University of Applied Sciences
Northwestern Switzerland

iNovitas
Mobile Mapping Solutions

3D Vision Mobile Mapping & Cloud-based 3D Exploitation

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University of Applied Sciences
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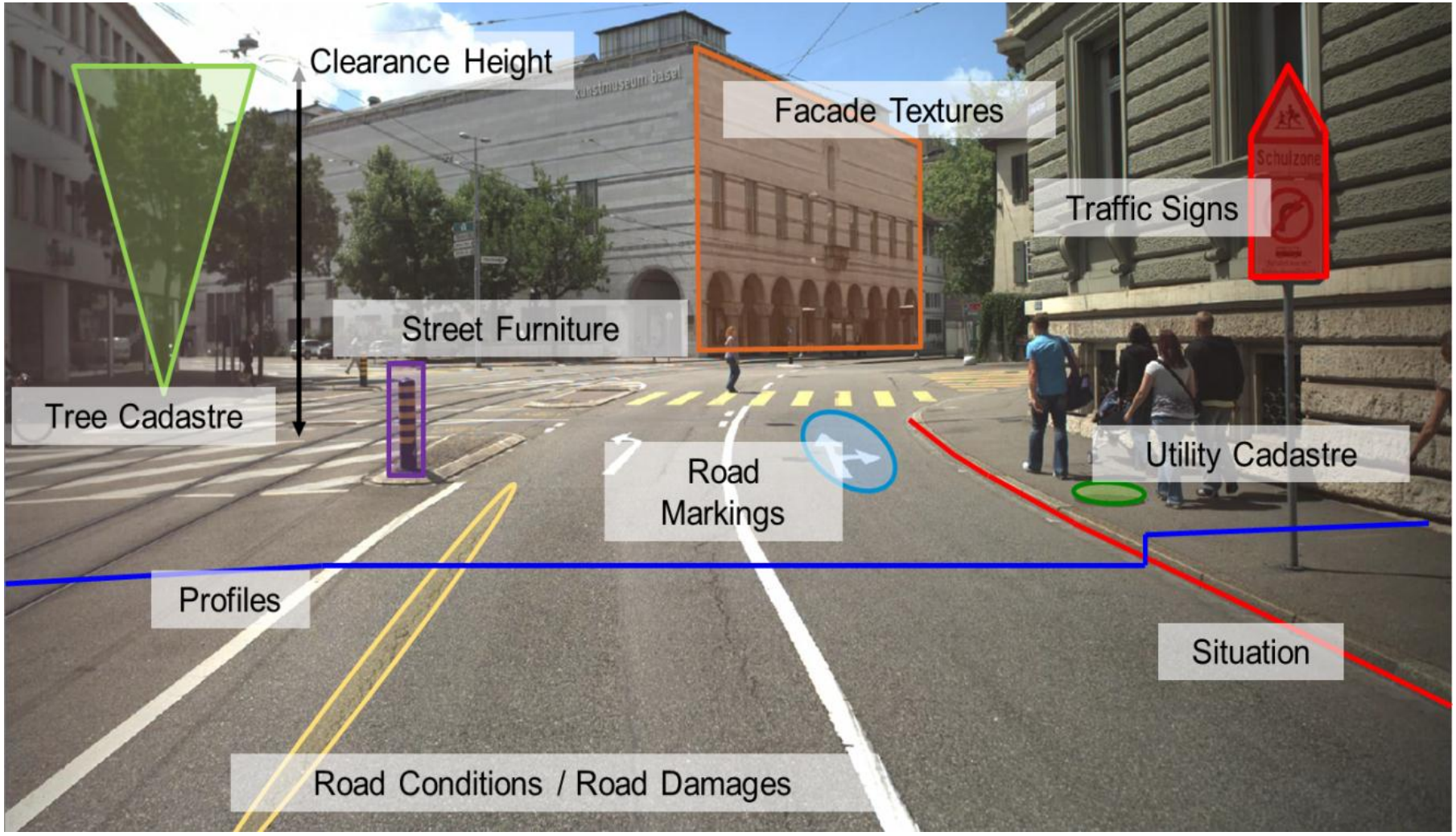
Mobile Mapping in the 2000's: dominated by Mobile Laserscanning

So why Imagery and why Image-based Mobile Mapping?



Why Imagery ? … and why 3D Imagery ?

- **Detailed and semantically rich content**
- **Humans see and think in images – not in point clouds …**
- **Imaging sensors provide unparalleled data capture rates**
- **Tremendous progress in sensors, storage capacities, computing power, parallel computing and web technologies such as HTML5 and WebGL**
- **And: new algorithms from computer vision and photogrammetry for the automated (3d) exploitation, integrated georeferencing etc.**

Last but not least: a long tradition to build upon …

1st Experimental Mobile Mapping Systems – OSU und University of Calgary

Ohio State University, GPSVan
Novak, 1991

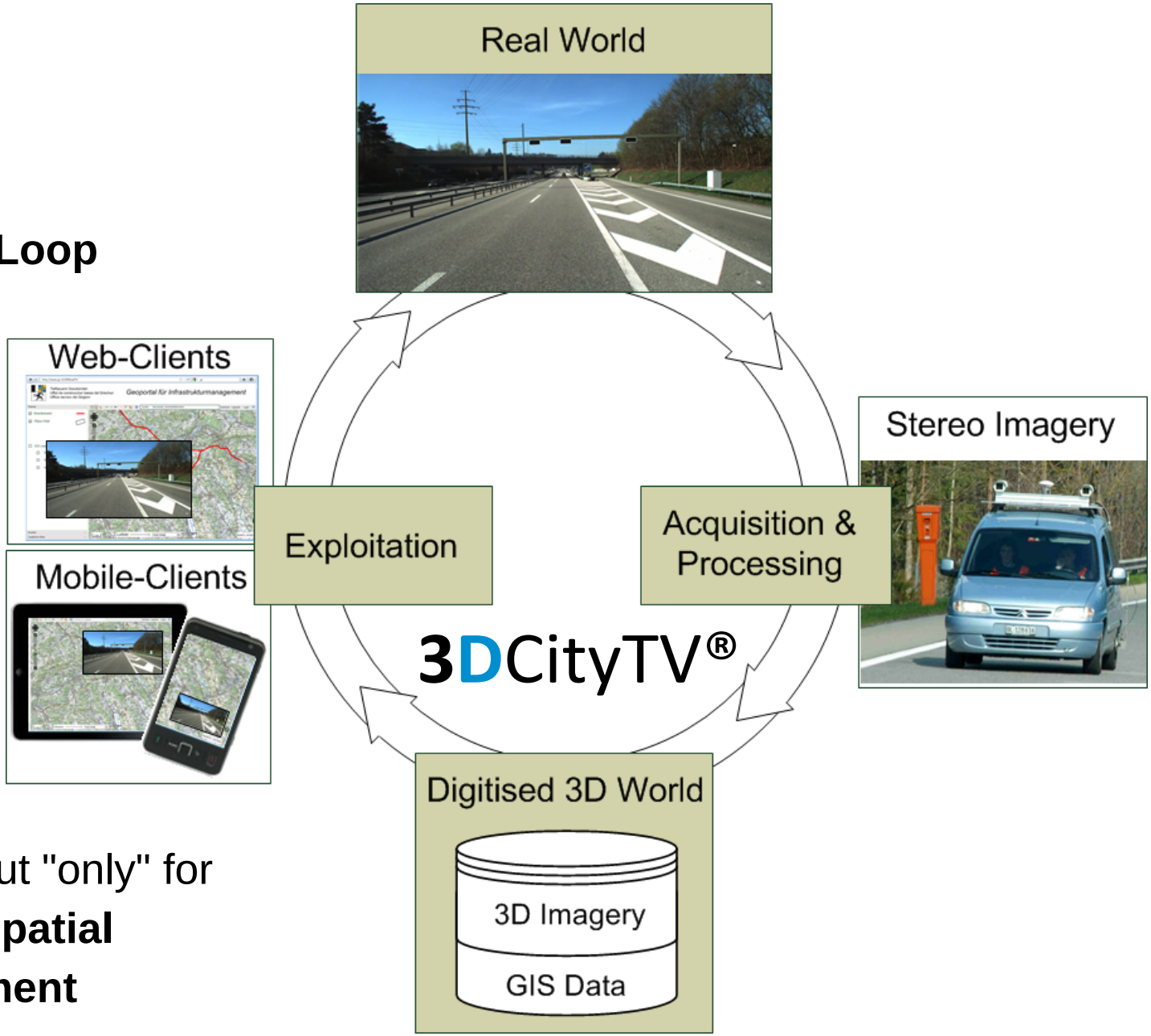
University of Calgary, VISAT Van
Schwarz et al., 1993

Vision

The 3D Geoinformation Loop

or:

"From the real-world to the digitised world and back"



- Mobile mapping as input "only" for **image-based 3d geospatial information management**

Agenda

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Image-based Mobile Mapping – Overview

3D Vision Mobile Mapping Technology

- Acquisition
- Processing
- Exploitation

Applications

Performance

Conclusions

Mobile Mapping – Acquisition Systems

Mobile Platform

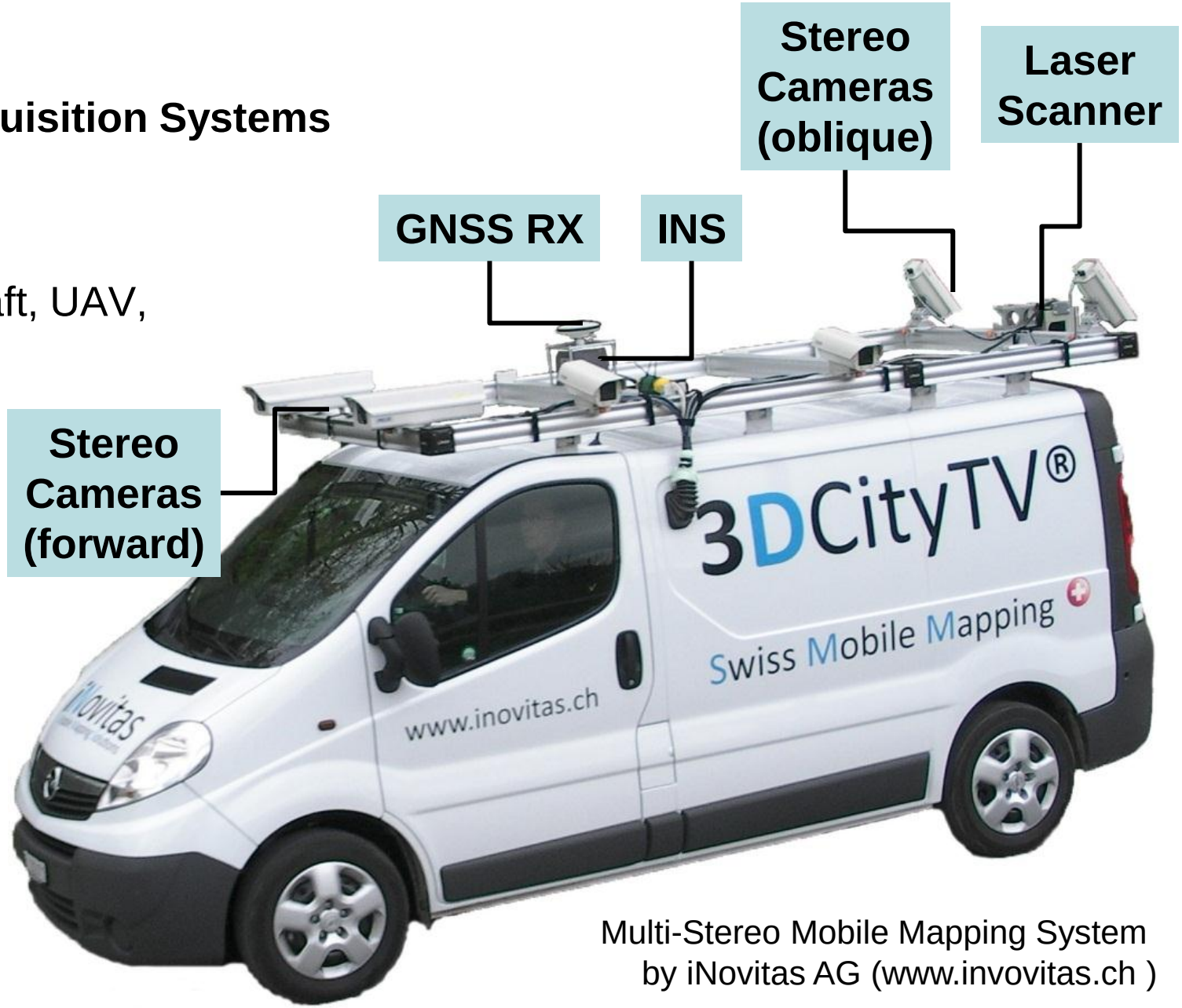
– Motor Vehicle, Aircraft, UAV, Train, Boat …

Positioning Sensors

– GNSS, INS, DMI

Mapping Sensors

– LiDAR, Imaging Sensors etc.



Multi-Stereo Mobile Mapping System
by iNovitas AG (www.invovitas.ch)

Mobile Mapping – Positioning Sensors

➢ **Kinematic Position AND Orientation Determination**

GNSS

Dual-frequency geodetic receiver

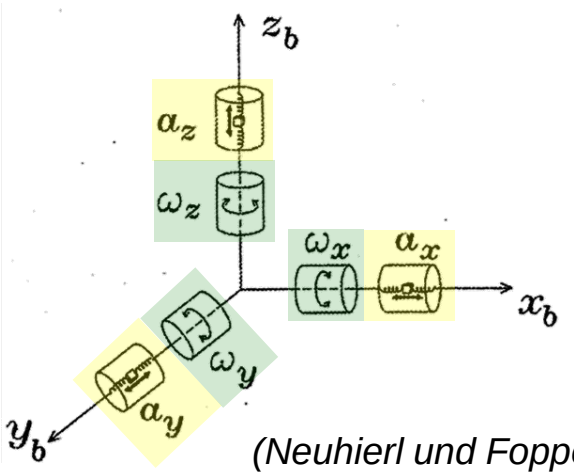
Measuring rates: ~ 10 Hz

INS (Inertial Navigation System)

Acceleration und rotation sensors

Measuring rates: ~ 100-200 Hz

Functional Principle INS



(Neuhierl und Foppe, 2004)

Accelerometers
→ Acceleration a [m/s²] → ∫∫ → **Position**
X, Y, Z [m]

Gyroscopes
→ Ang. velocity ω [deg/h] → ∫ → **Orientation angles**
Omega, Phi, Kappa [deg]

Mobile Mapping – Mapping Sensors

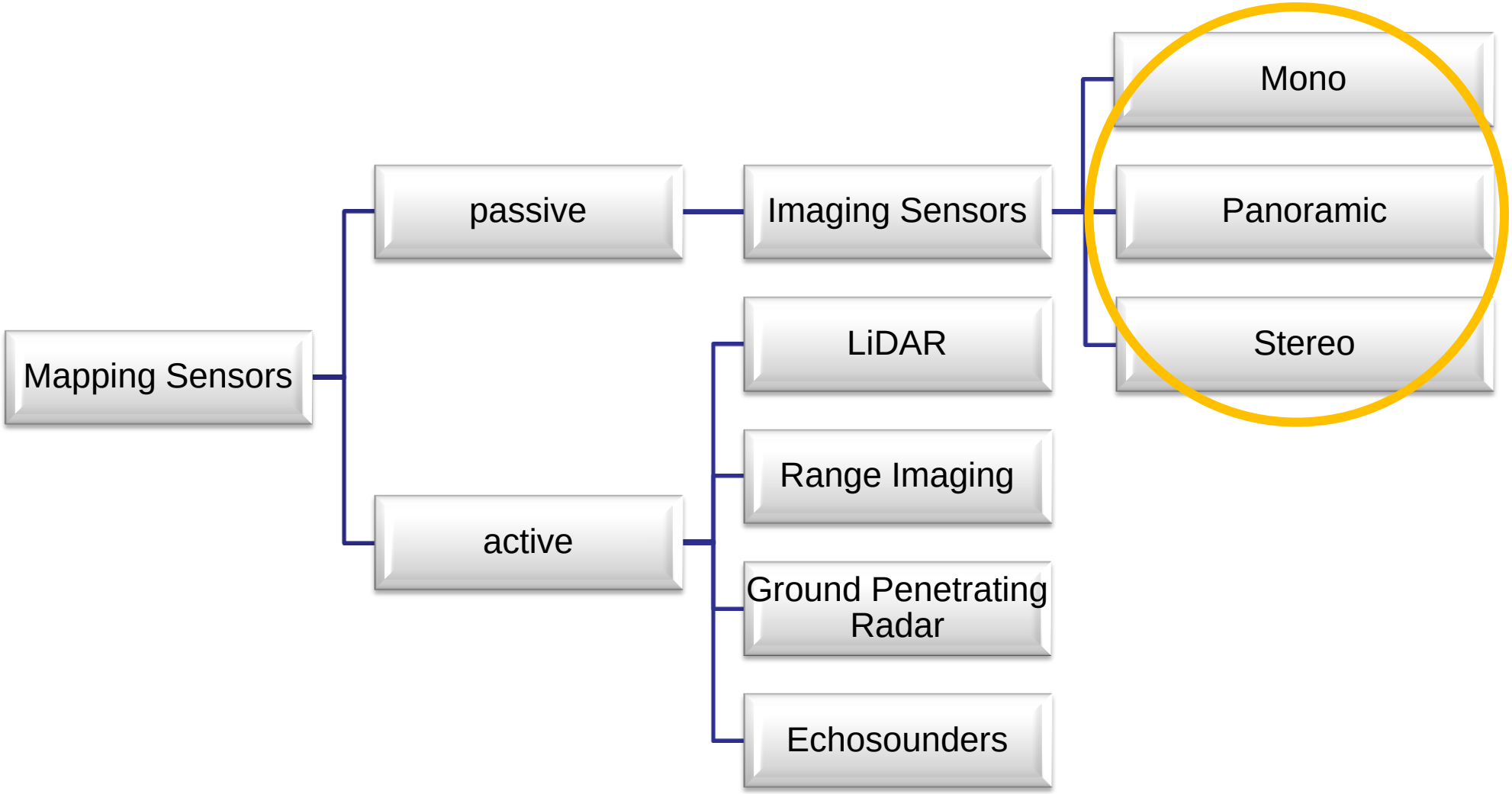
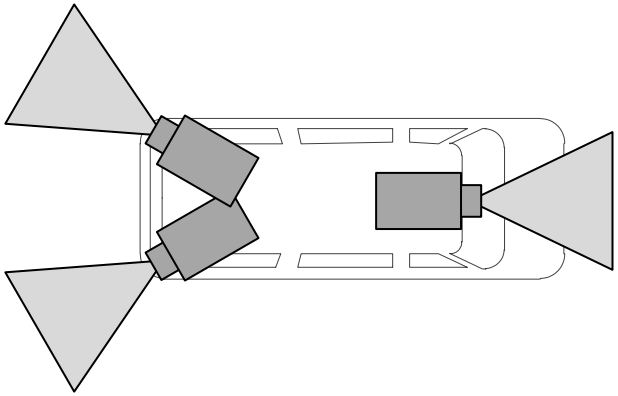


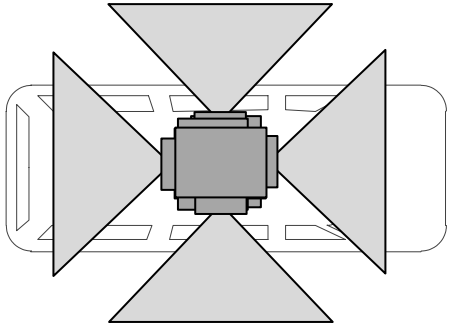
Image-based Mobile Mapping – Sensor Configurations

Monoscopic



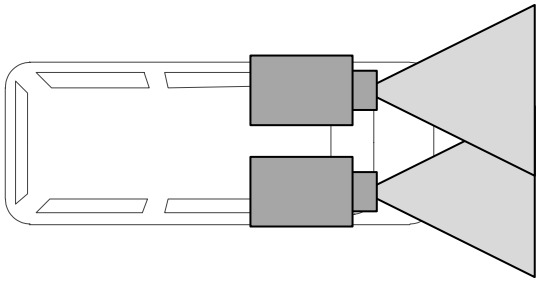
- flexible view directions, «simple» implementation
- no direct 2d /3d coordinate determination
- image documentation
- texturing of point clouds

Panoramic



- 360° coverage
- demanding camera design
- no direct 2d/3d coordinate determination
- «Google Street View like» products & services

Stereoscopic



- fixe viewing geometry (along-/cross-track etc.)
- demanding calibration
- accurate / direct 3d coordinate determination
- georeferenced 3d videos

Panoramic Imaging Principles

Integrated Multi-head Cameras

- z.B. Pointgrey LadyBug™3 (www.pointgrey.com)
- 6 * 2 MP cameras
- storage of 12 MP panoramas with up to 15 fps

2 Fisheye Cameras

(fwd / aft) e.g. Cyclomedia

Multi-Head Systems

(in combination with LiDAR)

- e.g. Google Street View

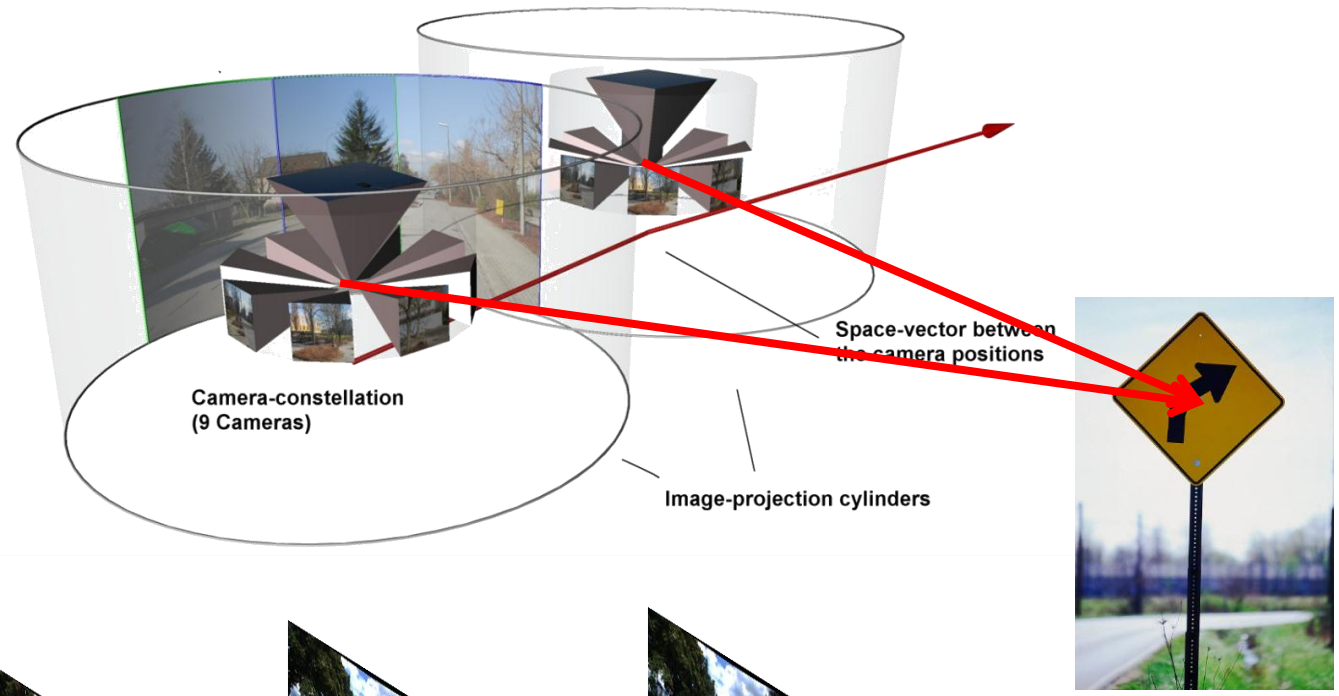
Multiple vertical stereo bases

- e.g. earthmine Inc.

3D Measuring Principle

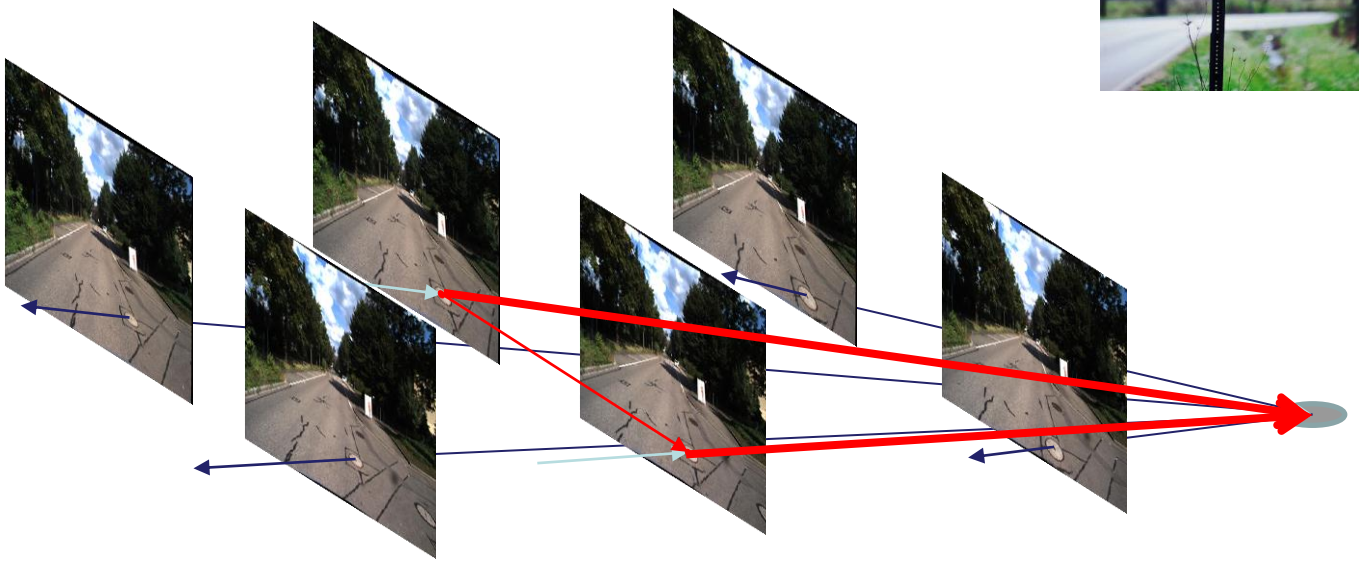
Monoscopic and Panoramic Imagery

- multiple monoscopic measurements across multiple epochs



Stereo Imagery

- interactive stereoscopic measurements in stereo pairs or sequences or
- 3d monoplotting including dense depth maps



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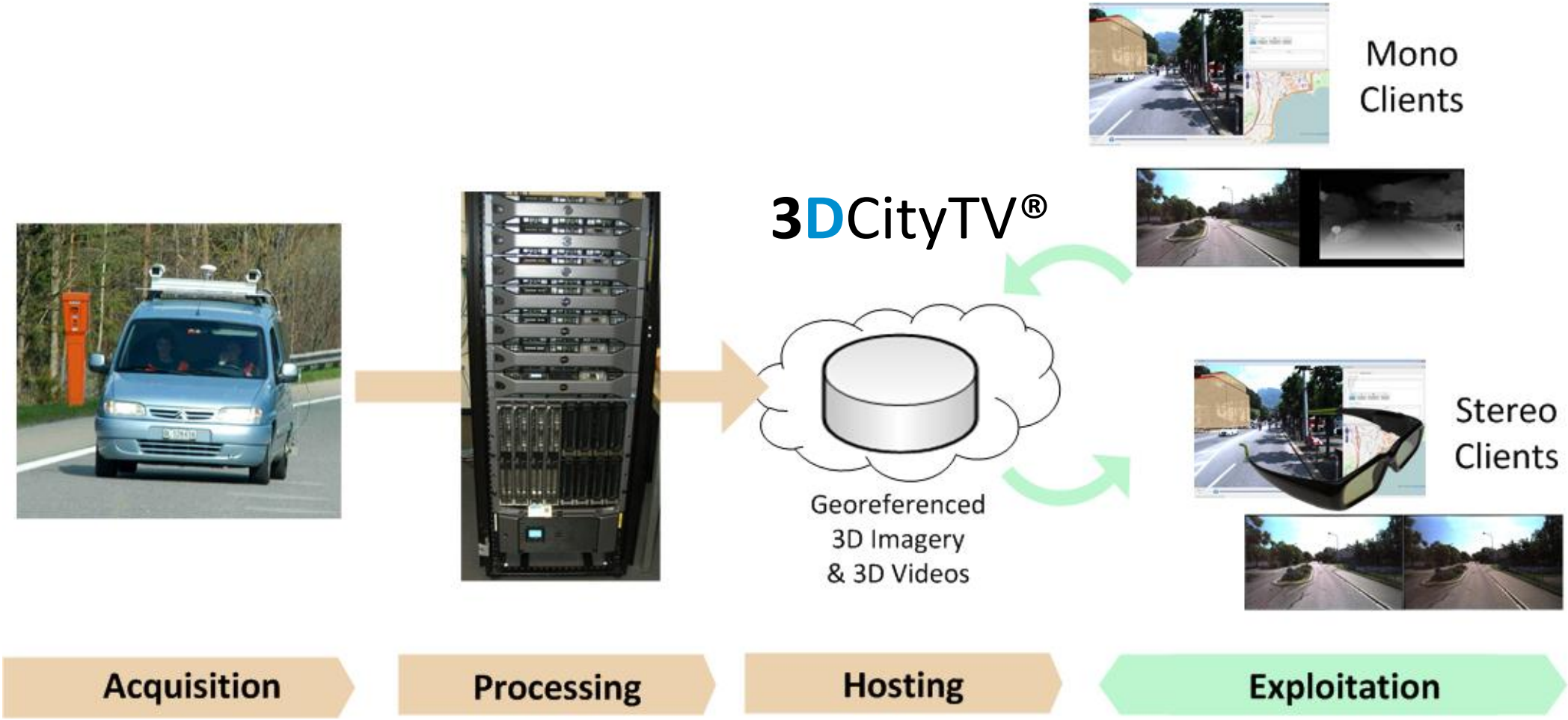
3D Vision Mobile Mapping – Components and Workflow



Our Acquisition Systems

GNSS/INS Positioning System

– Applanix POS LV or Novatel SPAN

Multiple Stereo Systems

– industry cameras with Gigabit Ethernet
– from Full HD to 11 MP, 5 to 30 fps
– up to 5 stereo systems (i.e. 10 cameras)

Profile Scanner (opt.)

Onboard data storage

– highly parallel
– 1-2 TB per hour

(*) For Multi-TB data sets using HPC- and Cloud-based parallel processing

3D Vision Mobile Mapping – Data Processing

System calibration

– interior orientation, relative orientation, determination of misalignment and lever-arm parameters for multi-stereo systems

Georeferencing

– direct georeferencing (GNSS/INS)
– integrated georeferencing incorporating vision-based observations

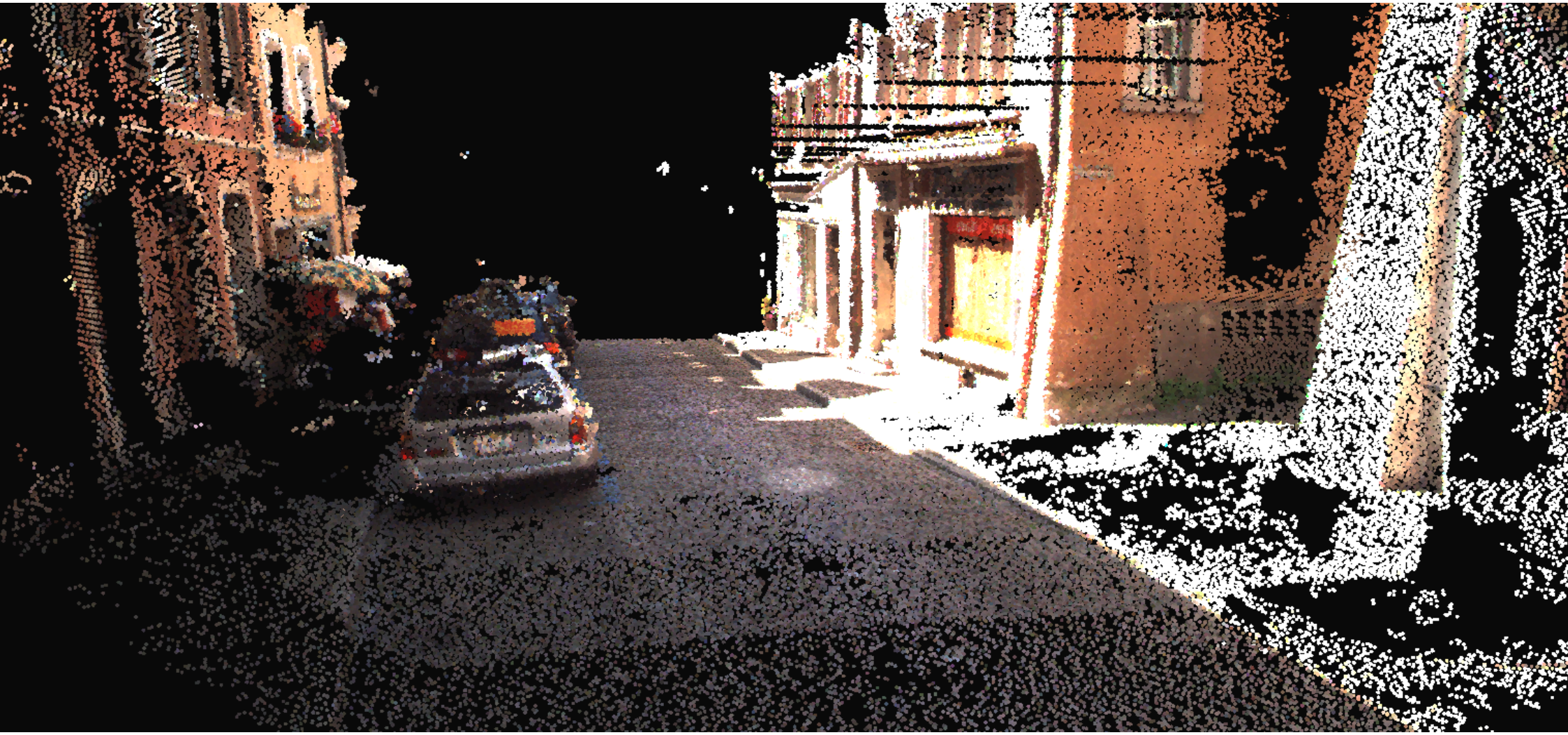
Stereo image pre-processing (*)

– generation of radiometrically corrected, distortion-free stereo normal imagery

Dense depth map extraction & 3d point cloud generation (*)

– using recent dense matching approaches, e.g. semi-global matching SGM (Hirschmüller, 2005 & 2008) or semi-global block matcher (OpenCV)

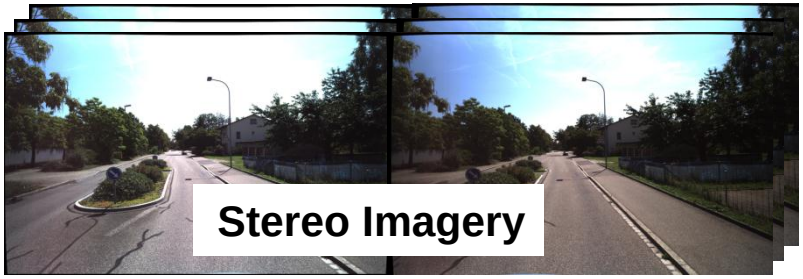
3D Point Cloud Extraction using Dense Stereo- or Multi-Image Matching



Precise 3D Measurements in 3D Image Space

Interactive 3D Exploitation

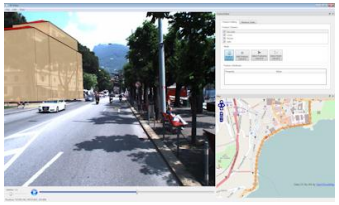
3D Imagery Repository



- navigation data
- stream metadata

3DCityTV®

Georeferenced 3D Imagery / Videos



Measurements based on 3D monoplotting

Monoscopic Exploitation

Interactive measurements in 3D videos

Stereoscopic Exploitation

Interactive 3D Exploitation

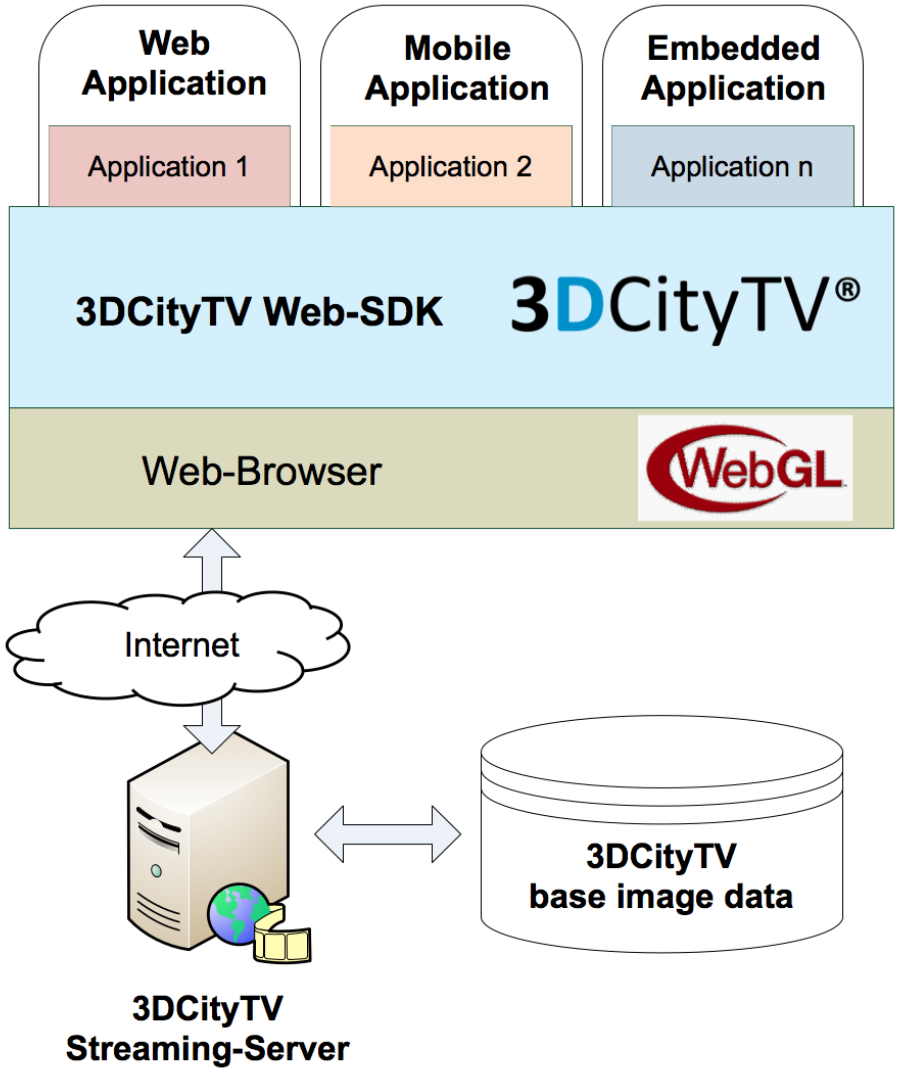
3DCityTV Web-Client

Features

- Mono-Client with 3D Monoplotting
- HTML5 & WebGL
- Plugin-free (Firefox, Chrome, Safari etc.)

3DCityTV Web-SDK

- for flexible development of Web clients, mobile and embedded applications and WebGIS services



Technology Demonstrator:

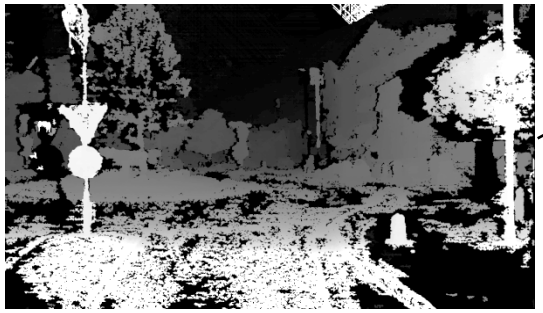
www.swissgeocloud.org/MuttenzDemo/

Automated Information Extraction: 3D Point Clouds and Profiles

Basis: Dense Depth Maps extracted from Stereo Imagery

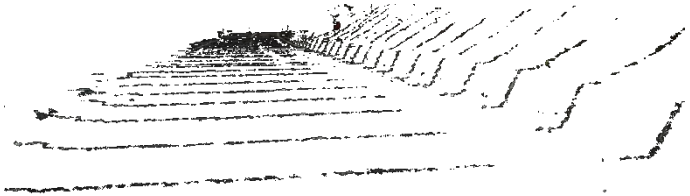
- Dense 3d point clouds with perfectly co-registered RGB values

Stereo Pair



Disparity / Depth Map

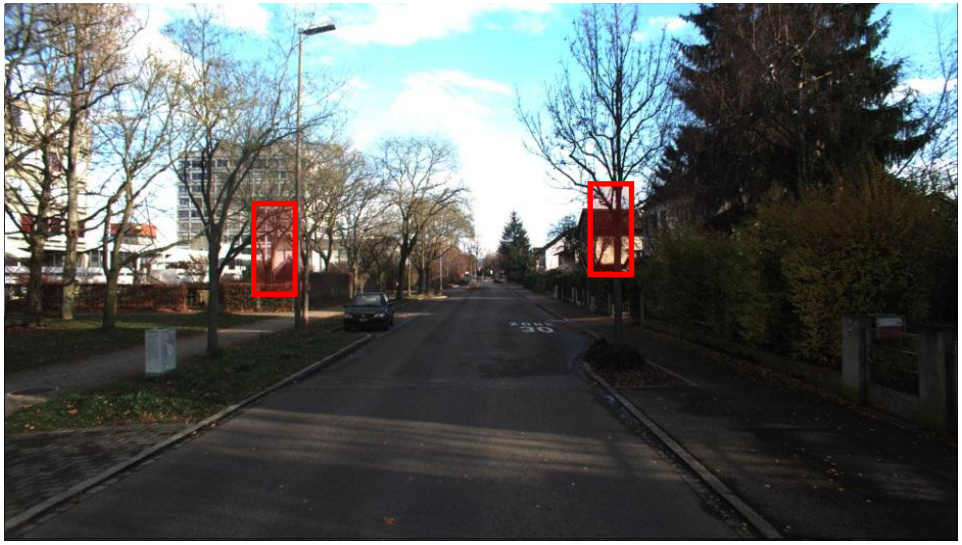
3D Point Clouds

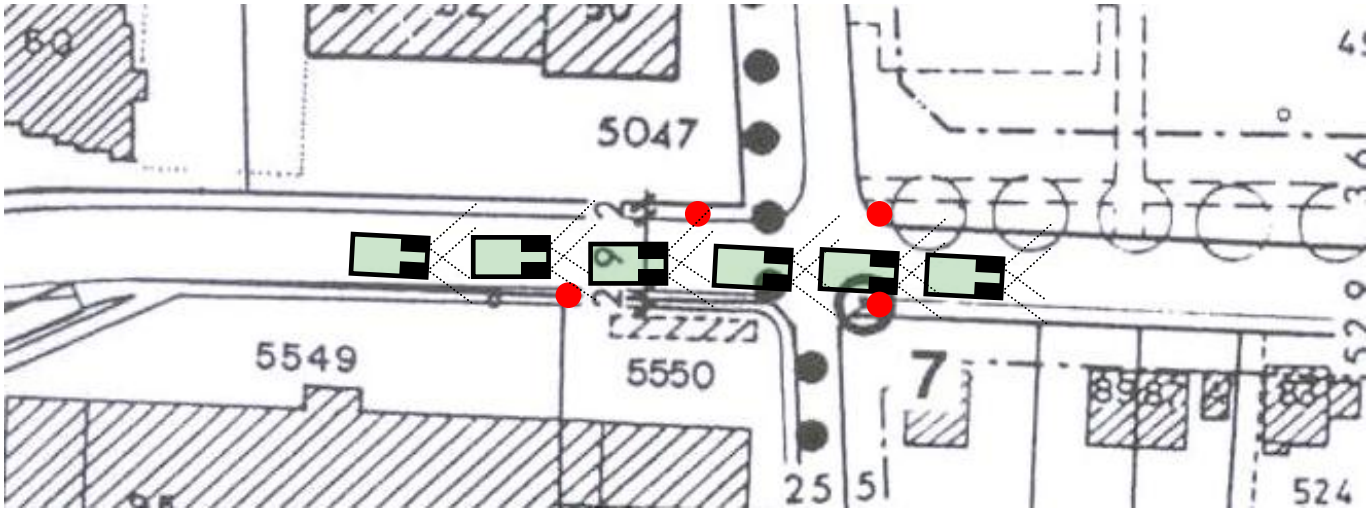


Road Profiles

Automated Information Extraction – e.g. 3D Mapping of Road Signs

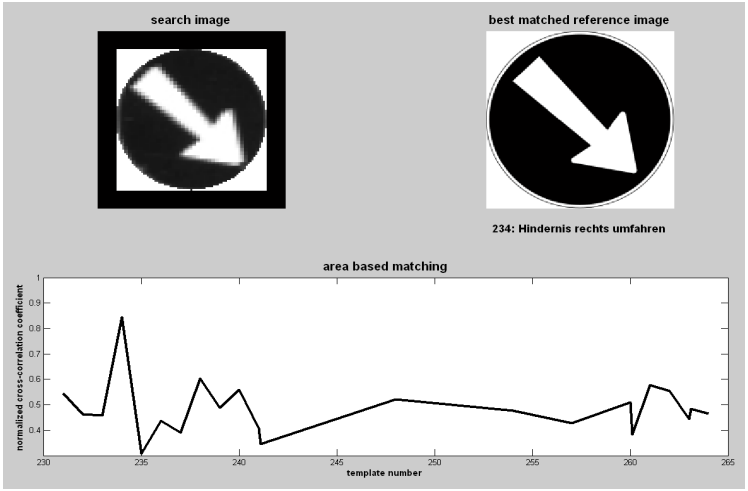
(Master Project Burkhard, 2009 und Master Thesis Cavegn, 2010)



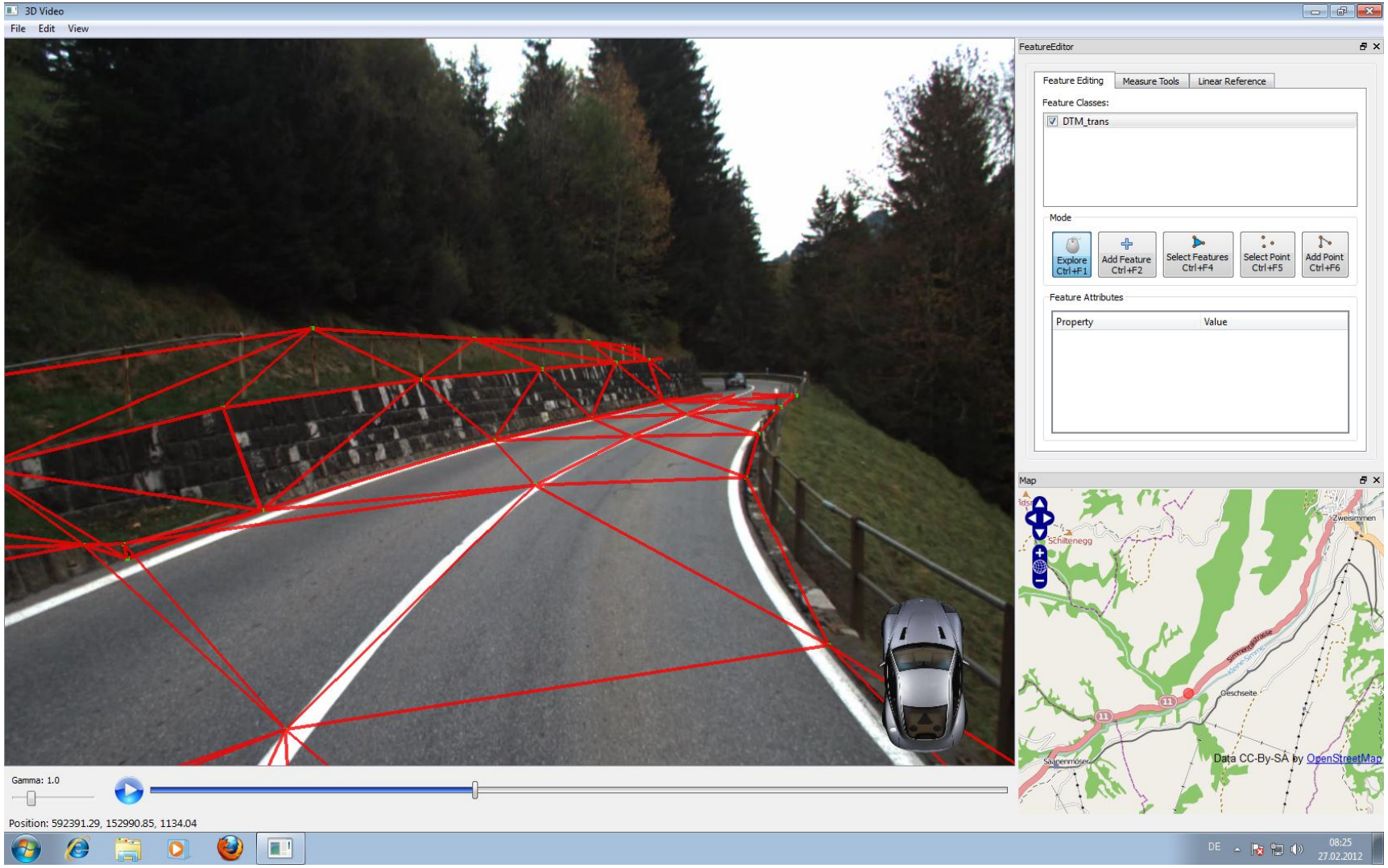


Automated Extraction and 3D Mapping of Road Signs

(Master Thesis Cavegn, 2010)

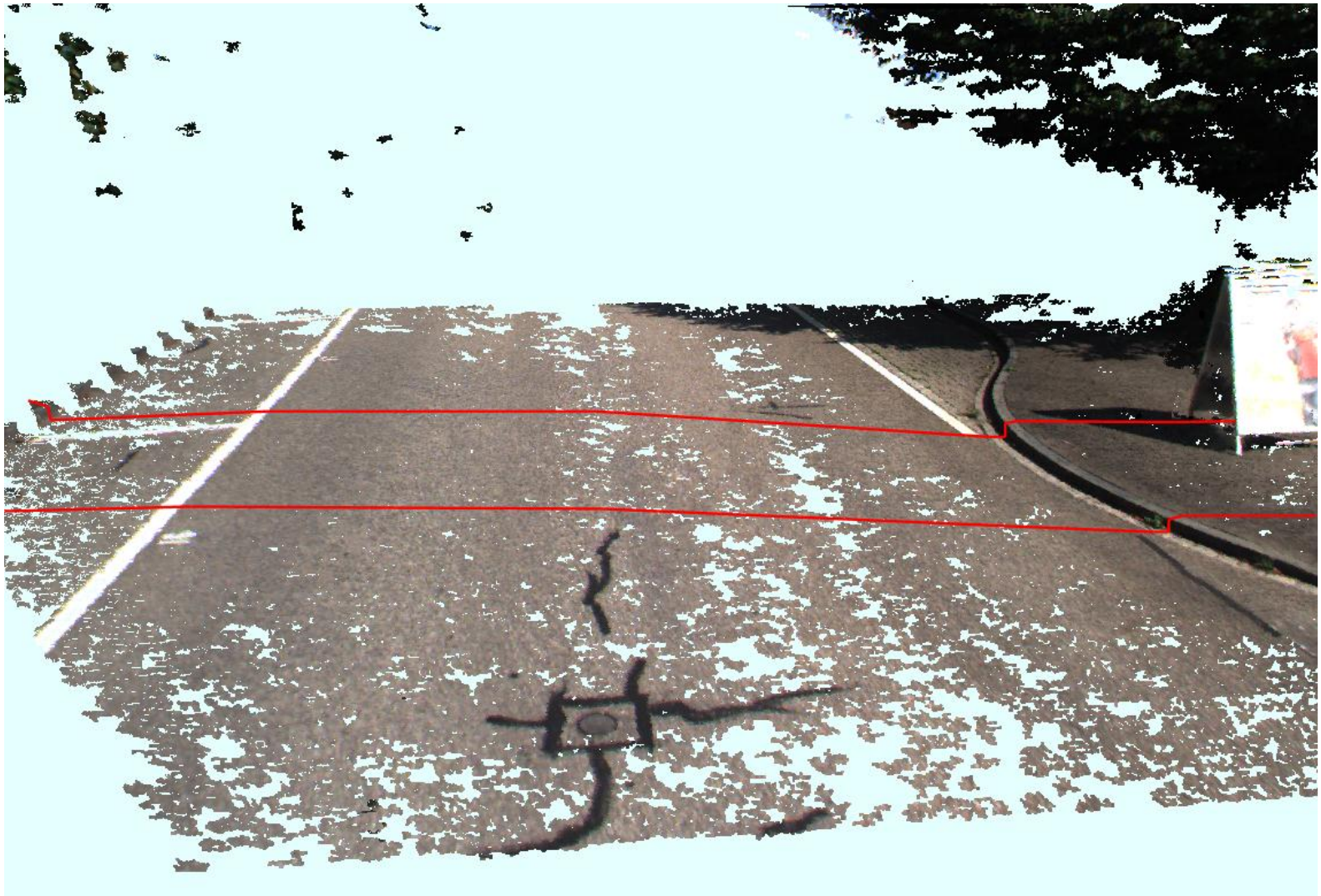


Applications – DTM Extraction, Editing and Superimposition / Verification

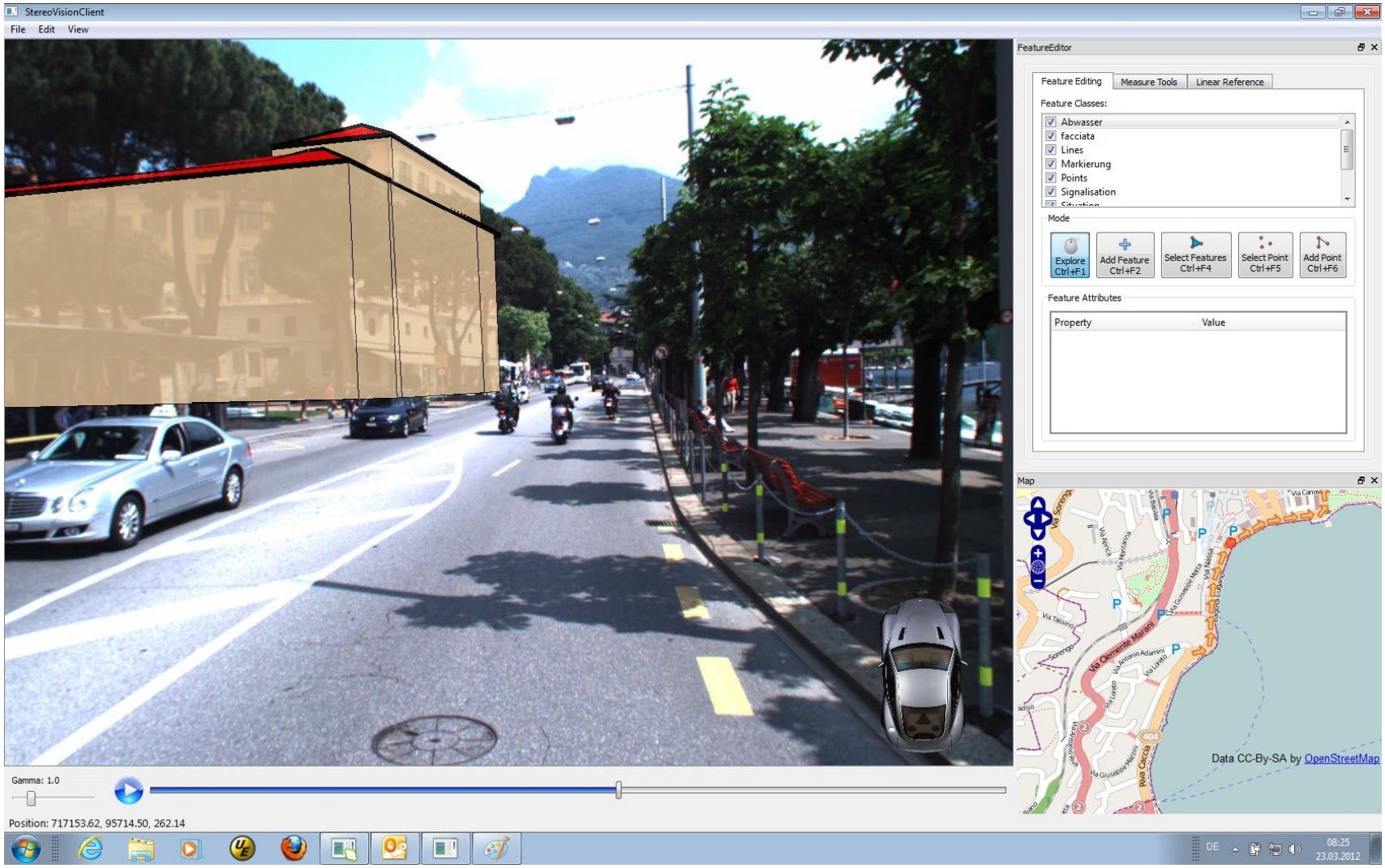


Applications – Highway Mapping for Noise Mitigation Planning

Applications – Road Profile Extraction



Applications – 3D Videos with 3D City Model Superimposition



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Results – 3D Point Coordinate Determination Accuracy

(MSc Project Cavegn, 2010; Bachelor Thesis Arnold, 2011)

Empirical Standard Deviations of Coordinate Differences

– stereovision mobile mapping vs. tachymetry (reference)

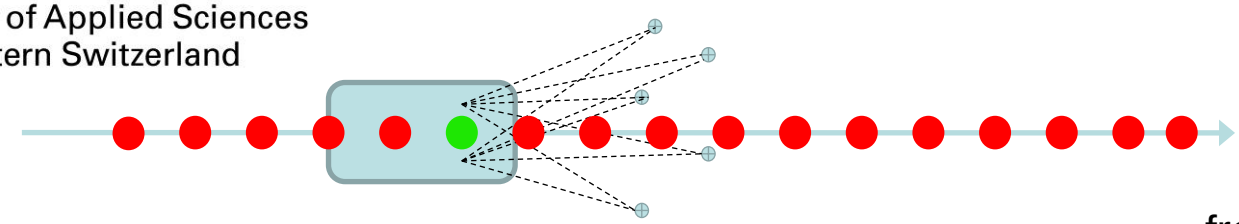
– approx. 50 check points

	Position	**Height**	**3D**
Absolute	3-4 cm	2 cm	4 cm

	3D Distance
Relative	< 1 cm

➢ **globally achievable accuracy**

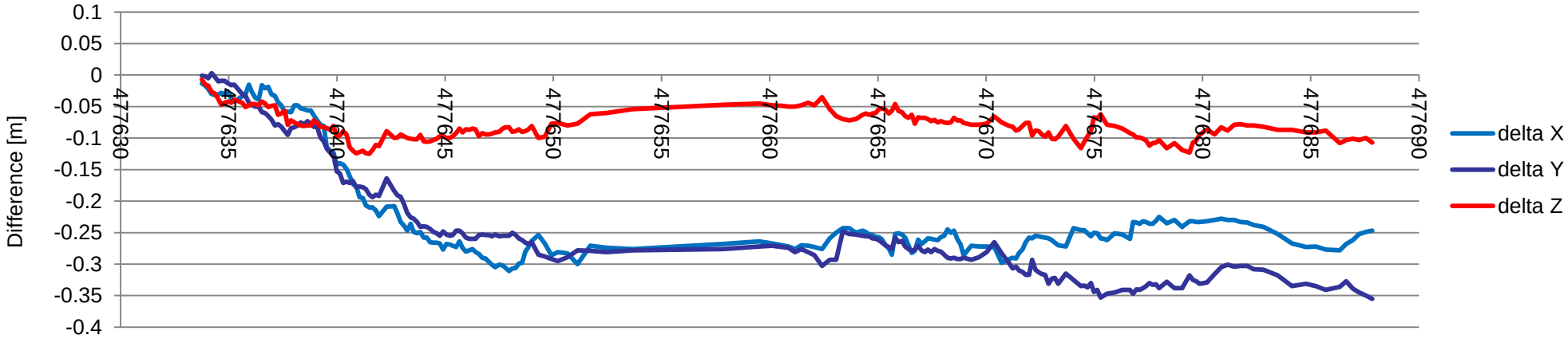
➢ **under good GNSS conditions**



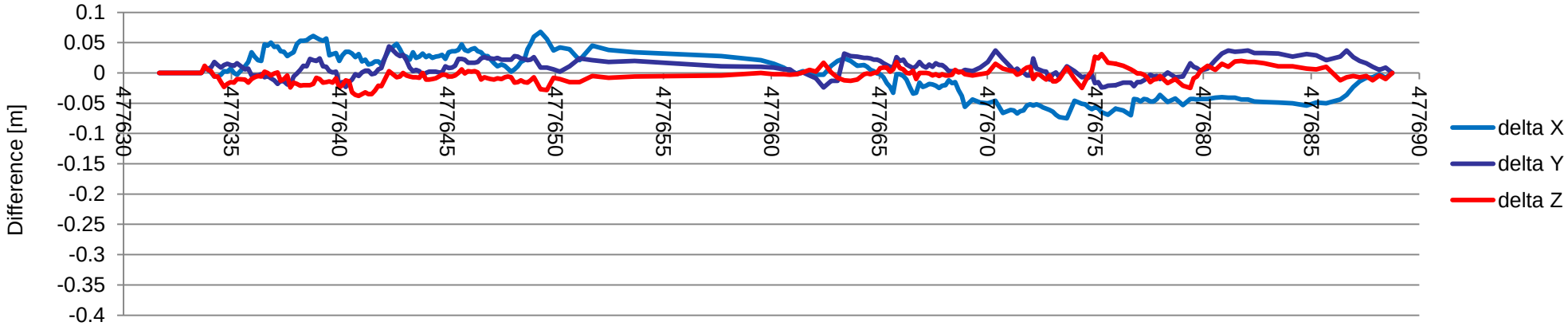
Results for single stereo base (0.9 m), forward looking, reference trajectory from bundle adjustment with 180 GCP & 440 TP

Results Integrated Georeferencing (MSc Project Huber, 2011)

Differences Original Trajectory vs. Reference Trajectory



Differences Integrated Georeferencing (3 GCP groups, every 26-28 sec.) vs. Ref. Traj.



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Strengths of 3D Vision-based Mobile Mapping

- very dense stereo image sequences => redundancy, accuracy …
- easy-to-use 3d environment / ideal for non-geospatial experts
- automatic 3d point measurements
- very powerful integrated georeferencing possibilities
- strong automatic object extraction capabilities
- possibility to use LiDAR as secondary sensor system

3D Vision Mobile Mapping & Cloud-based 3D Exploitation

- powerful, accurate and operational solution
- ideally supports the vision of "The Geoinformation Loop"
- and we are only at the beginning …

Thank your very much!

Questions ?

Contact

stephan.nebiker@fhnw.ch

or

www.inovitas.ch

Comparison of Mobile Mapping Technologies

Technology	Image-based			
	Mono	Panoramic	Stereo	Laser
Visualisation / inspection	✓	✓	✓	✓
Interpretation / object identification	✓	✓	✓	(✓)
Accurate measurements of distances, areas and heights	–	(✓)	✓	(✓)
3d coordinate determination	–	(✓)	✓	✓
DTM generation / profile extraction	–	–	(✓)	✓
Automatic information extraction (incl. coordinate determination)	–	–	✓	(✓)
Superimposition / verification of existing geodata	✓	✓	✓	(✓)
Visualisations incl. videos	✓	✓	✓	✓
Post-mission accuracy improvements (e.g. integration within local reference framework)	–	–	✓	✓