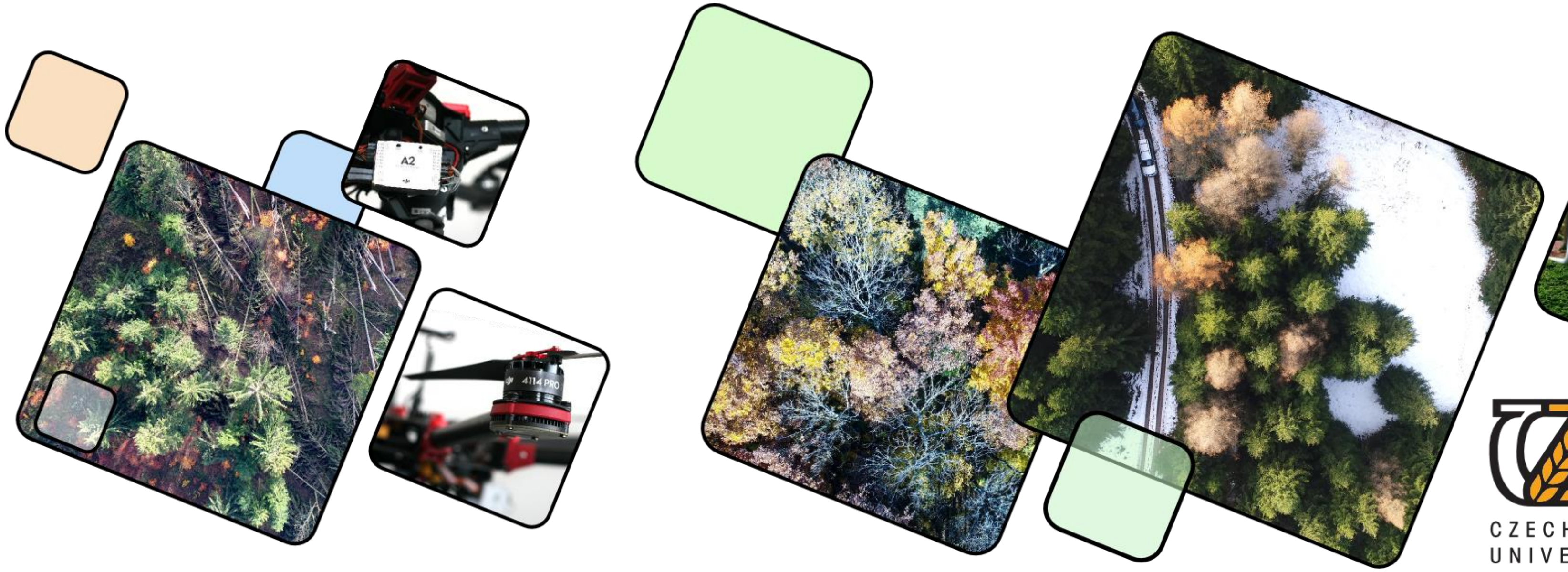


CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

3D DATA ACQUISITION

FOR VIRTUAL REALITY

KAREL KUŽELKA

VR DATA

3D MODEL

TREE TEMPLATES

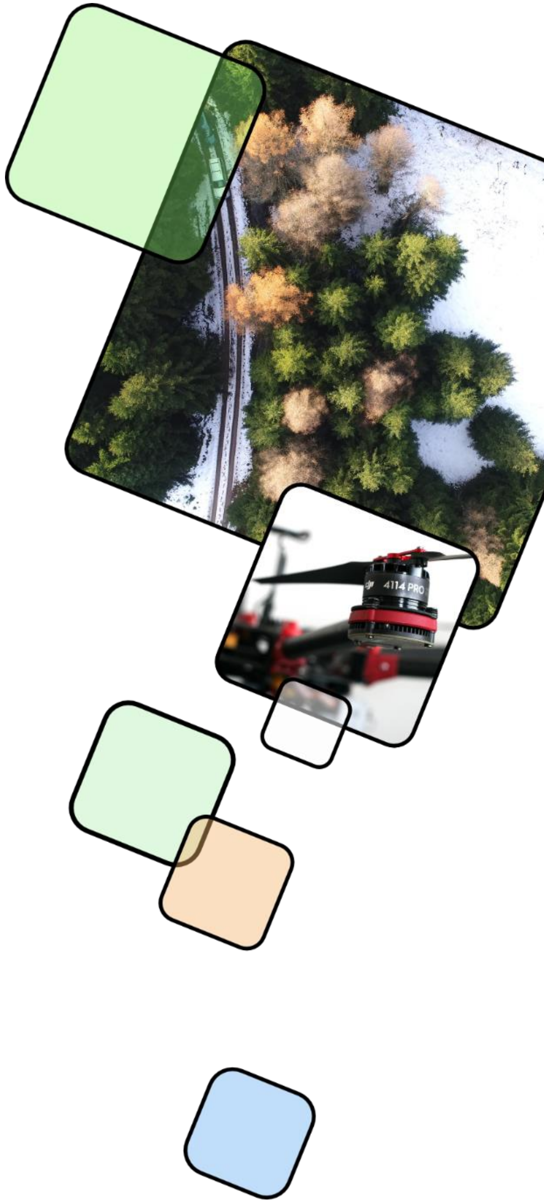
CLOSE-RANGE REMOTE SENSING

LiDAR

PHOTOGRAMMETRY

SIMULATION

REAL FOREST



3D DATA ACQUISITION

PHOTOGRAMMETRY (SFM)
POINT POSITION CALCULATED FROM PARALAX BASED ON A SEQUENCE OF PHOTOS

+ CHEAP EQUIPMENT (any digital camera)
- NECESSITY OF REFERENCING
- ACCURACY DEPENDEND ON USER SKILLS, IMAGE QUALITY…

LASER SCANNING (LiDAR)
POINT POSITIONS FROM RETURNS OF LIGHT PULSES

+ ACCURACY
+ SPEED
- EXPENSIVE EQUIPMENT

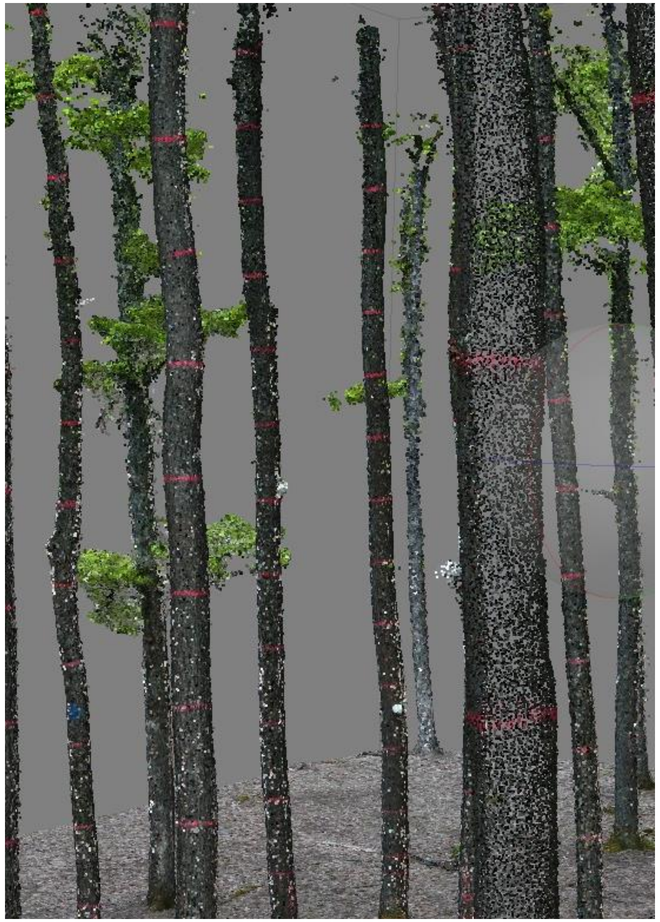
RESULT
3D POINT CLOUD
3D MODEL

SFM/LIDAR OUTPUT

POINT CLOUD

SET OF POINTS (XYZ)

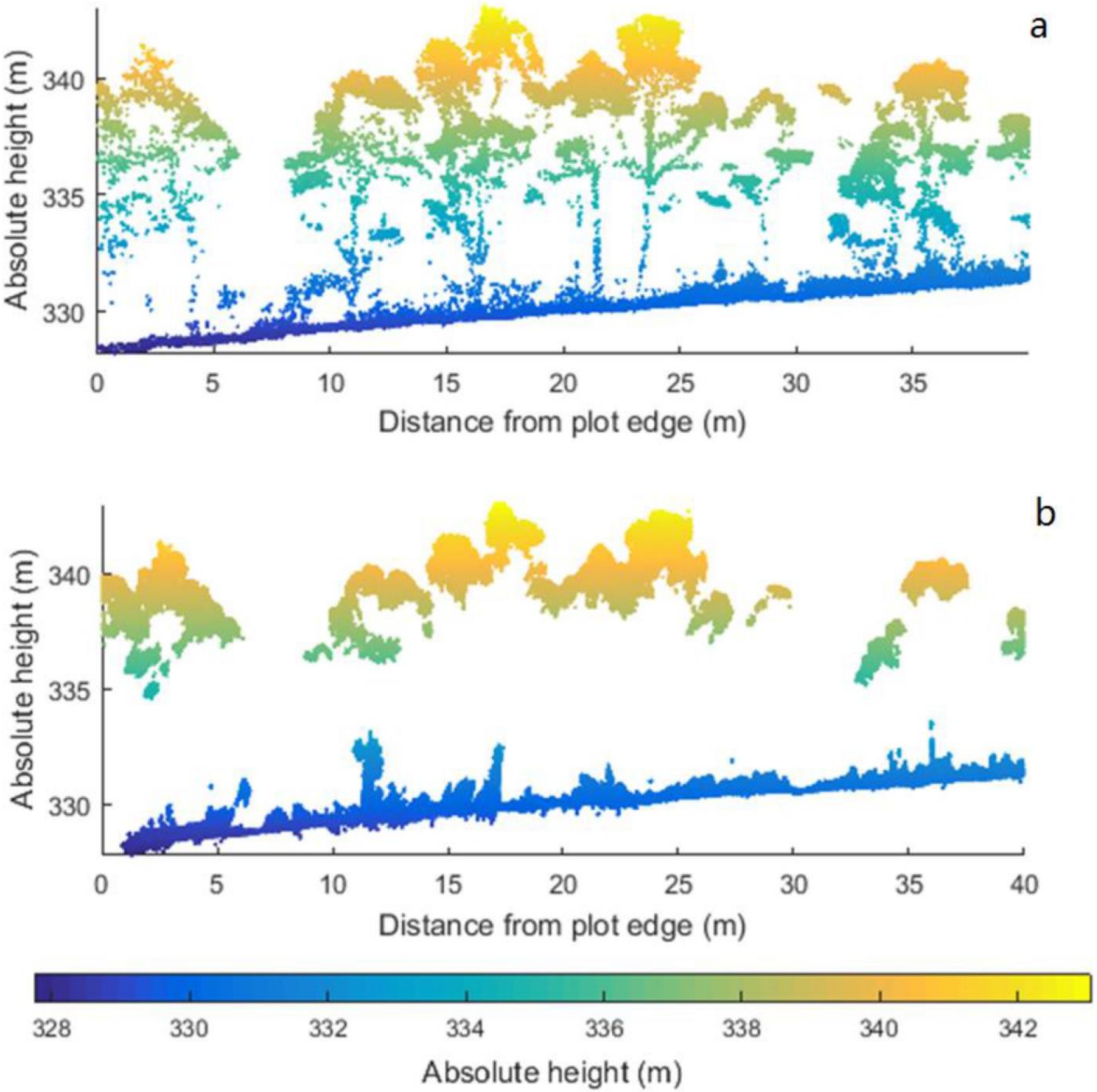
+ COLOR



3D MODEL (POLYGONAL MESH)

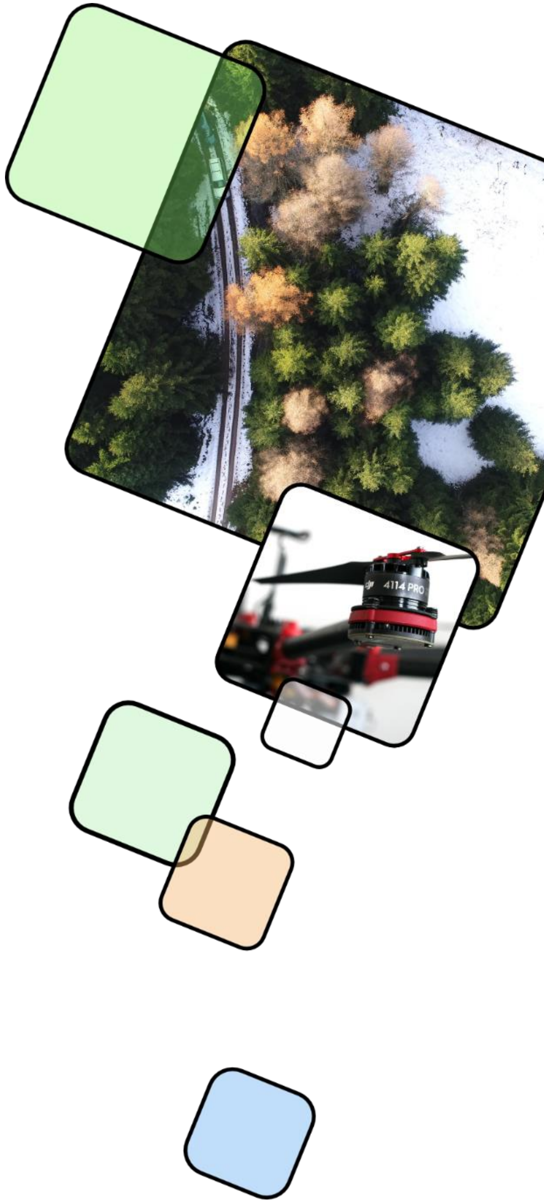
PLANES (triangulation)

+ TEXTURE



LIDAR

FOTOGRAMMETRIE



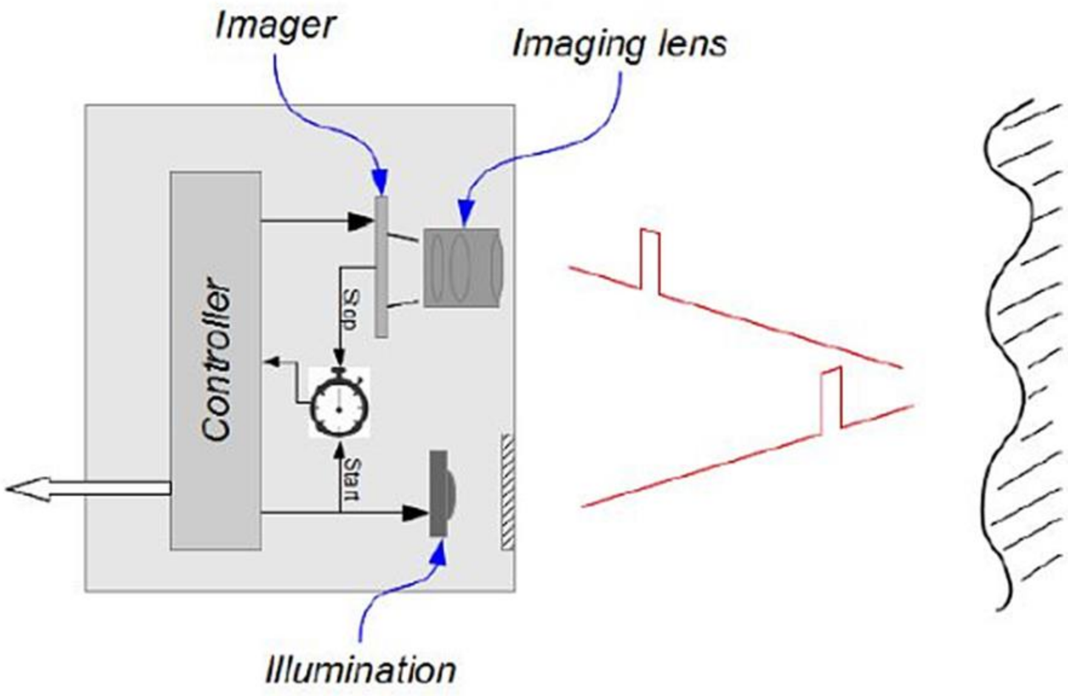
LASER SCANNING

LIDAR

TIME-OF-FLIGHT

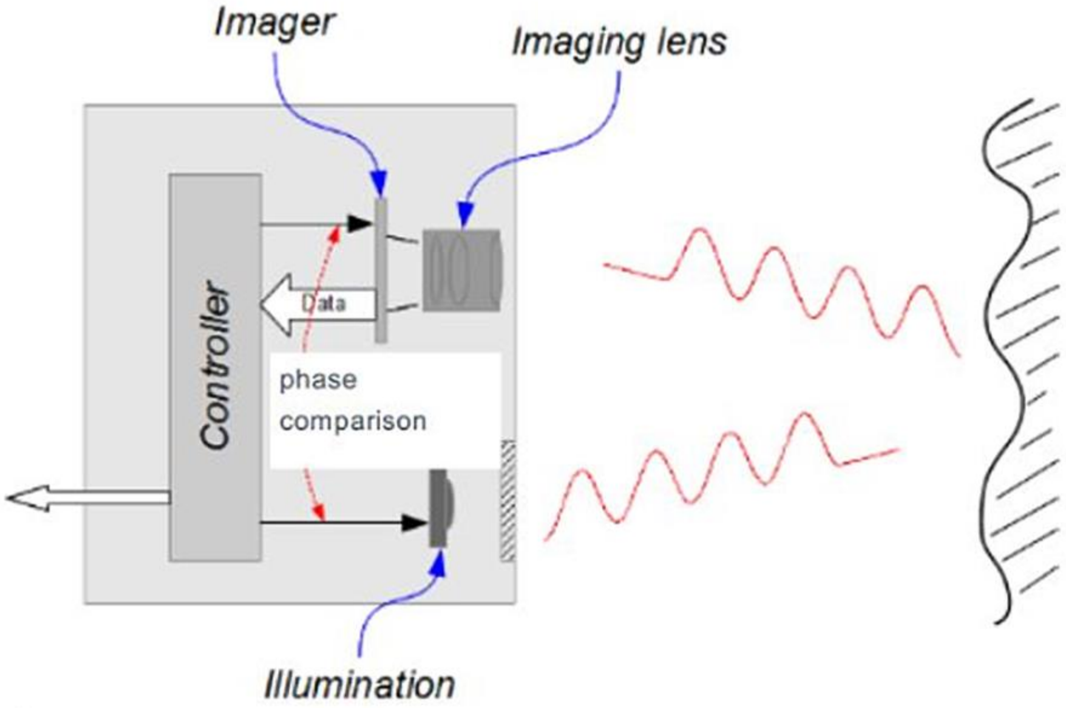
TIME BETWEEN BEAM EMISSION AND RETURN

LONG-RANGE, FAST, EXPENSIVE, HEAVY

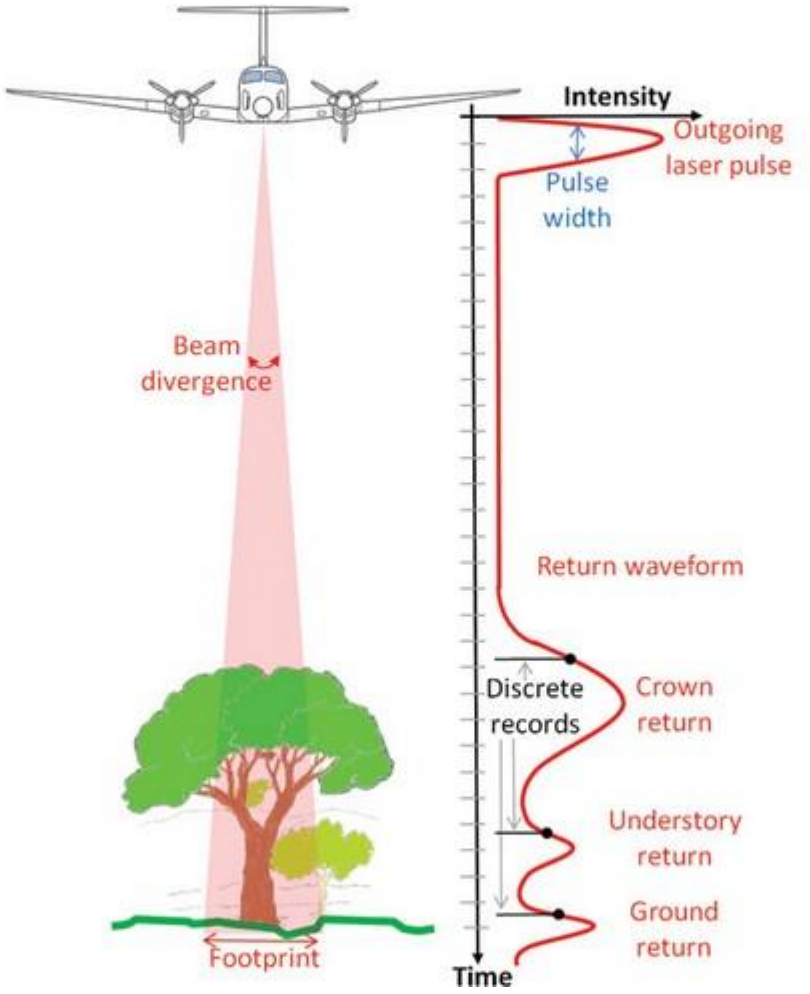


PHASE SHIFT

PHASE SHIFT BETWEEN EMITED AND RETURNED WAVE



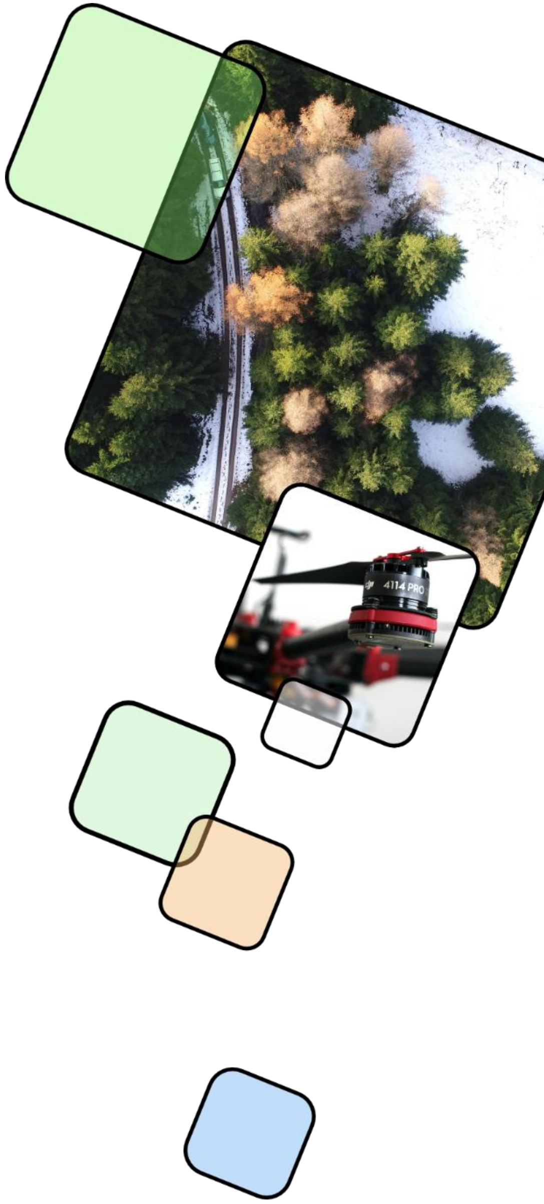
LiDAR



COUNT OF RETURNS
SINGLE RETURN
MULTIRETURN
FULL WAVE FORM

RANGE
METERS TO KILOMETERS

FREQUENCE
UP TO 2 MHz



REFERENCING

POSITION & ORIENTATION

STATIONARY SCANNER

- KNOWN POSITION AND ORIENTATION

MOVING SCANNER

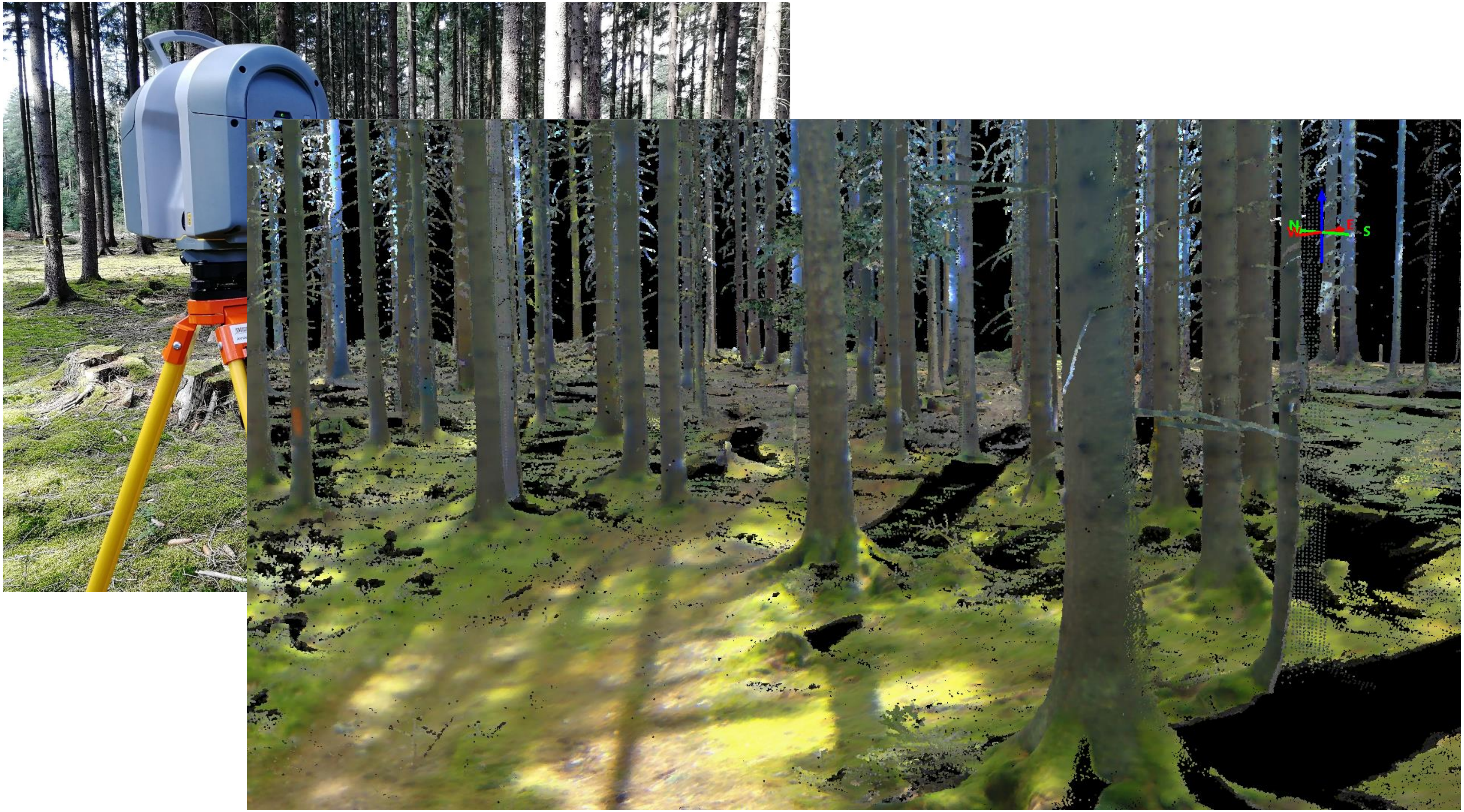
- GNSS (RTK OR PPK)
- IMU (INERCIAL MEASUREMENT UNIT)

(TRAJECTORY BASED SOLUTION)

SLAM (SIMULTENEOUS LOCATION AND MAPPING)

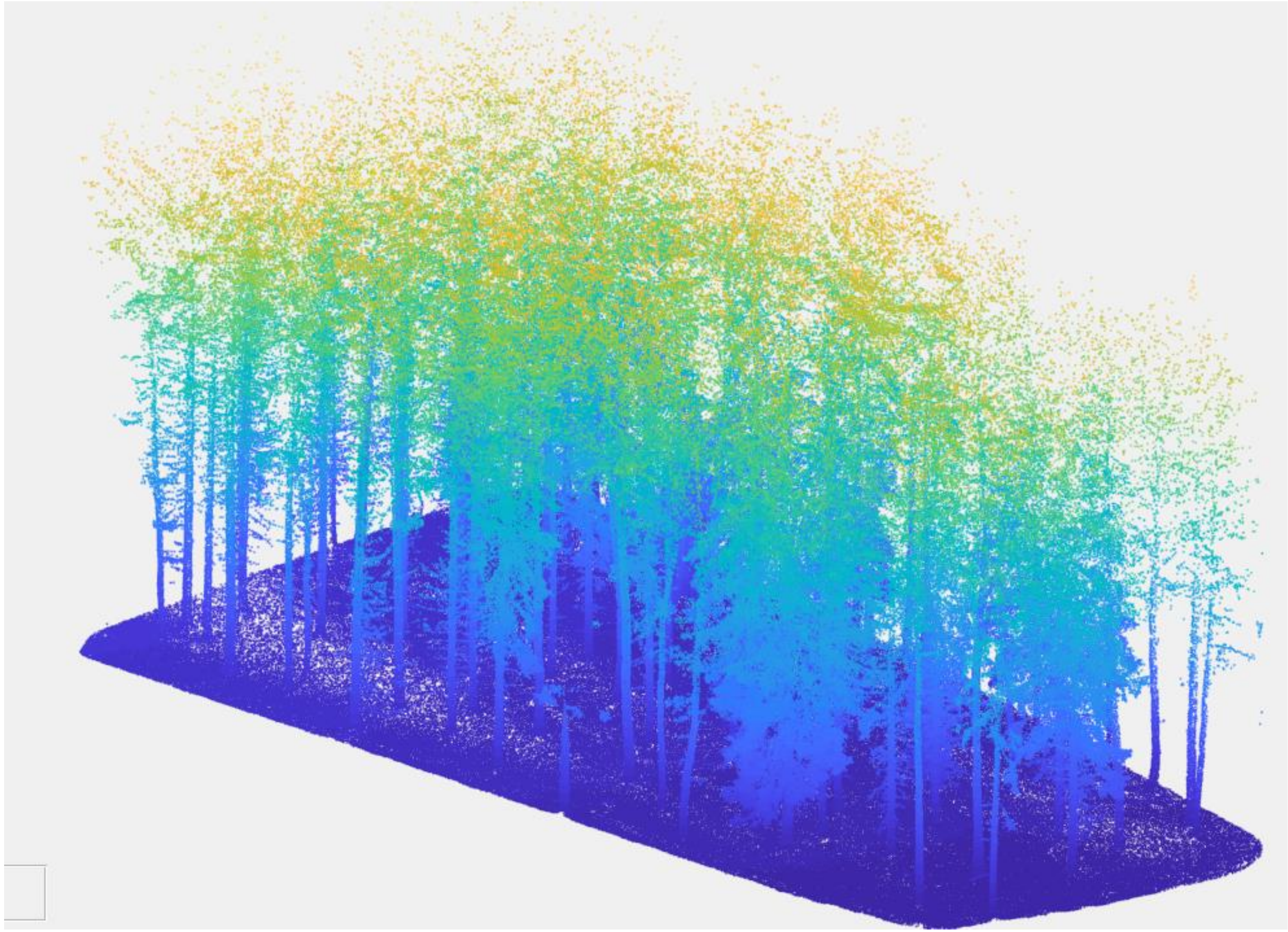
ONLY MOVING SCANNERS

(REAL TIME VS POST PROCESSING)

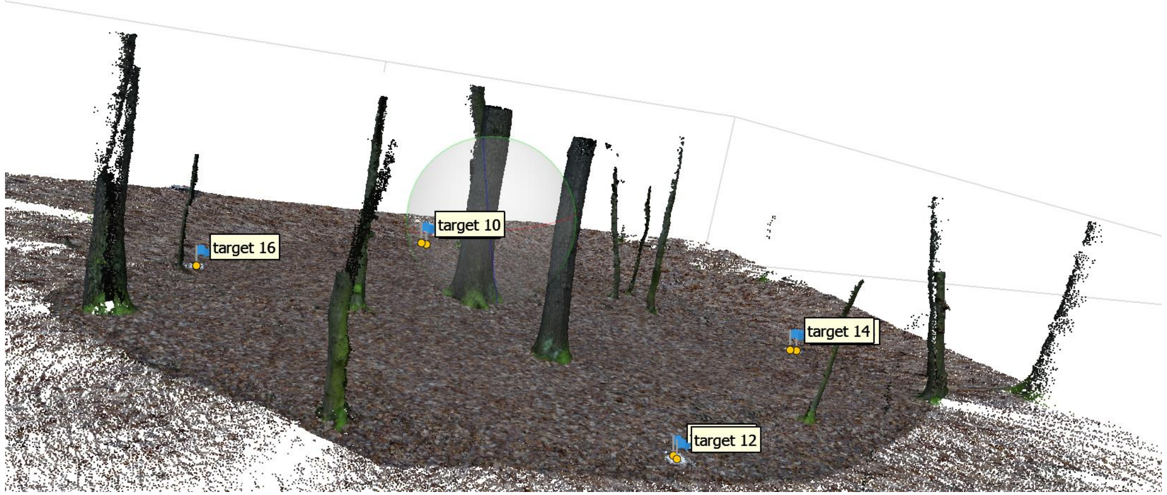


http://maps.tuzvo.sk/pointclouds/sk02_oak/index.html

SLAM: SIMULTANEOUS LOCATION AND MAPPING

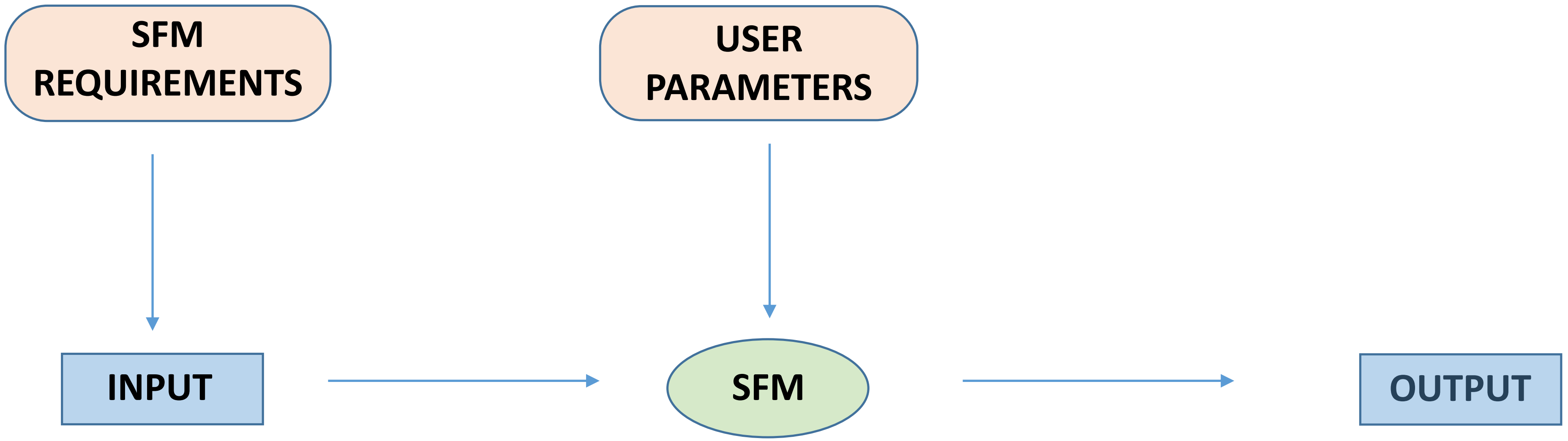


PHOTOGRAMMETRY



PHOTOGRAMMETRY

STRUCTURE FROM MOTION TECHIQUE



A SEQUENCE OF IMAGES OF AN OBJECT FROM DIFFERENT POSITIONS

- POINT CLOUD
- 3D MODEL: POLYEDRIC OBJECT (POLYGONAL MESH)

STRUCTURE FROM MOTION

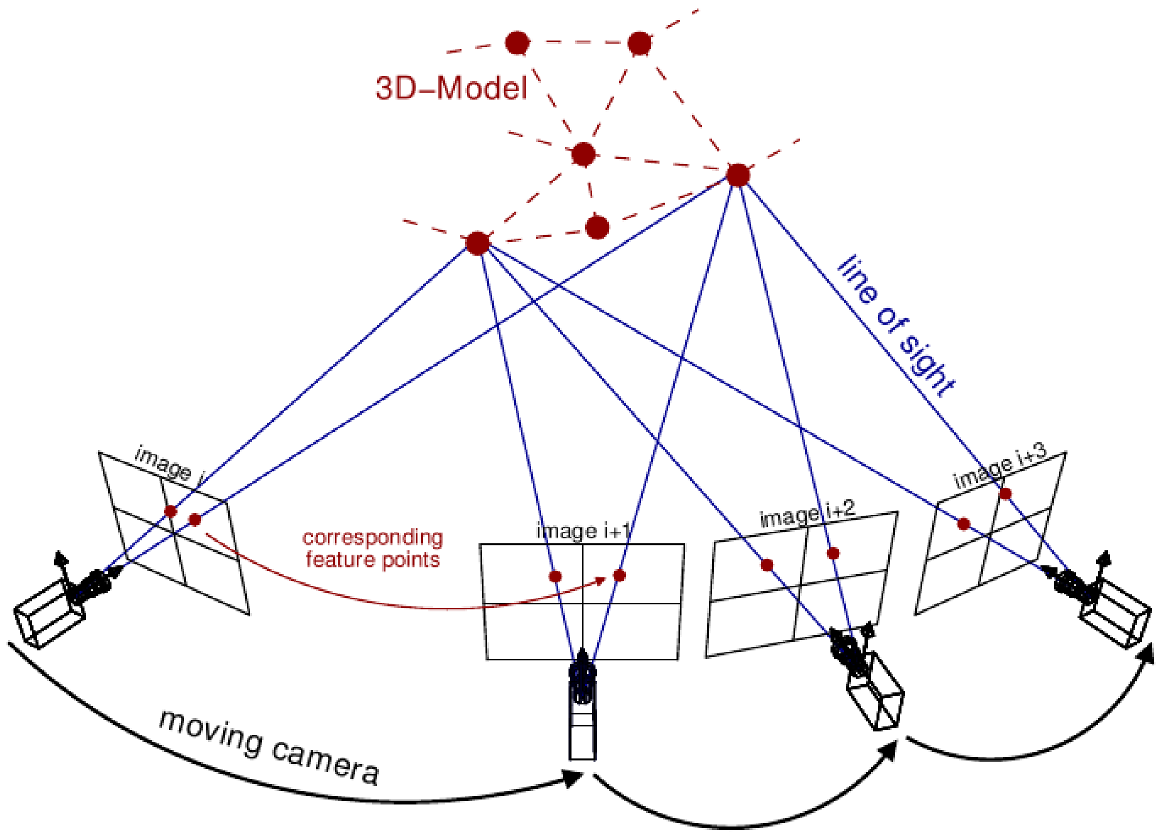
INPUT: A SEQUENCE OF IMAGES OF AN OBJECT FROM DIFFERENT POSITIONS

WORKFLOW:

- DETECTING IDENTICAL FEATURES IN IMAGES
- PARALAX MEASUREMENT, CALCULATION OF CAMERA 3D POSITIONS AND TIE POINTS POSITIONS CALCULATING 3D POSITIONS OF ALL DETECTABLE POINTS
- REFERENCING

REQUIREMENTS:

- SUFFICIENT NUMBER OF IMAGES
- SUFFICIENT OVERLAP
- GRADUAL CHANGE OF DIRECTION AND SCALE

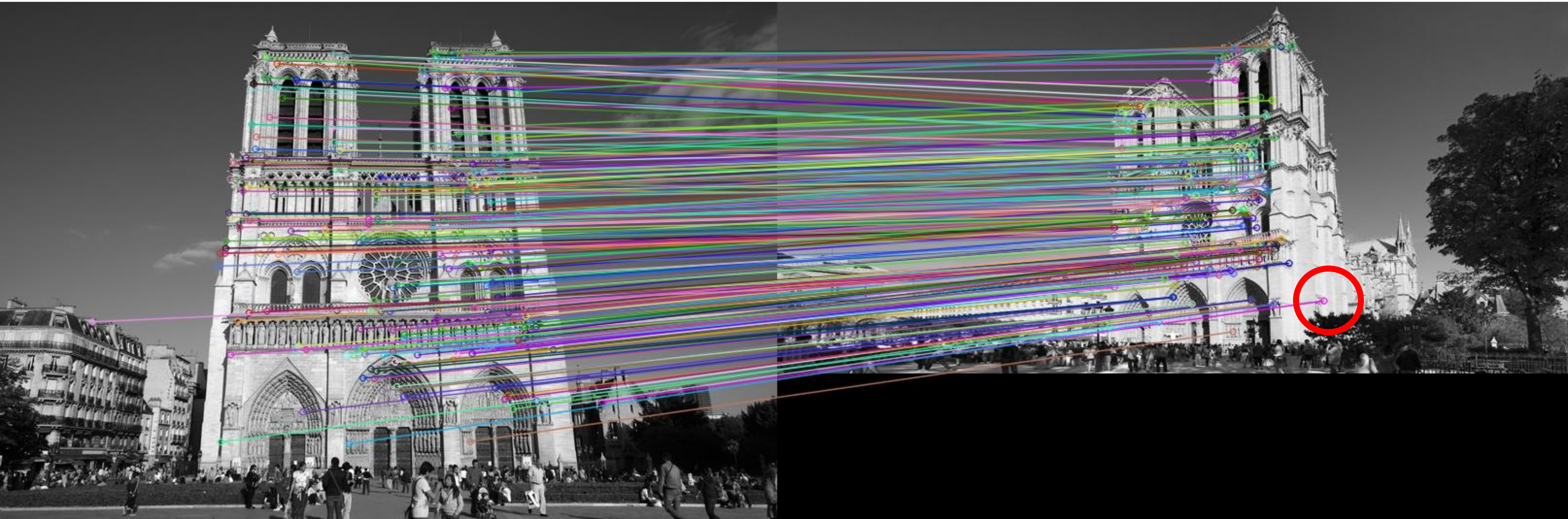


DETECTING KEY POINTS

1999 SIFT (SCALE INVARIANT FEATURE TRANSFORM)

2006 SURF (SPEEDED UP ROBUST FEATURES)

KEY POINTS SELECTION -> TIE POINTS



1999 SIFT (SCALE INVARIANT FEATURE TRANSFORM)

SIMULATES NEURON BEHAVIOUR FOR EVAULATION OF VISUAL PERCEPTIONS

FEATURES – DISTINCT GROUPS OF PIXELS (CONTRAST)

SCALE INVARIANT – ROBUST AGAINST TRANSFORMATION (ROTATION 20°, RESP. 60°)

KEY POINT CLUSTERS – MAINTAINING RELATIVE POSITION

2006 SURF (SPEEDED UP ROBUST FEATURES)

MORE ROBUST AND FASTER

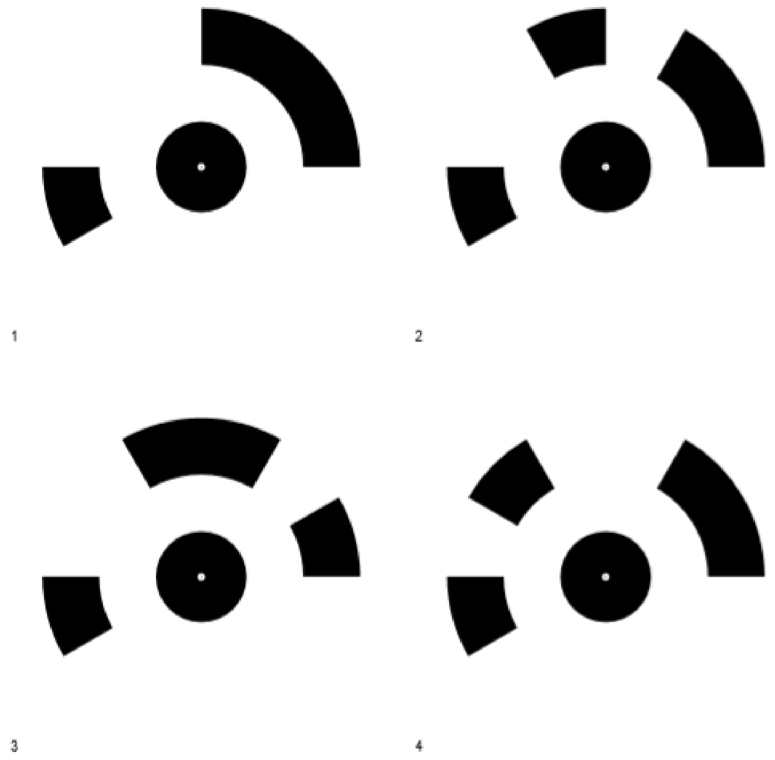
REFERENCING

- CONTROL POINTS
- GNSS POSITIONS (EXIF)
    - RTK/PPK POSITIONS
- SCALE BAR

REFERENCING

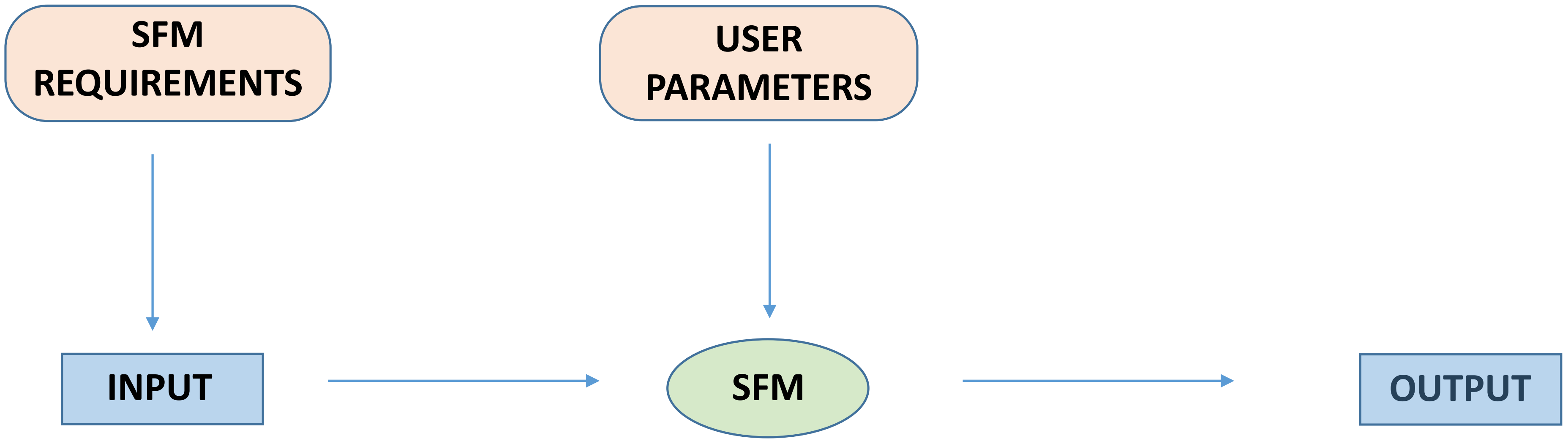
CONTROL POINTS

Agisoft Metashape:
We recommend distributing the control points evenly over the survey object. It is also necessary that the markers are not located on one straight line



PHOTOGRAMMETRY

STRUCTURE FROM MOTION TECHIQUE



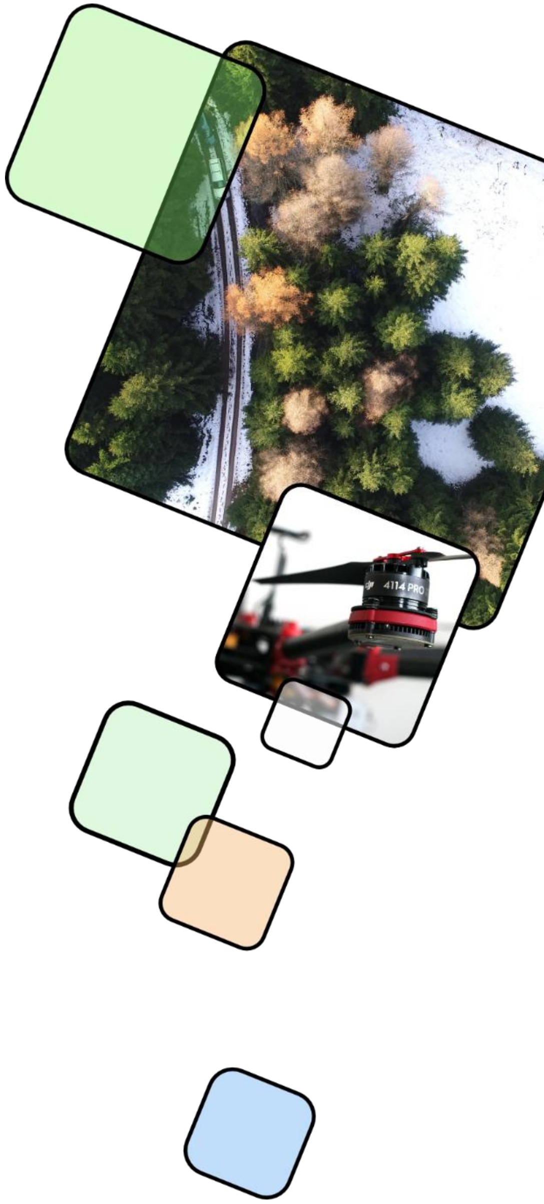
A SEQUENCE OF IMAGES OF AN OBJECT FROM DIFFERENT POSITIONS

- POINT CLOUD
- 3D MODEL: POLYEDRIC OBJECT (POLYGONAL MESH)

3D POINT CLOUD QUALITY

- OBJECT MATERIAL:
    - TEXTURE
    - REPEATED PATTERNS
    - REFLECTIONS (METAL, WATER)
    - MOTION (BRANCHES, LEAVES, WATER)
- CAMERA DIRECTION – REFLECTIONS (POLARIZATION), CONTRAST
- LIGHT CONDITION – DIFUSE LIGHT, CONSTANT LIGHT CONDITIONS (NO FLASH, NO LIGHTNING FROM CAMERA DIRECTION)

- GSD/RESOLUTION – DISTANCE SENSOR- OBJECT
- ANGLE BETWEEN IMAGES
- COUNT OF OBSERVATIONS – IMAGE OVERLAP



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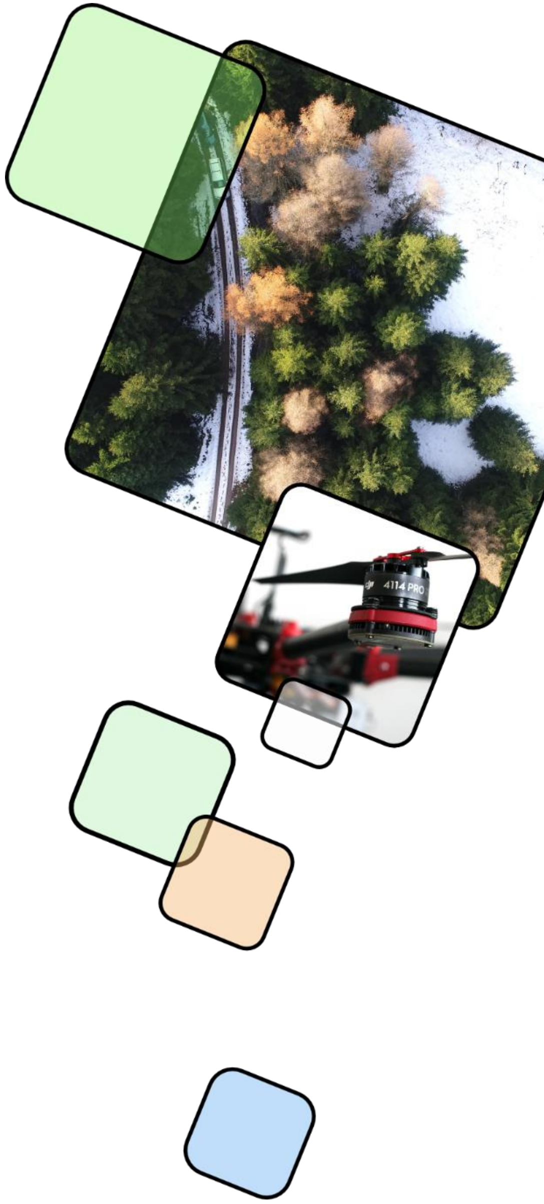
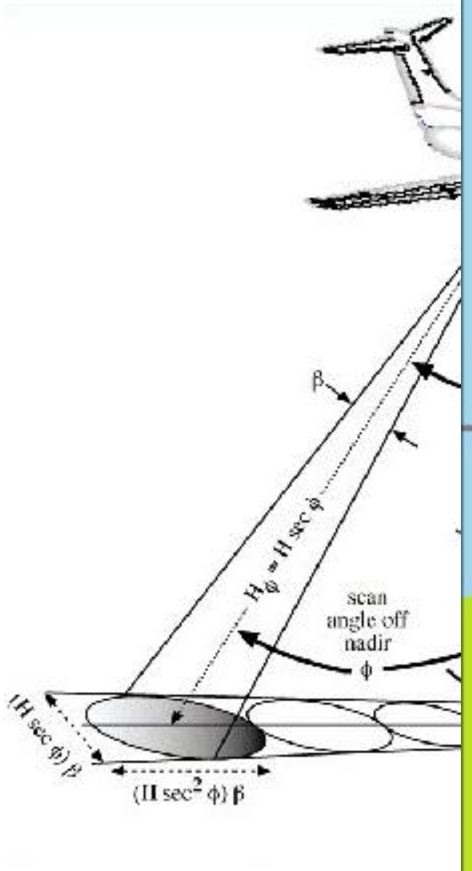
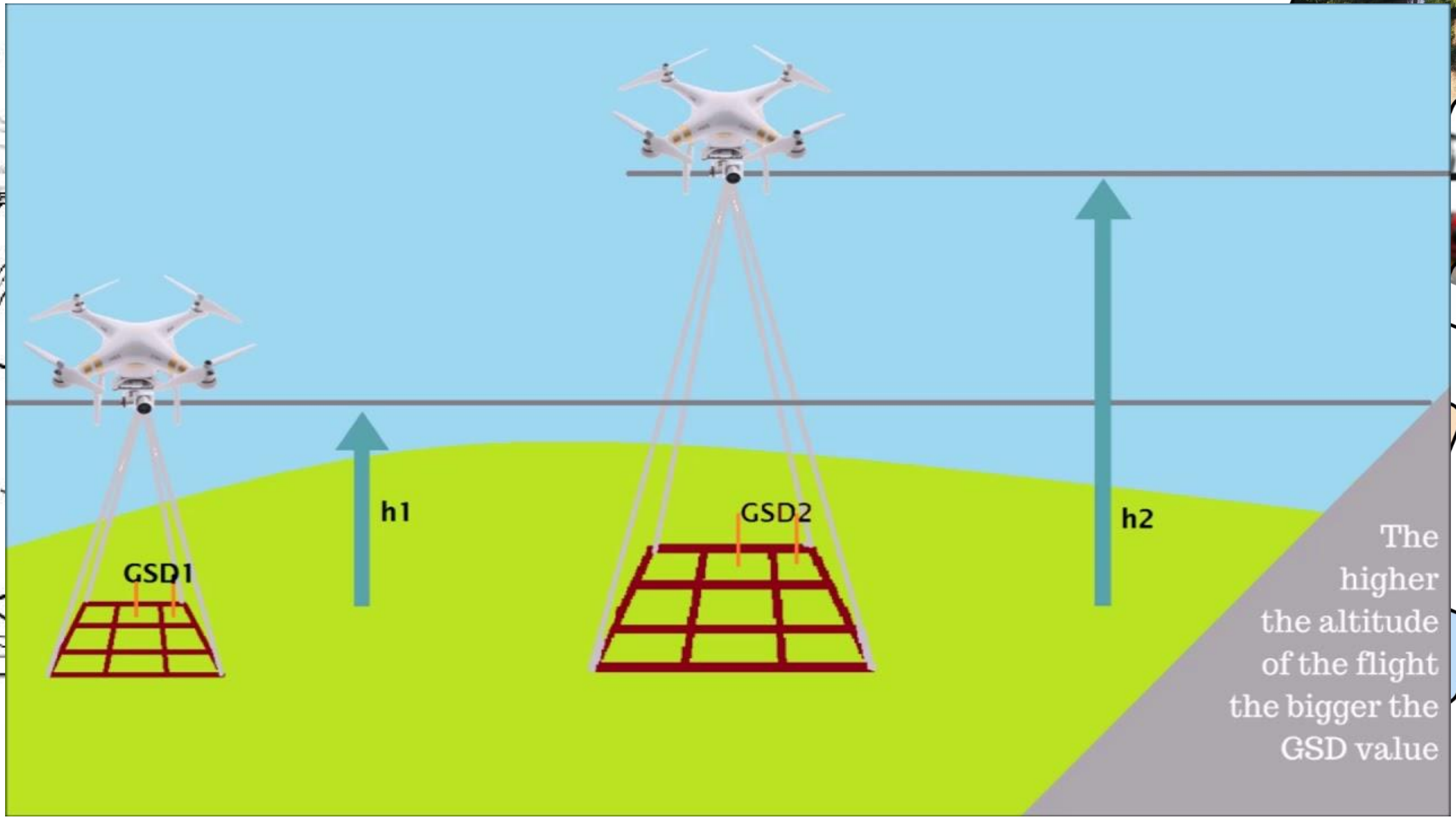
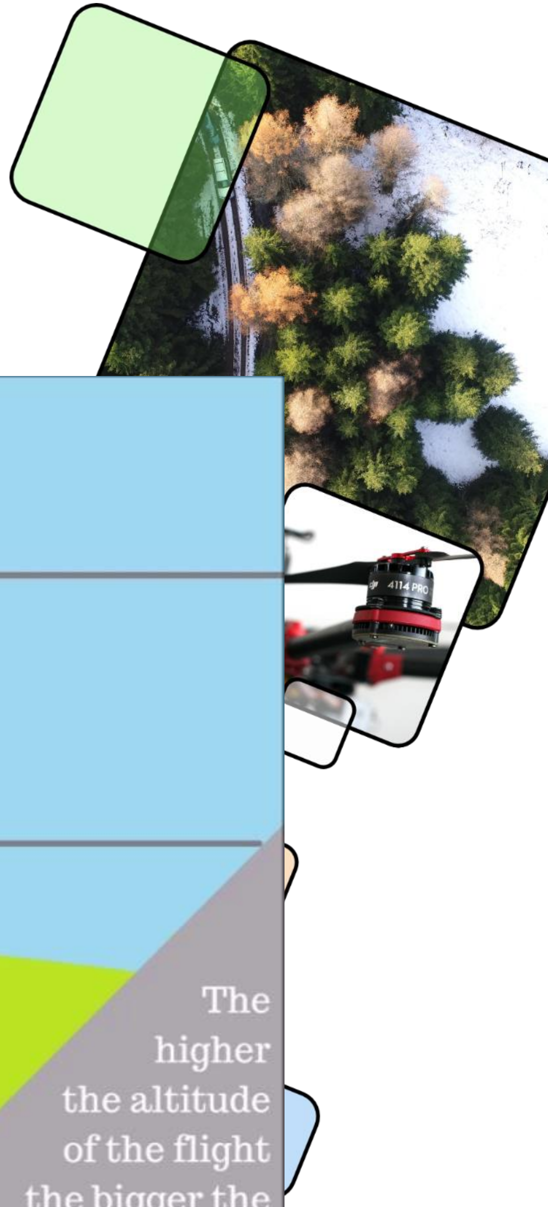
- **GSD/RESOLUTION – DISTANCE SENSOR- OBJECT**
- ANGLE BETWEEN IMAGES
- COUNT OF OBSERVATIONS – IMAGE OVERLAP



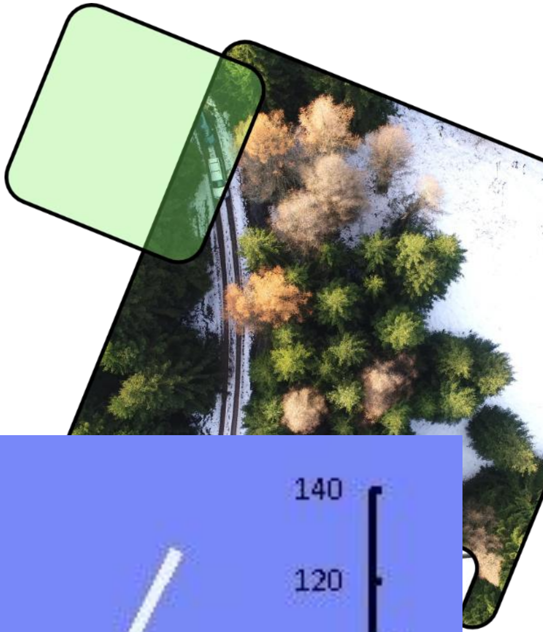
GSD – GROUND SAMPLE DISTANCE

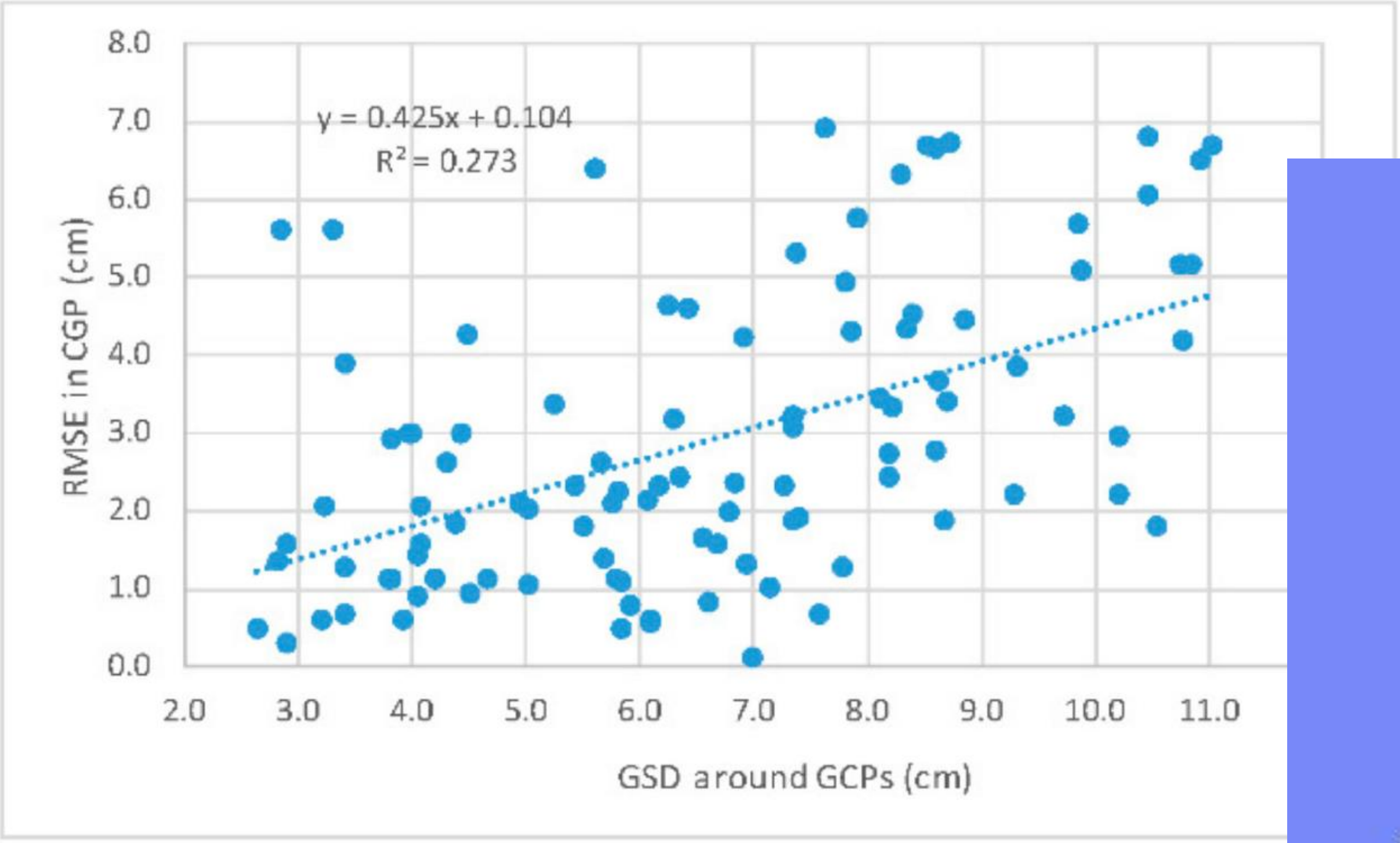


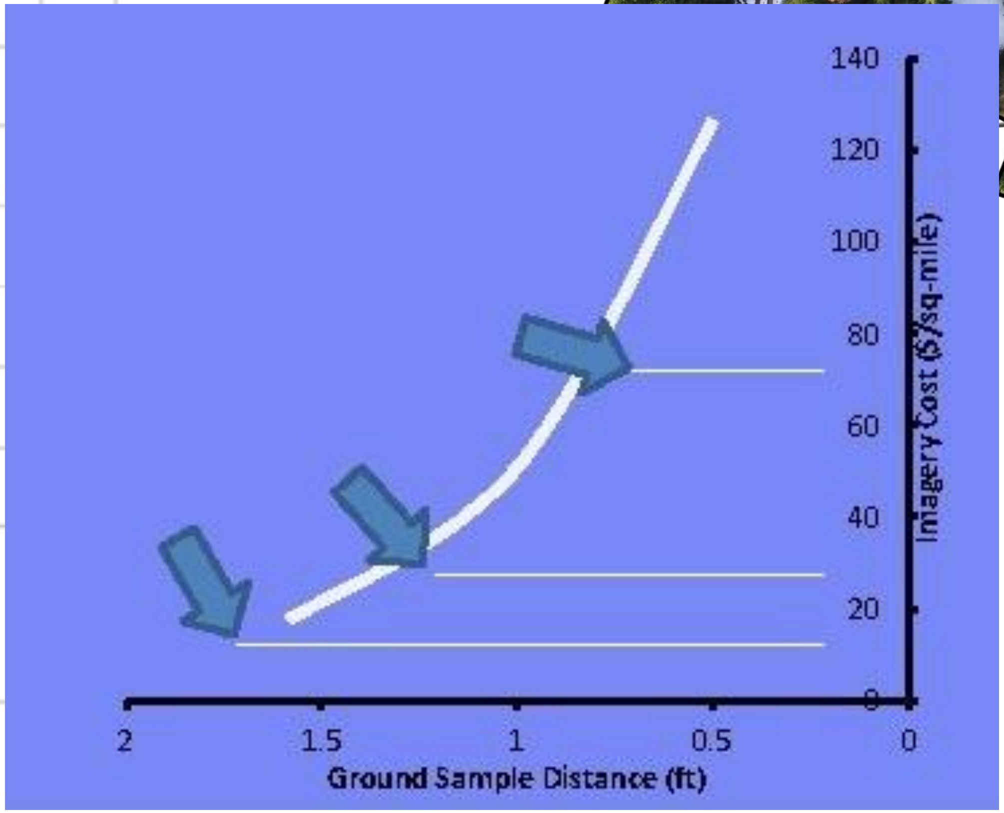




GSD – GROUND SAMPLE DISTANCE







Sanz-Ablanedo, E.; Chandler, J.H.; Rodríguez-Pérez, J.R.; Ordóñez, C. Accuracy of Unmanned Aerial Vehicle (UAV) and SfM Photogrammetry Survey as a Function of the Number and Location of Ground Control Points Used. *Remote Sens.* **2018**, *10*, 1606.

3D POINT CLOUD QUALITY

- OBJECT MATERIAL:
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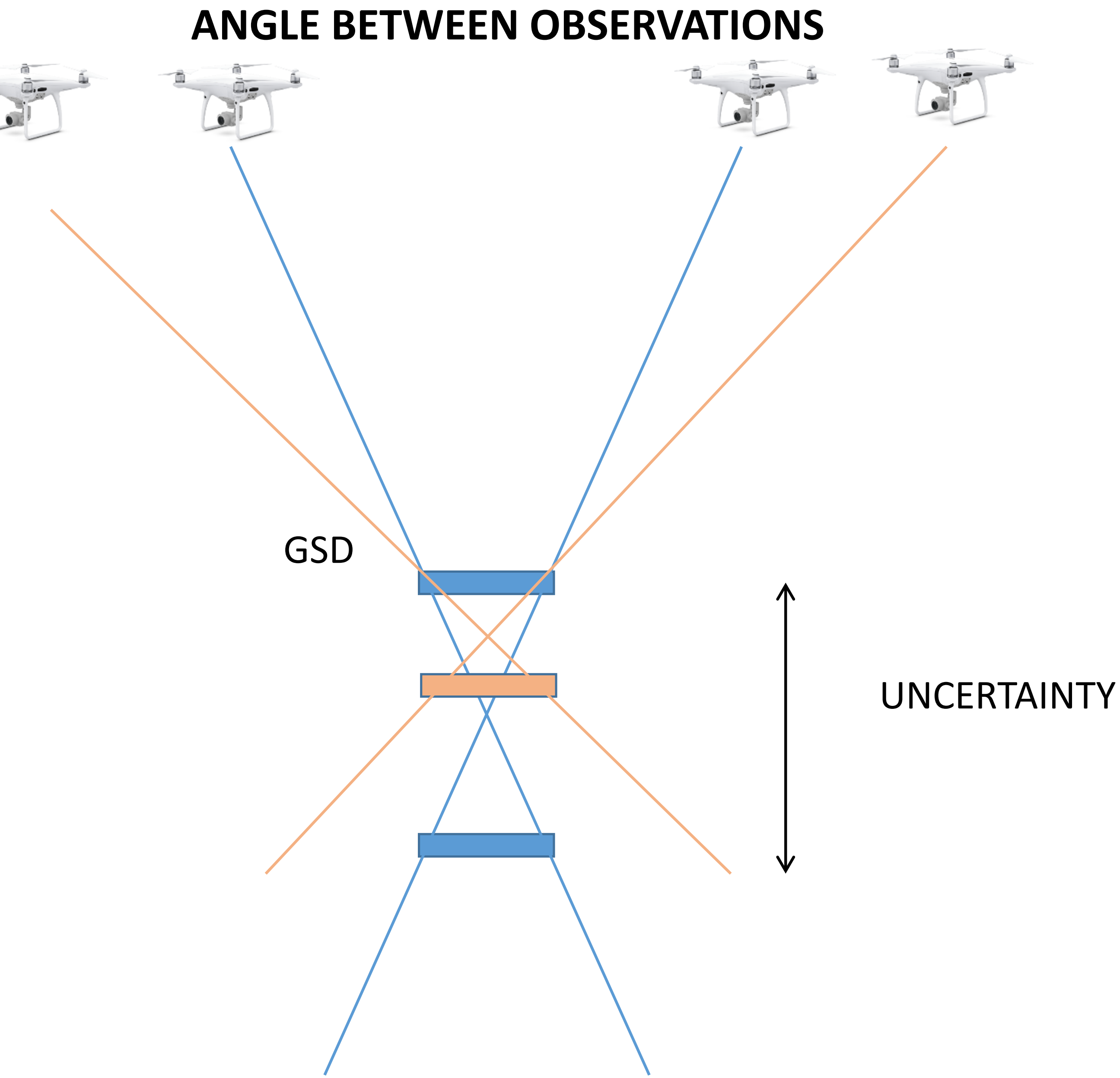
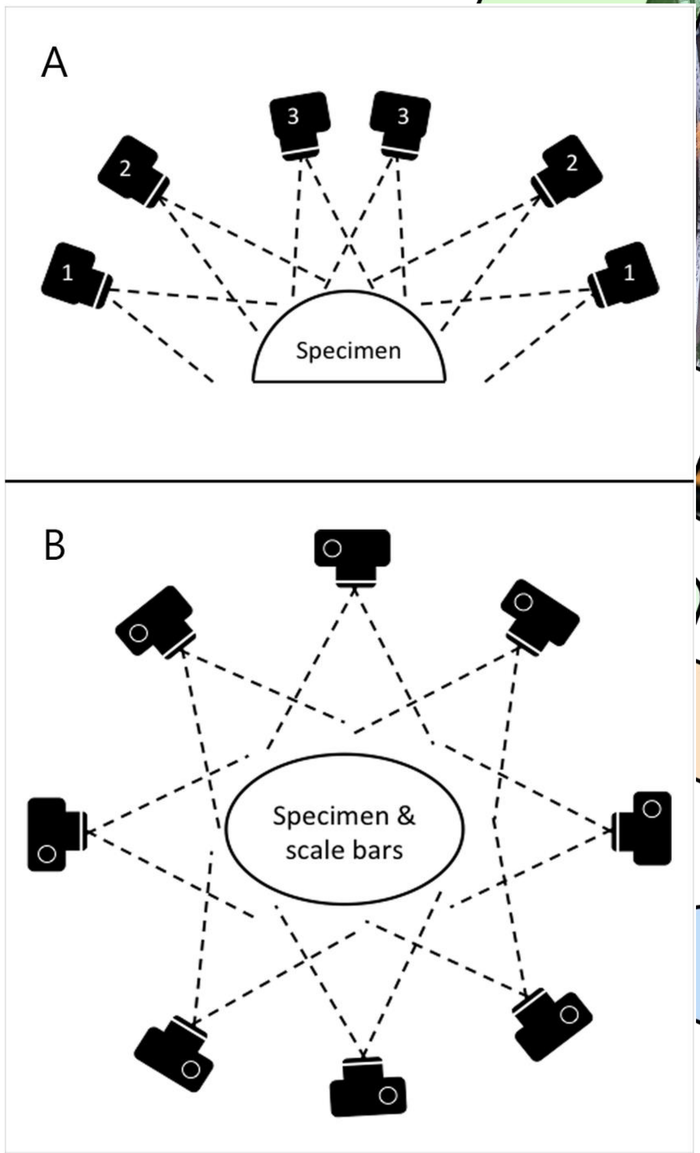
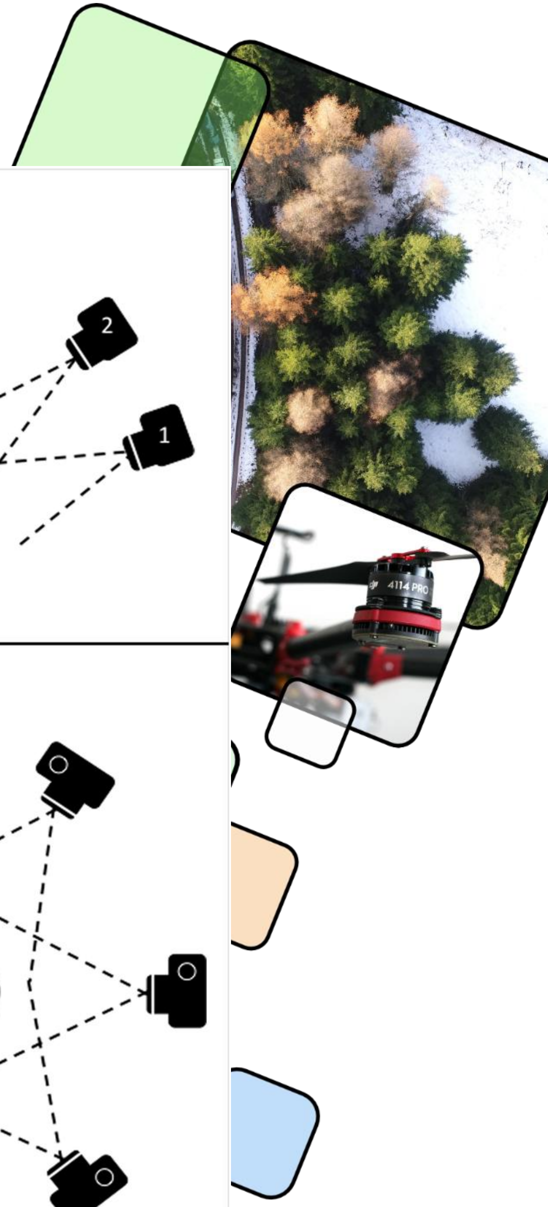
- GSD/RESOLUTION – DISTANCE SENSOR- OBJECT
- **ANGLE BETWEEN IMAGES**
- COUNT OF OBSERVATIONS – IMAGE OVERLAP


ANGLE BETWEEN OBSERVATIONS
GSD
UNCERTAINTY


A
3
3
2
2
1
1
Specimen
B
Specimen &
scale bars

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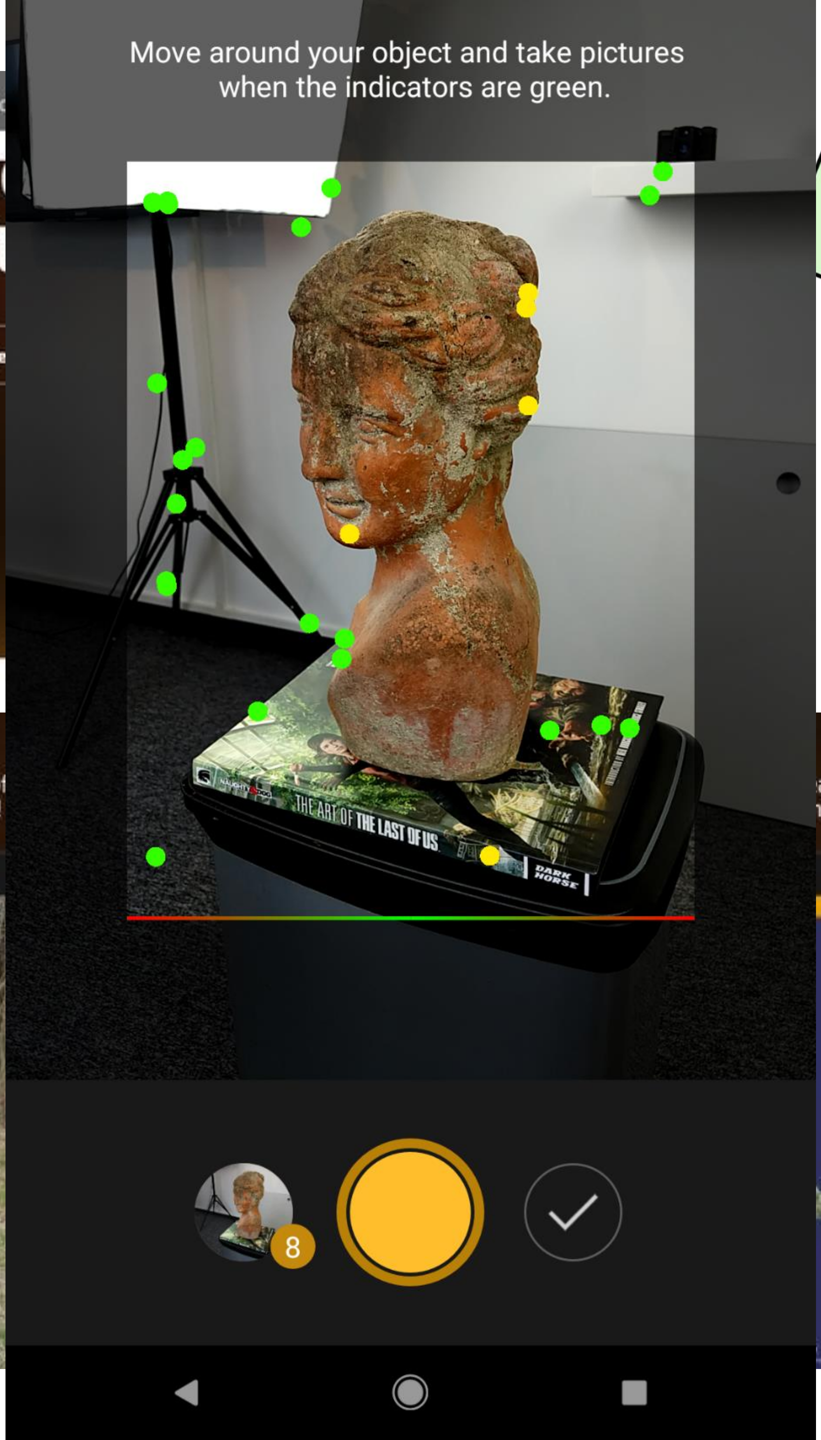
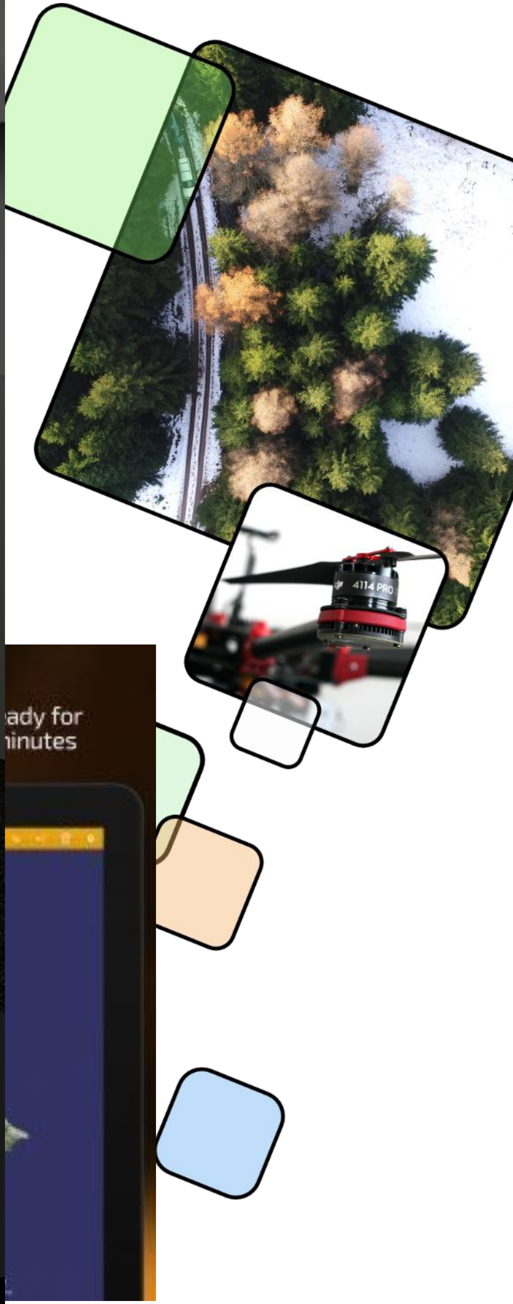

Move around your object and take pictures
when the indicators are green.
8



3D POINT CLOUD QUALITY

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  - REPEATED PATTERNS
  - REFLECTIONS (METAL, WATER)
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- LIGHT CONDITION – DIFUSE LIGHT, CONSTANT LIGHT CONDITIONS (NO FLASH, NO LIGHTNING FROM CAMERA DIRECTION)

- GSD/RESOLUTION – DISTANCE SENSOR- OBJECT
- ANGLE BETWEEN IMAGES
- **COUNT OF OBSERVATIONS – IMAGE OVERLAP**

OVERLAP

FORWARD DIRECTION

- SLOWER FLIGHT
- SMALLER AREA

+ BETTER ALIGNMENT

90 %

LATELAR OVERLAP

- DENSER TRAJECTORY
- SMALLER AREA

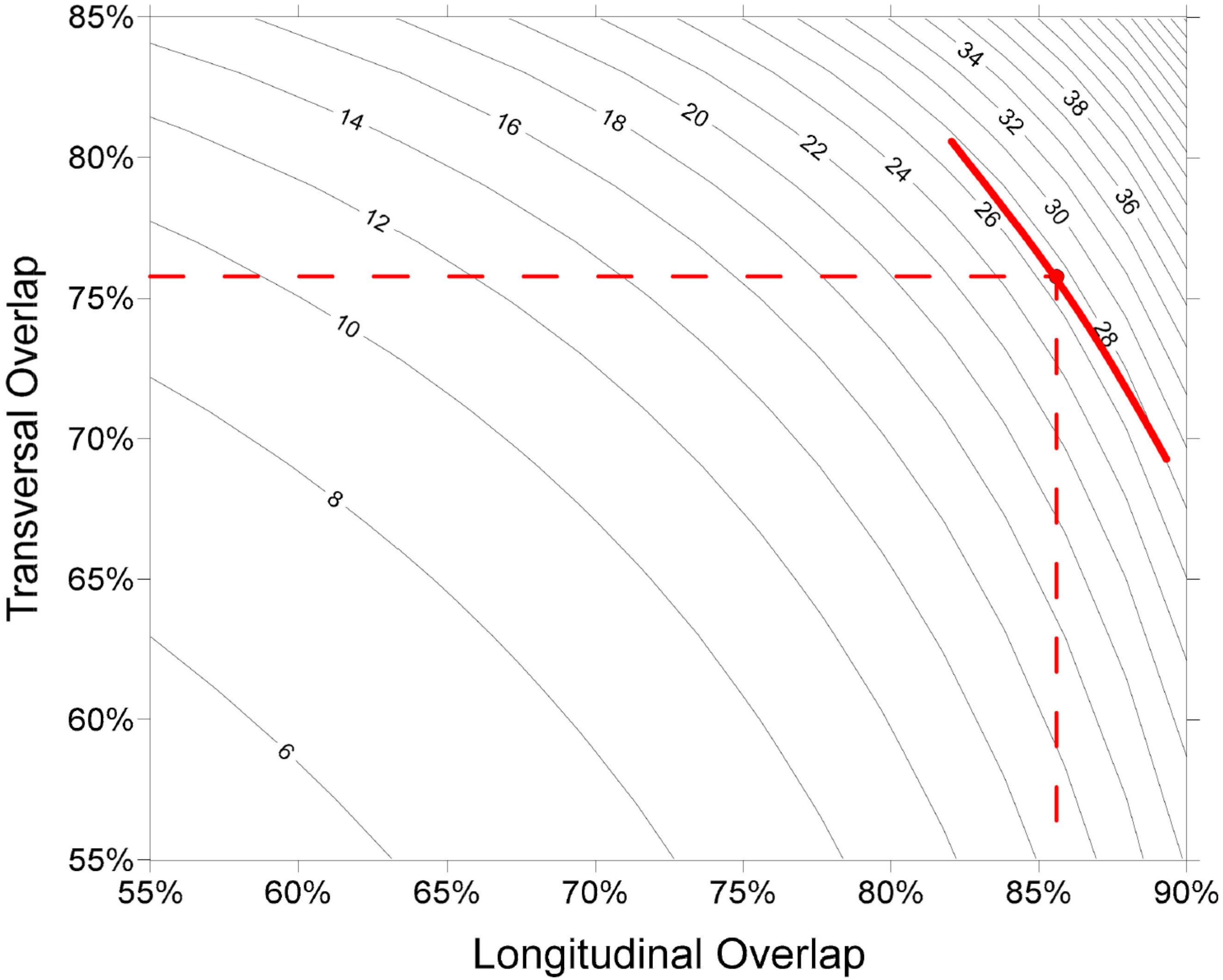
70 %

Agisoft Metashape:
In case of aerial photography the overlap requirement can be put in the following figures: 60% of side overlap + 80% of forward overlap. When making a survey over a forest, it is recommended to increase the overlap value to 80% and 90% respectively.

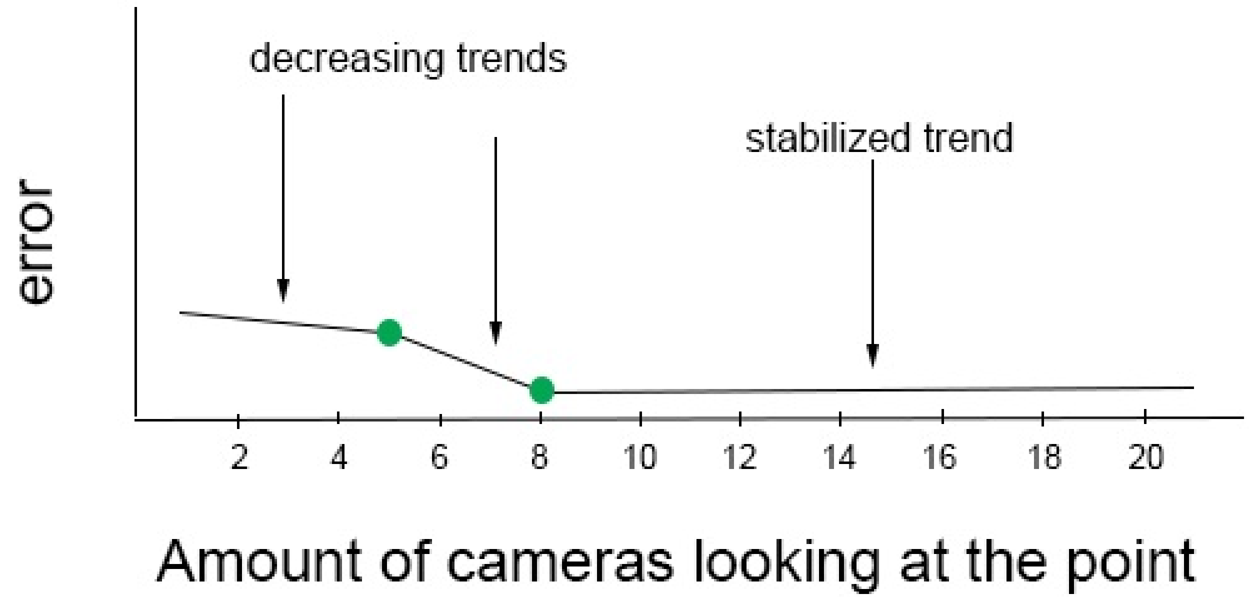
- POSSIBLE ALIGNMENT PROBLEMS

SYNTHETIC OVERLAP INDEX (SOI)

SUM IMAGED AREA / TOTAL AREA



Accuracy of 3D point reconstruction using SFM technique



Surový, P.; Yoshimoto, A.; Panagiotidis, D. Accuracy of Reconstruction of the Tree Stem Surface Using Terrestrial Close-Range Photogrammetry. *Remote Sens.* **2016**, *8*, 123.

PHOTOGRAMMETRY

CONCLUSIONS & PRACTICAL TIPS

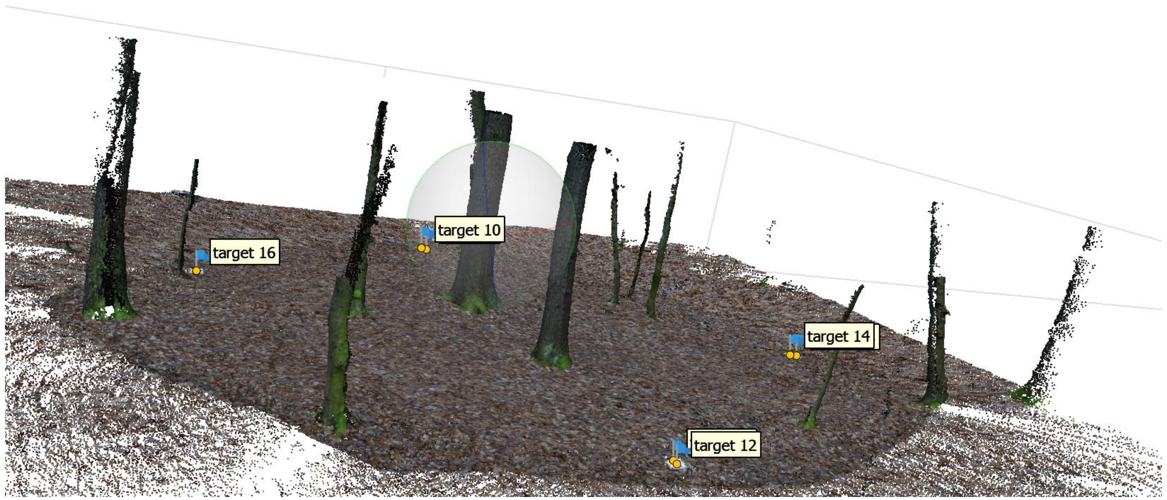


IMAGE GEOMETRY

STRONG PHOTOGRAMMETRIC NETWORK SHOULD HAVE TWO MAIN FEATURES:

1. HIGHLY REDUNDANT IMAGERY AND HENCE POTENTIALLY HIGHLY REDUNDANT MEASUREMENTS,

2. AND DIVERSITY IN CAMERA ROLL ANGLES, ARRANGED IN A STRONGLY CONVERGENT IMAGING CONFIGURATION. INTRODUCING OBLIQUE IMAGES IN A PERPENDICULAR DATASET ALLOWS LARGER ANGLES BETWEEN HOMOLOGOUS RAYS THAT MINIMIZE SYSTEMATIC ERRORS

Sanz-Ablanedo, E.; Chandler, J.H.; Rodríguez-Pérez, J.R.; Ordóñez, C. Accuracy of Unmanned Aerial Vehicle (UAV) and SfM Photogrammetry Survey as a Function of the Number and Location of Ground Control Points Used. *Remote Sens.* **2018**, *10*, 1606.

IMAGE GEOMETRY

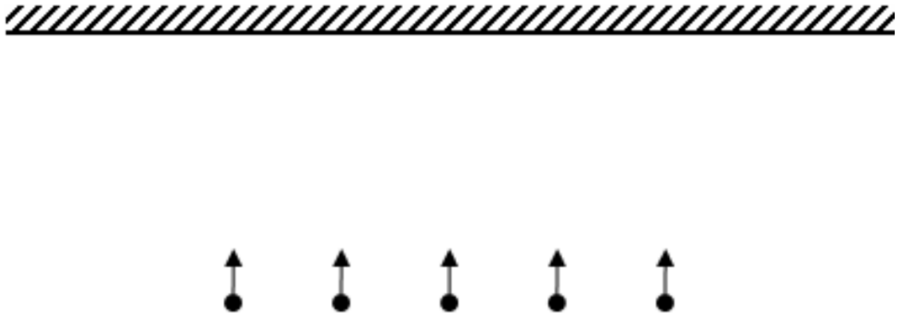
- TRAJECTORY: **CIRCULAR (MULTIPLE CONCENTRIC CIRCLES)** VS. SERPENTINE
- CAMERA: LANSCAPE VS. PORTRAIT
- VERTICAL DIRECTION: SLIGHTLY DOWN (TERRAIN)
- SCALE CHANGE FACTOR: NOT MORE THAN 2
- ANGLE CHANGE: NOT MORE THAN 30 DEGREES; BETTER 5 TO 10 DEGREES

LIGHT CONDITIONS

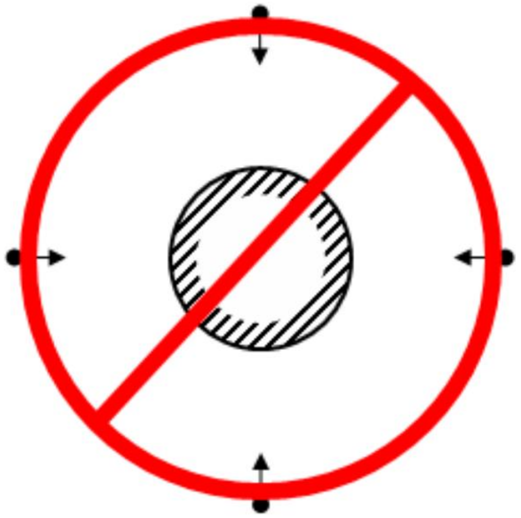
- DIFFUSE LIGHT
- IF POSSIBLE AVOID HIGH CONTRAST (SUN IN THE IMAGE)

Facade (Incorrect)

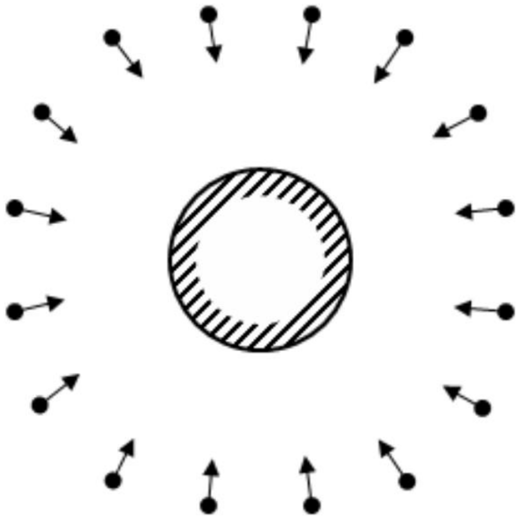
Facade (Correct)

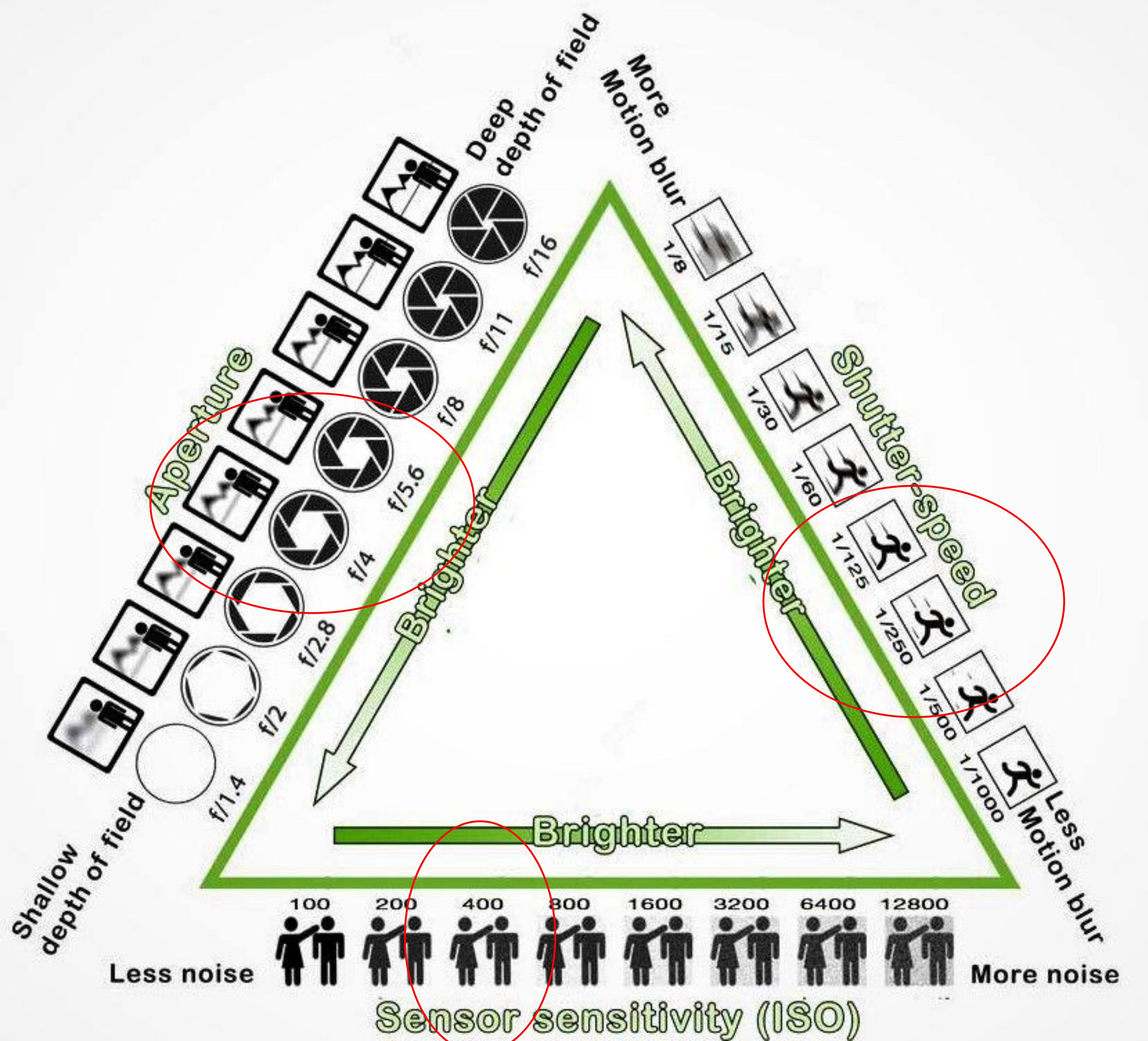


Isolated Object (Incorrect)



Isolated Object (Correct)





Deep depth of field
More Motion blur
Aperture
f/16
f/11
f/8
f/5.6
f/4
f/2.8
f/2
f/1.4
Shallow depth of field
Shutter-speed
1/8
1/15
1/30
1/60
1/125
1/250
1/500
1/1000
Less Motion blur
Brighter
Brighter
Brighter
100
200
400
800
1600
3200
6400
12800
Less noise
More noise
Sensor sensitivity (ISO)

Exposure

White balance

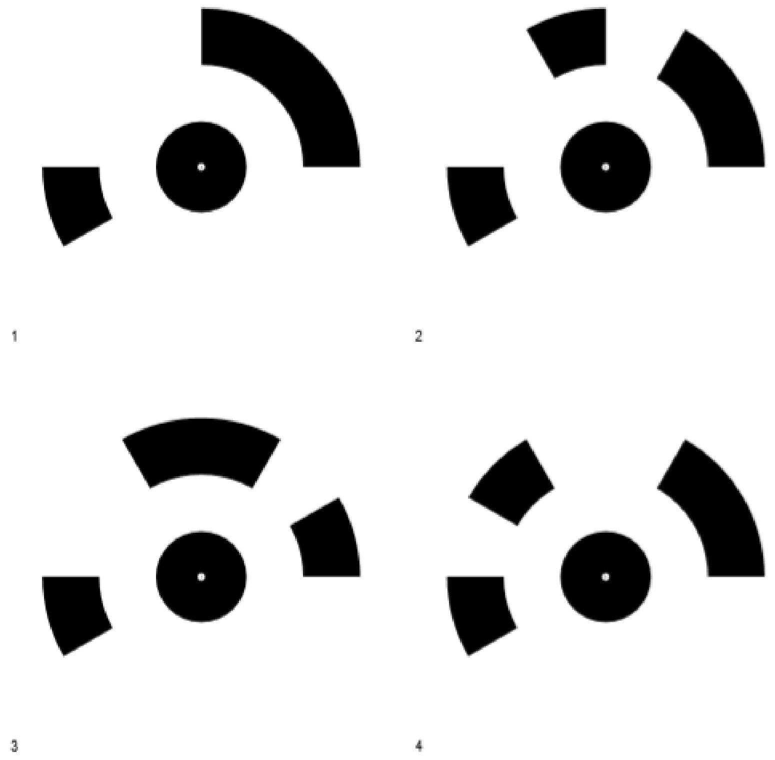
REFERENCING

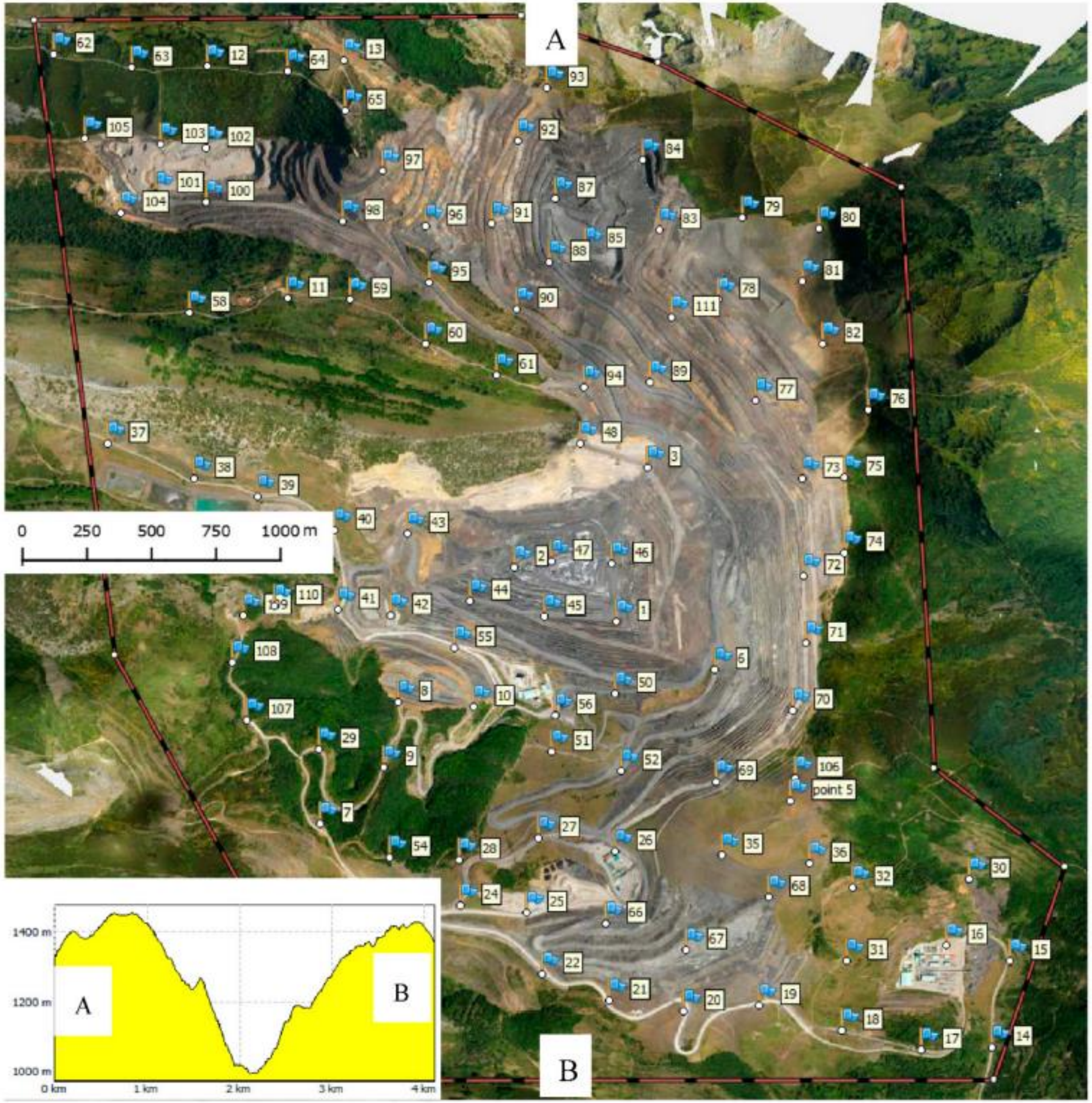
- CONTROL POINTS
- GNSS POSITIONS (EXIF)
  - RTK/PPK POSITIONS
- SCALE BAR

REFERENCOVÁNÍ

CONTROL POINTS

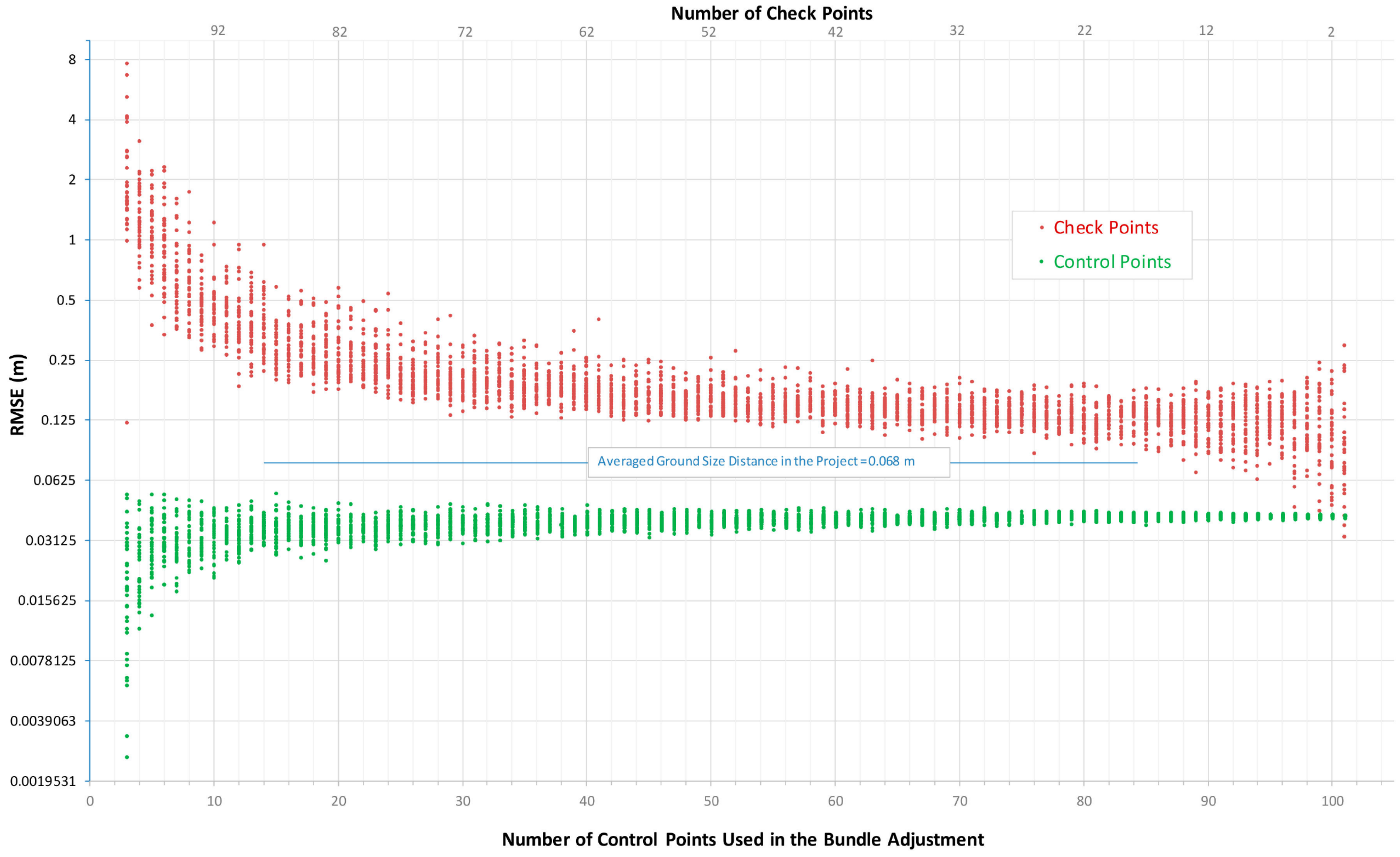
Agisoft Metashape:
We recommend distributing the control points evenly over the survey object. It is also necessary that the markers are not located on one straight line



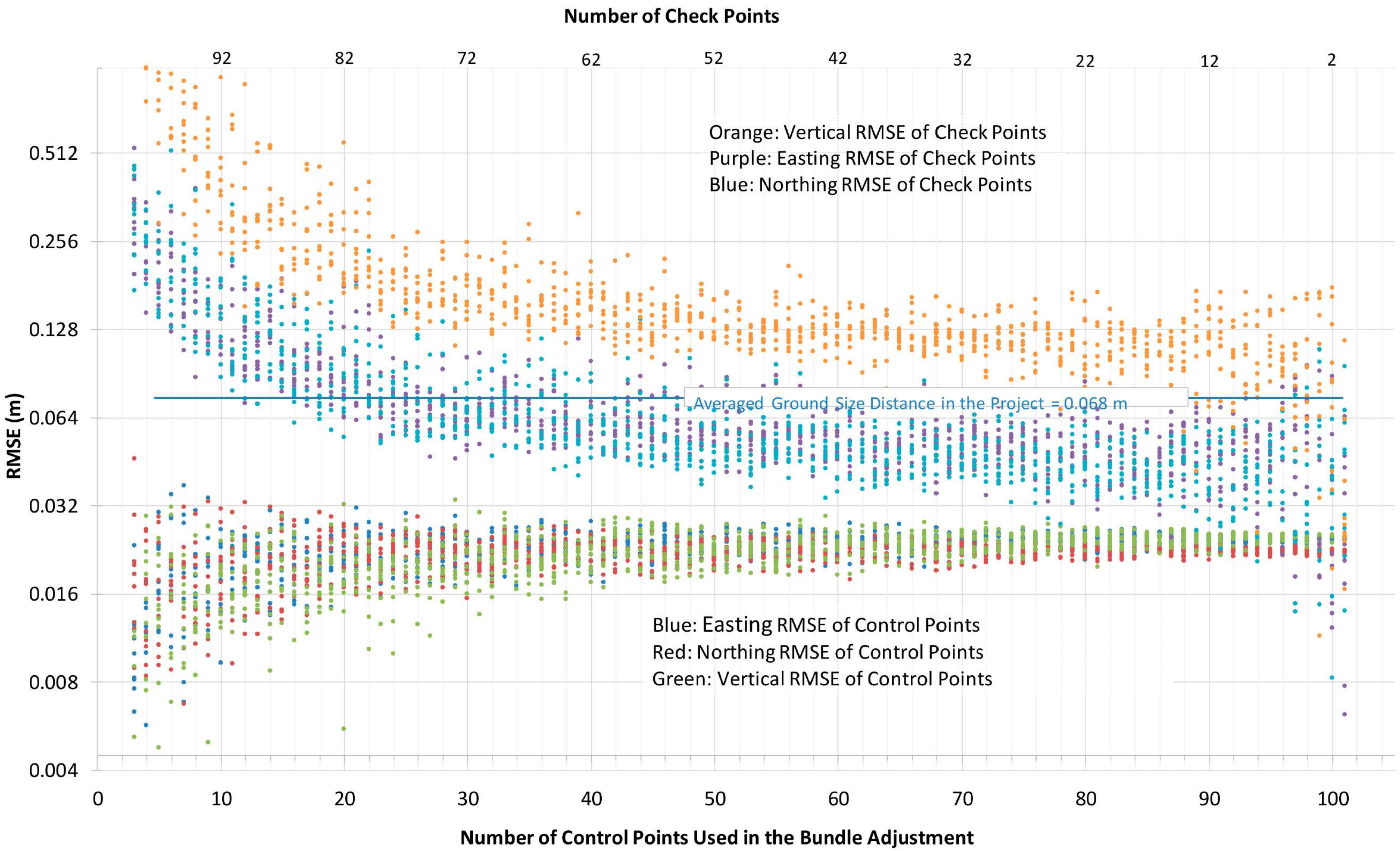


- 1220 ha (3 x 4 km)
- 2540 images

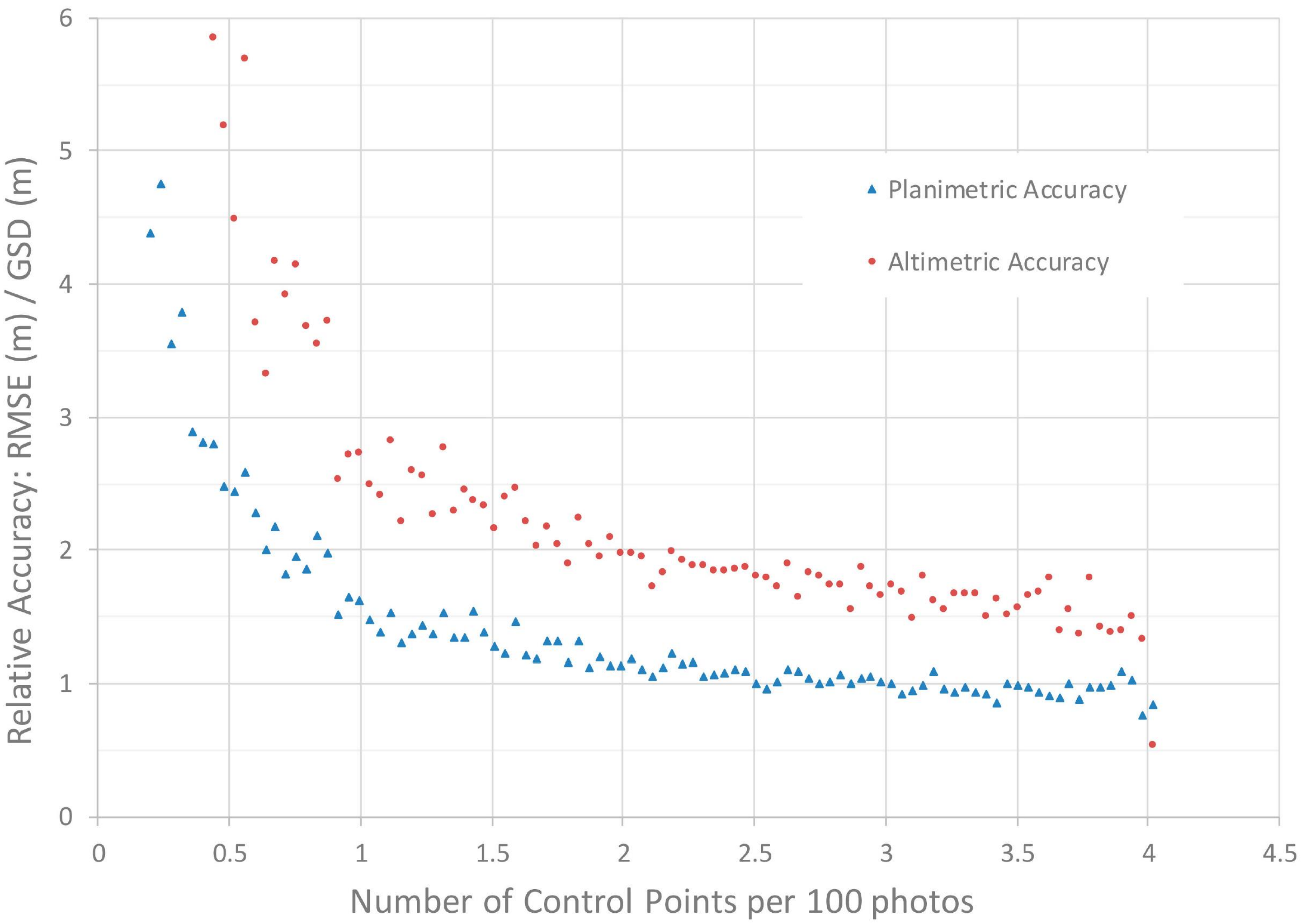
Sanz-Ablanedo, E.; Chandler, J.H.; Rodríguez-Pérez, J.R.; Ordóñez, C. Accuracy of Unmanned Aerial Vehicle (UAV) and SfM Photogrammetry Survey as a Function of the Number and Location of Ground Control Points Used. *Remote Sens.* **2018**, *10*, 1606.



Number of Check Points
92
82
72
62
52
42
32
22
12
2
RMSE (m)
8
4
2
1
0.5
0.25
0.125
0.0625
0.03125
0.015625
0.0078125
0.0039063
0.0019531
Check Points
Control Points
Averaged Ground Size Distance in the Project = 0.068 m
0
10
20
30
40
50
60
70
80
90
100
Number of Control Points Used in the Bundle Adjustment



Number of Check Points
92
82
72
62
52
42
32
22
12
2
Orange: Vertical RMSE of Check Points
Purple: Easting RMSE of Check Points
Blue: Northing RMSE of Check Points
Averaged Ground Size Distance in the Project = 0.068 m
Blue: Easting RMSE of Control Points
Red: Northing RMSE of Control Points
Green: Vertical RMSE of Control Points
RMSE (m)
0.512
0.256
0.128
0.064
0.032
0.016
0.008
0.004
0
10
20
30
40
50
60
70
80
90
100
Number of Control Points Used in the Bundle Adjustment



Relative Accuracy: RMSE (m) / GSD (m)
Number of Control Points per 100 photos
Planimetric Accuracy
Altimetric Accuracy
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

PHOTOGRAMMETRY

STRUCTURE FROM MOTION TECHIQUE

SFM REQUIREMENTS

USER PARAMETERS

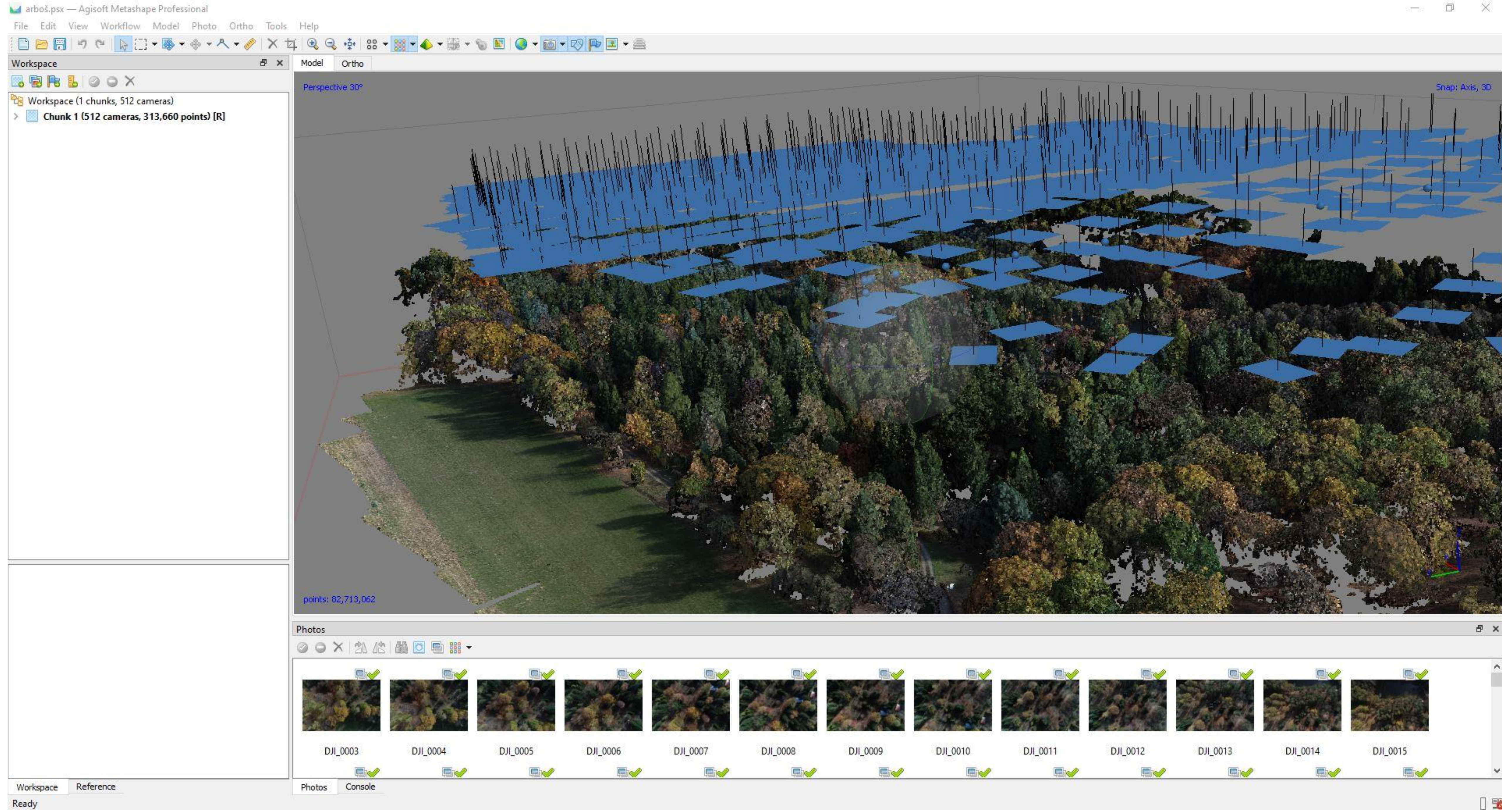
INPUT

A SEQUENCE OF IMAGES OF AN OBJECT FROM DIFFERENT POSITIONS

SFM

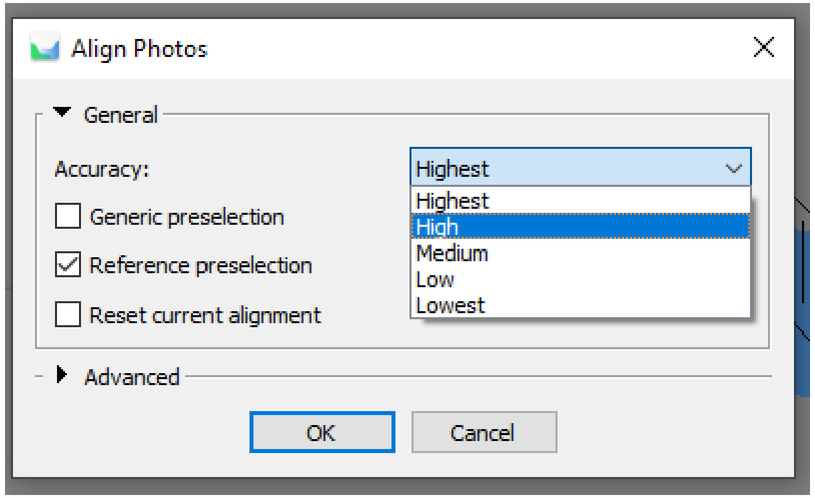
OUTPUT

- POINT CLOUD
- 3D MODEL: POLYEDRIC OBJECT (POLYGONAL MESH)

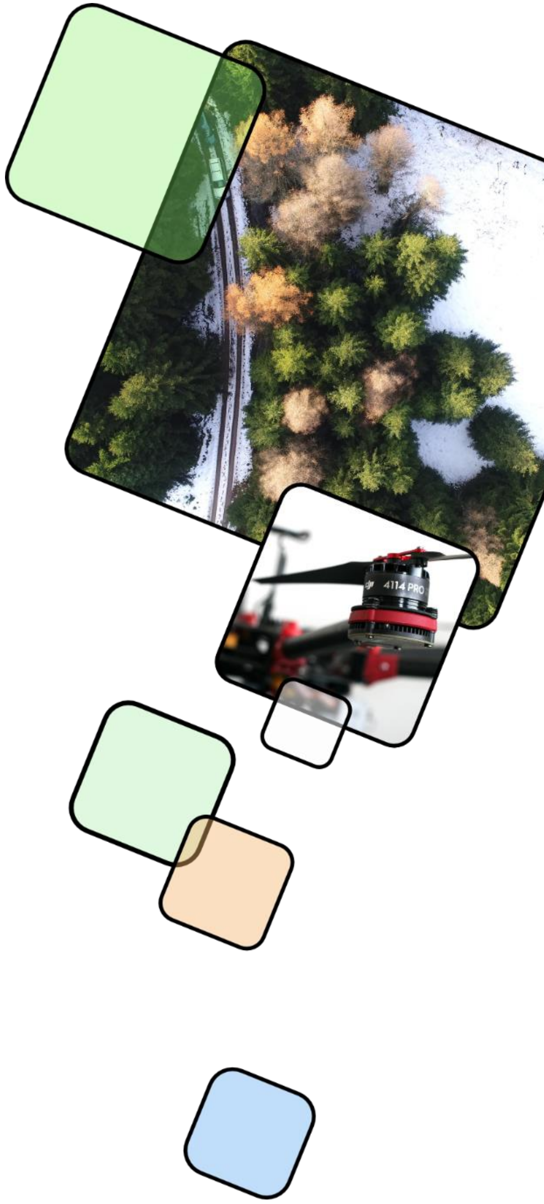

arboš.psx — Agisoft Metashape Professional
File Edit View Workflow Model Photo Ortho Tools Help
Workspace
Model Ortho
Perspective 30°
Snap: Axis, 3D
Workspace (1 chunks, 512 cameras)
Chunk 1 (512 cameras, 313,660 points) [R]
points: 82,713,062
Photos
DJI_0003 DJI_0004 DJI_0005 DJI_0006 DJI_0007 DJI_0008 DJI_0009 DJI_0010 DJI_0011 DJI_0012 DJI_0013 DJI_0014 DJI_0015
Workspace Reference
Photos Console
Ready

TIE POINTS (ŘÍDKÉ BODOVÉ MRAČNO)

ACCURACY



GENERIC PRESELECTION
REFERENCE PRESELECTION



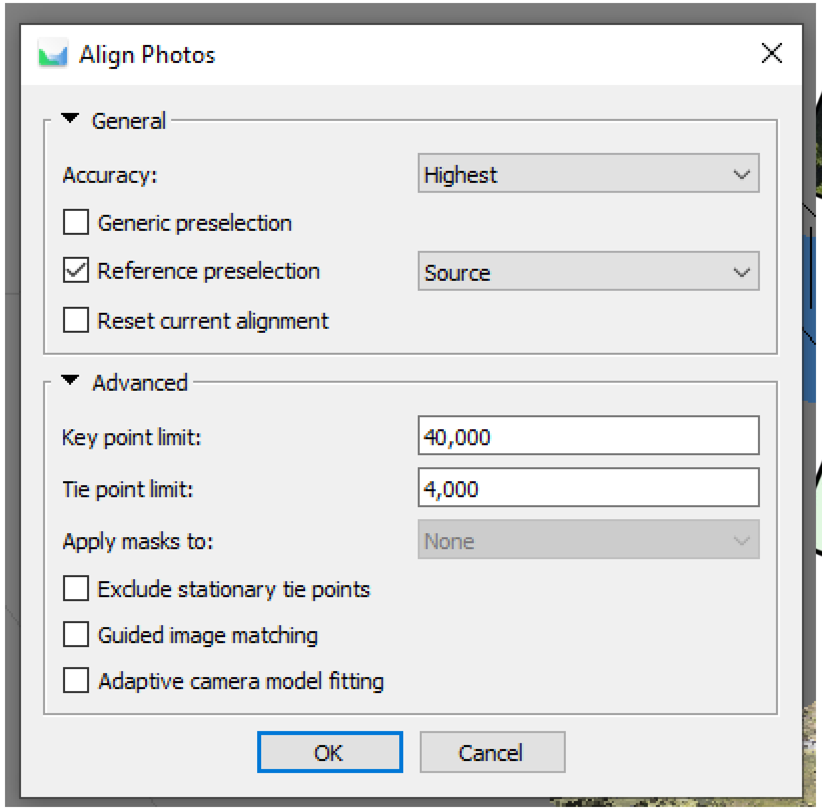
KEY POINT LIMIT

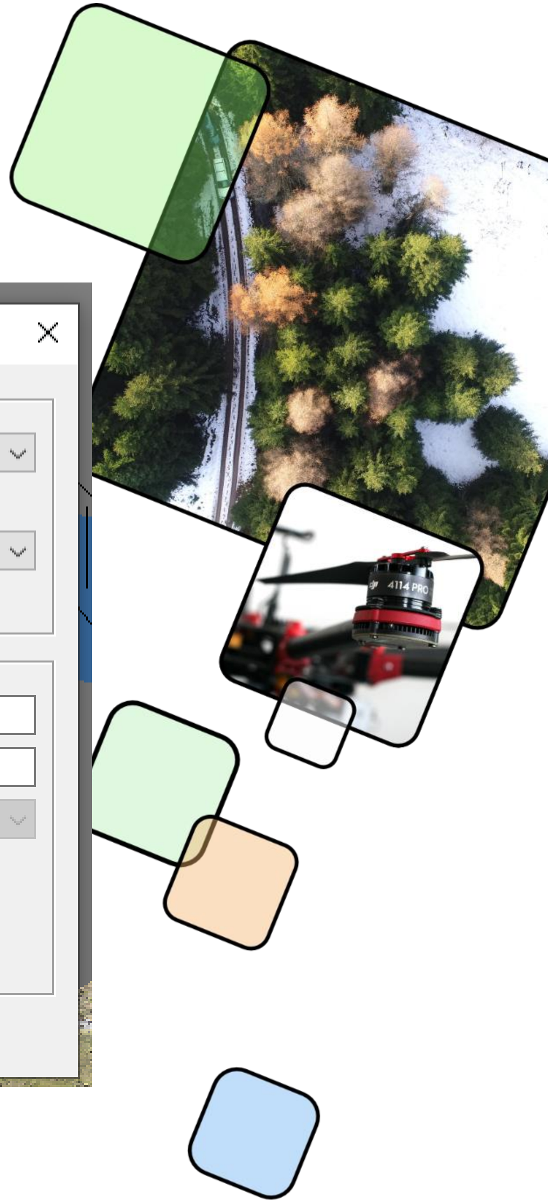
KLÍČOVÉ BODY (KEY POINTS)
ZAJÍMAVÉ BODY (FEATURES) IDENTIFIKOVANÉ V KAŽDÉM SNÍMKU

TIE POINT LIMIT

UZLOVÉ BODY (TIE POINTS)
SPÁROVANÉ FEATURES VE DVOJICI SNÍMKŮ

LIMIT 0 = NENÍ OMEZENO





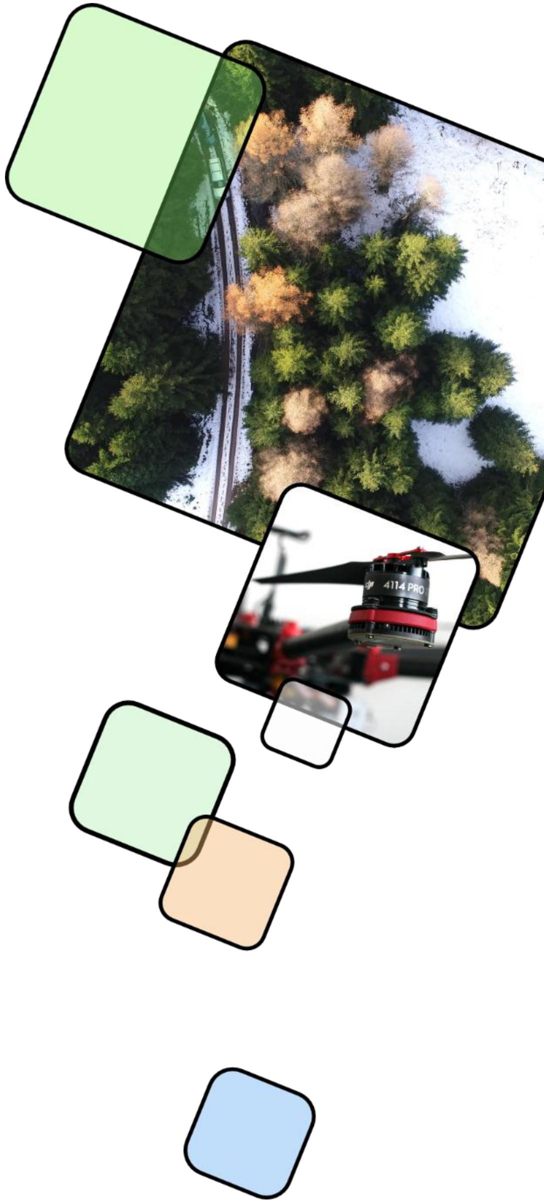
TIE POINTS FILTERING

REPROJECTION ERROR

High reprojection error usually indicates poor localization accuracy of the corresponding point projections at the point matching step. It is also typical for false matches. Removing such points can improve accuracy of the subsequent optimization step.
(INCONSISTENT POINTS, ERRORS)

RECONSTRUCTION UNCERTAINITY

High reconstruction uncertainty is typical for points, reconstructed from nearby photos with small baseline. Such points can noticeably deviate from the object surface, introducing noise in the point cloud. While removal of such points should not affect the accuracy of optimization, it may be useful to remove them before building geometry in Point Cloud mode or for better visual appearance of the point cloud.
(ERROR ELLIPSOID)



TIE POINTS FILTERING

IMAGE COUNT

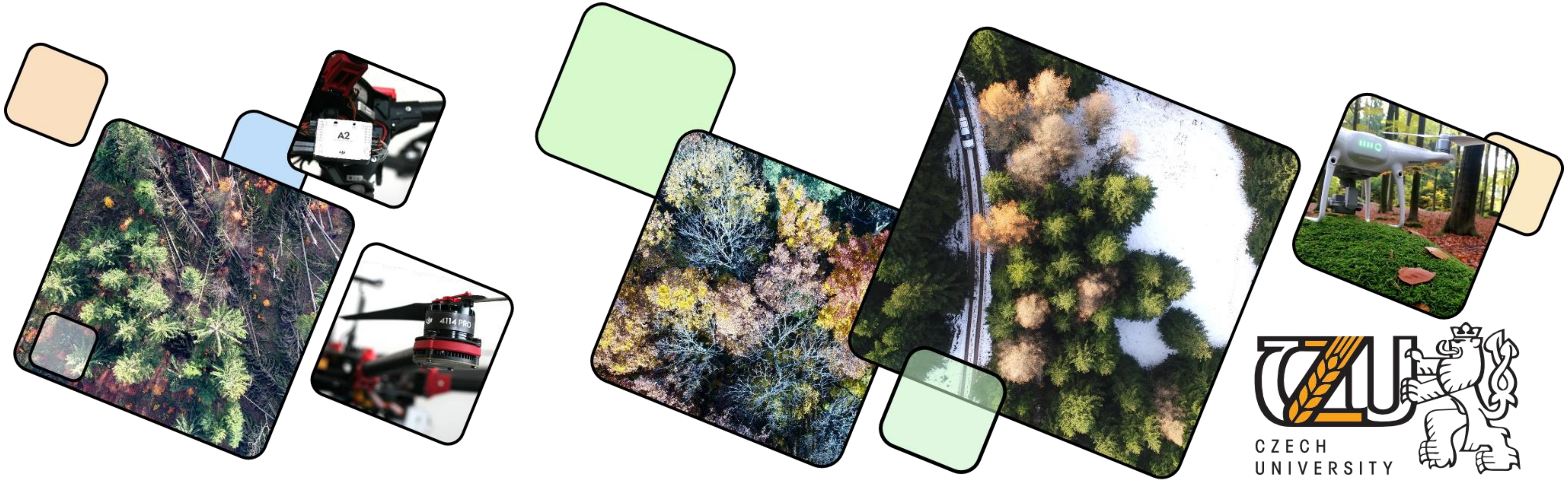
Metashape reconstruct all the points that are visible at least on two photos. However, points that are visible only on two photos are likely to be located with poor accuracy. Image count filtering enables to remove such unreliable points from the cloud.

PROJECTION ERROR

This criterion allows to filter out points which projections were relatively poorer localized due to their bigger size.

OPTIMIZE CAMERAS

To ensure maximum geometric accuracy of processing results, it is important to always optimize cameras after adding or editing measured values and/or their accuracies, e.g. loading GPS camera coordinates, adding GCPs, changing accuracy settings



THANK YOU

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