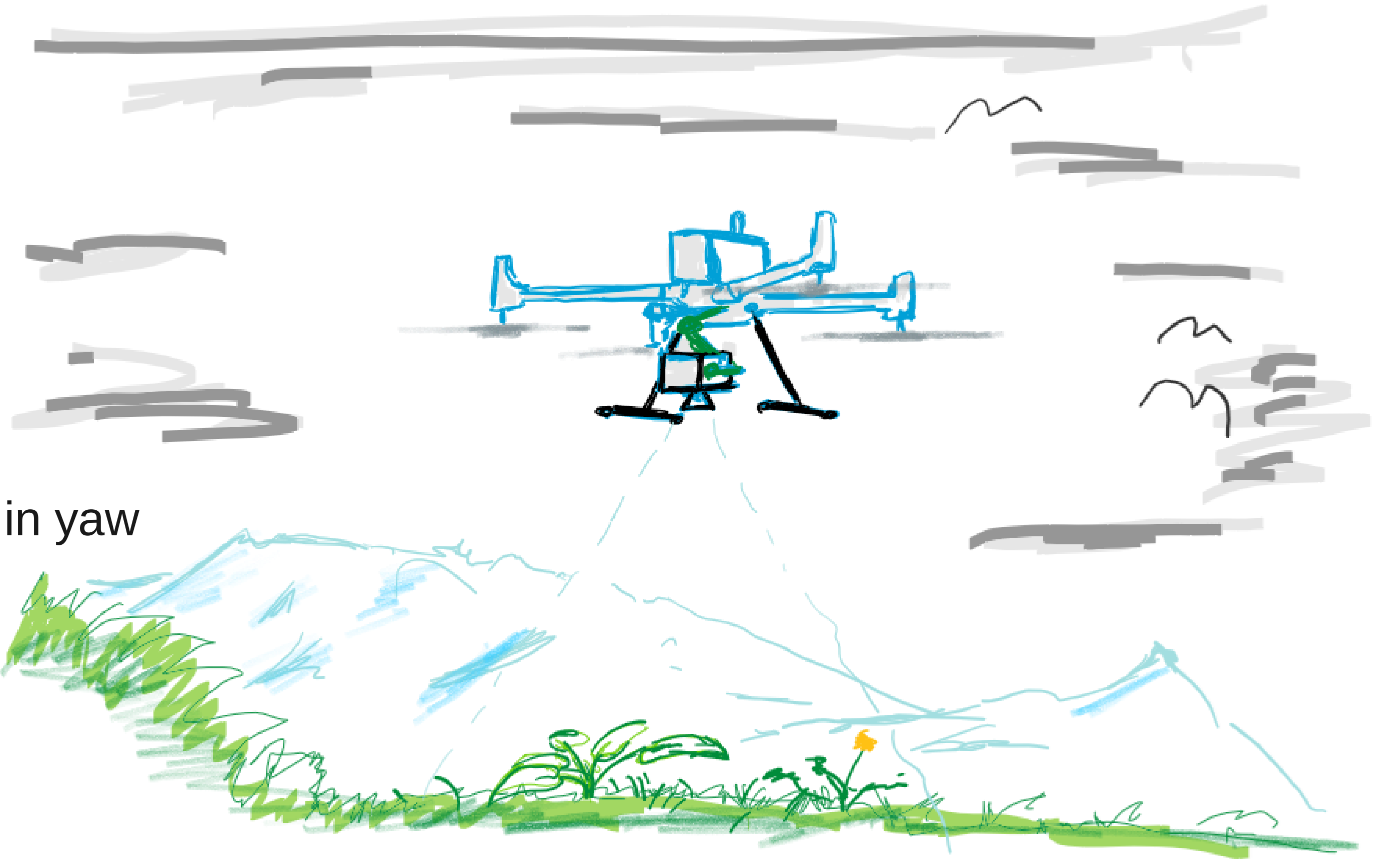
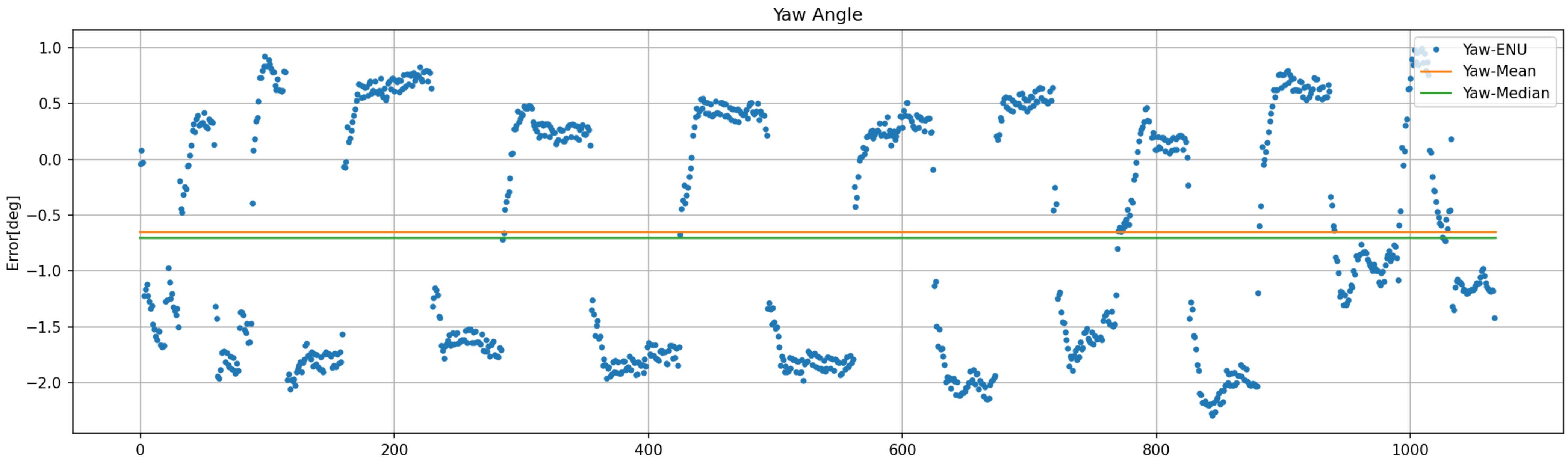
Facts about UAV

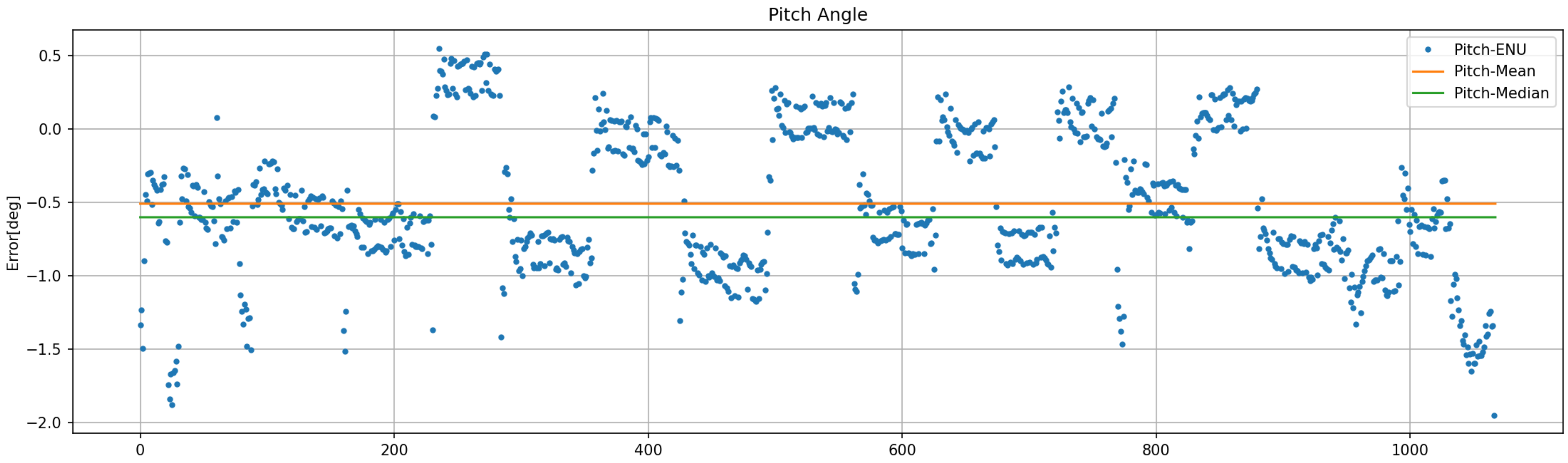
- UAV:
  - RTK GNSS system
  - 48 Mpix Zenmuse P1 RGB camera
  - Inertial system for sensor orientation
- System flaws:
  - RTK corrections loss, cycle slips
  - IMU drift, up to five degrees deviations in yaw and pitch angles
  - Low image sensor dynamics



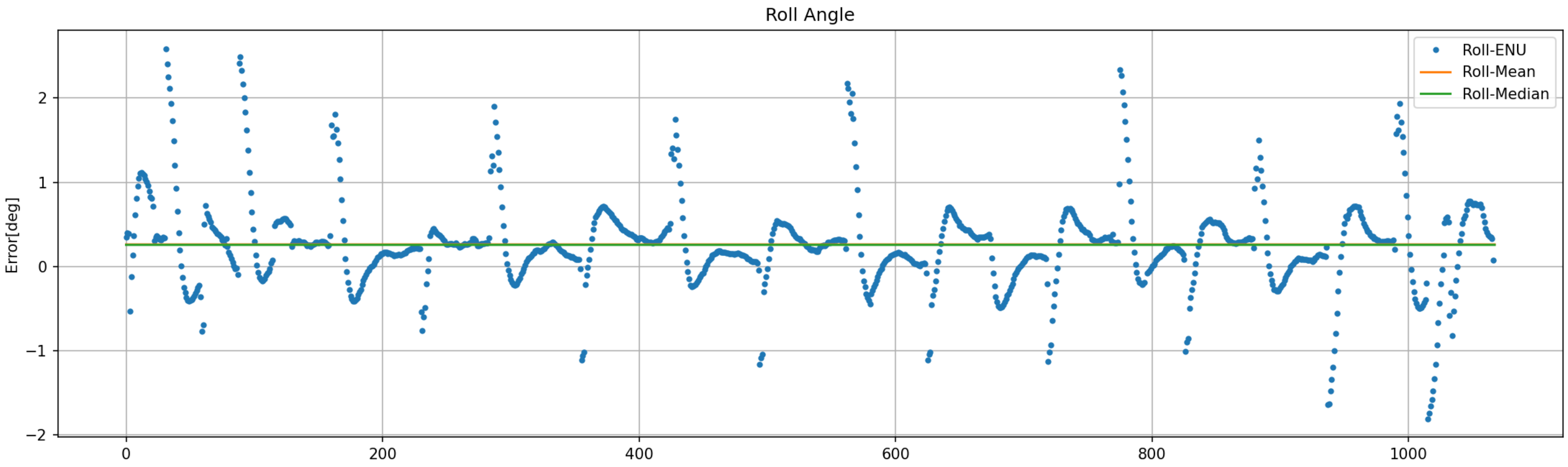
Orientation Analysis Using Metashape: Bildacher



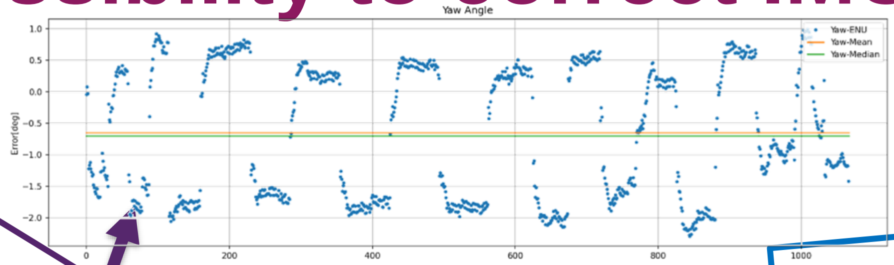
Orientation Analysis Using Metashape: Bildacher



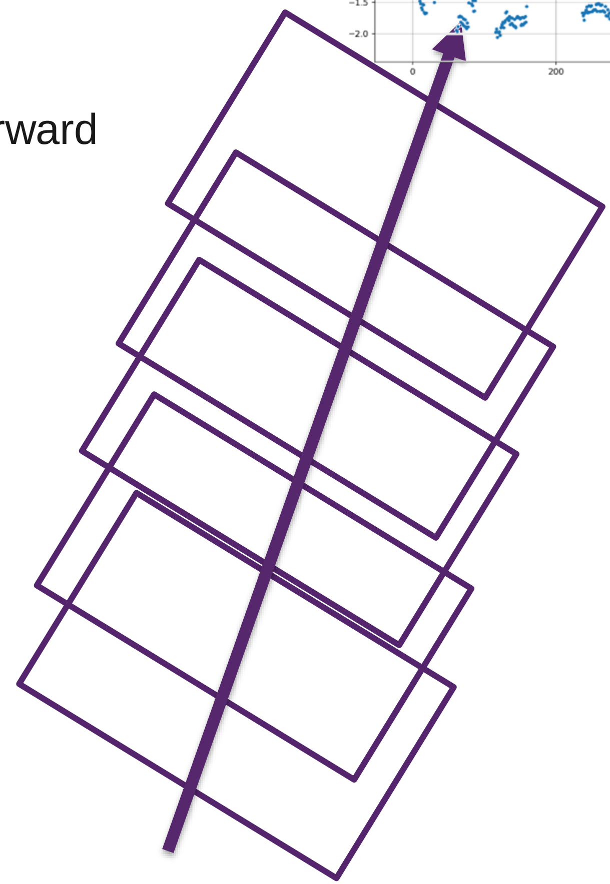
Orientation Analysis Using Metashape: Bildacher



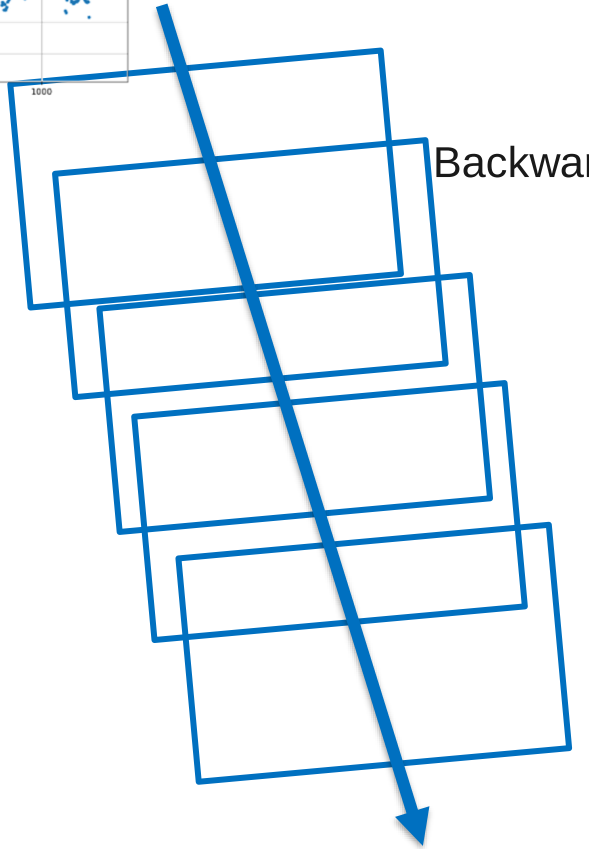
UAV has no possibility to correct IMU drift.



Forward



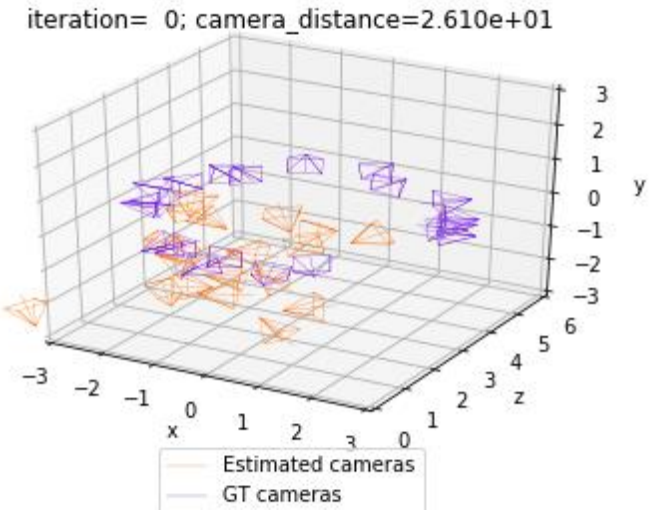
Backward

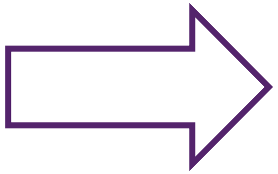


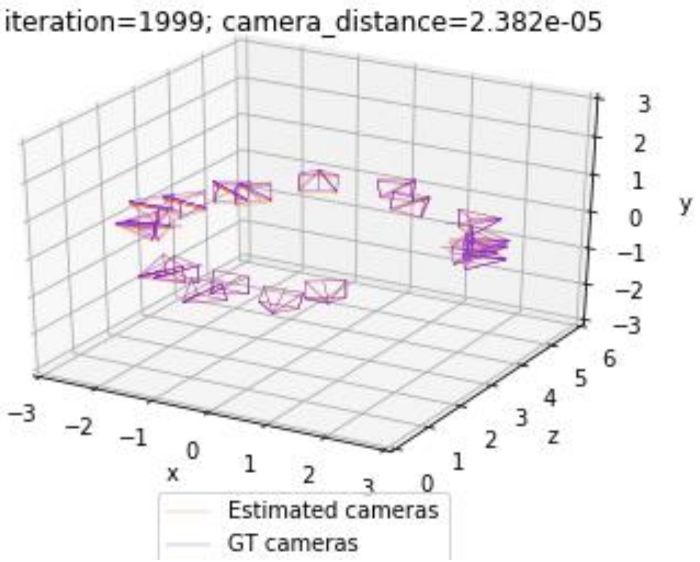
IMU error and it’s effect on flight path and stripe orientation

Bundle adjustment solves the problem

- Using tie points on the ground optimal orientation is computed (low a-priori accuracy for RPY angles is **changed** during session processing)
- RTK accuracy obtained by receiver is **not changed**
- The adjustment compensates the orientation errors caused by low accuracy of an IMU
- **Good bye real-time: High accuracy bites the real-time information service!**





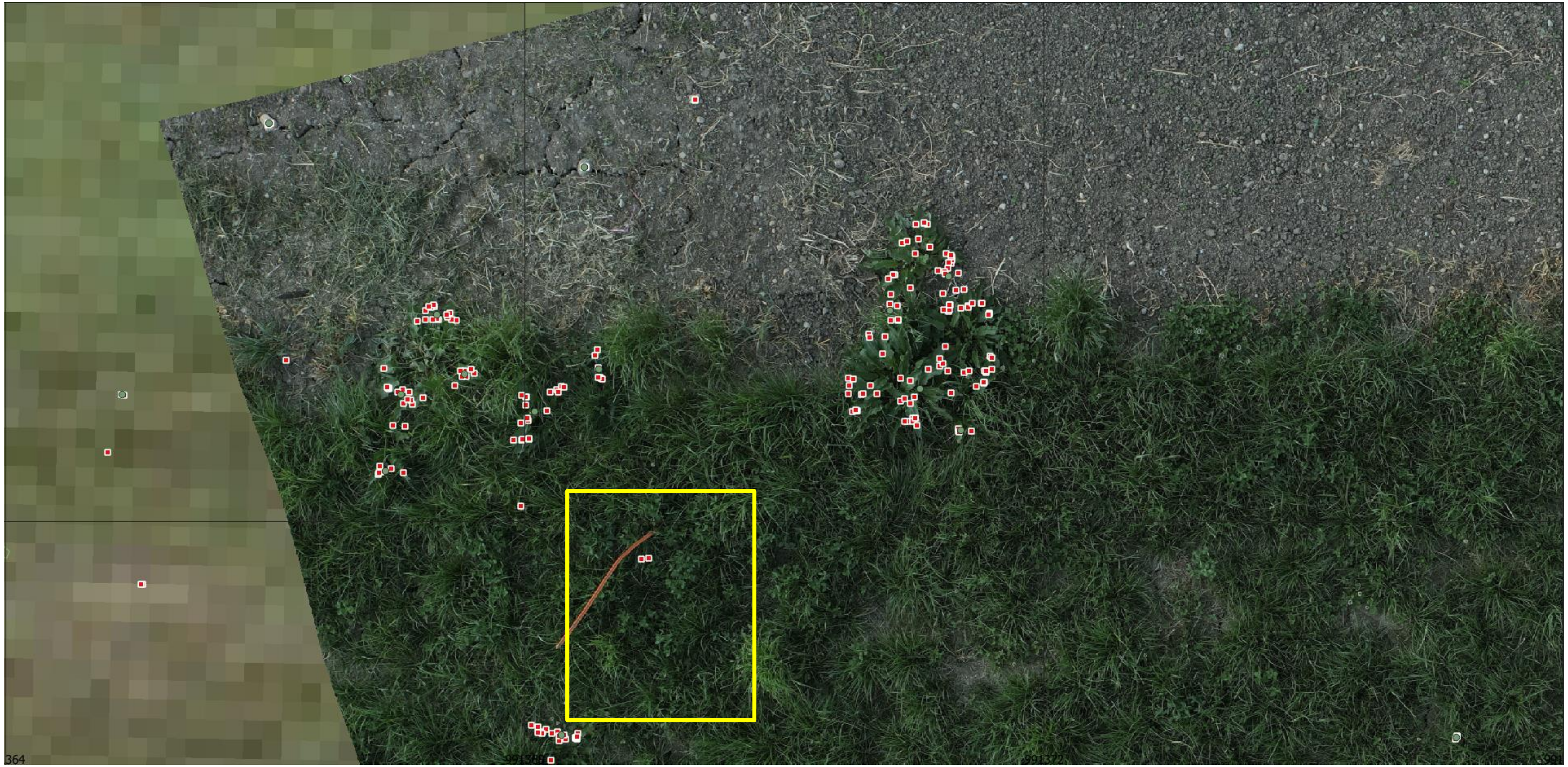


Results

Localisation and Mapping

Variations on the ground introduce additional errors

Variations on the ground introduce additional errors



Bundle adjustment solves the IMU drift problem

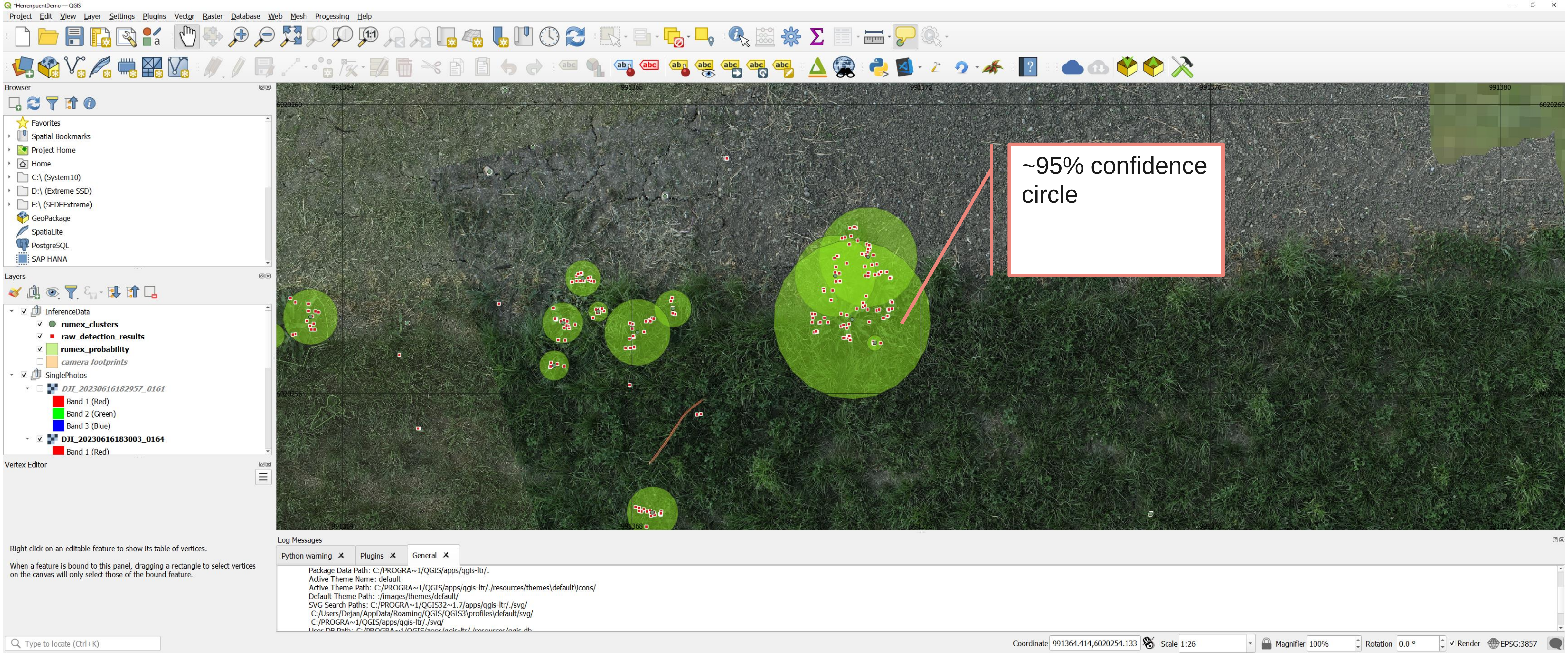
Perfect meadow map can be created and provided to a user

Image “stitching” is almost perfect
Seamlines are almost invisible in orthomosaic

On steep and variable field bundle adjustment will still produce best maps than any other approach

Demo

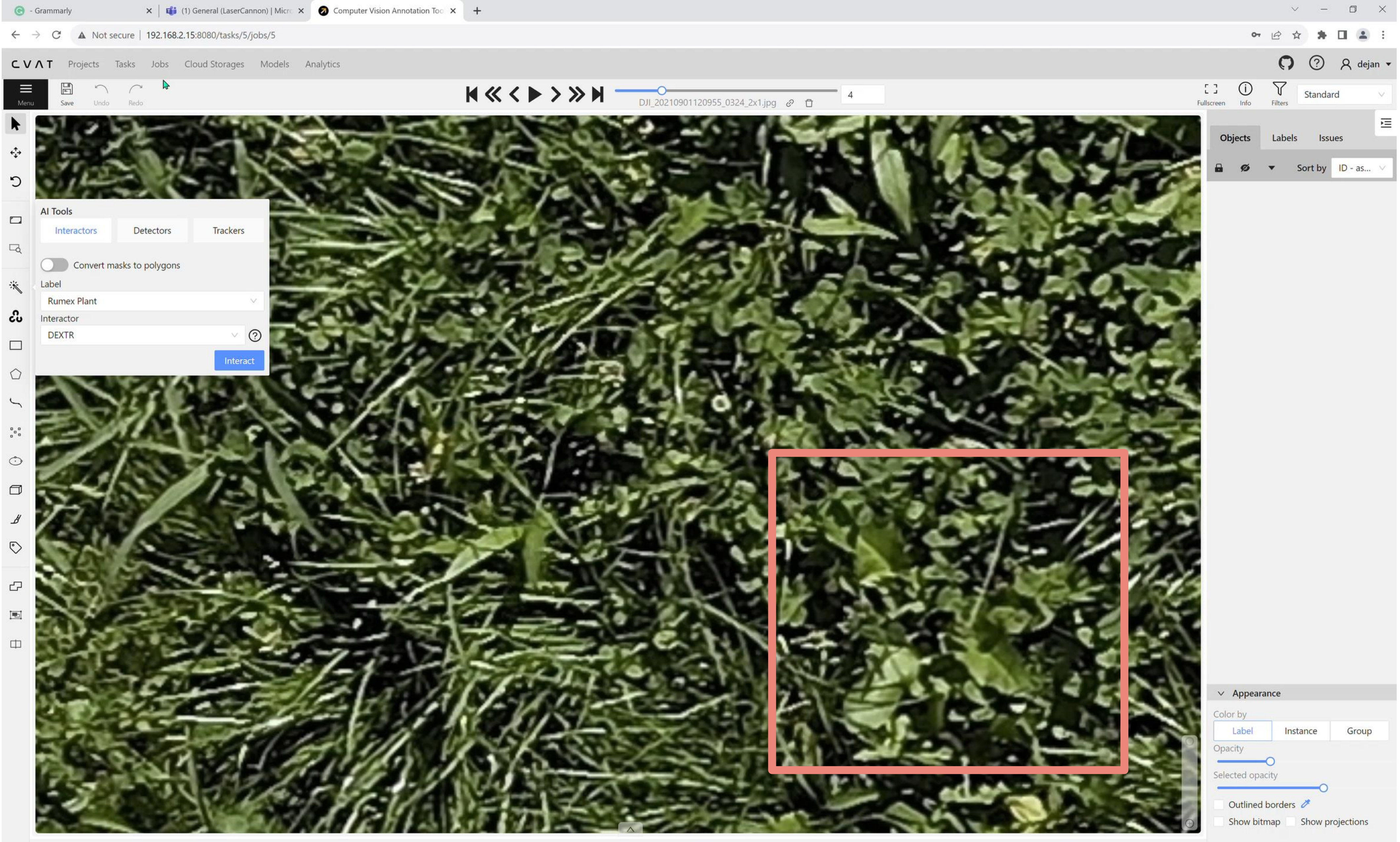
Data Export to QGis



Autolabeling

How to avoid tedious labeling job?

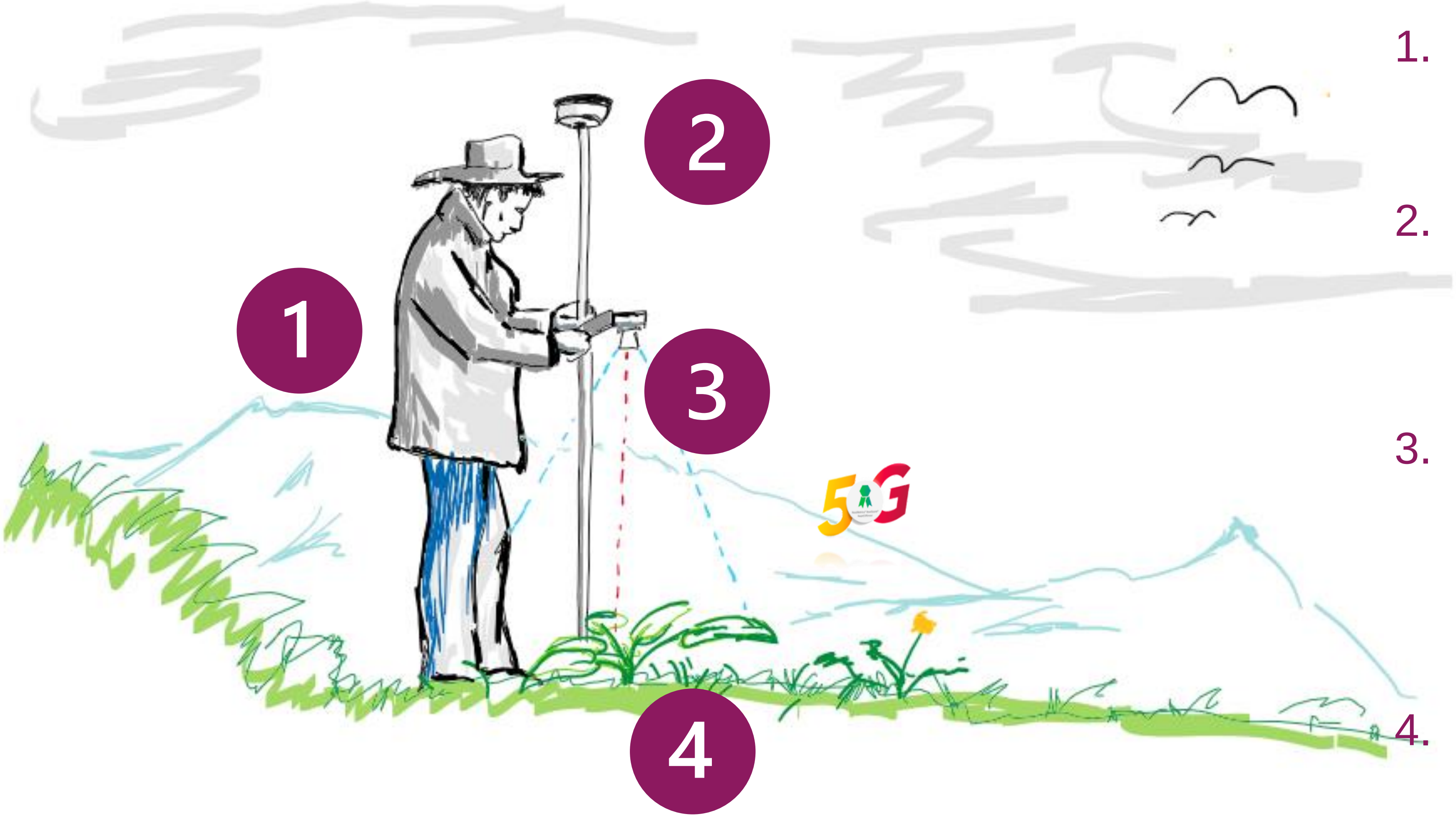
Looks familiar?



Manual Labeling Process

- Manual labeling process is labor intensive.
- A human has to label the image on the computer:
  - Load the image
  - Find a rumex in the image
  - Draw a plant contour (cyan) or
  - Draw a leaf contour (orange) or
  - Create a bounding box
- Labeling UAV images is even more time intensive

Data Acquisition: Ground Segment, HUMINT



1. Operator in the field localizes the plant species (HUMINT)
2. GNSS-RTK receiver determines the position of a species in 1-3 cm accuracy
3. A camera acquires a full screen image of a plant in 12 MP resolution (PX=0.11mm). Area ~47x35 cm.
4. Plant on the ground

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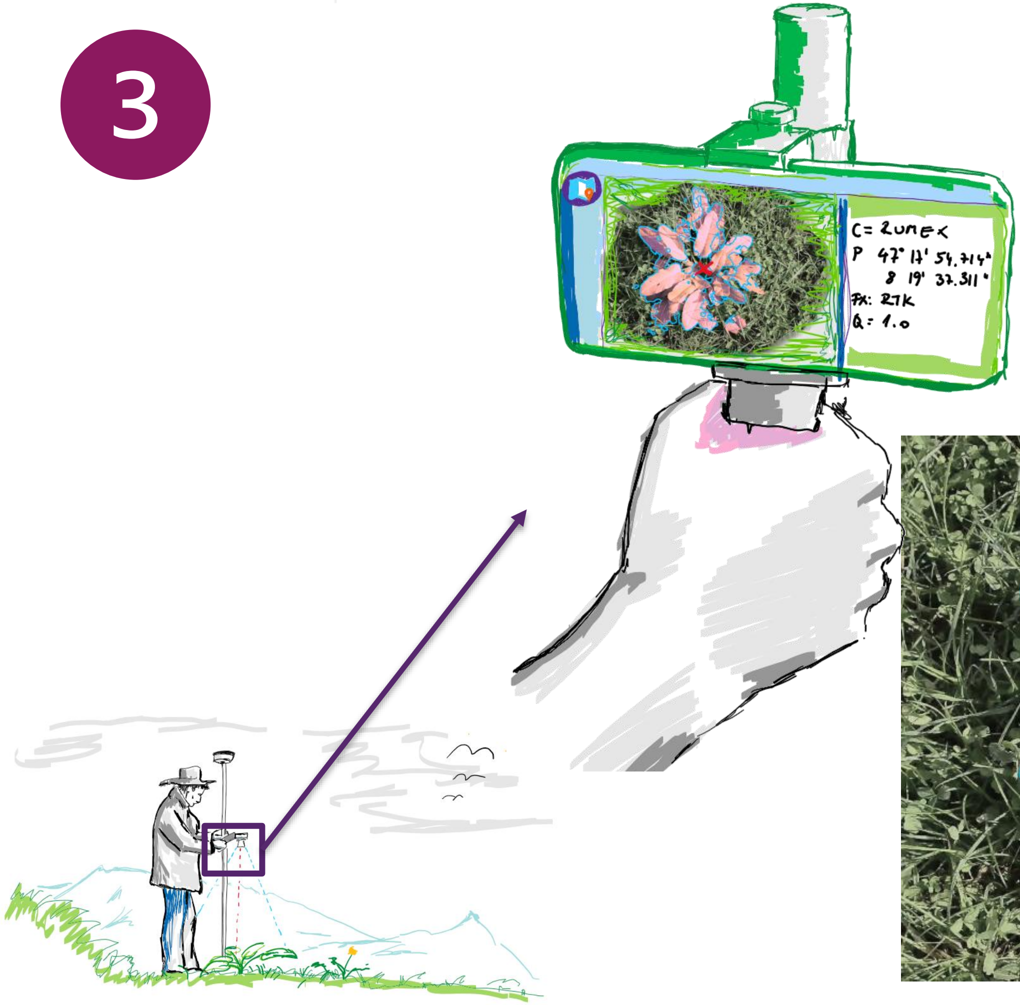
Labeling Assistant: Edge Computer with RTK, the Idea

3



- SBC with a camera acquires images with high spatial accuracy
- The plant center is located by a human in the field
- The images are processed with existing CNN
- Segmented pixels are overlapped with areal images

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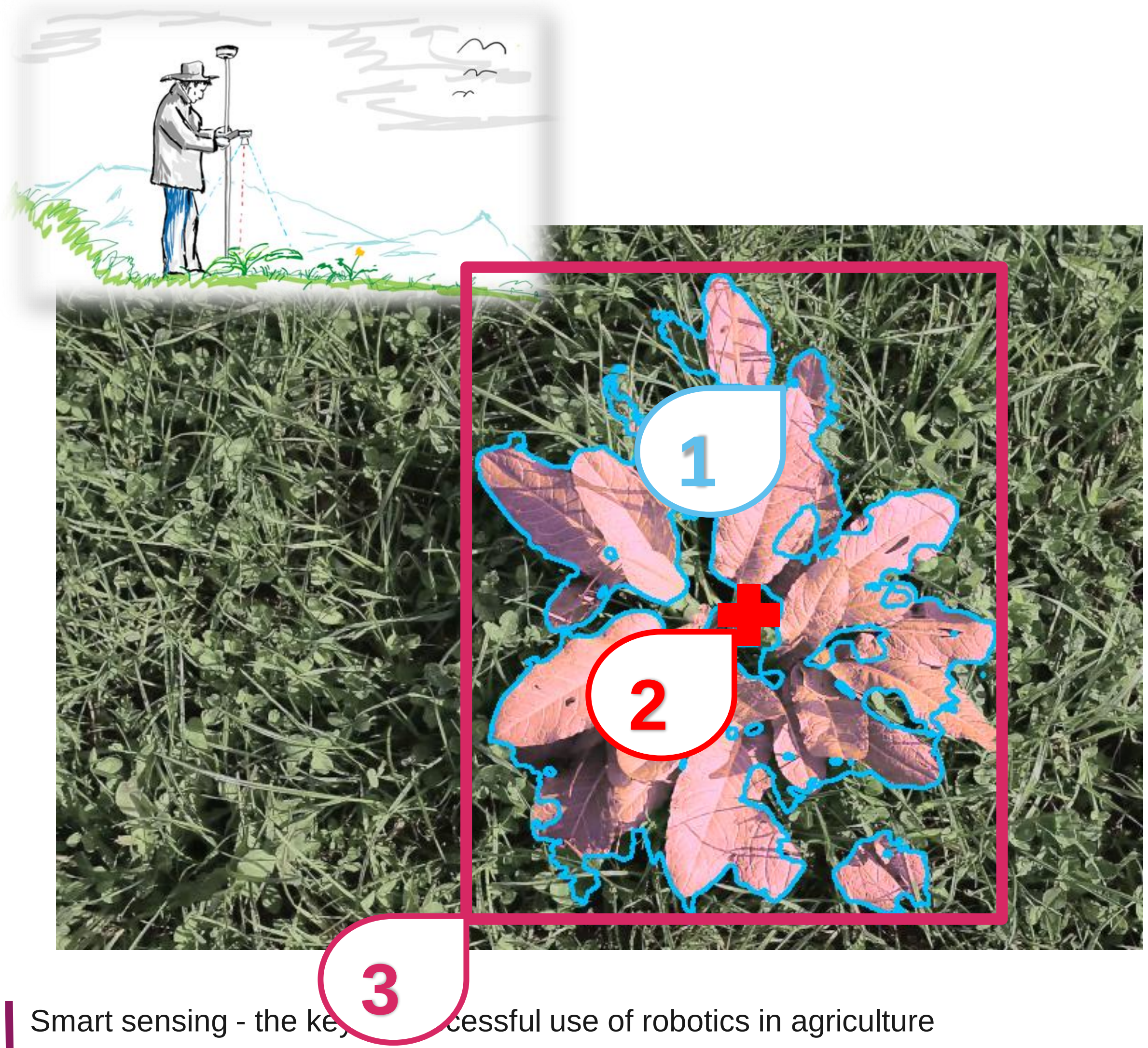
Ground Truth Using GNSS RTK, details



The goal of this task is to use RTK to label the plants in the field.

1. The leaf segmentation is performed automatically by existing algorithm (Schori et. al.)

2. The plant center (root) is observed in the field and coordinates are obtained by GNSS (red cross)

3. Bounding box is computed by the computer using detection mask (raspberry rectangle). Root position is computed from inference mask and compared with the field values.

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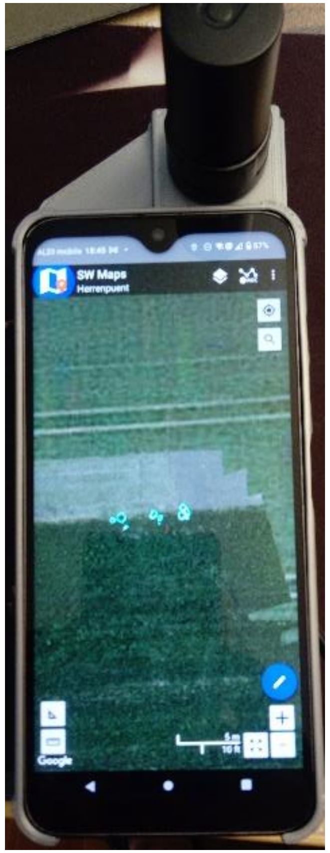
Labeling Assistant

PhotoPi

Mobile Phone Add-On

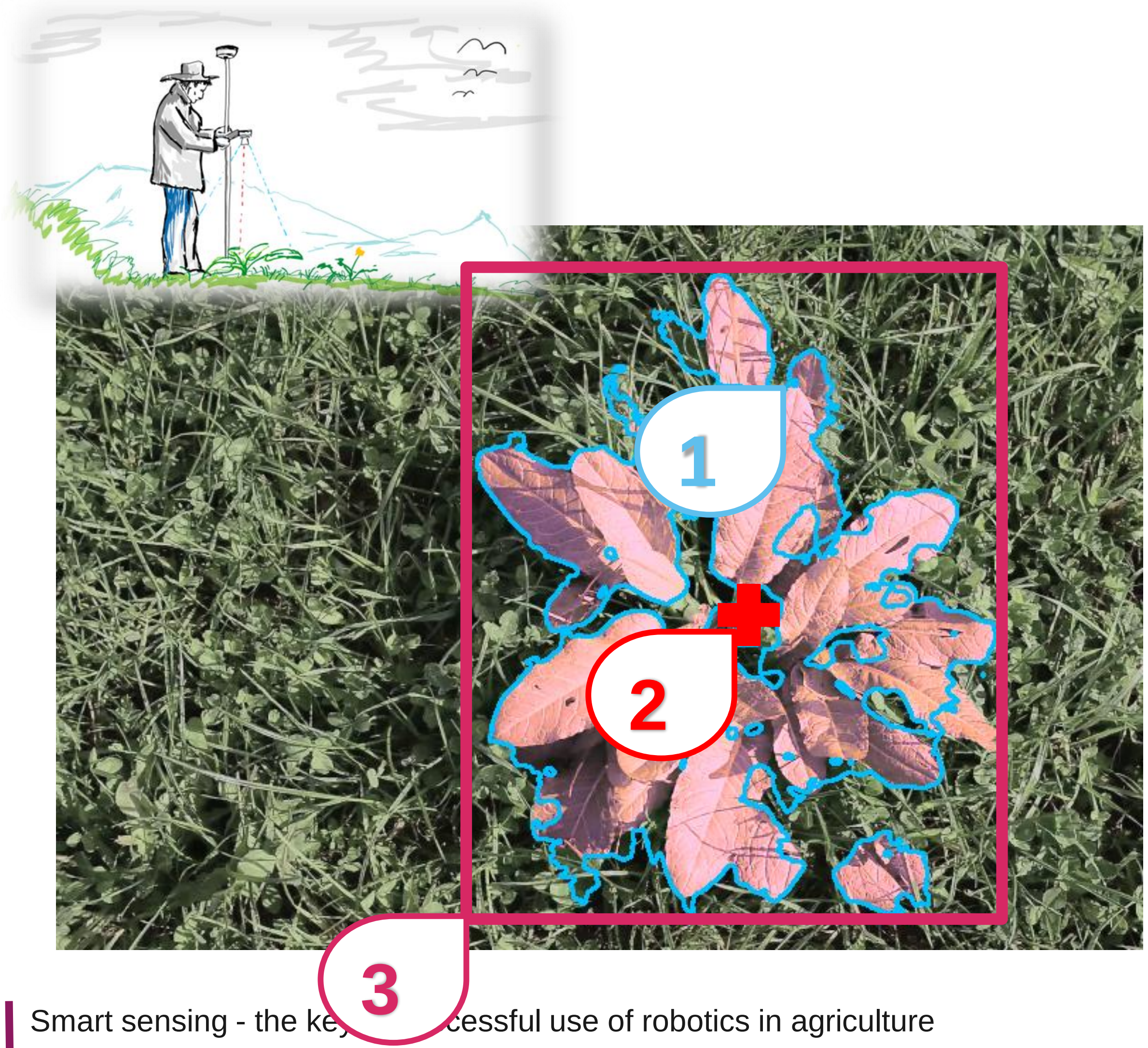


One label, many images

- User annotates plants in the orthophoto
- System projects annotation to all images

Label on a single UAV image

Ground Truth Using GNSS RTK



- With this method, the ground truth for a field is created, and all plant images are acquired from the close range (13 MP), 0.1mm pixel size on the ground, 47x35 cm area.
- The computer labels drone images.
- A human can walk a 1 ha field in 1-2 hours and acquire cm accurate plant positions and plant images.
- A computer can label images within an hour
- A human can control the labels within half of a day.
- Saving: Up to 2000 hours for 500 images

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Smart sensing, conclusion

- Intelligent sensor fusion provides ten times more accurate locations than necessary.
- Wise use of commercial software allows swift result retrieval:
  - 2000 images in 15’ and delivers orthophoto in 60’ (2.5 ha, the flight takes 40’)
- Extracted information allows automatic monitoring through experts and advisors
- Imaging, IMU and GNSS enable one-time annotation:
  - Requires a small network of trained on 500 close-range images to annotate thousands of UAV images
- 90% of necessary software components are free and open-source
- Runs on laptop computers and cloud-systems
- And soon, on mobile phones

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Thank you for your attention

Q & A

Creating fully qualified map for field use.

Metashape Photogrammetry
- Align images
- Compute terrain model (tie points)
- Compute mesh from tie points
- Create orthomosaic

Apply Inference Results
- Import detected points
- Compute model coordinates
- Compute most probable positions
- Compute probability (extent)

Export
- Export results as GPKG
- Export markers
- Export KML, Tiles, KMZ
- Export CSV

MAP (QGis)
- Start plugin
- Choose input directory (Cloud, Share, local disk)
- Create map
- Export map to phone

Inference result

Object detection, overlapping rectangles

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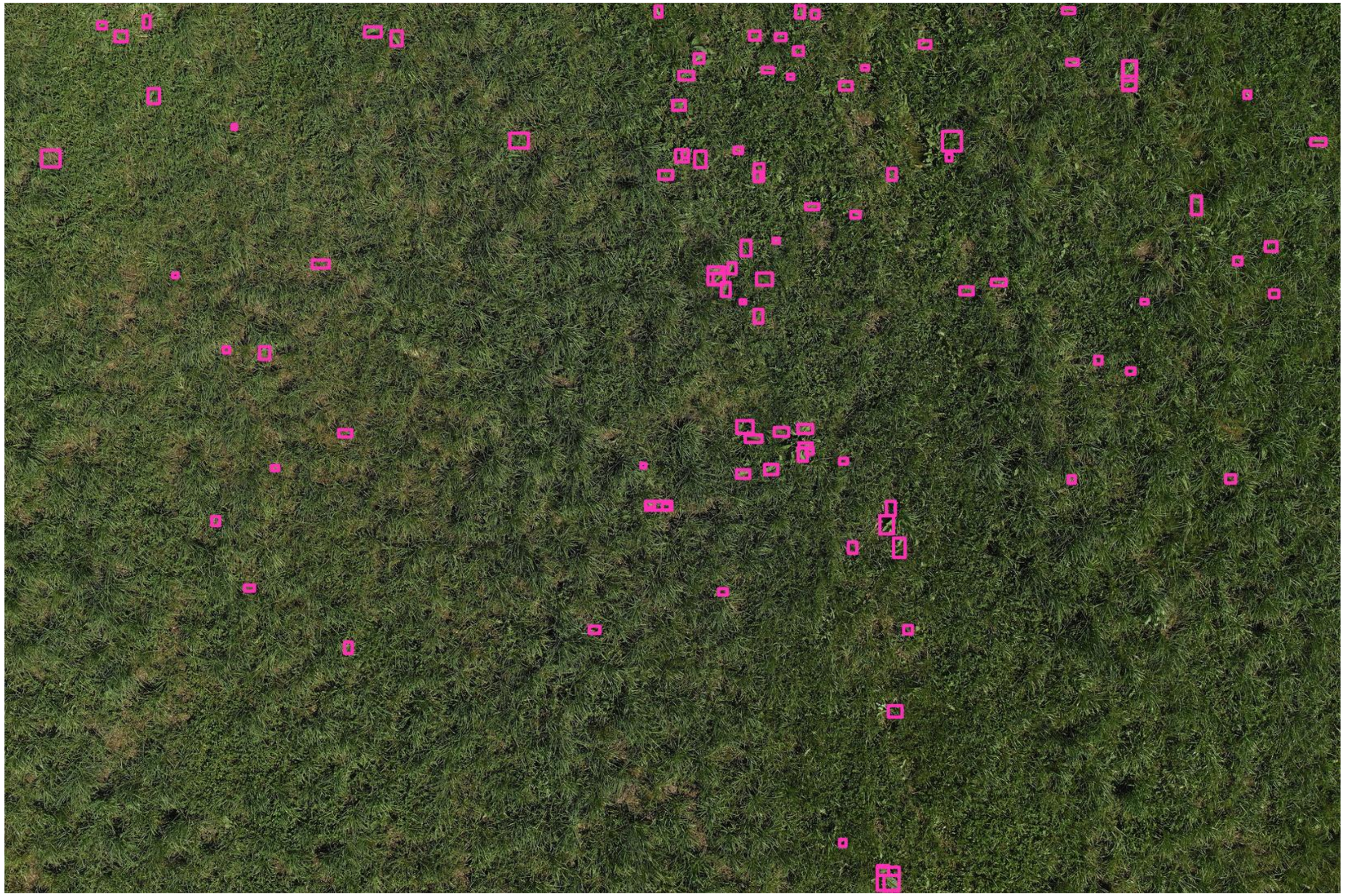
Object detection, overlapping rectangles

- Rectangle unifying is necessary
- Each rectangles middle point is used for the computation of the rumex coordinates
- Reprojection error is the measurement of corresponding points
- ETA of the procedure implemented is end of May 2023
- We have sufficient number of images to make the process stable.

Another inference result

… zoomed results

Third image



Results3


score: 0.88
score: 0.89
score: 0.89
score: 0.99
score: 0.96
score: 0.83
score: 0.87


score: 0.99
score: 0.99