JOANNEUM RESEARCH DIGITAL

DIGITAL - Institute for Information and Communication Technologies

ALPEN-ADRIA UNIVERSITÄT KLAGENFURT I WIEN GRAZ

Lakeside Labs SELF-ORGANIZING NETWORKED SYSTEMS

umwelt data E.C.O.

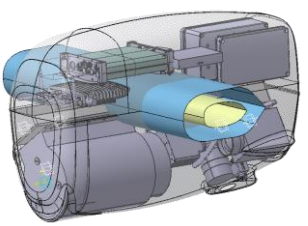
Introducing a Drone Based Oblique Stereo Camera System

Karlheinz Gutjahr, Stephan Weiss and Evsen Yanmaz

Barcelona, 10.10.2017

ALPEN-ADRIA UNIVERSITÄT Lakeside Labs umwelt data E.C.O. JOANNEUM RESEARCH DIGITAL

ADAM^{C} Airborne Data Acquisition Module



Cameras
- RGB digital camera
- Near infrared camera
- Thermal camera

Laserscanner
- RIEGL VQ580

Georeferencing components
- GPS and IMU

Control unit
- rugged PC / data storage

Independent power supply
- alternator
- batteries

Software

3

- RSG - Remote Sensing software package Graz
  - Software for geometric processing of remote sensing image data since 1980
  - Parts integrated at various “ground segments”, e.g. DLR (ERS-SRTM), Infoterra (TerraSAR-X), ESA (GPOD), PhaseOne (CIR stacking, 190 MP fusion), …
  - Offered/distributed to project partners and universities but also commercially available
  - Participated in benchmarks… zuerich_color.mp4, muenchen_upper_mesh.mp4

RSG Expert

RSG Photo

RSG Space

RSG InSAR

Content

4

Forest-IMATE

Forest-Inventorying with Micro Aerial vehicles for autonomous Tree-parameter Estimation

- Set-up
- Navigation
- Calibration
- Field campaign

Objectives

5

- Set-up a research platform prototype consisting of one unmanned aerial vehicle (UAV) navigating autonomously through managed mature forest providing sufficiently dense visual data for accurate 3D reconstruction
- GPS independent, vision based autonomous UAV navigation, including self-healing state estimation, vision based obstacle avoidance, and adaptive path planning
- Extraction of ecological forest parameters in unprecedented precision and efficiency in both time and cost

THE INNOVATION COMPANY

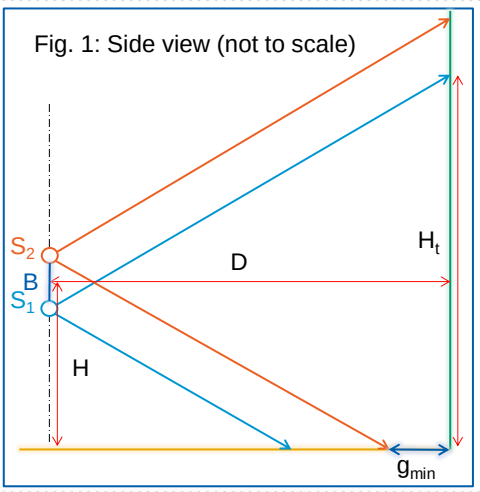
Catalogue of Forest Parameters

6

Indicator	Accuracy (ecology)	Accuracy (economy)
Size (height, BHD) of trees	Height +/- 1 m, BHD in 5 cm classes	Height +/- 0,5 m, BHD +/- 1 cm
Tree diameter in different heights above ground up to 30-50% tree height; 3-10 more diameter measurements at variable positions	-	Height of measurement +/- 10 cm, DBH as mean value (vertically +/- 15 cm) DBH as min / max if elliptic stem section
Absolute position of trees	+/- 1 m horizontal	+/- 1 m horizontal
Orientation of trees (straight vertical, horizontal, inclined)	+/- 20° of inclination of trunk	+/- 10° of inclination of trunk
Ground vegetation cover, Existence / coverage / height of natural regeneration	+/- 20% of coverage	+/- 20% of coverage
Tree is dead or alive	80 % correct	80 % correct
Total living/dead biomass	+/- 20 % of total volume	+/- 20 % of total volume
Crown cover	+/- 20 % of coverage	+/- 20 % of coverage
Vertical position of crown layer(s) (begin of lower branches > 5 (10) cm diameter	Position in height +/- 1 m of vertical distance	Position in height +/- 1 m

Stereo Disposition: 5 MP Camera/ 5.0 mm Lens

7



- Set-up:
  - Physical stereo base B: 40 cm (vertical)
  - Nom. resolution: 2 mm
  - Min. length on grd: 20 cm
- Output:
  - Scene extend:
    Hor. 4.1 m x vert. 5.2 m
  - Horizontal dist. D: 2.1 m
  - Height of UAV H: 2.1 m
  - Height of trunk H_t : 4.5 m
  - Intersect. acc.: 1.0 cm

Camera Selection

8

- Cameras
  - Basler ace series acA2440-35um
  - 2448 x 2048 pxl (5MP)
  - Color 12 bits
  - Global shutter

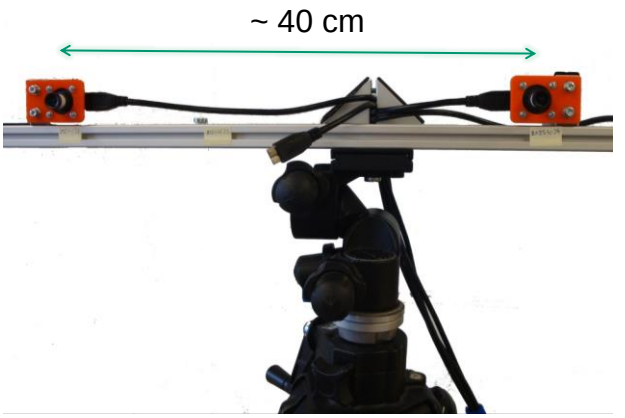
http://www.baslerweb.com/en/products/cameras/area-scan-cameras/ace/aca2440-35uc

- Kowa lens
  - Focal length 5.0 mm
  - Resolution 120/100 lp/mm (1 MP)
  - Angle of view 82.4° / 66.9°

http://www.kowa-europe.com/lenses/en/LM5JCM.2992.php

Science Cameras Mock-up

9



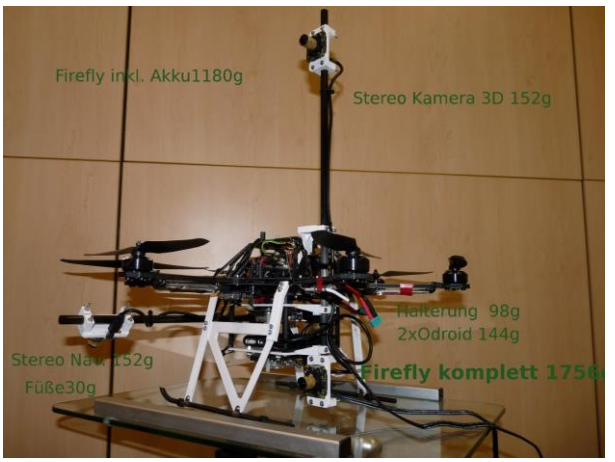
Research Platform Prototype

10

- Platform
  - “Firefly” by Ascending Technologies (http://www.asctec.de/en/uav-uas-drones-rpas-roav/asctec-firefly/#pane-0-1)
  - Max. payload 600 g
- Payload
  - Navigation cams (mvBlueFOX-MLC200wg, 752x480 pxl)
  - Science cams (acA2440-35um, 2448x2048 pxl)
  - Odroid PC
  - Wlan antenna, GPS, …
- =>Flight time ~ 12 min

Research Platform Prototype

11



THE INNOVATION COMPANY

Content

12

- Set-up
- Navigation
- Calibration
- Field campaign

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT · Lakeside Labs · umwelt data · E.C.O. · JOANNEUM RESEARCH DIGITAL

Autonomous Navigation

13

- Localization
- Path planning
- Obstacle avoidance

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT · Lakeside Labs · umwelt data · E.C.O. · JOANNEUM RESEARCH DIGITAL

Localization

14

- Vision based state estimation
  - Only based on passive on-board sensing and computation: one camera 6DoF IMU
  - Low position drift for mid-range GPS independent missions
  - Continuous system self-calibration requires minimal user expertise
  - Can automatically geo-reference location through sparse/opportunistic GPS readings if desired
- CNS-PTAM-Test.avi

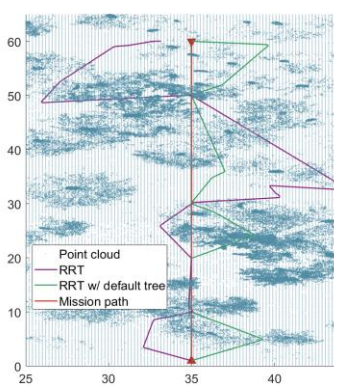
THE INNOVATION COMPANY

Path Planning

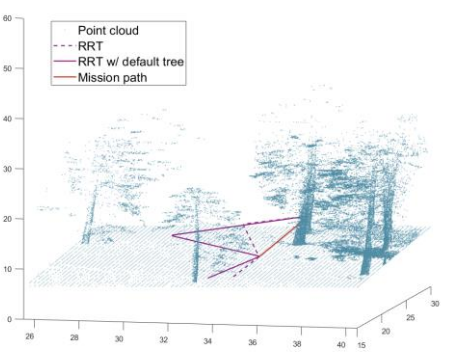
15

- Global planner:
  - Real-time path (re-)planning to follow general direction and way points roughly indicated by the user
  - Almost straight line from start to end (and return) at constant height above ground
  - Automated adjustment of flight according to slope direction
  - Paths aim at maintaining distance to trees for optimal 3D reconstruction
  - Designed to not yield biases in the subsequent biomass estimation procedures
- Local planner:
  - Generate 3D point cloud
  - Check line of sight obstacles
  - Generate collision-free paths using 3D random tree approach
  - Select shortest path among viable routes
- TrialRun_1_11-07-17.mp4

Generated Paths



Travelled path



Obstacle avoidance

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

Obstacle Avoidance

17

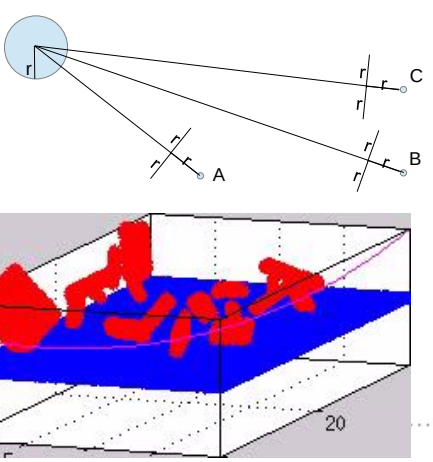
- Passive through coarse, local, and real-time stereo reconstruction (depth map) and collision space expansion
- Interleaved with path planning to ensure arrival at global goal point
- Accumulated local depth maps serve as guidelines for return flights and visualization for the user

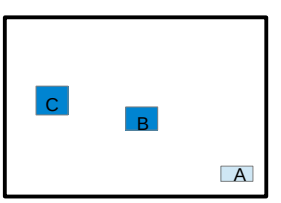
ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

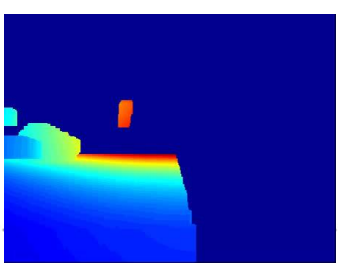
Obstacle Avoidance

18

- Collision-space expansion for local path planning







ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

19

Content

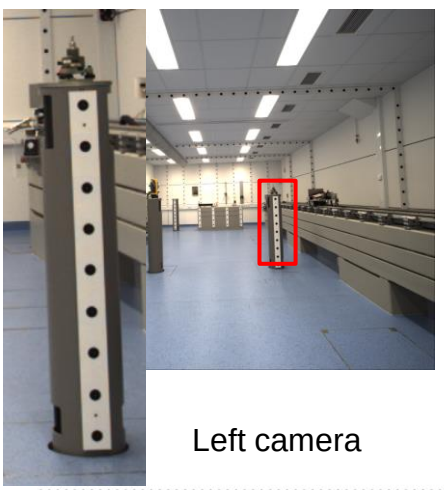
- Set-up
- Navigation
- Calibration
- Field campaign

THE INNOVATION COMPANY

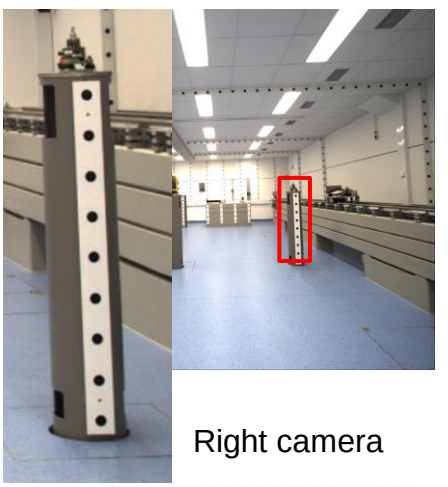
ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

20

Image Examples Lab



Left camera



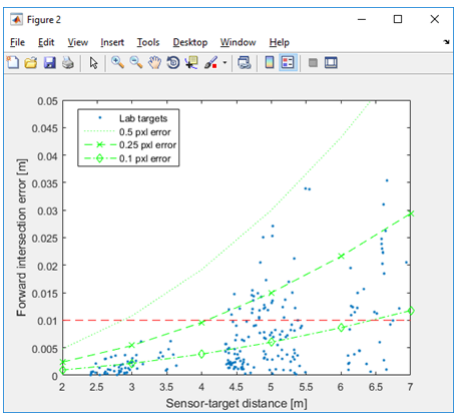
Right camera

THE INNOVATION COMPANY

Results Lab Calibration

21

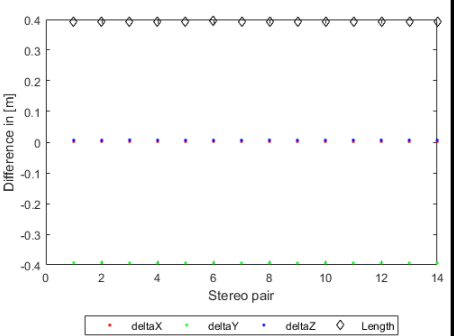
- Distortion left and right camera
- Boresight angles
- Leverarm
- But also proof of intersection quality



Leverarm

22

- Position difference left – right camera in system of left camera
- deltaX = -0.0014 ± 0.00008 m
- deltaY = - 0.3996 ± 0.00039 m
- deltaZ = -0.0025 ± 0.00027 m



ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Content

23

- Set-up
- Navigation
- Calibration
- Field campaign

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Field Test

24

- Test forest Gerlitzen/Austria
- References:
  - Airborne laserscanning
  - Terrestrial laserscanning
  - Manual measurements
  - 2016-10-10_TLSRGB-StemUpDown_UWD.mp4

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

Image Examples

25

Left / upper camera

Right/ lower camera

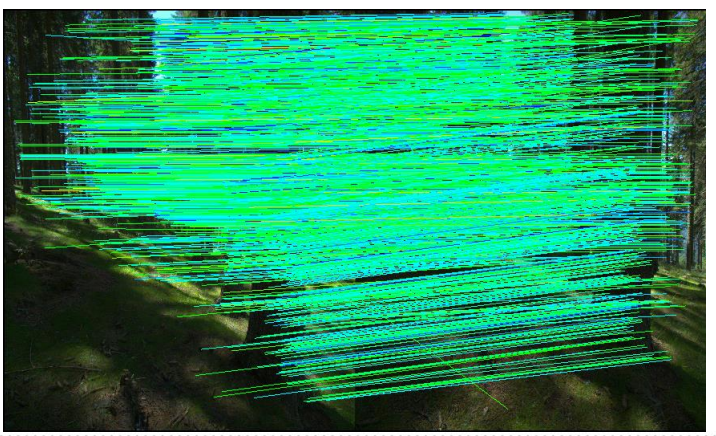
THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

Tie-pointing

26

- „In stereo“



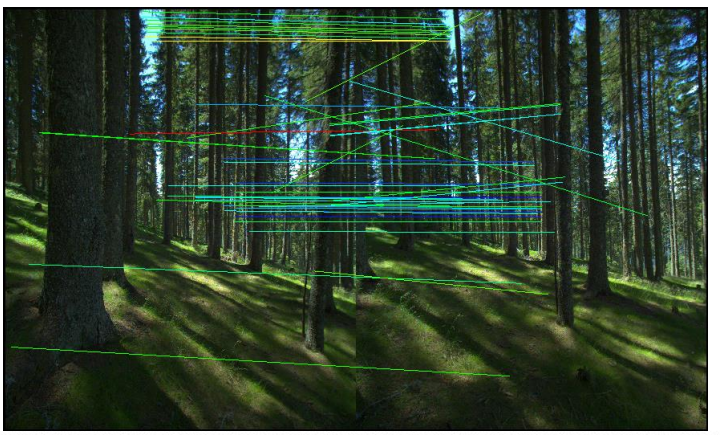
THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Tie-pointing

27

- „Across stereo“ without rotation

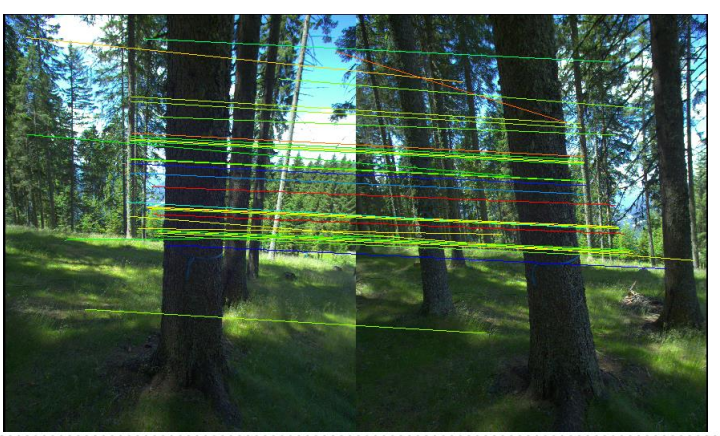


ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Tie-pointing

28

- „Across stereo“ with rotation



ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

Epipolar Rectification Image 1

29

stereo parallax

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O | JOANNEUM RESEARCH DIGITAL

Epipolar Rectification Image 2

30

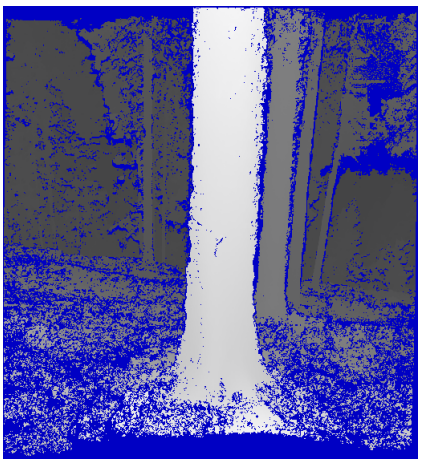
stereo parallax

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Disparity Map (Stereo Parallax)

31



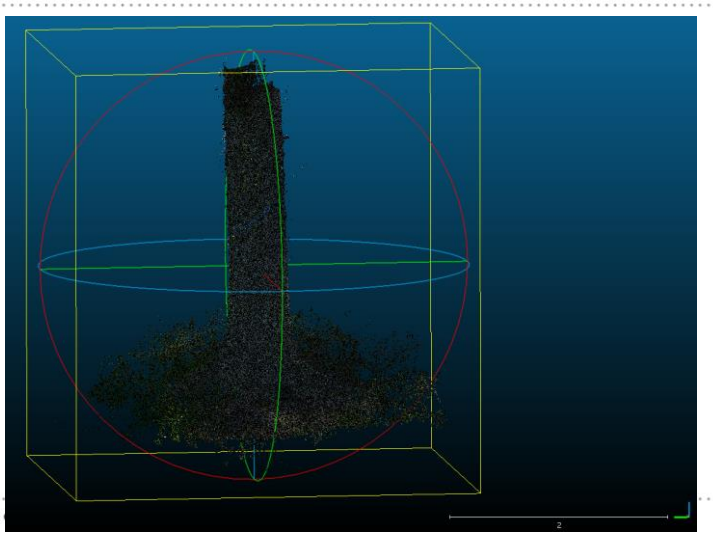
Bright colors indicate that objects are closer to the camera

THE INNOVATION COMPANY

ALPEN-ADRIA UNIVERSITÄT | Lakeside Labs | umwelt data | E.C.O. | JOANNEUM RESEARCH DIGITAL

Colourized Point Cloud

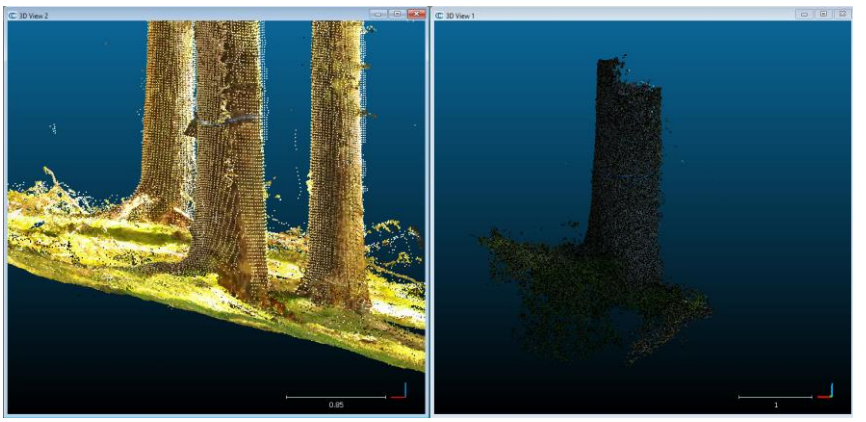
32



THE INNOVATION

Colourized Point Cloud

33



THE INNOVATION COMPANY

Forest-IMATE project
http://forest.aau.at/

Karlheinz Gutjahr
+43 316 876 1718
karlheinz.gutjahr@joanneum.at

JOANNEUM RESEARCH
Forschungsgesellschaft mbH
Institute for Information and
Communication Technologies
www.joanneum.at/digital

THE INNOVATION COMPANY