Section 6

Automated and semi-automated object extraction (mainly roads and buildings)

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Introduction

Object extraction (OBEX) from what images, sensor and platform?

-> aerial and satellite images increasingly converging

-> close-range images very different, more control possible (position of sensors, illumination, texturing etc.), easier to automate OBEX

Role of sensor type (e.g. digital camera, laser, radar etc.) decisive

-> here focus on camera data in the visible spectrum from spaceborne platforms

Introduction

Types of objects to be extracted from imagery

- **General types, „all“ objects, e.g. land use/cover classification**
- **Specific objects, e.g. buildings, roads, forests, coastlines etc.**

Here, focus on last case

Terminology

- **Various similar but different terms used: detection, classification, recognition, identification, localisation, extraction, reconstruction, attributation etc.**
- **Here, focus on 3D geometric description of an object which includes detection, localisation and coarse classification but NO specific classification or attributation**

Introduction

Automation

- **Currently not achieved for almost all objects, except simple well defined tasks**
- **Will probably never be achieved 100% for most objects. NO problem!**
- **Key issues are success rate, RELIABILITY, and less speed and costs.**
- **Certain amount of manual help and guidance can be very useful and should be used, espec. before the automated process starts**

Introduction

Key issues to achieve high success rate and reliability

- **Examine thoroughly the different types of object to be extracted and their context and other similar objects. Break down the problem to various cases (context) and start from the easiest one.**
- **Choose the proper sensors and data characteristics (e.g. image scale, overlap, spectral channels etc.)**
- **Use complimentary AND redundant data**
- **Combine good quality algorithms for the various subtasks (e.g. edge detection, matching etc.)**
- **Extract and combine various cues (indicators) for the object**
- **Use any a priori knowledge that exists (coarse data, rules, models, context etc.)**

Introduction

Recent tendencies in research on OBEX

- Object extraction techniques have become more holistic/general and mature, while system architectures make often use of semantic and Bayesian nets, while in pure image classification artificial neural networks (ANNs), evidence theory and fuzzy logic are frequently employed.

- 3D multi-image approaches become standard (although in practical work more than 2 images are rarely used); object-oriented, hierarchical and multiscale approaches are often used in both processing and object modelling.

- Early transition to 3D, as knowledge, models, rules etc. are often expressed in this space and their use in 2D space means information reduction (loss).

Introduction

Recent tendencies in research on OBEX

- Close interaction between 2D and 3D processes, since in 3D some information does not exist or is less complete.
- More attention to object modelling, with models being more generally applicable.
- Increased use of a priori knowledge, but still not often enough and without full exploitation.
- Increasing number and variety of sensor data (laser scanners, digital cameras and high-resolution satellites being the most important "newcomers") is used, while their combined use is also becoming more common, although full data integration is often still weak (e.g. laser data and imagery).

Introduction

Recent tendencies in research on OBEX

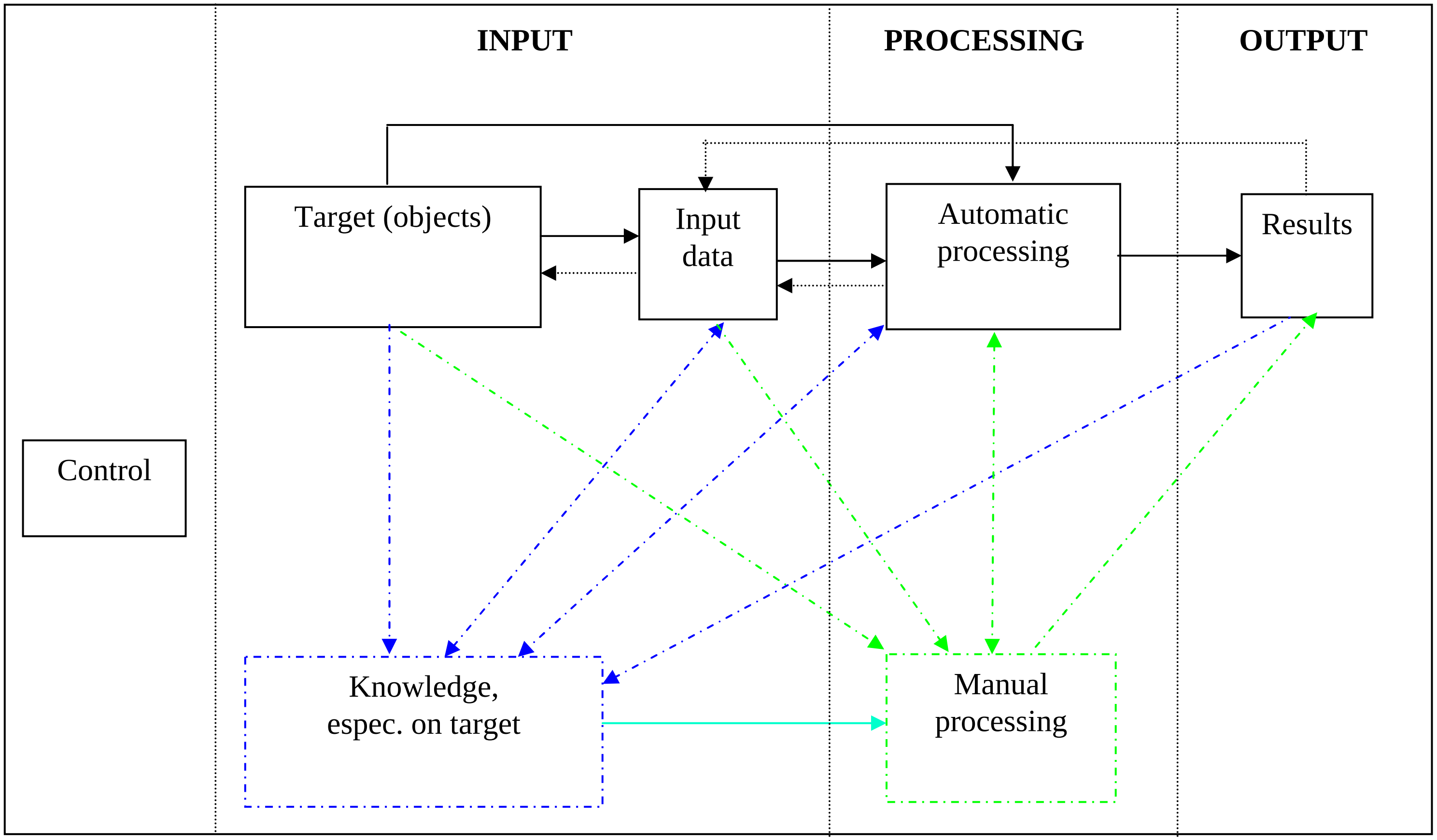
- An increased number of cues are derived from the above data and are combined; multispectral information in particular is increasingly used; correct cue combination and uncertainty propagation largely remains an unsolved problem (often used approaches include fuzzy logic, Bayesian/probabilistic approaches, Dempster-Shafer theory of evidence and belief functions and ad hoc methods).

- More use of context, especially in the form of the scene content and the relations between neighbouring objects.

- Small steps towards semi-automation and derivation of (quasi)operational systems (mainly for buildings and 3D city models).

- Reliability and completeness of automated results together with their automatic evaluation remain the major problems.

Introduction - Possible architectures of image analysis systems

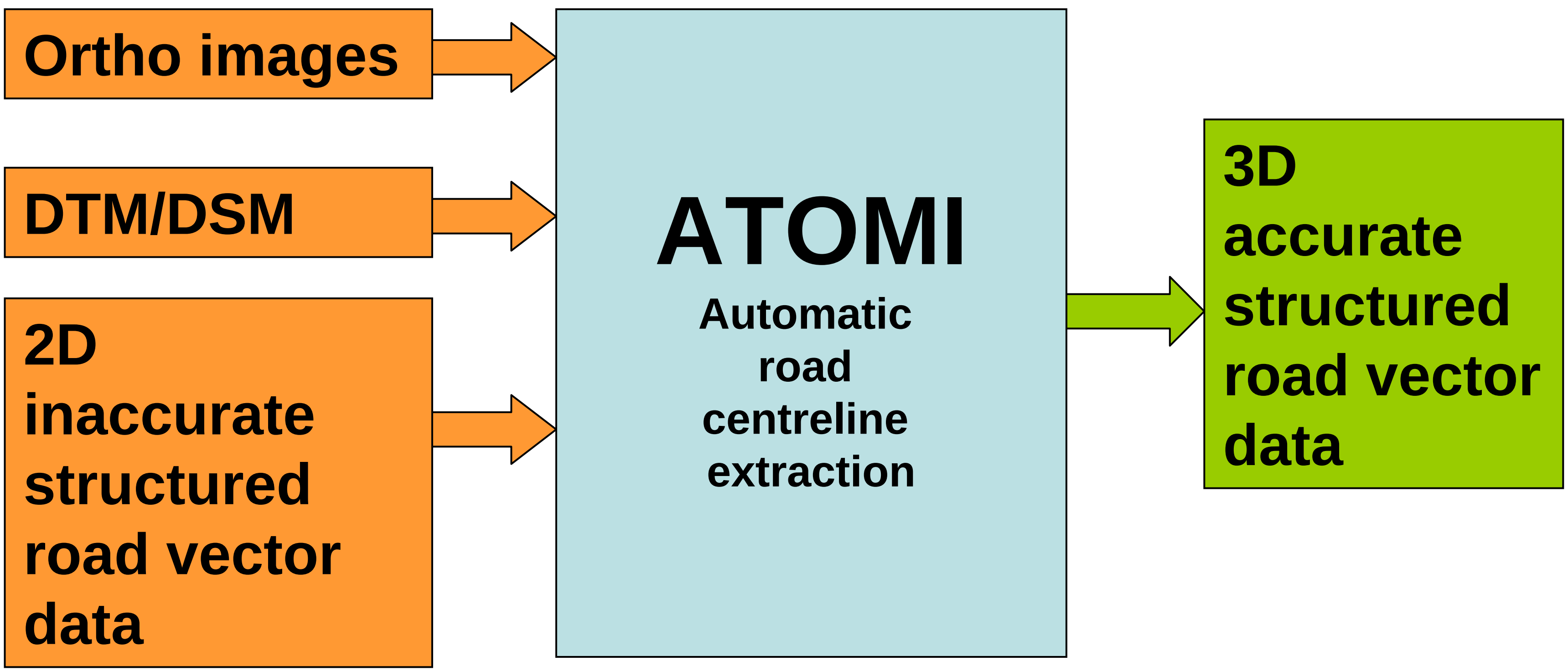


Architectures and components of image analysis systems, especially for object extraction. The doted lines (.....) indicate weak relations, usually in feedback loops. In doted blue and green, the components and relations regarding the knowledge and manual processing components, and in cyan color the relation between the last two components.

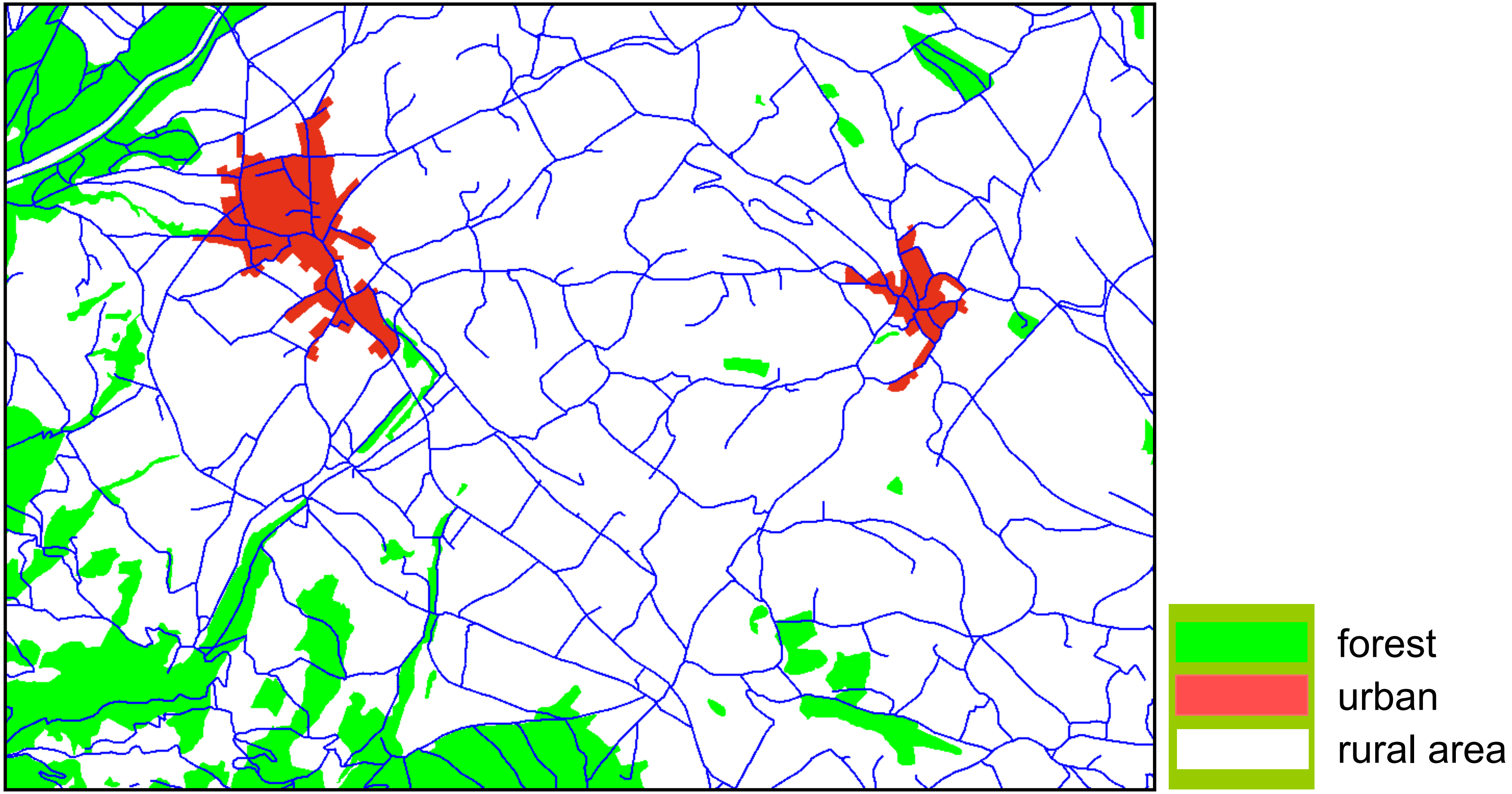
Road Extraction – Project ATOMI

- **A**utomated Reconstruction of **T**opographic **O**bjects from Aerial Images using **M**ap **I**nformation.
- It's a co-operation between swisstopo (Swiss Federal Office of Topography) and ETH Zurich, financed by swisstopo.
- ATOMI uses edge detection and existing knowledge and cues about road existence to detect road centrelines from orthophotos.
- ATOMI is used to remove cartographic generalisation and fit the geometry of roads to the real world to an accuracy of better than 1m in x, y and z
- ATOMI keeps the topology and attributes of the input vector map data set (VECTOR25)
- The result is a new accurate 3D road centreline data set without gaps, containing the topology and attributes of the input data as well as new weighted mean road width attributes

ATOMI input and output data



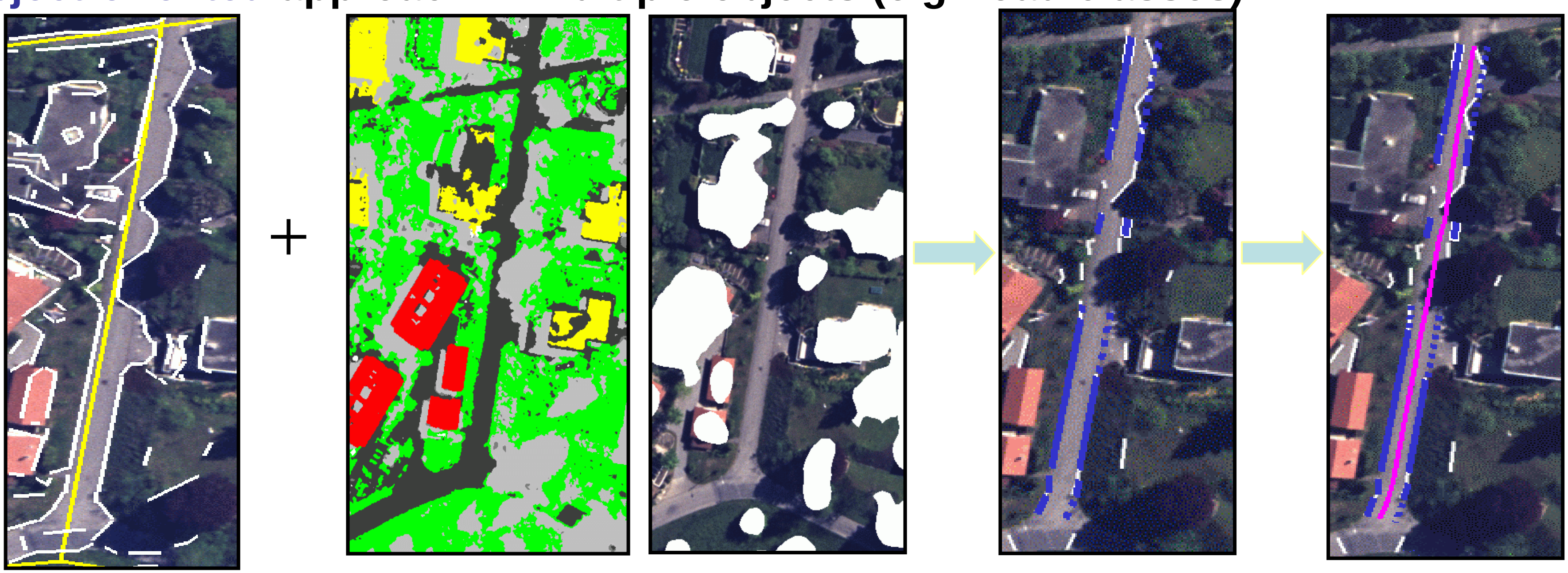
Classification of roads according to landcover



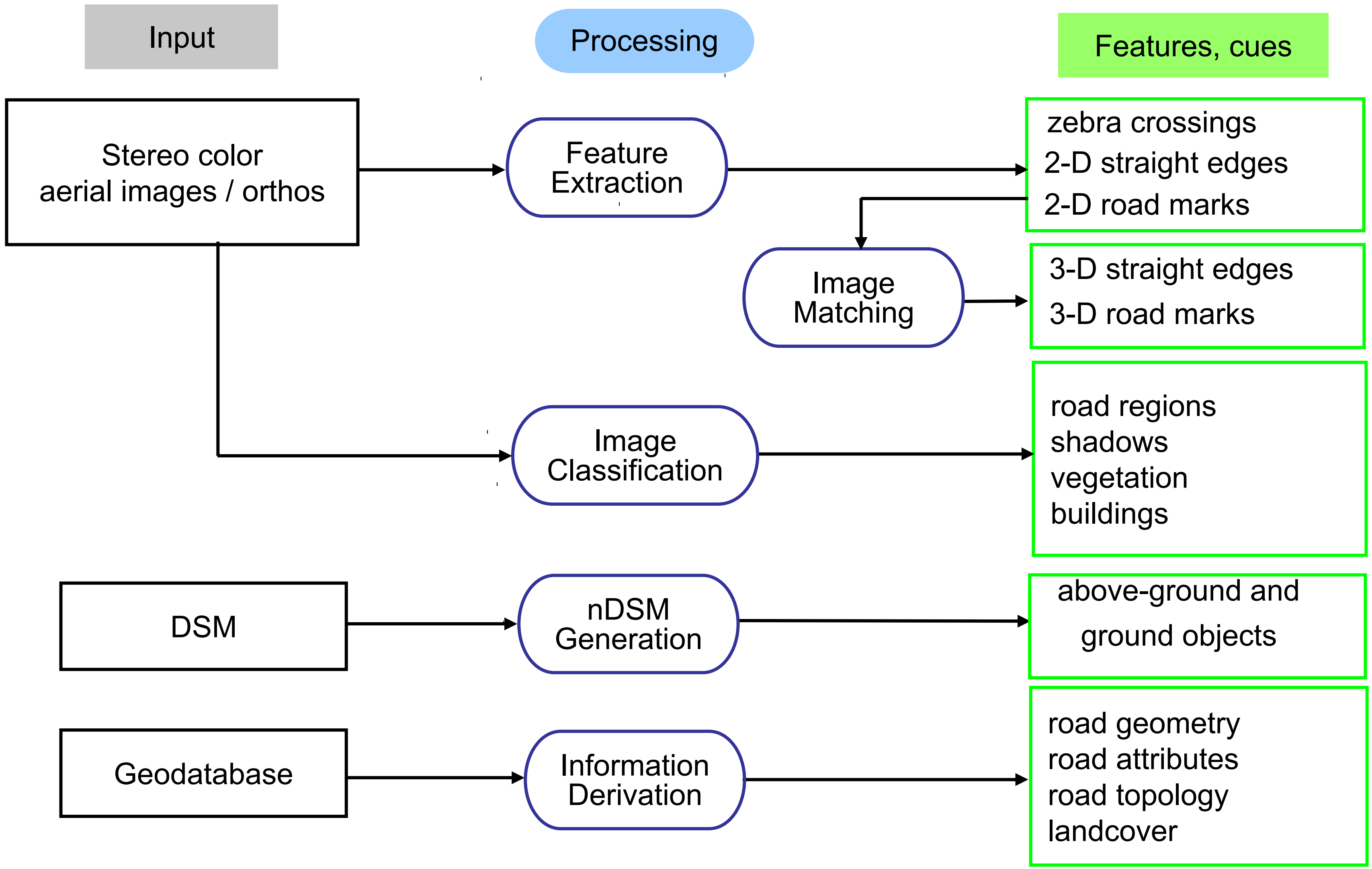
Current work only in rural areas

General Strategy

- Use of existing knowledge, rules and models
- Use and fusion of multiple cues about road existence
- Creation of redundancy through multiple cues to account for errors
- Early transition to object space, use of 2D and 3D interactions to bridge gaps and missing road parts
- Object-oriented approach in multiple objects (e.g. road classes)



Features, Cues and Algorithms



How ATOMI road extraction works

a. Straight edge extraction

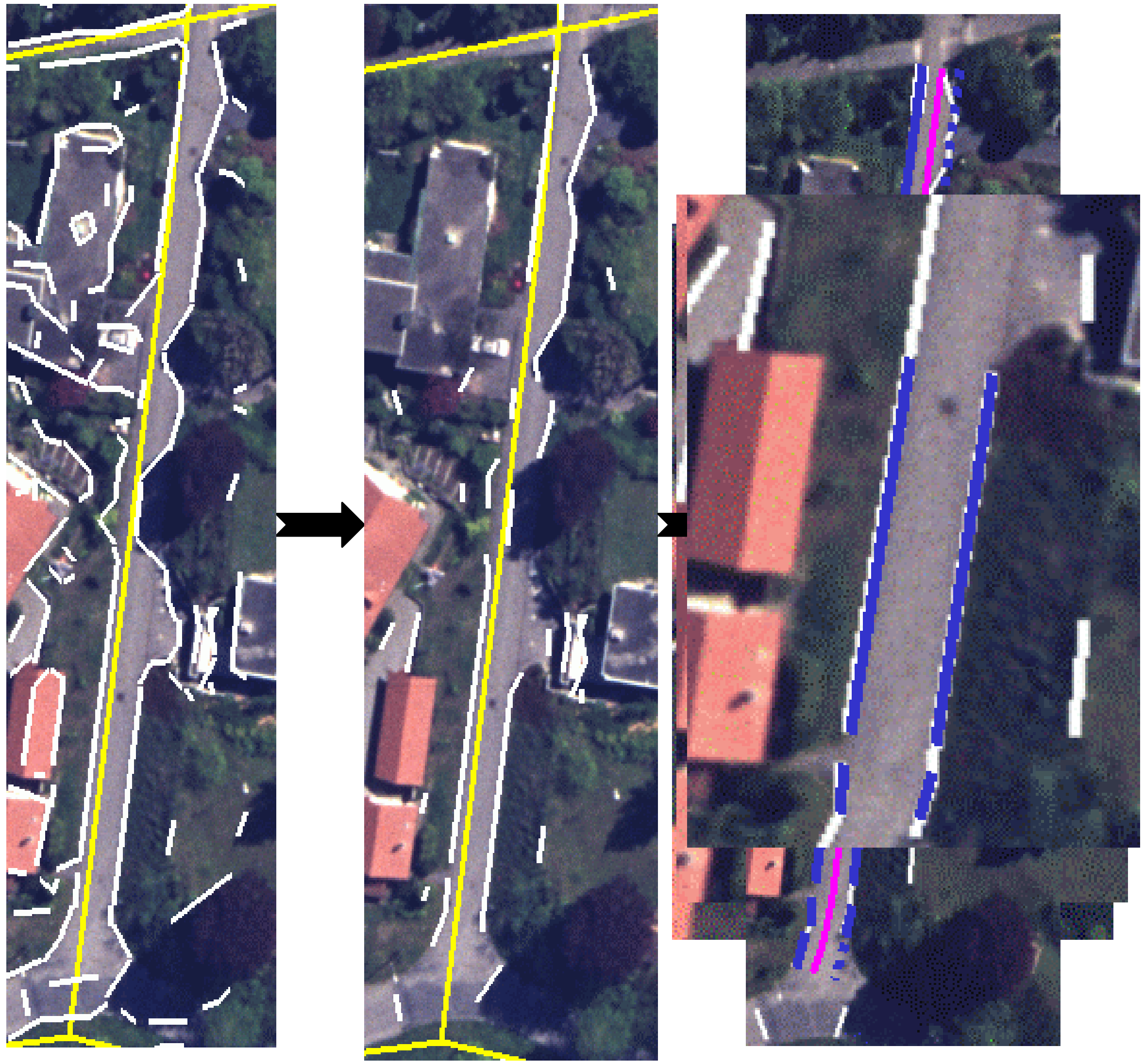
b. Removal of irrelevant edges

c. Detection of Parallel Road Sides

d. Evaluation of Missing Road Sides

e. Bridging Gaps

f. Linking Road Sides to Extract Roads



Test site in Switzerland

Geneva 7km²

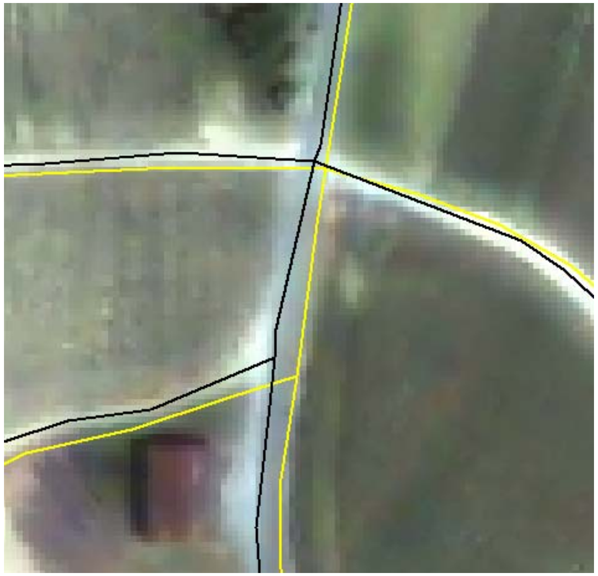
Aerial Film 50cm **(summer '98)**

IKONOS PSM 100cm **(May '01)**

Quickbird PSM 70cm **(July '03)**

Manually measured reference data from 50cm orthophotos

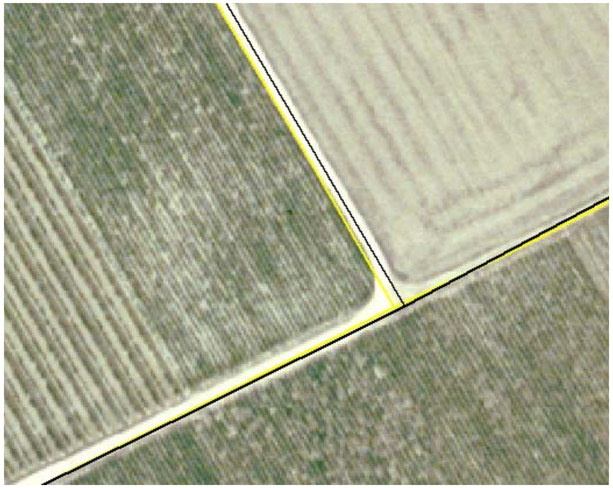
Results from Geneva (yellow VECTOR25, black result)

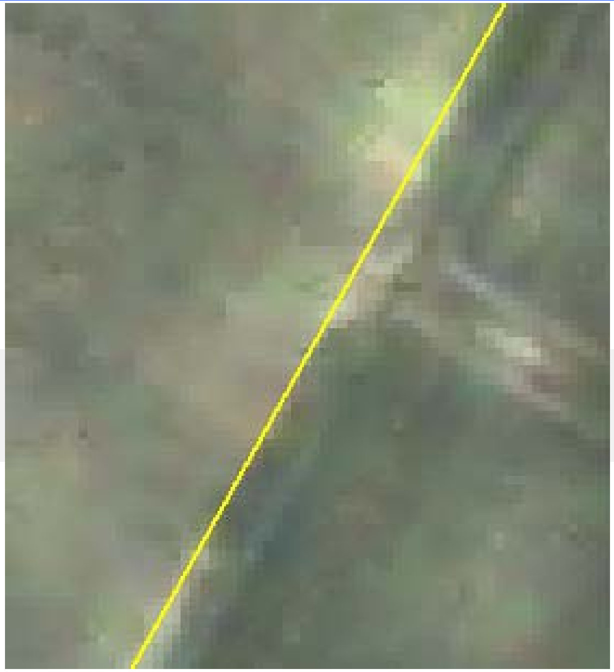



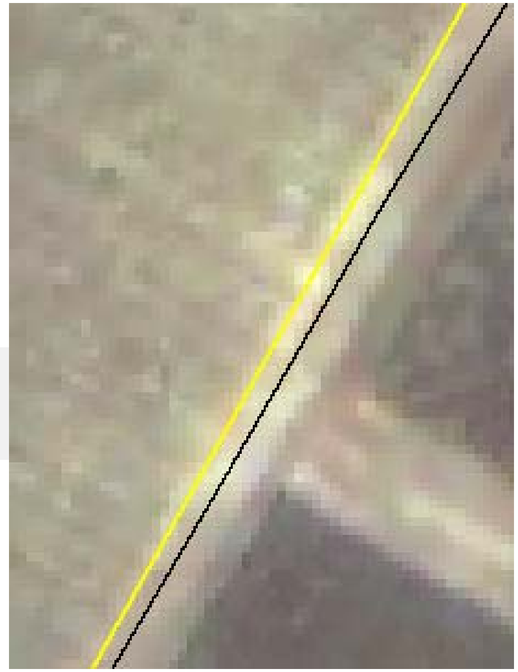

50cm Aerial Film

100cm IKONOS

70cm QUICKBIRD





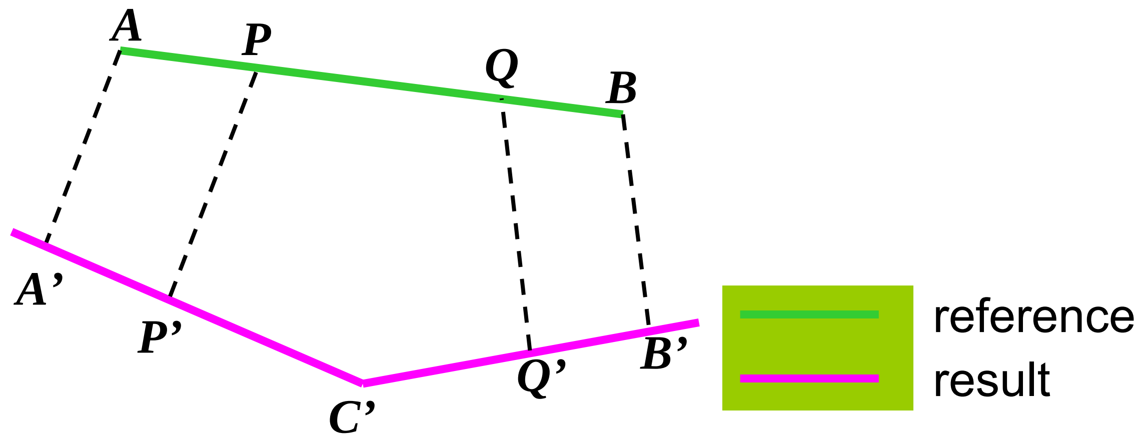


50cm Film

100cm IKONOS

70cm QUICKBIRD

Quality Evaluation



$$\text{completeness} = \frac{\text{length of matched reference}}{\text{length of reference}}$$

$$\text{correctness} = \frac{\text{length of matched extraction}}{\text{length of extraction}}$$

RMS: distances between the extracted roads and the reference data

Quality evaluation of the results of Geneva

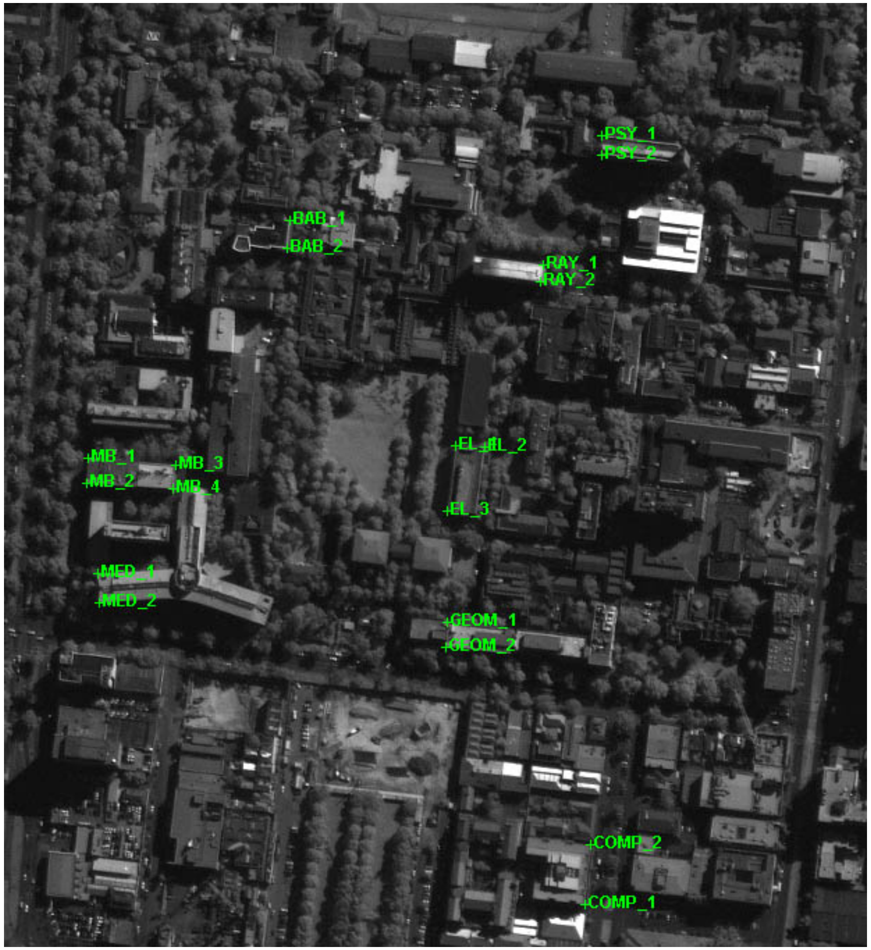
Quality measures		Aerial 50cm	IKONOS-PSM 100cm	Quickbird-PSM 70cm
Completeness		90.89%	54.22%	72.68%
Correctness		95.36%	81.22%	89.58%
Length of reference (km)		50.72	50.72	50.72
Length of extraction (km)		48.35	33.87	42.16
RMS error (m)	x	0.62	0.93	0.81
	y	0.56	0.82	0.75
Mean error (m)	x	0.07	-0.73	-0.44
	y	-0.05	0.34	0.50
Process time (s)		1510	992	924

Results from Geneva

- The system achieved good results with the 50cm aerial film imagery with 90% of rural roads extracted.
- The performance (mainly the completeness) of the satellite data was inferior to aerial imagery, especially the 1m IKONOS imagery
- In the satellite data, higher class (wider) roads were usually extracted, while most lower class (narrower) roads were not. This is because of ATOMI's algorithm requirement of min. 3 pixels road widths was not fulfilled.
- The smaller GSD of Quickbird made more roads visible and the road surface and road edges were clearer. But compared to aerial film the completeness was lower.
- With smaller GSD, correctness and accuracy do not deteriorate much, but completeness yes.
- Other road extraction methods and results with aerial and Ikonos images as part of EuroSDR working group on road extraction
- See paper Mayer et al. in coming ISPRS Com. III Symposium, Bonn, September 2006

Building Extraction, Ikonos, Melbourne

Roof corners



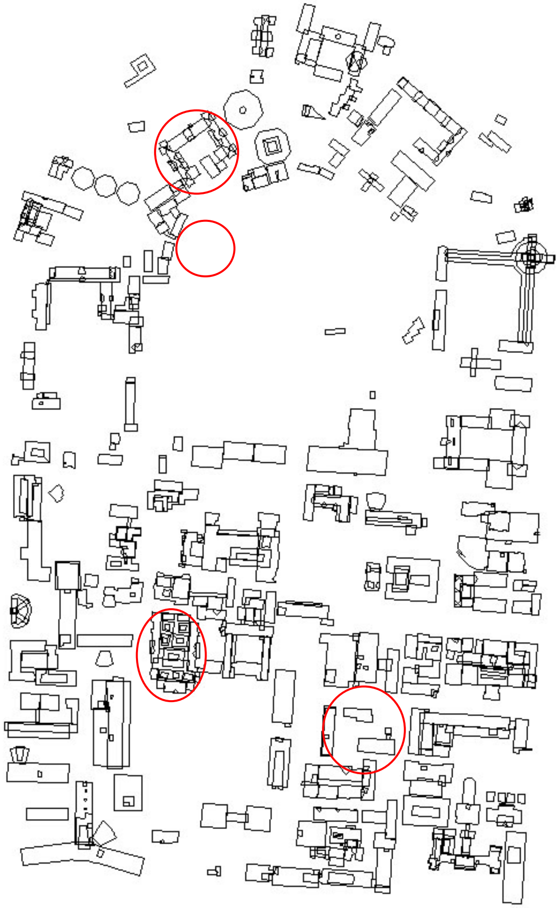
- **19 roof corners measured by GPS**
- **Measured in mono and stereo in all three images of Melbourne**

Results from stereo images and 6 GCPs (RMSE):

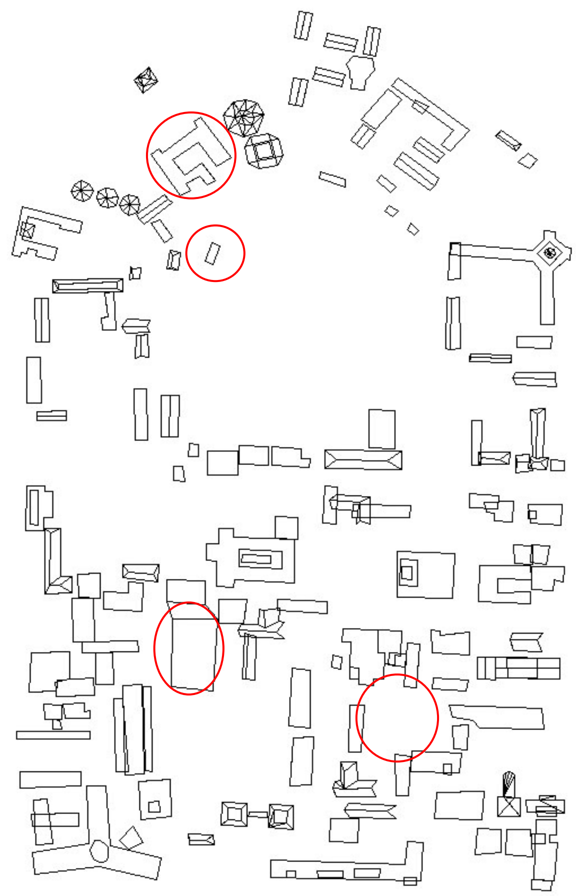
RPCs: XY = 0.7m
Z = 0.9m

Building Extraction

Aerial Photography (1:15,000)



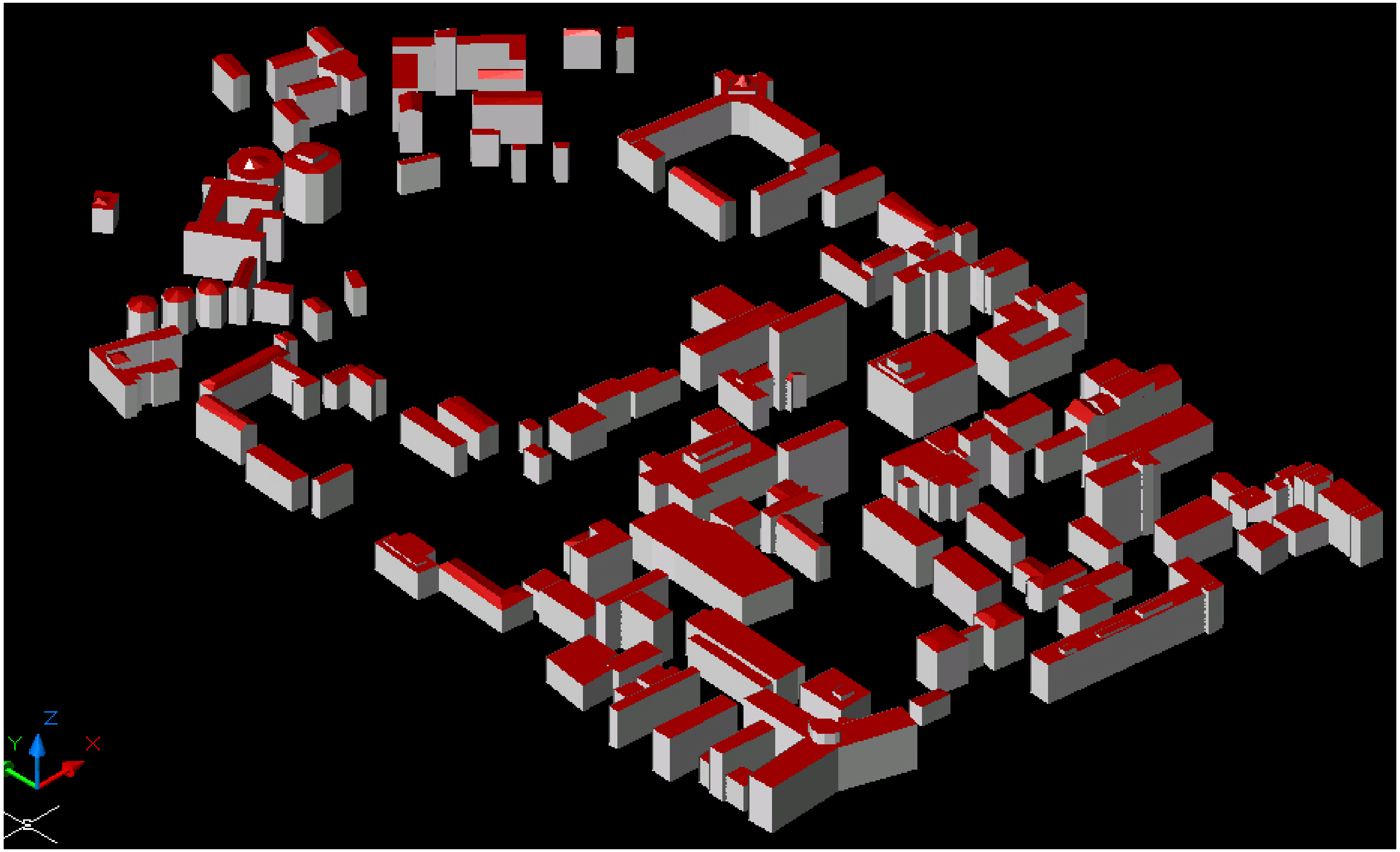
***Ikonos* 1m Pan Stereo**



- **Omission of 15% of buildings (small & large)**

Building Extraction

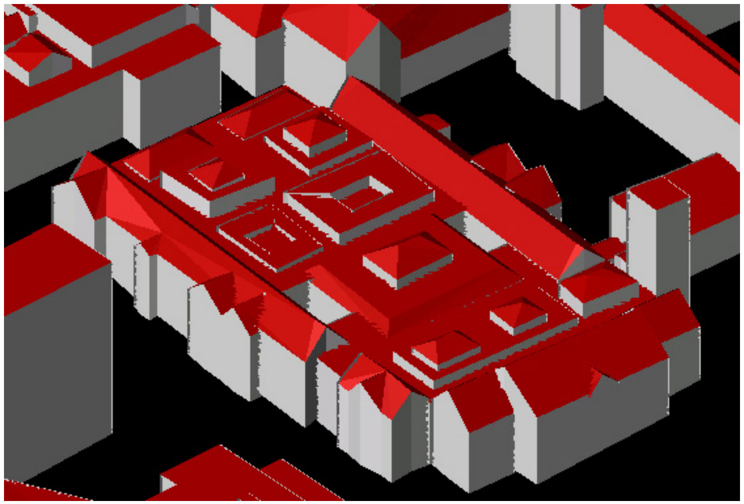
3D Model of University of Melbourne Campus from *Ikonos* 1m PAN Stereo

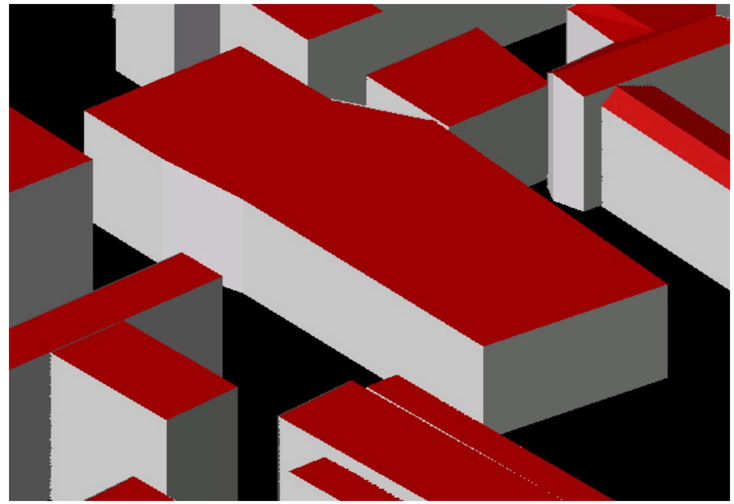


Produced with CyberCity Modeler

Building Extraction

Aerial Photography (1:15,000) | **Ikonos 1m Stereo Imagery**





Building Extraction

Aerial Photography (1:15,000)

Ikonos Stereo

Ikonos Nadir Pan-Sharp.

Conducive to building feature measurement

Building Extraction

Aerial Photography (1:15,000)

Ikonos Stereo

Ikonos Nadir Pan-Sharp.

Ikonos stereo of questionable value to building feature measurement in this case

Building Extraction

Ikonos Stereo

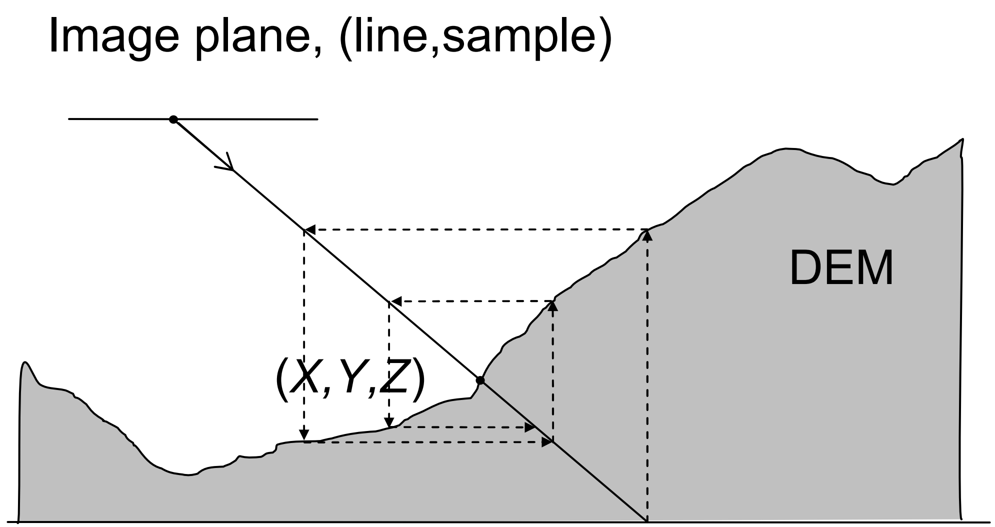
Ikonos Nadir Pan-Sharp.

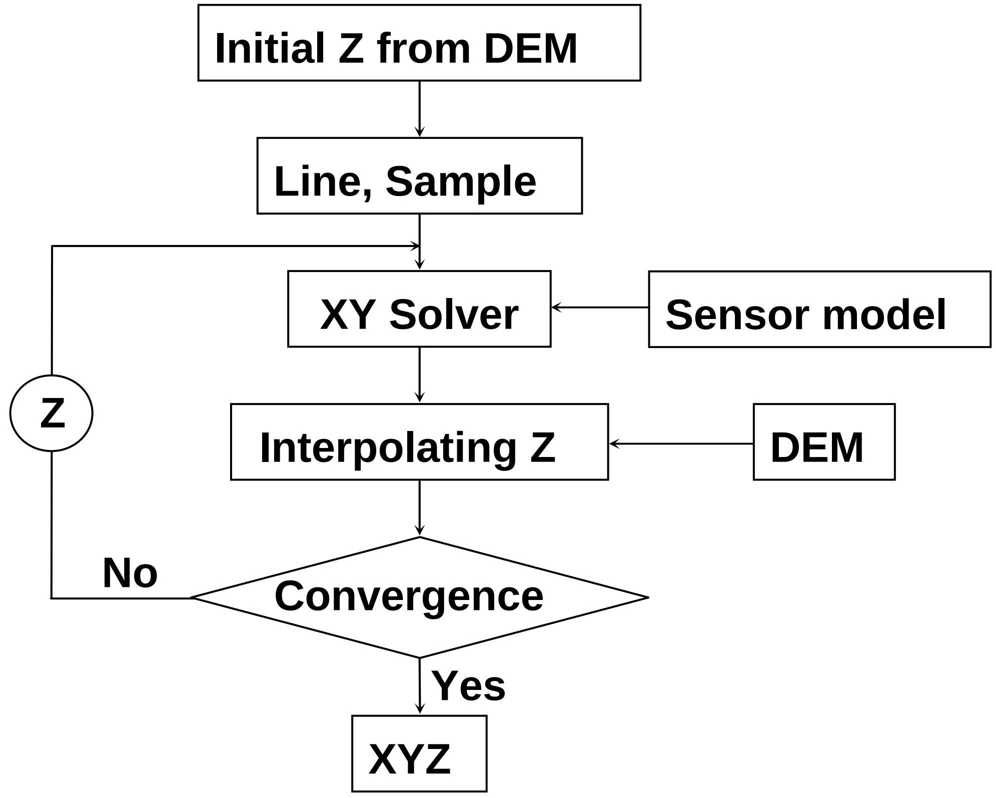
Aerial Photography (1:15,000)

Ikonos stereo of questionable value to building feature measurement in this case

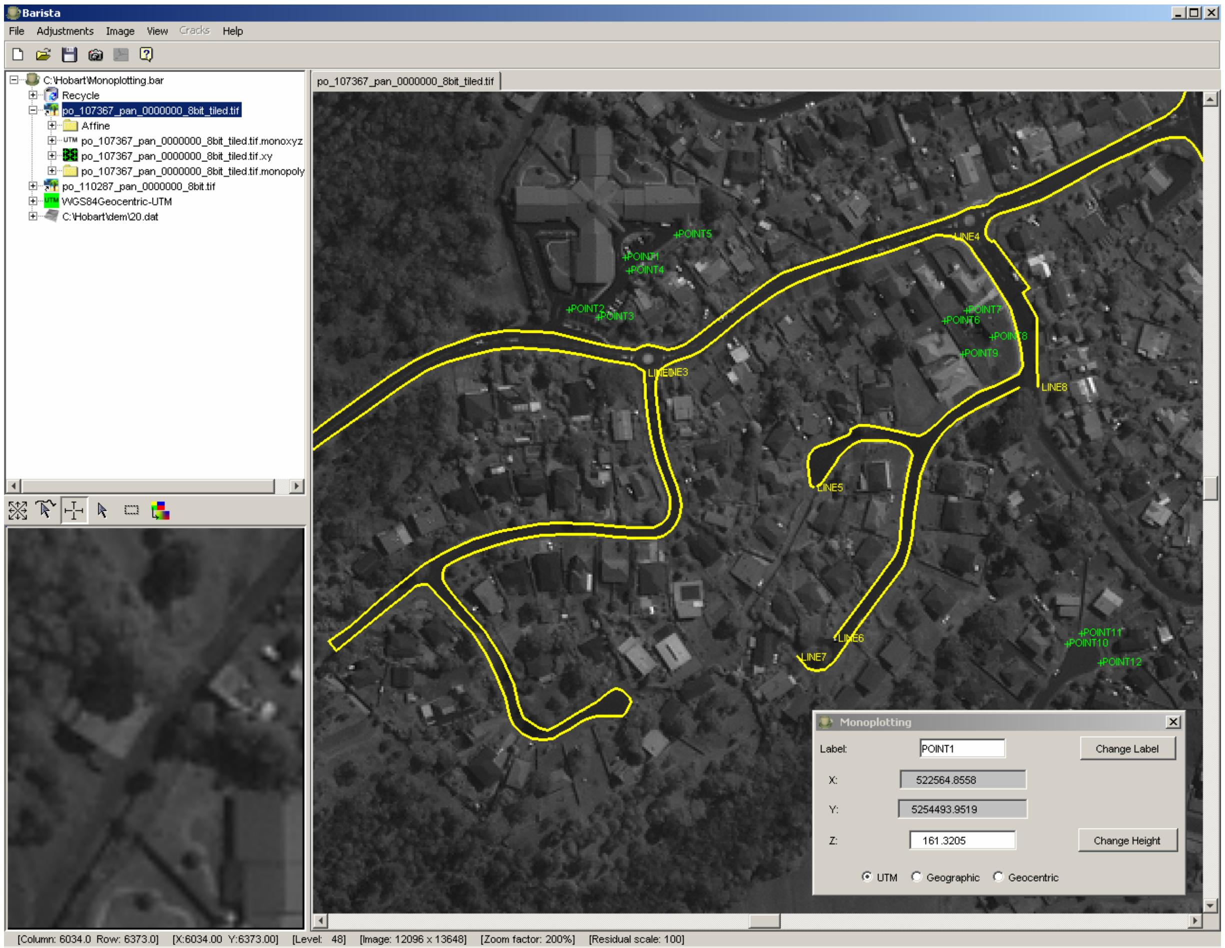
Monoplotting: 3D Information Extraction from Single Satellite Images

(implemented In Barista software, C. Fraser, Univ. of Melbourne)





3D mapping of points and linear features by monoplotting

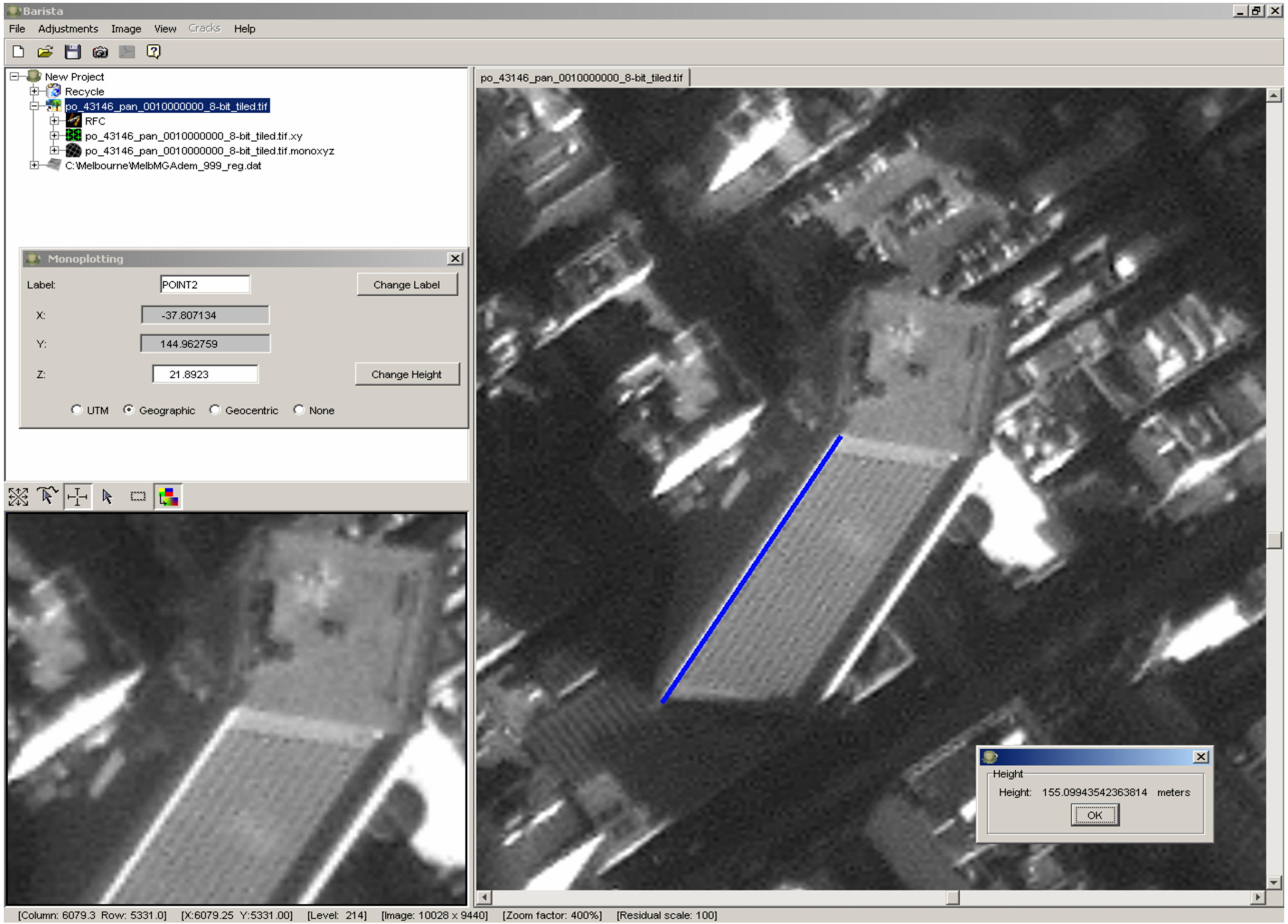


Measure single points in monoplotting mode using one image in combination with a DEM

Measure polylines/closed polyline
in monoplotting mode

→ 3D mapping of points and linear features

Height measurement of buildings by monoplotting



Measure groundpoint using one image in combination with a DEM

→ XYZ

Measure roofpoint

→ Z from line,sample and XY

→ Height ΔH

3D mapping of buildings from single IKONOS image

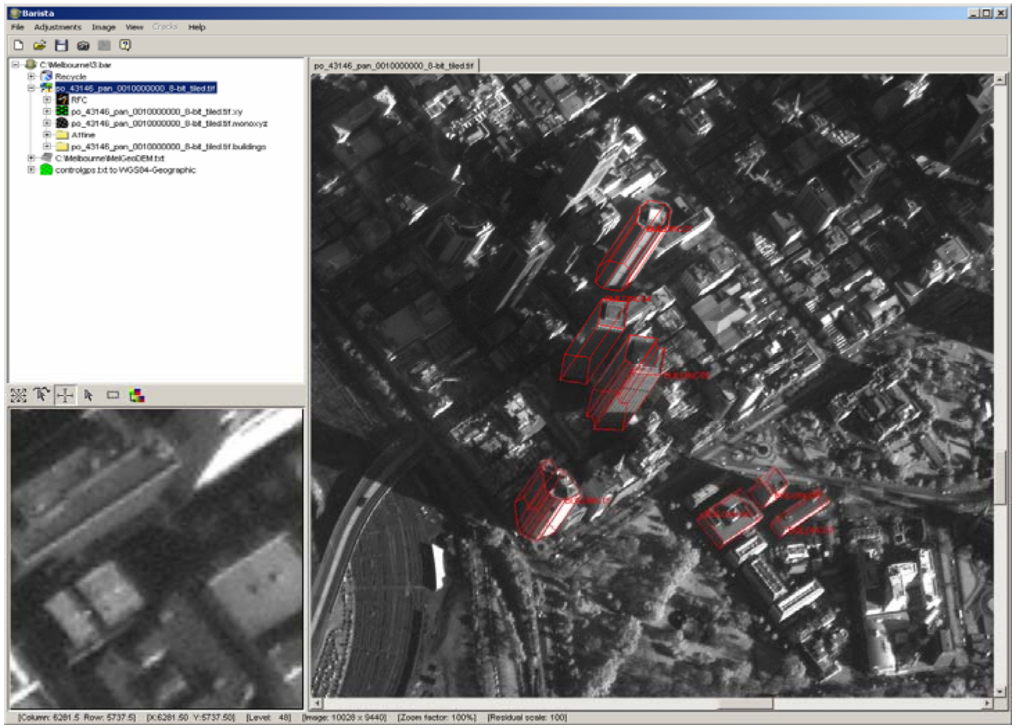
Measure first ground point of the building (by monoplotting)

Measure first roof point, assuming the same XY-position as ground point

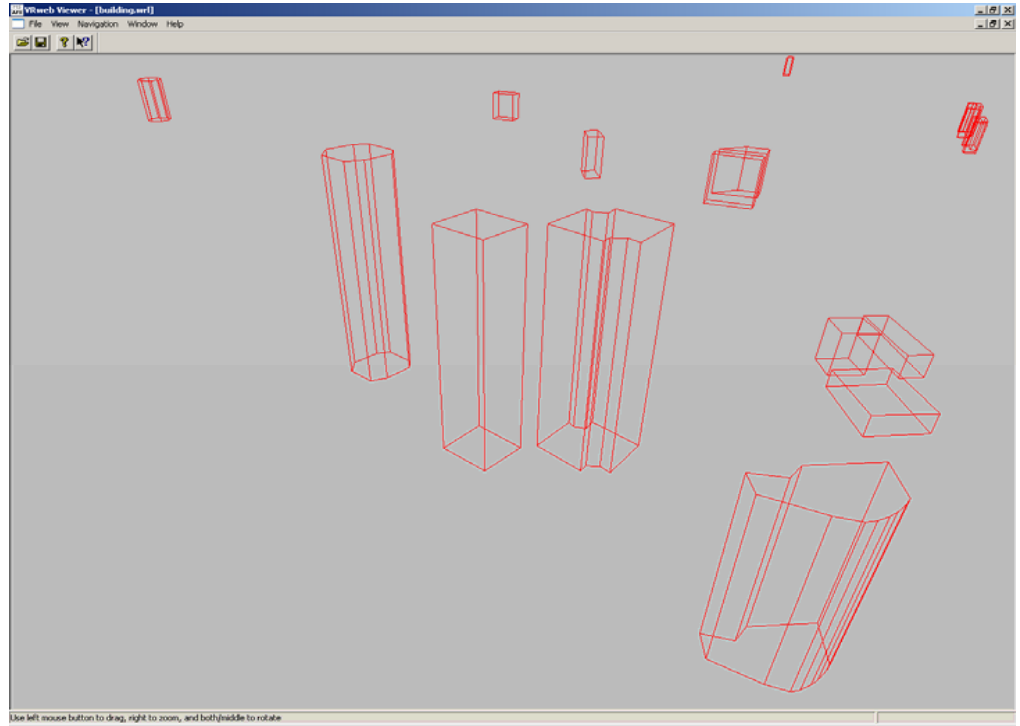
Force same height for other roof points and find XY
Get other ground points by keeping XY-position and interpolate height from underlying DEM

>>> 3D building reconstruction

Building reconstruction from single IKONOS image



Data collection with *Barista*



Export of buildings in VRML data

Quality assessment of results derived from IKONOS and Quickbird imagery

- GCPs and multi-image data used as reference
- Single image point positions and building heights were measured
- Bias-corrected RPCs and affine sensor model was used
- Measurements were performed in three IKONOS and two Quickbird images
- Regular monoplotting mainly depending on DEM quality
- Single-image height measurement affected significantly by off-nadir angle

Quality assessment of results derived from Ikonos and Quickbird

Accuracy of Building Height Determination

Quickbird

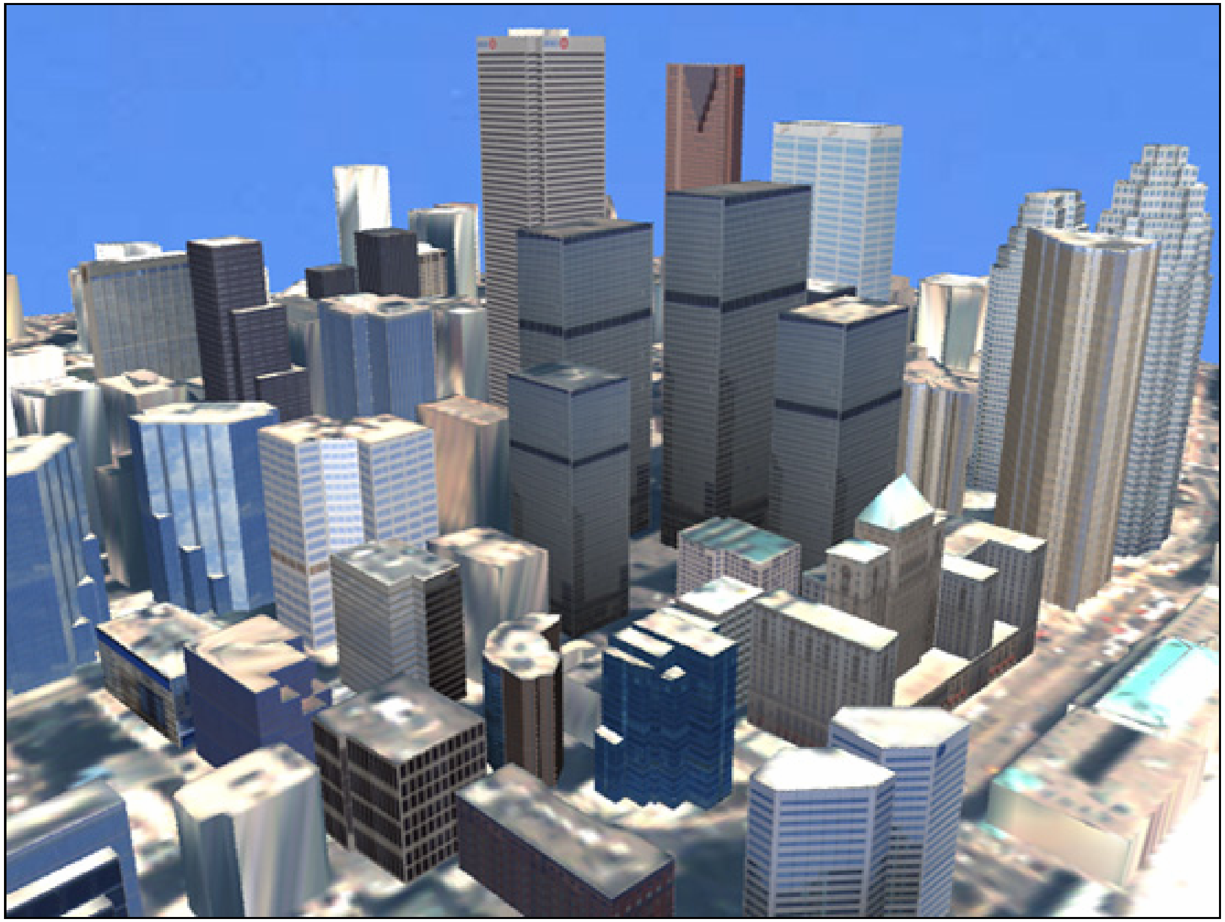
Sensor orientation model	Height RMS discrepancy at CPs (m) e = 60°	Height RMS discrepancy at CPs (m) e = 58°
RPCs	**1.01**	**1.03**
No. of CPs	***30***	***30***
3D-Affine	**1.34**	**1.33**
No. of CPs	***29***	***29***

Ikonos

Sensor orientation model	Height RMS discrepancy at CPs (m) e = 83°	e = 61°	e = 61°
RPCs	**6.59**	**1.08**	**1.31**
No. of CPs	***20***	***23***	***22***
3D-Affine	**3.05**	**0.69**	**0.76**
No. of CPs	***20***	***24***	***22***

Accuracy gets worse with higher elevation

3D site modeling (Silvereye from Geotango, CA)


3D building model of Downtown Toronto produced with SilverEye

Semi-automatic system, using one oriented image (monoplotting) and additional information (similar to Barista). Software for 3D site modeling and orthoimage generation. Not available any more (company bought by Microsoft)

3D city modeling (Cybercity AG)

Quickbird stereo images, Phoenix, USA

WEB-based 3D earth visualisation and Location Based Services

- Google Keyhole (Quickbird)
- Similar devepments by Microsoft (Orbimage)
- Geotango's (CA) Globeview (company bought by Microsoft)

- Use of satellite images, espec. HR
- DSM from usually unknown sources
- 3D building models
- Driving directions
- Location of various services