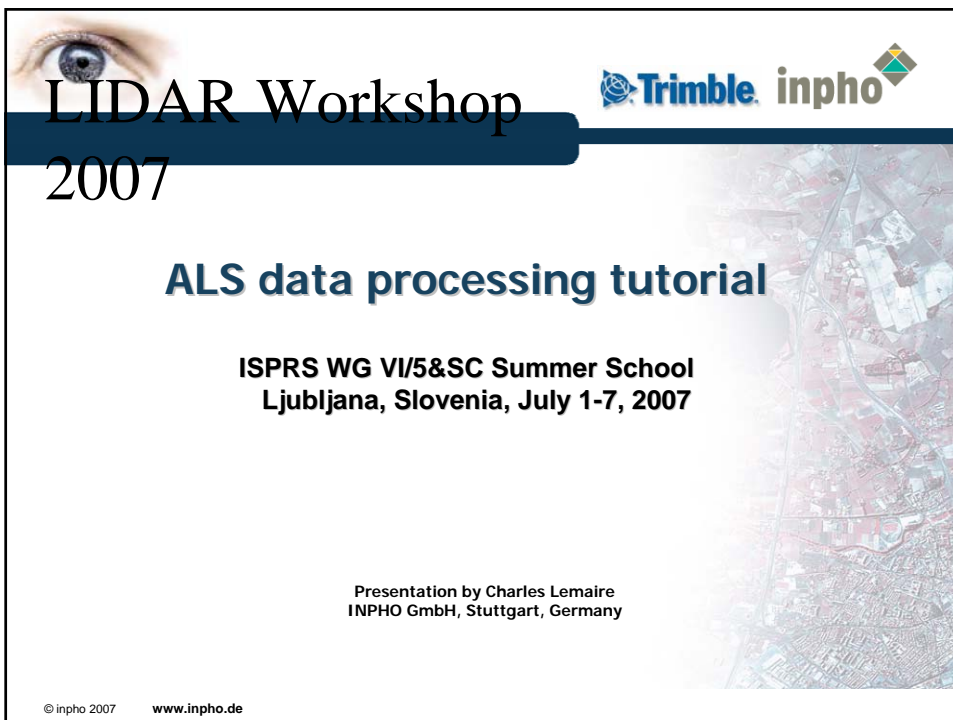




See the world with different eyes



LIDAR Workshop 2007



ALS data processing tutorial

ISPRS WG VI/5&SC Summer School
Ljubljana, Slovenia, July 1-7, 2007

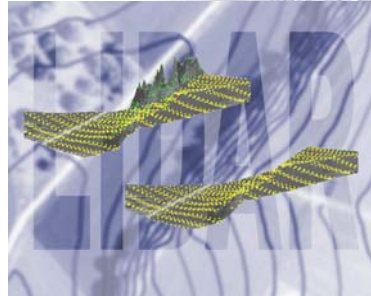
Presentation by Charles Lemaire
INPHO GmbH, Stuttgart, Germany

ALS data processing



Program tutorial

- About INPHO
- ALS post-processing workflow
- The INPHO solution SCOP++ Kernel & LIDAR
 - Break
- The INPHO solution DTMaster
- Practicals
- Questions, answers



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Inpho – Our Profile



Milestones

- **1980: Founded by Prof. Ackermann**
Active in aerial triangulation and DTM processing
- 1985: First developments on digital image matching
- 1991: GPS-supported aerial triangulation (PATB+SKIP)
- 1991: Automatic DTM generation (MATCH-T)
- 1996: Automatic aerial triangulation (MATCH-AT)
- 1999: Orthophoto mosaicking (OrthoVista)
- **2000: Full photogrammetric system supplier**
- 2000: Ortho-rectification (OrthoMaster)
- 2003: LIDAR filtering (SCOP++)
- 2004: New DTM editing (DTMaster)
- **2007: Inpho is a Trimble company**

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INPHO Group

Our world-wide network

- Headquarters in Stuttgart, Germany
 - inpho GmbH a Trimble company
- Sales and support office in Baton Rouge, LA; USA
 - inphoUSA Inc
- 25 + distribution partners worldwide



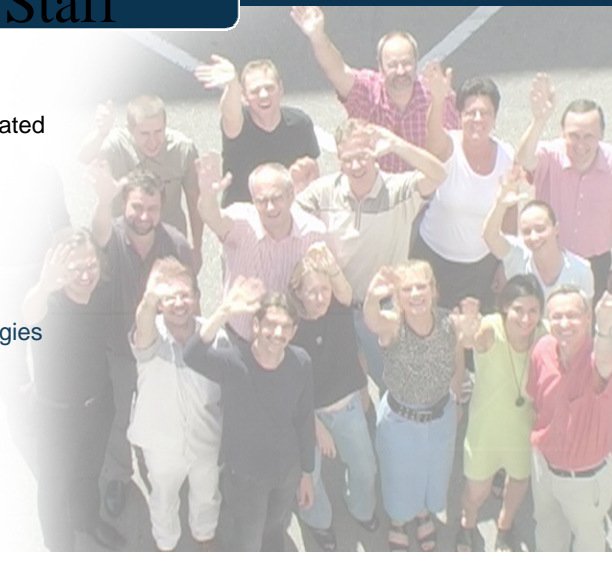
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Inpho – Our Staff

inpho's staff

- 24 experienced and dedicated software developers, photogrammetrists and surveying engineers
- Committed to offering
 - leading-edge technologies
 - customized solutions
 - personalized support



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Our Partners

Cooperative partnerships

- Dat/EM - Manufacturer of Summit Evolution (digital stereo plotter)
- Stellacore - Original developer of OrthoVista (orthophoto mosaicking)
- VEXCEL - Manufacturer of UltraScan 5000 (photo scanner)
- TU-WIEN - Co-developer of SCOP++ (DTM / LIDAR processing)

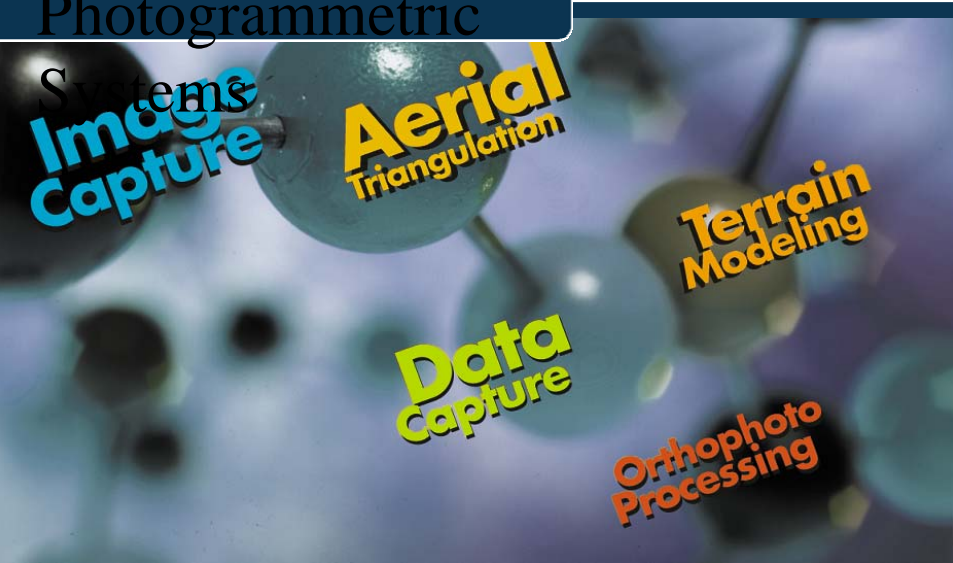


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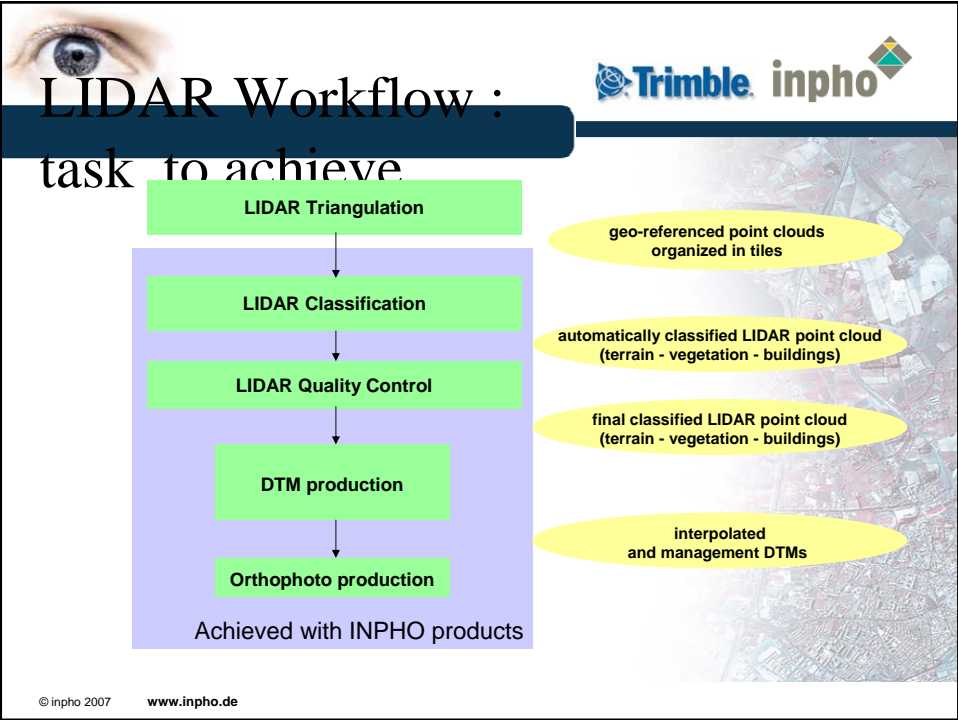
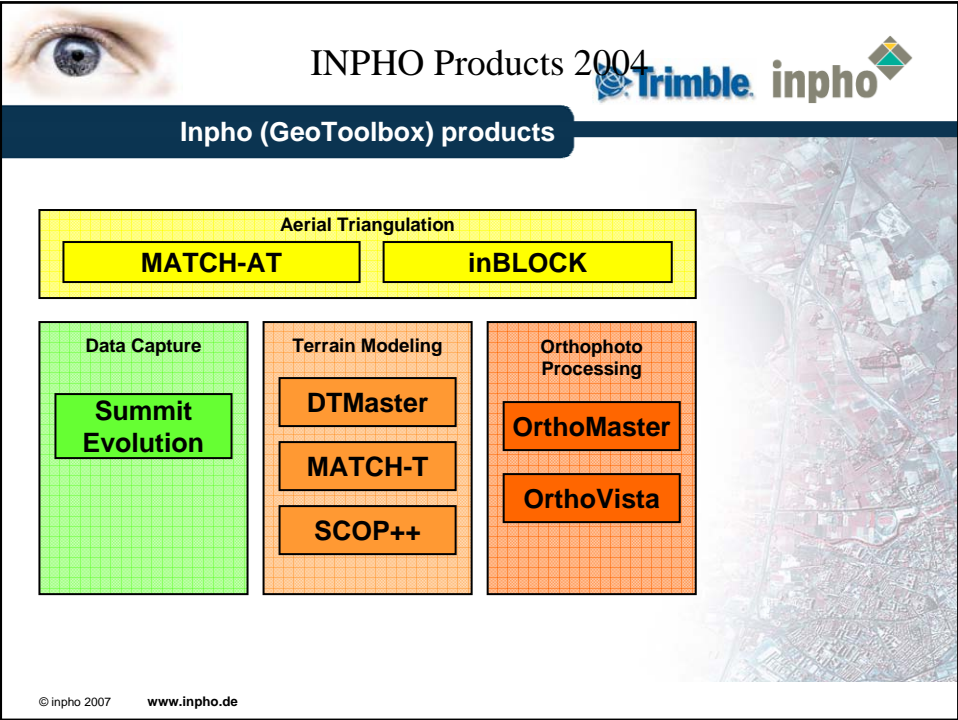





Complete Photogrammetric Systems

- Image Capture
- Aerial Triangulation
- Terrain Modeling
- Data Capture
- Orthophoto Processing



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Challenge in LIDAR data processing

- Biggest challenge in LIDAR data processing is **interactive quality control**
 - costly, labor intensive and time consuming task
 - Data management

- Workload can be reduced by using
 - 1) highly effective filter techniques delivering high quality
 - 2) optimized tools for quality control and editing of LIDAR data




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LIDAR Workflow : FAQ

FAQ about the productions

- When should a LIDAR triangulation be done?
 - When the INS platform and or LIDAR platform are not stable
 - When a better quality should be achieve than with direct georeferencing
- Is the classification possible without image information?
 - The automatic classification is possible
 - For quality control images are strongly recommended
- What kind of images should be use?
 - The best choice is to use oriented aerial image (XYZ, omega, phi, kappa)
 - The second choice is to use an orthoimage with a good resolution better than 50cm.
- Is LIDAR data editing complicate?
 - No, in many aspect it is easier to edit than photogrammetric data



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LIDAR Workflow :



FAQ

FAQ about the processing time

- How long does the reading of 10 Million points take?
 - About 10 seconds
- What is the most effective size for the tiles?
 - Between 1 km² and 4 km²
- How long does the editing of 1 km² take?
 - Between 5 min and 1 hour
- How long does the automatic filtering of 1 km² with SCOP++ take?
 - For a 1 m Resolution about 5 minutes
- How long does the interpolation of 1 km² with SCOP++ take?
 - About 1 min



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LIDAR Workflow :

FAQ

FAQ about the data

- How many points for 1 km²?
 - Between 1 and 16 million
- What is the best format for LIDAR Data?
 - LAS is at the moment the best choice
- Are breaklines obsolete?
 - No, because points are only 1D object
- Can true orthophotos be produced with Lidar data?
 - Not with a wide angle camera
 - With a narrow angle camera there are still some artifacts



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LIDAR BOX



INPHO's solution for LIDAR processing is **LIDAR Box software bundle** covering the complete workflow of LIDAR based DTM generation

- **SCOP++ LIDAR**

- fast & fully automatic filtering process
- classification of point clouds into
 - terrain/ground points
 - building points
 - off-terrain points
- consideration of break lines, if available, for improving DTM quality

- **DTMaster (Stereo)**

- developed for quality assurance of DTM data
- combines LIDAR with photogrammetry
 - stereoscopic measurement for absolute quality control
 - acquisition of breaklines for improving the quality of the DTM

LIDAR Box

DTMaster

SCOP++

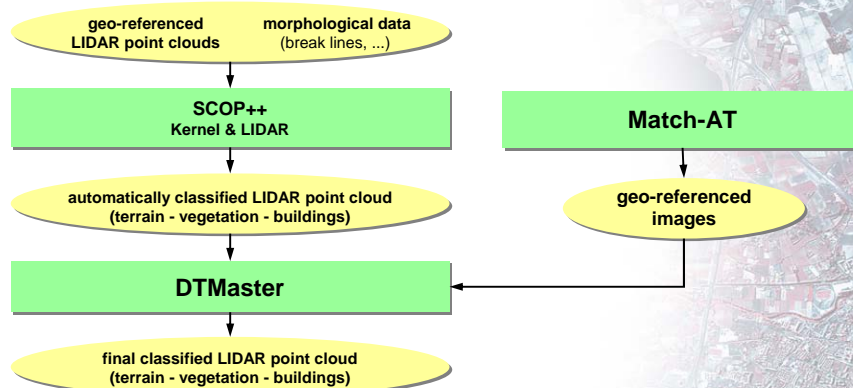
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LIDAR Box




Workflow : SCOP++


LIDAR



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SCOP++ LIDAR



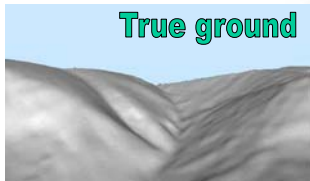
SCOP++ LIDAR - highly effective LIDAR Filtering


- Parameter setup: Point density, a-priori accuracy, more or less rigid filter
- **STAGE 1:** Classification of artificial objects (buildings)
- **STAGE 2:** Hierarchical robust filter process using point cloud pyramids
 - 1. Approximation of surface
 - 2. Weighted and robust surface interpolation
 - 3. Elimination of gross errors
 - 4. Classification of points into classes (terrain, off-terrain, building)

Raw data




True ground






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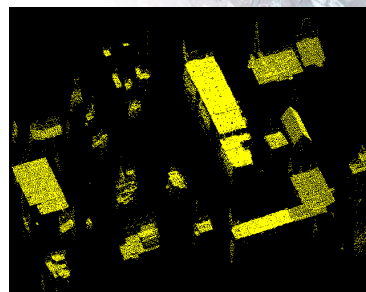
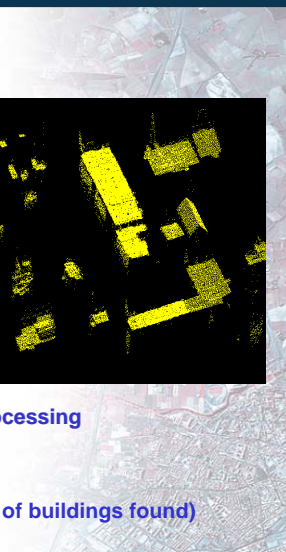
SCOP++ LIDAR



Workflow

STAGE 1: Classification/filtering of buildings

- Edge detection**
 - Point cloud is tiled into small raster cells
 - Computation of gradient of each raster cell
 - Detection of cells with steep gradients
- Region growing to detect area of each object**
 - Detects objects completely circumscribed by steep gradients, i.e. buildings
 - Inner courtyards are detected
- Points belonging to buildings are excluded from further processing**
 - Using first and last impulse data will improve quality
 - Works fast and is very reliable (~1 Mio pts/min; ca. 95% of buildings found)

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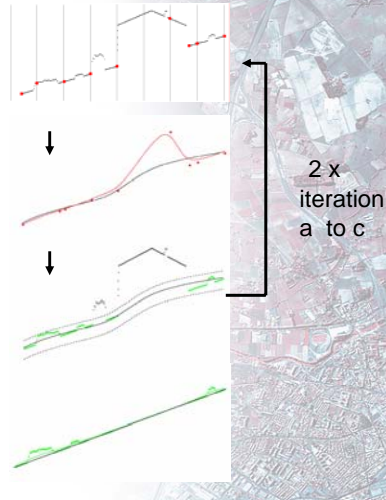
SCOP++ LIDAR



Workflow

STAGE 2: Hierarchic robust filtering

- Generation of a low resolution data pyramid using the original data (xyz-coordinates of the lowest points in a grid)
- Computation of a low resolution DTM using robust interpolation along with blunder detection
- Elimination of LIDAR points outside a predefined tolerance band (here +/- 1 m)
- Computation of a DTM with full resolution using robust interpolation along with blunder detection



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SCOP++ LIDAR

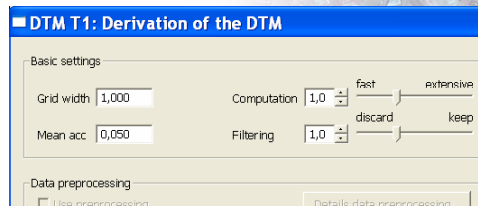


Setup

LIDAR filtering workflow

A. Basic settings

- Grid width :**
e.g. 1m for LIDAR Data with 1 point / sqm
- Mean Accuracy:**
e.g. 0.050 m; depends on the flying height and surface type
- Filtering factor:**
controls the weight function and tolerances
- (Computation time: less significant; default value recommended)**



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SCOP++ LIDAR - Setup

LIDAR filtering workflow

B. Defining filter strategy

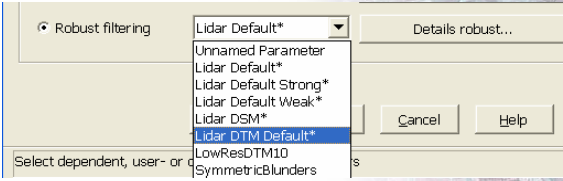
Several predefined, effective strategies are available:

For classifying points

- Lidar Default : → three output files : ground points, off-terrain points, building points
- Lidar Default Strong: → more points classified as off-terrain points
- Lidar Default Weak : → more points classified as terrain points

For computing DTM or DSM

- Lidar DSM : → result is digital surface model (DSM)
- Lidar DTM Default: → result is digital terrain model (DTM)



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SCOP++ LIDAR - Setup

LIDAR filtering workflow

C. Defining export in LAS format

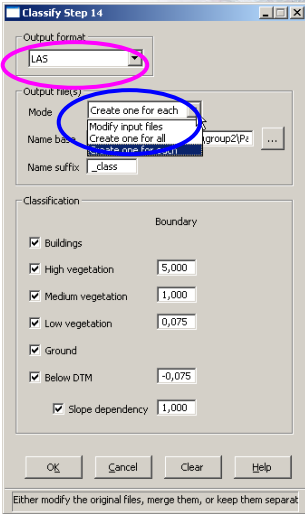
Soon upcoming functionality for

- classifying
- exporting


the filtered point clouds

Four new classes :


- high vegetation
- mean vegetation
- low vegetation
- below DTM



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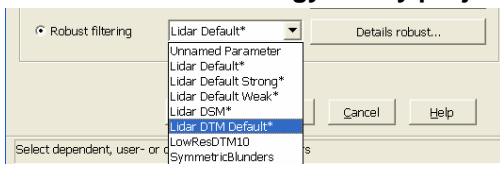


SCOP++ LIDAR




parameter tuning

What is the best strategy for my project?


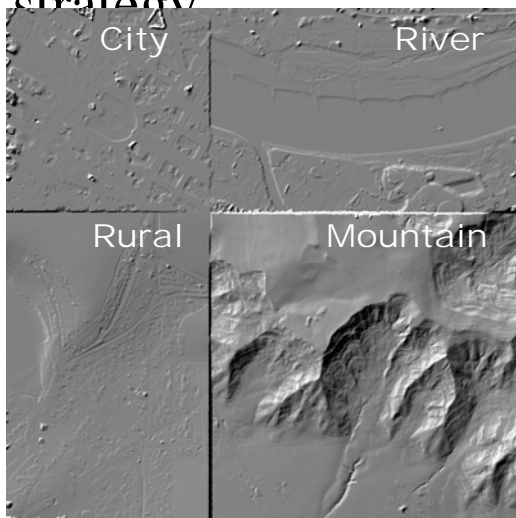


- The default strategy will give the best result if you need a very precise DTM.
- The strong strategy is recommended when you are doing orthophoto production.
- In areas with little vegetation, the weak strategy delivers better results.

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Choosing the best strategy


Strategy weak

- No DTM structures are lost
- Small buildings are not correctly classified
- Small dense tree groups are not correctly classified
- The filter parameter will not improve the quality of the result
- **The result are not sufficient**

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Choosing the best strategy




City River

Rural Mountain


Strategy default

- No DTM structures are lost
- Some small buildings are not correctly classified
- Small dense tree groups are not correctly classified
- lowering the value of the filter parameter will improve the quality of the result

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Choosing the best strategy




City River

Rural Mountain

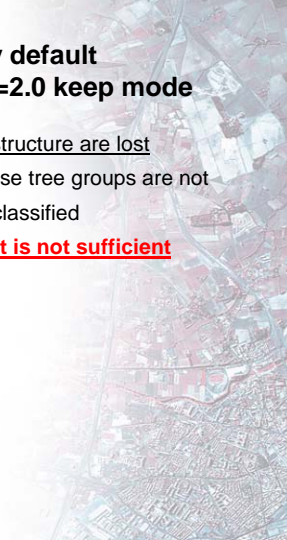


Strategy strong

- No DTM structures are lost
- small buildings are correctly classified
- Small dense tree groups are correctly classified
- The result is sufficient

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Tuning the filtering parameter



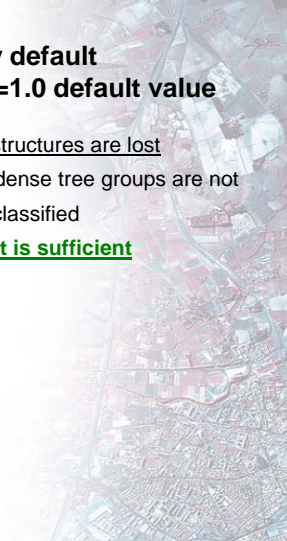


**Strategy default
filtering=2.0 keep mode**

- No DTM structure are lost
- Small dense tree groups are not correctly classified
- **The result is not sufficient**

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Tuning the filtering parameter



**Strategy default
filtering=1.0 default value**

- No DTM structures are lost
- Very few dense tree groups are not correctly classified
- **The result is sufficient**

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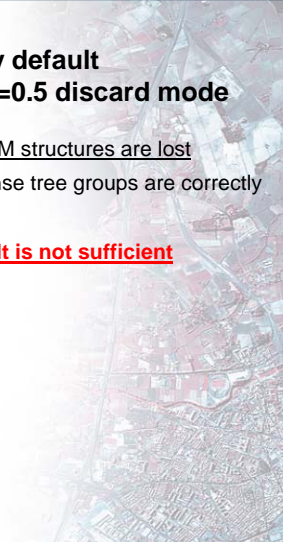


Tuning the filtering parameter



Strategy default
filtering=0.5 discard mode

- Some DTM structures are lost
- Small dense tree groups are correctly classified
- **The result is not sufficient**



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SCOP++ LIDAR - Benefits



Benefits of the SCOP++ LIDAR approach

- **Very easy setup**
 - Only three significant parameters to set - no need for special skills
 - Parameters work well with all different kind of data sets
- **Effective filtering of buildings**
- **Advanced hierarchical robust filtering**
 - Fast processing due to usage of point cloud pyramids
 - Works also in areas with few terrain points, like forests
 - Even small terrain structures are preserved without flattening them
 - Morphological data (breaklines) are considered, if available, for improving DTM quality

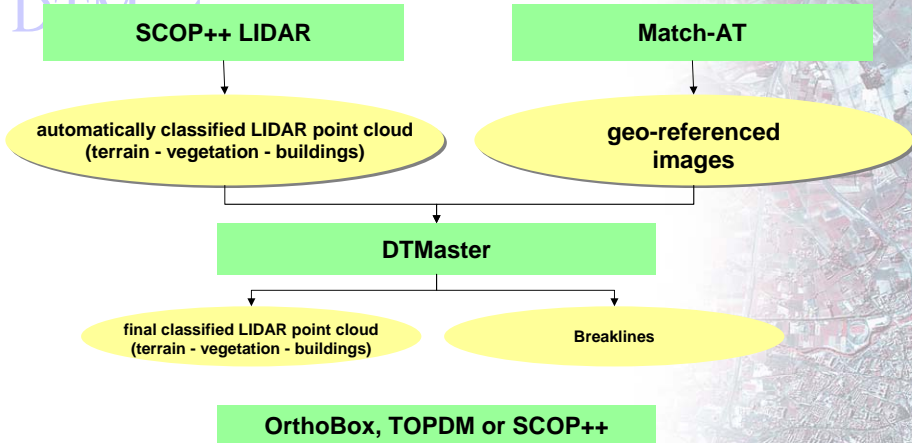


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LIDAR Box



Workflow :



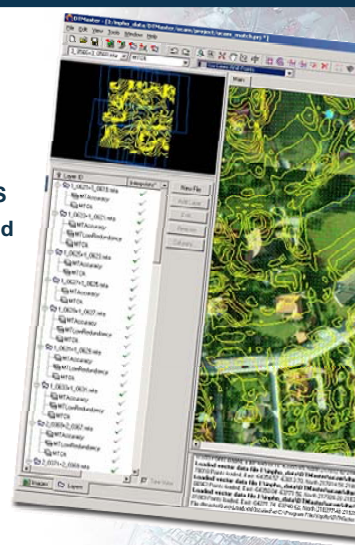
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DTMaster : manually edition




User significant Features


- Allows very fast and efficient DTM analysis
- Fast access on huge amount of data
- Stand-alone tool which needs no external CAD or GIS
- Several data sets can be combined and superimposed
- Extended export and import formats
- Seamless project-wide stereo and ortho mosaic
- Automated editing functions



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DTMaster - Quality Control




DTM Quality Control, screen shot examples


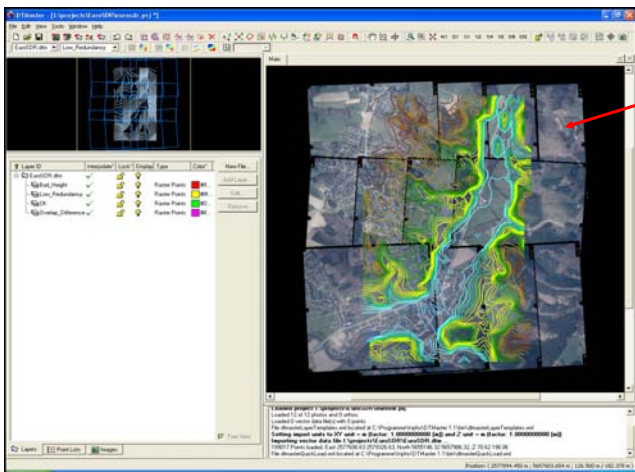
- Mono & stereo; on-line contour generation
- Perspective view
- Profile view
- Color coded view


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DTMaster - Main View


- orthophotos
- aerial images
- satellite images
- stereo models



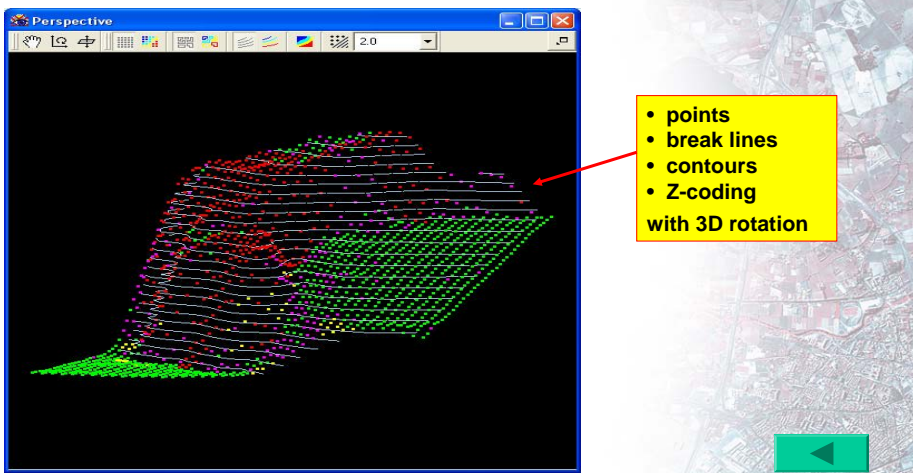
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DTMaster -




Perspective view




- points
- break lines
- contours
- Z-coding with 3D rotation

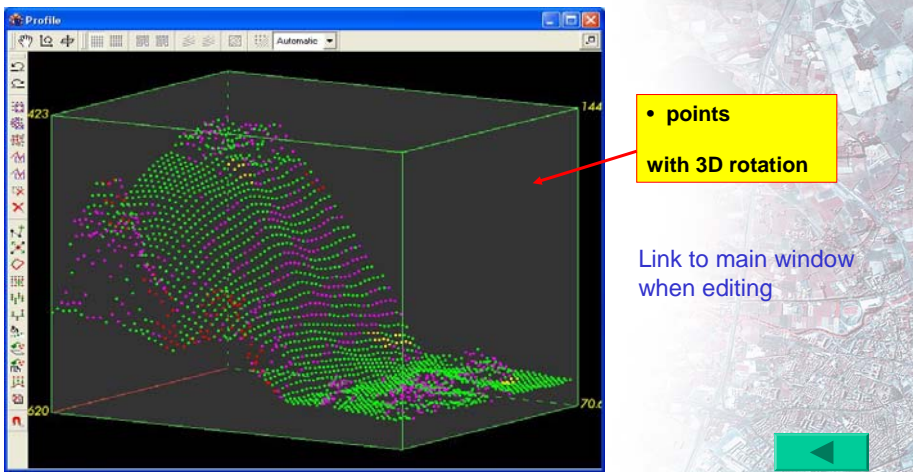
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DTMaster - Profile




view




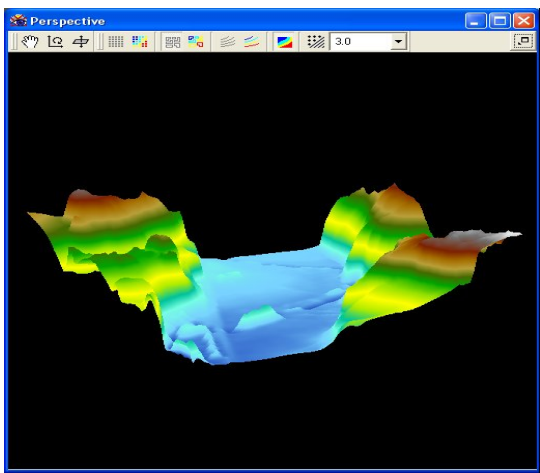

- points with 3D rotation

Link to main window when editing


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DTMaster - Colour coded view

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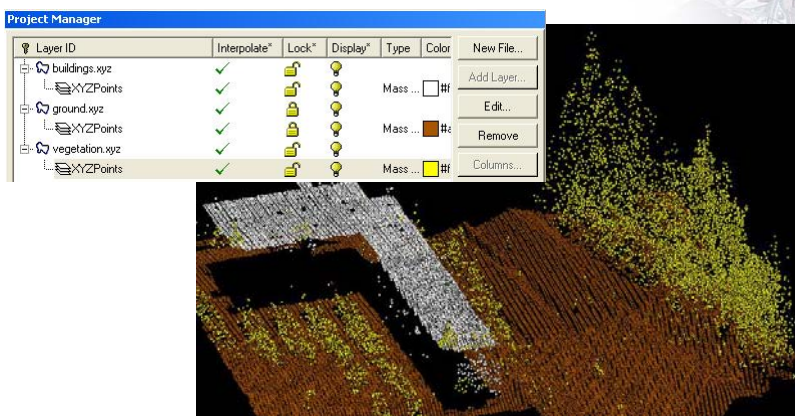


DTMaster - Features




Handling of several files in different layers (no CAD necessary!)

- up to 50 Mio points at a time




Layer ID	Interpolate*	Lock*	Display*	Type	Color	
buildings.xyz	✓	🔒	💡	Mass ...	#f	New File...
XYZPoints	✓	🔒	💡	Mass ...	#f	Add Layer...
ground.xyz	✓	🔒	💡	Mass ...	#z	Edit...
XYZPoints	✓	🔒	💡	Mass ...	#z	Remove
vegetation.xyz	✓	🔒	💡	Mass ...	#f	Columns...
XYZPoints	✓	🔒	💡	Mass ...	#f	

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DTMaster – Online



Workflow


Check / Edit with DTMaster

- Zooming, navigating
- Import / export
- Selection tools (points/lines, rectangular, fence...)
- Active layer
- Editing tools


Left mouse + ctrl = unselect!

Create / edit | close | move selected | set absolute | fill gap | move to | list | re- | remove | snap
 line | polygon | xy or z relative shifts | z | interpolate | layer | |interpolate | doubles

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DTMaster – Online




Workflow

Check / Edit with DTMaster

- Mouse actions in stereo
- When using a standard mouse instead of a 3D cursor
 - Left mouse button according to action selected
 - Right mouse button = height movement
 - Right mouse button + Ctrl. = pan mode
 - Right mouse button + Ctrl. + Shift = context menu for action
- Context menu e.g. in line measurement mode would offer: close&end, end, cancel...

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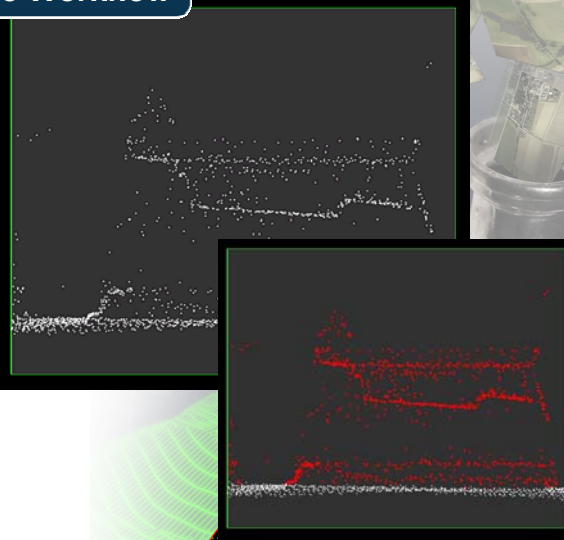


Trimble inpho


DTMaster – Online Workflow

Checking / Editing:

- DTM Edit
 - Area manipulation
 - Fence selection, select within polygon
 - Shifts defined as key-in or via 3D cursor in stereo view
 - Deleting points
 - Re-interpolation
 - Re-measurements
 - Fill gaps



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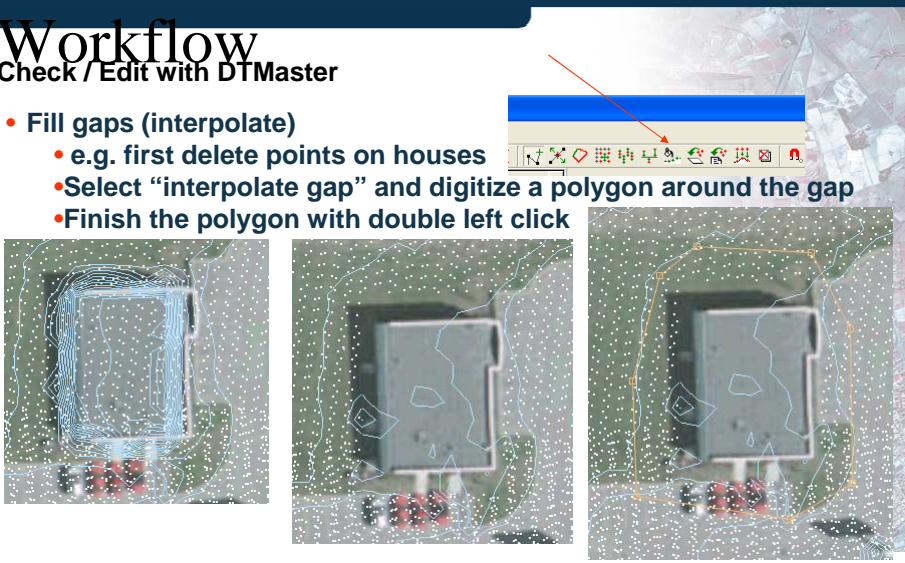


Trimble inpho


DTMaster – Online Workflow

Check / Edit with DTMaster

- Fill gaps (interpolate)
 - e.g. first delete points on houses
 - Select “interpolate gap” and digitize a polygon around the gap
 - Finish the polygon with double left click



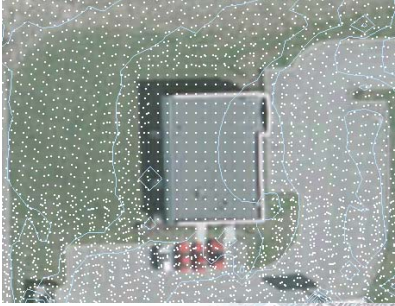
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DTMaster – Online 


Workflow

Check / Edit with DTMaster

- Fill gaps (interpolate)
 - Select a layer to store the new points
 - If no SCOP DTM was imported, then a grid width is to be given
 - New points are interpolated from all points inside the polygon



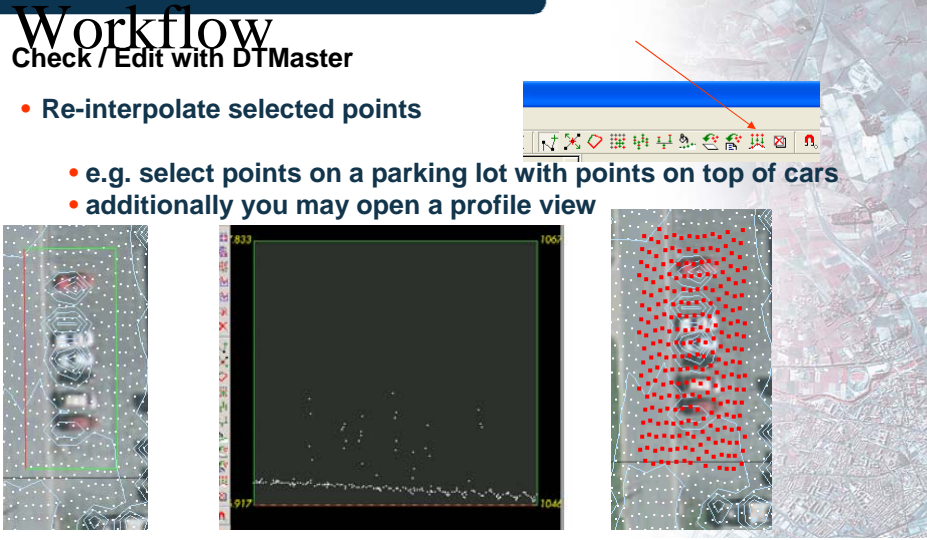
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DTMaster – Online 


Workflow

Check / Edit with DTMaster

- Re-interpolate selected points
 - e.g. select points on a parking lot with points on top of cars
 - additionally you may open a profile view




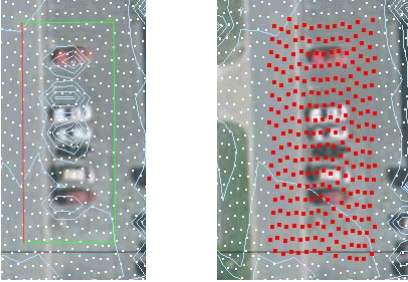
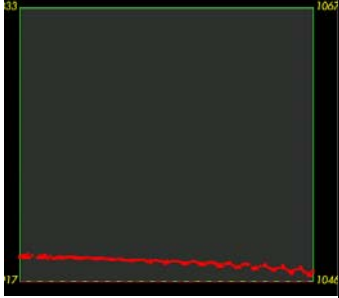
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DTMaster – Online 


Workflow

Check / Edit with DTMaster

- Re-interpolate selected points
 - Press the re-interpolate button
 - All selected points will be re-interpolated from surrounded unselected points (see contours / profile)


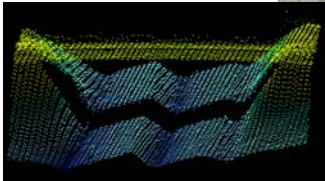




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DTMaster – Online Workflow 

Classification

- Open a profile view
- If not yet done, create a new layer for off-ground data
- Select the points to be re-classified
- Move them to the new layer

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Working with LIDAR data in DTMaster

An example of Quality Control steps

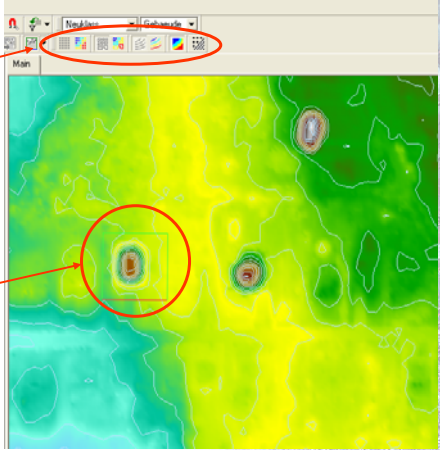
Step 1: Definition of Graphic-Layout

- Switch off "Show points"
- Switch on "Contours" and "Z-Coding"

Step 2: Visual check of the dataset

Step 3: Processing of "doubtful" objects

- Option A) "Profile View" function
- Option B) "Brush Filter" function



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Working with LIDAR data in DTMaster

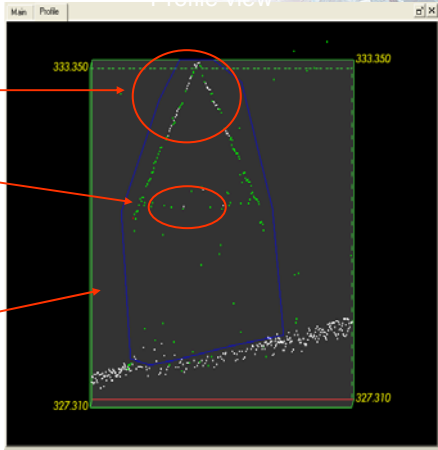
Re-classifying wrongly classified points with "Profile View"



A number of

- building points (green)
- and
- off-ground points (yellow)

are classified in this data set as ground points (white)

Manual re-classification is done by Selecting these points with "FenceSelection" (blue Polygon)

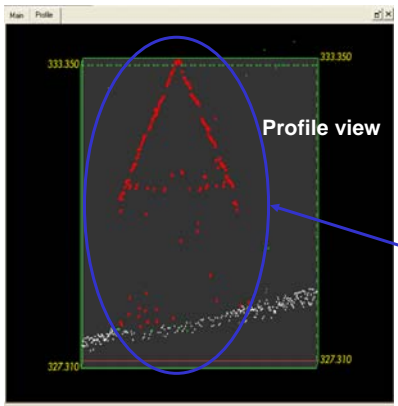


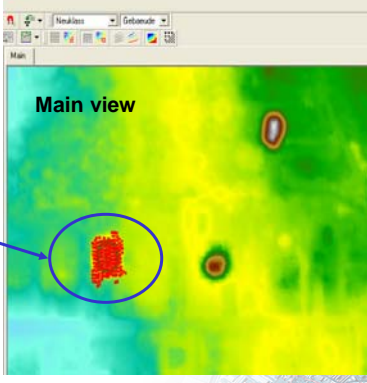
Working with LIDAR data in DTMaster

Visualization of the selected points (red color)



- Link between Profile and Main views



Profile view



Main view

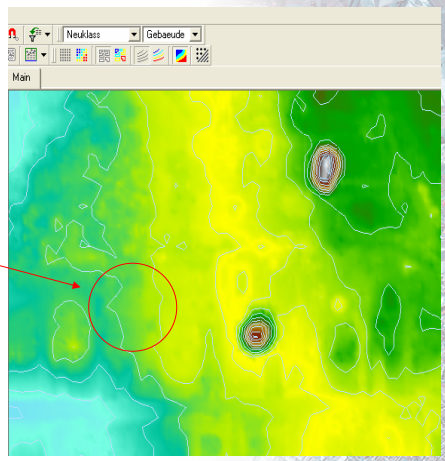





Working with LIDAR data in DTMaster

Result of re-classification

- After activating the *FenceSelection* all selected points are moved to the currently active layer (Buildings) by using the *Classify* function
- **Z-Coding** and **Contours** are updated automatically after the interactive re-classification has been completed

VIDEO



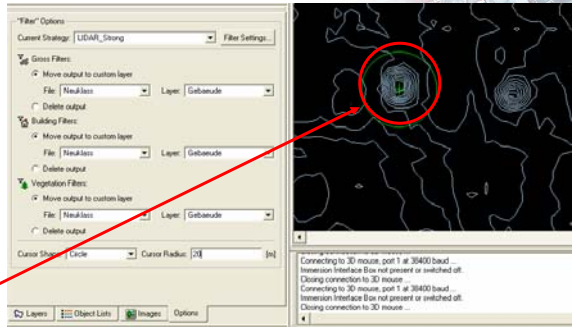


Working with LIDAR data in DTMaster

Re-classifying wrongly classified points using “Brush Filter”

Advanced “almost” automatic local filtering functionality for re-classifying LIDAR data

- A. Select **Filtering Strategy**
- B. Select **Layer** for the classified points
- C. Select the **Cursor** shape (circle or rectangle) and size
- D. Move and click **Cursor** over the target object

→ Filtered points are moved to the selected layers

Working with LIDAR data in DTMaster

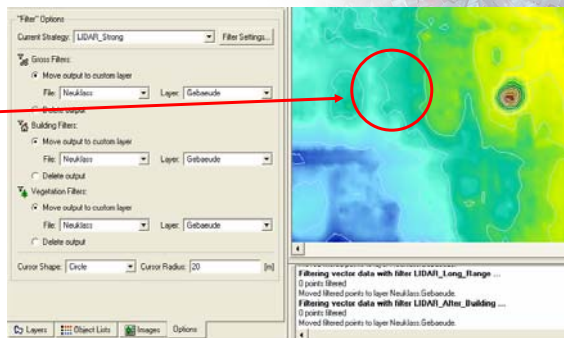
Results of the Local Filtering



Z-Coding and contours are automatically updated

Predefined Adapted Filtering strategies available, e.g.:

- Lidar Strong
- Lidar Quick

VIDEO

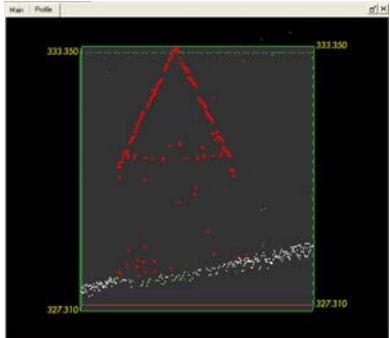
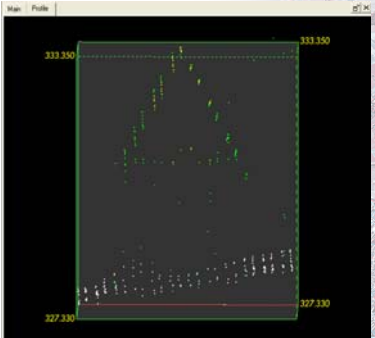







Working with LIDAR data in DTMaster

Comparison of *Profile View* (left) and *Brush Filter* (right) results

- the results are identical
- “almost” automatic new *Brush Filter* at least 6 x faster than manual *Profile View*
- *Brush Filter* is optimal tool for post-processing classified LIDAR data

DTMaster – Online Workflow

Create a new file for breaklines in DTMaster

Add File

Layer ID: _____

File Name: Breaklines

Layer Name: _____

OK Cancel

Visuals:

Interpolate: [v]

Lock: [L]

Display: [D]

Layer ID	I*	L*	D*	C*	Type	New File...
Qho_b1.brwp	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	Add Layer...
Qho_wNPPoints	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	Edit...
Qho_gd.brwp	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	Remove
Qho_wNPPoints	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	
Qho_veg.brwp	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	
Qho_wNPPoints	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Mass Points	

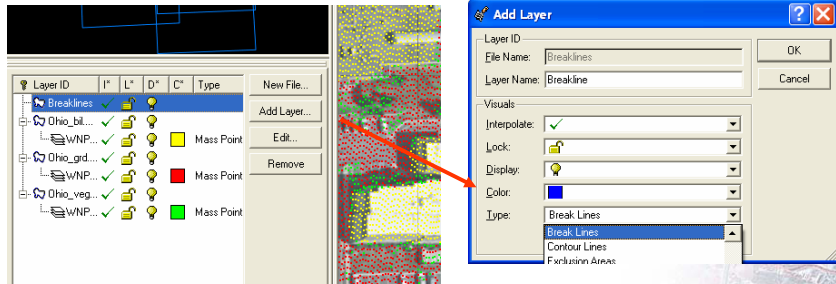
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DTMaster – Online



Workflow

Create a layer for breaklines in DTMaster



- Separate layers for different DTM objects

DTMaster – Online

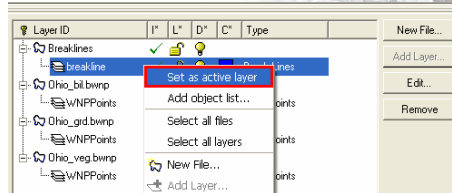
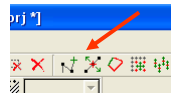


Workflow

Measure breaklines in DTMaster


- Right-click onto layer name and select

- Activate the measure mode



- Digitize polygons for the appropriate layer
 - Possible in stereo and in mono
 - With 3D cursor or with standard mouse
 - Standard mouse: left click = new point, right click = end

VIDEO

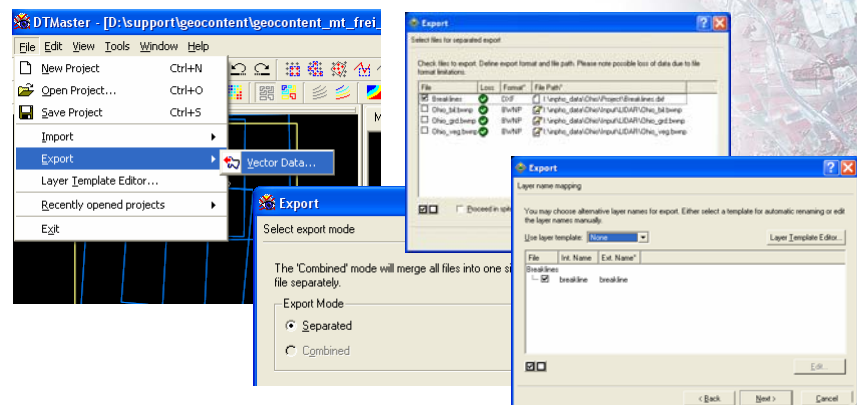


DTMaster – Online


Workflow

Measure breaklines in DTMaster

- Export data into a dxf file (unit m)



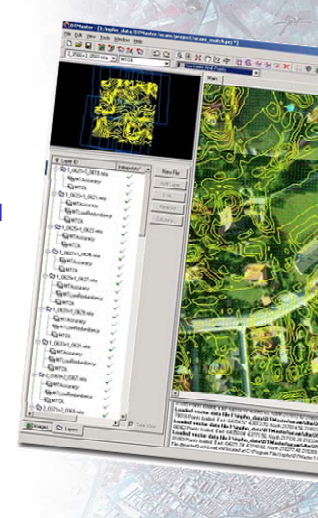
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DTMaster - Benefits

Benefits of the DTMaster approach


- Very fast and efficient DTM control
- Fast access on large data volumes
- Stand-alone tool - no CAD or GIS required
- Multi-data sets can be combined & superimposed
- Seamless project-wide superimposition on
 - orthophoto views (aerial & satellite)
 - stereomodels (aerial & satellite)
- Advanced Local Filtering functionality



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LIDAR BOX -




Benefits

Benefits of LIDAR Box


- capable of handling huge amounts of data
- high productivity through high degree of automation and batch processing capabilities
- highest accuracy by sophisticated filtering and rigorous consideration of breaklines
- easily adaptable to point densities and terrain types
- highly comprehensive functionality for all kinds of projects
- autonomous solution, i.e. no CAD or GIS system required
- easy integration into any third-party workflow



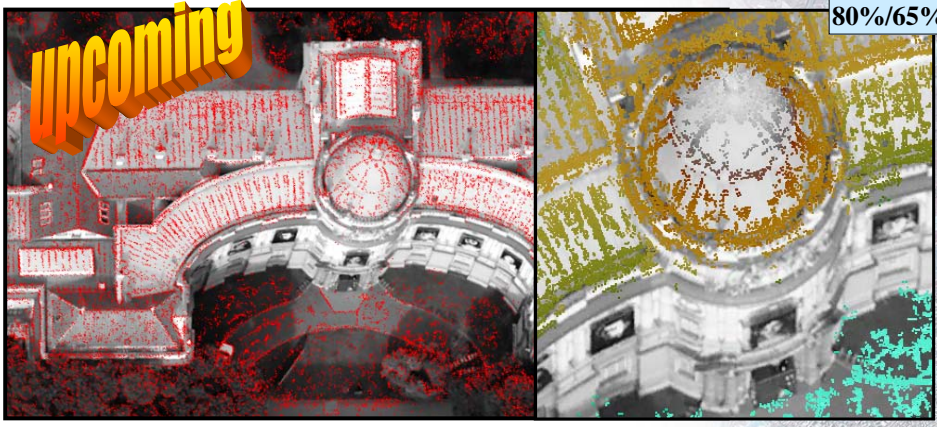
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Photogrammetry vs LIDAR



Point cloud from MATCH-T



UCAMD
GSD=0.07m
80%/65%

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