Advanced Use of Lidar Data - Automatic Building Vectorization and Contour Production

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SUMMARY

Today airborne laser scanning is widely used for map production and data collection. With advanced software solutions the point clouds can be accurately calibrated and with good reference measurements very high accuracy, down to 5 centimeters, can be achieved even from high altitude flights. With automated ground detection and point classification the points can be effectively classified to ground, vegetation, building roofs etc.

The latest development efforts in Terrasolid's products algorithms have been in automatic production of vector building models and contours. In this presentation the author describes the process and the possibilities of automatic building vectorization and contour production.

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AUTOMATIC CONTOUR PRODUCTION

For a long time contour lines have been produced based on stereophotography by topographic mappers. The work is both very time consuming and physically demanding. It may take an experienced operator two weeks to digitize the contours for an area of 9 sq.km.

However, it is possible to produce the contours automatically based on properly calibrated and classified laser scanned data. The data is accurate enough but there have been difficulties to handle the vast amount of data and to produce smooth contours.
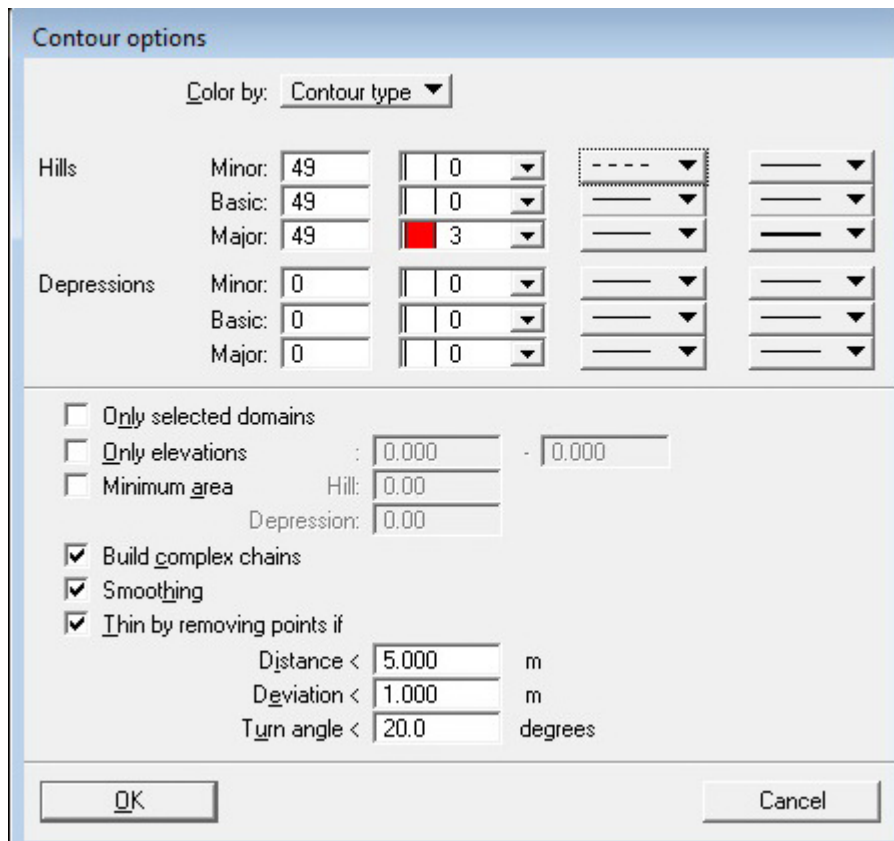
Let's first compare the purpose of a digital terrain model and the purpose of contours. Digital terrain model is used to pass information about terrain elevations to a computer. From a DTM it is possible to compute quantities, draw profiles, classify laser points and visualize the terrain on screen among other things. The purpose of contours is to be plotted on paper and to pass information about terrain elevations to a human.

DTM's created from laser points are very accurate. The problem is that a highly accurate terrain model produces ugly contours. In order to produce pretty and smooth contours the terrain model must be generalized, contours can not be accurate and pretty at the same time. You have to balance between accuracy and prettiness when producing contours. Bad model makes good contours !
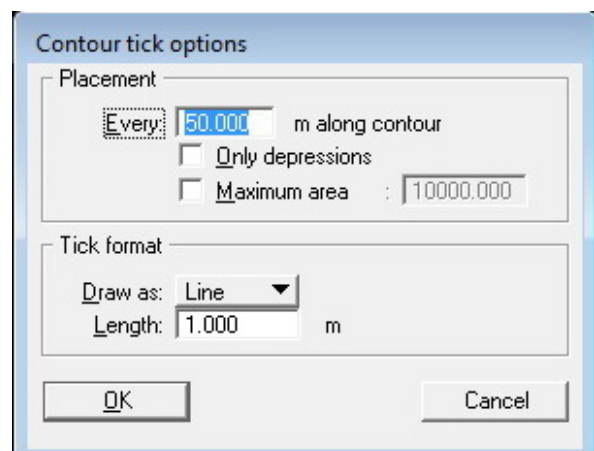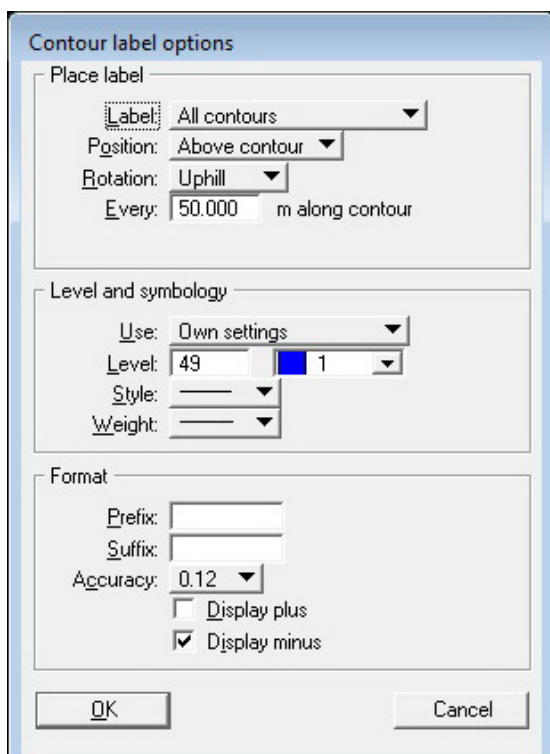
A ground model from laser data is very accurate and has high density. It is also noisy – the points have elevation variations. Laser data is difficult for producing contours. It is difficult to accept how bad you have to make the model to produce good contours. The process to automatically produce contours with Terrasolid applications has been tailored to create smooth contours which are fully user configurable.

Before running the automatic contour processing it is important to first do proper setup.

User can fully control how the contours are drawn. Settings for color, level, line style and line weight can be set to individually.

Also the contour label settings and contour ticks can be fully controlled.

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The next step is to set up the rules for handling vector elements like holes, breaklines and building footprints. User can set up different rules on how to handle vector elements based on the level they're located in the vector file. You can set the contours not to be drawn over hole elements like lakes and building footprints. Also different breaklines will make the contours follow them.
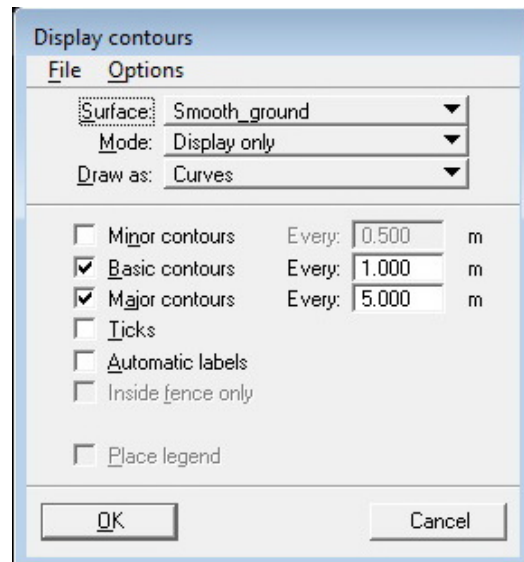
Classify contour keypoints

The next step is to run the contour keypoint selection routine. At this point the terrain model is generalized based on user settings to create smooth and nice looking contours. User controls how big volumetric difference to true ground are allowed.
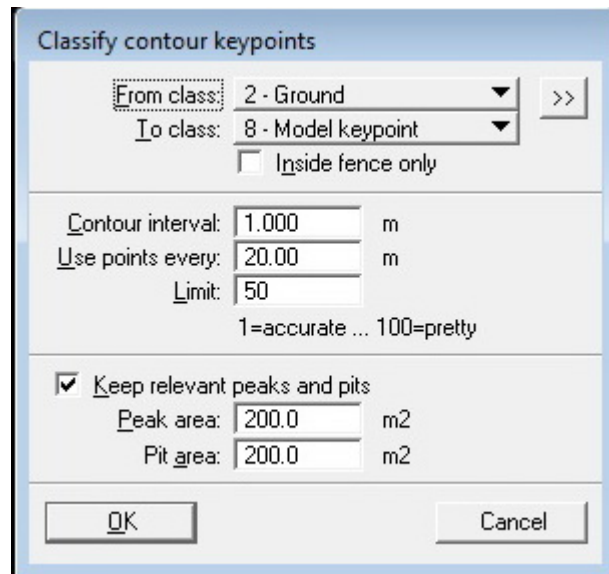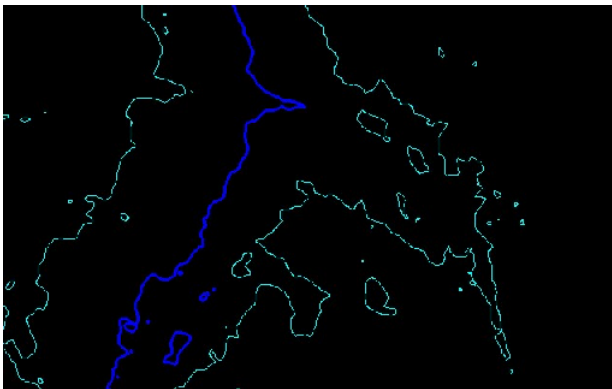

Contour keypoint classification is designed to achieve as pretty contours as possible without degrading surface accuracy too much.

PRODUCE CONTOURS

The contour production is fast and automatic and is based on the settings we've just reviewed. It is normally done so that each map sheet is drawn to its own file to allow production of very large data sets on one run so that possible drawing file size limits don't stop the processing.

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Display and compare the results

When contours have been processed you should first see if they meet your smoothness conditions and are visually satisfying. You can also automatically check how the contours match the original precise terrain model and see if they meet your demands.

In the table below we've compared the average z-difference of the contours versus the precise terrain model. In the actual terrain model there were 836 069 points. When generalizing to keypoints with 10 cm distance the number of points goes down to 162 329 points and the average dz is only 2,6 cm. When ran with smooth-option and 10 cm distance with smoothness key setting at 40 (0 to 100, 100 smoothess) the number of ground model points drops to 18 339 points and the average dz is 10 cm.

	Points	Avg dz
All ground points	836 069	
Model keypoints 10 cm	162 329	2.6 cm

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Model keypoints 20 cm	66 270	5 cm
Smooth 10 cm, key 40 cm	18 339	10 cm
Contour key 1	813 782	0.1 cm
Contour key 13	160 737	3.0 cm
Contour key 23	64 395	6 cm
Contour key 50	14 772	11 cm
Contour key 100	3 961	16 cm

CONCLUSIONS

It is very difficult to create perfect contours and labeling automatically. Some manual editing is always needed especially in the positions of labels. The precision of the contours is fully comparable with contours produced with any other method. It is therefore our suggestion that contours were produced from laser points and the valuable manual work would be saved for final editing of the countours.
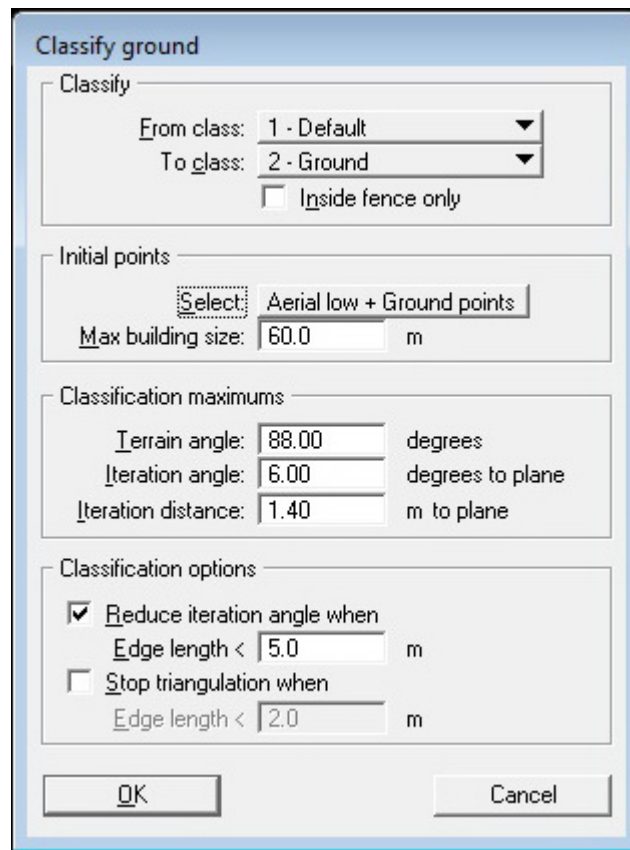
AUTOMATIC BUILDING VECTORIZATION

The purpose of automatic building vectorization is to produce approximate 3D vector models of buildings and building roofs rapidly.

The automatic building vectorization is based on properly classified point clouds. One must first be able to recognize and classify ground points and point hits on building roofs.
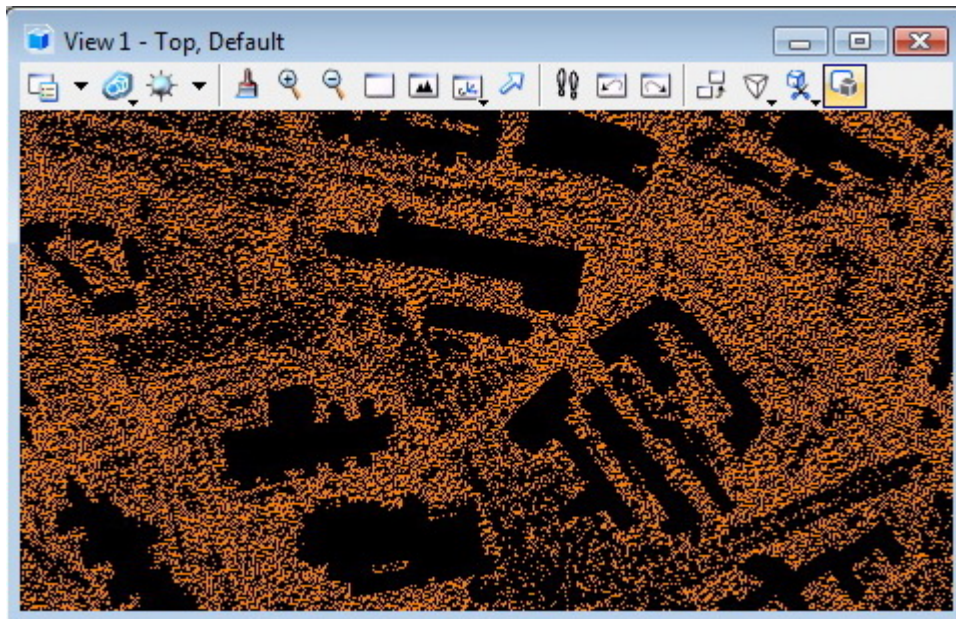
This can be done automatically with specific algorithms in TerraScan. The point clouds must also first be calibrated and tied into measured reference points. This is often done with TerraMatch which utilises also the trajectory data to find the best solution for the matching.

When the multiple flight passes have been calibrated with each other the overlapping point clouds should be classified to their own class, often called Overlap.

Once this is done it is recommended to first isolate error points like points below ground which can be a result of laser pulse been mirrored from multiple windows or other shiny areas. The low points can cause difficulties in ground classification.

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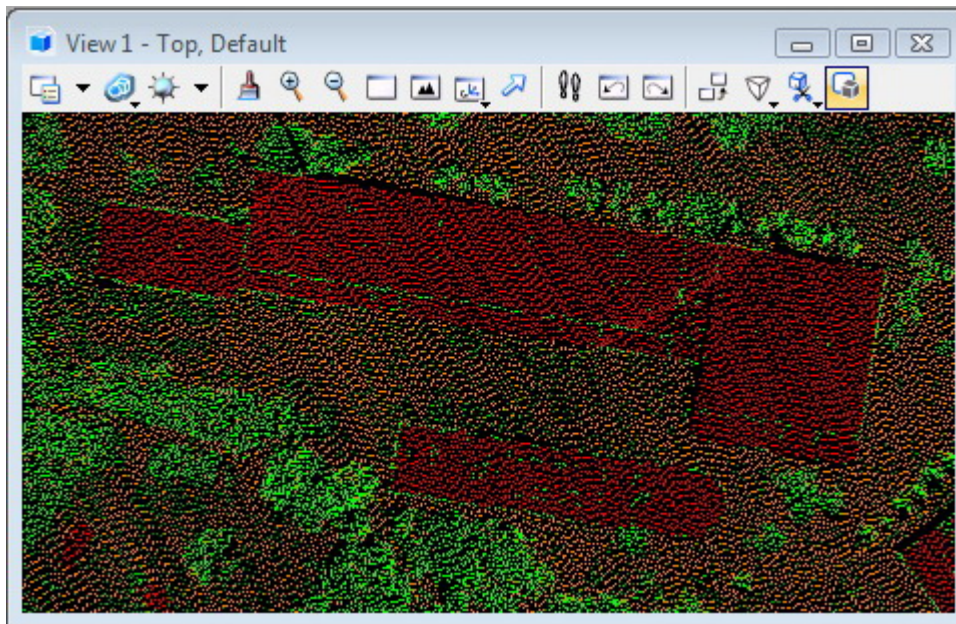Sydney, Australia, 11-16 April 2010

The ground classification routine starts triangulating the terrain and is controlled by user definable parameters. The algorithm goes through all of the laser points and decides which are part of ground. As a result of the ground classification there are holes in the ground where there are buildings or other large objects, this is controlled by the maximum building size setting. If the setting is too small some large buildings could be classified as ground thus it is important to review the data set prior to classification. In this process aerial photos are very useful.

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Once ground is classified you can classify some of the remaining points to different vegetation classes based on the height from ground. Normally low vegetation is anything from 0 to 25 cm above ground, medium vegetation up to 2 meters and anything above that is high vegetation aka. trees or other high object like power line towers or buildings. The classify building routine classifies points which appear to be hits on building roofs. The algorithm tries to fit planes onto point clouds based on user settings.
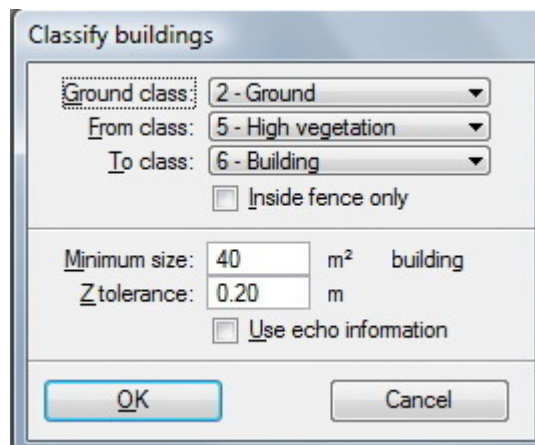
Once the classification has been done the point clouds may look something like this from the top view.

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One can easily cut sections of the point cloud to review the results. A typical view may look like this. There are still some high vegetation points left on top of the ground, they may be antennas or other small objects on the roof which are not part of the continuous roof surfaces.
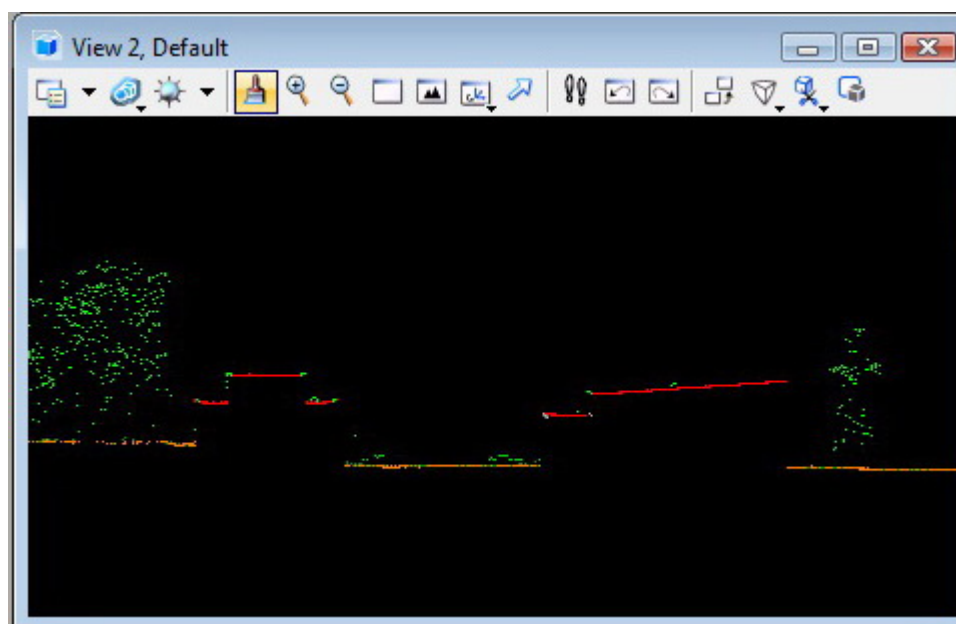

It is also advisable to check the classification result with aerial photographs for any anomalities. It is possible to run the building vectorization right after the automatic classifcation but it is advisable to go through some manual check and manual classification as there may be some strange points left in the classfication which may be a result from errors or for example roof windows.

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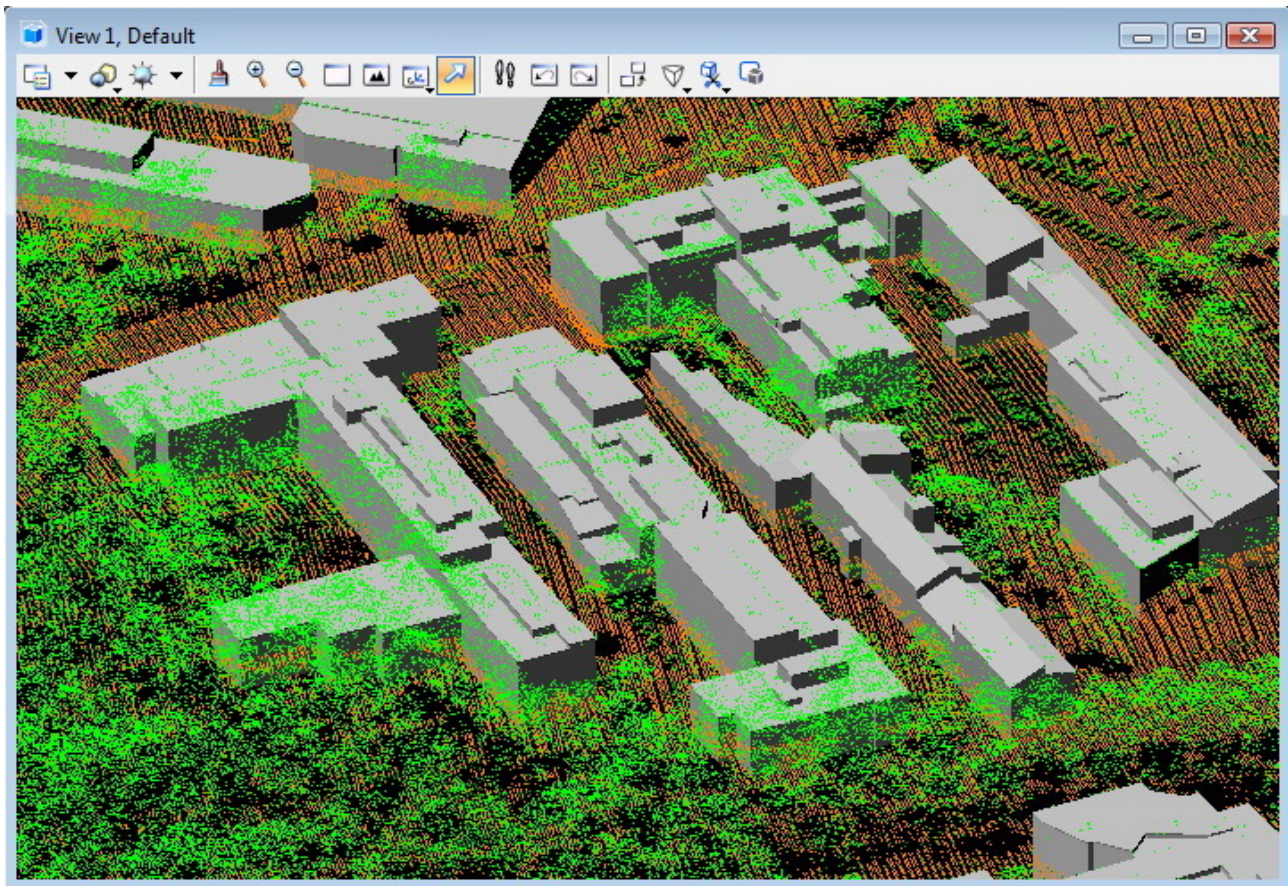Sydney, Australia, 11-16 April 2010

BUILDING VECTORIZATION PARAMETERS

The building vectorization algorithm goes through the points in the building class and tries to fit planes to the points and find a solution where the different planes meet each other and form a closed area. Once the roof solution has been found walls are extruded to the ground and all the faces are grouped into one cell or a block.

User can set a number of parameters like the maximum allowed gap, planarity tolerance, minimum building area to avoid cars or wood piles being vectorized.
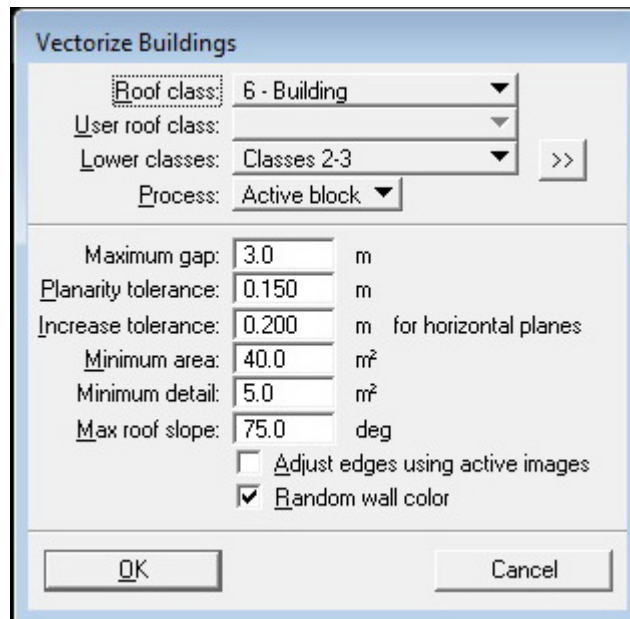

The vectorization algorithms have been optimized and produce results very rapidly. For example a test area from Helsinki University of Technology campus area which is som 4 sq. meters large and has got 270 buildings is vectorized in two minutes with a normal laptop computer. Example results below.

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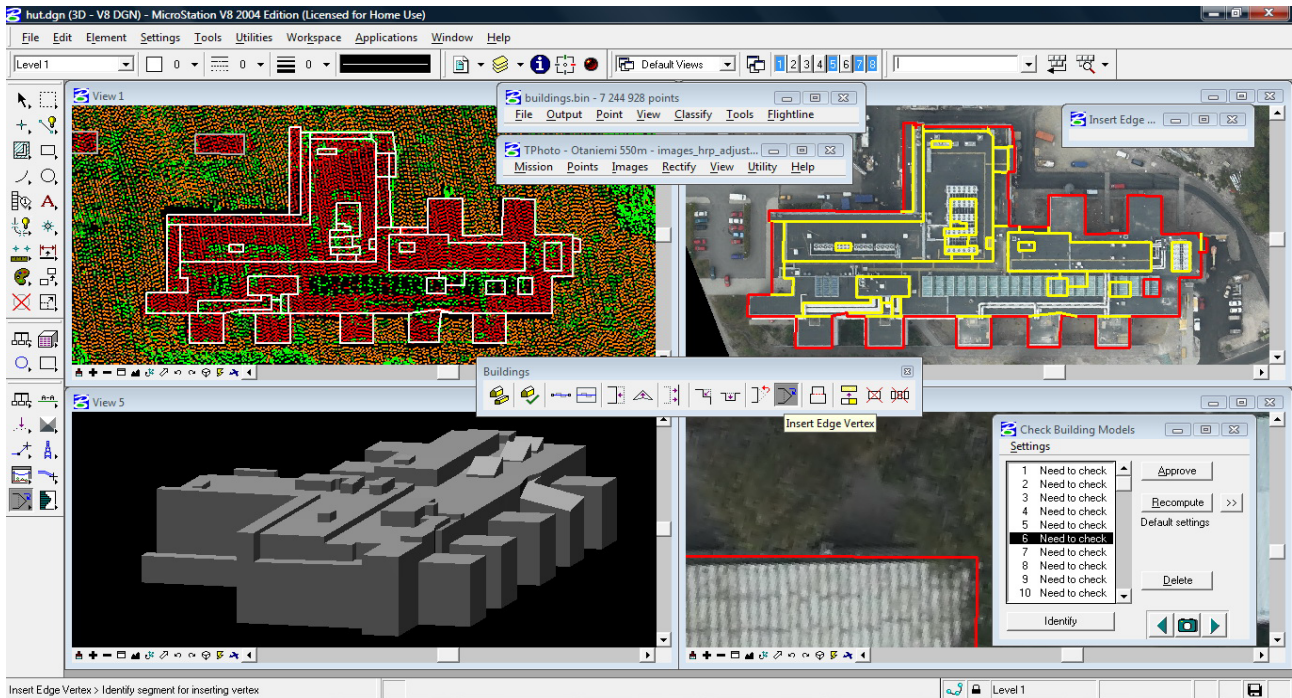Sydney, Australia, 11-16 April 2010

We ran numerous tests with different materials. An other example is a close to 2000 km² area of Finland National Land Survey data where we had approximately 3 billion points with point density of 1.5 points / m² after the flight line overlap was cut. The points were scanned from 2 km altitude.

We ran automatic ground and did no manual editing. After that we ran automatic building classification with no manual editing. We then ran the automatic building vectorization and did no manual editing. The automatic vectorization took 6 hours on notebook and the data was located on an USB drive. There were over 72,000 buildings in the area. See picture below.

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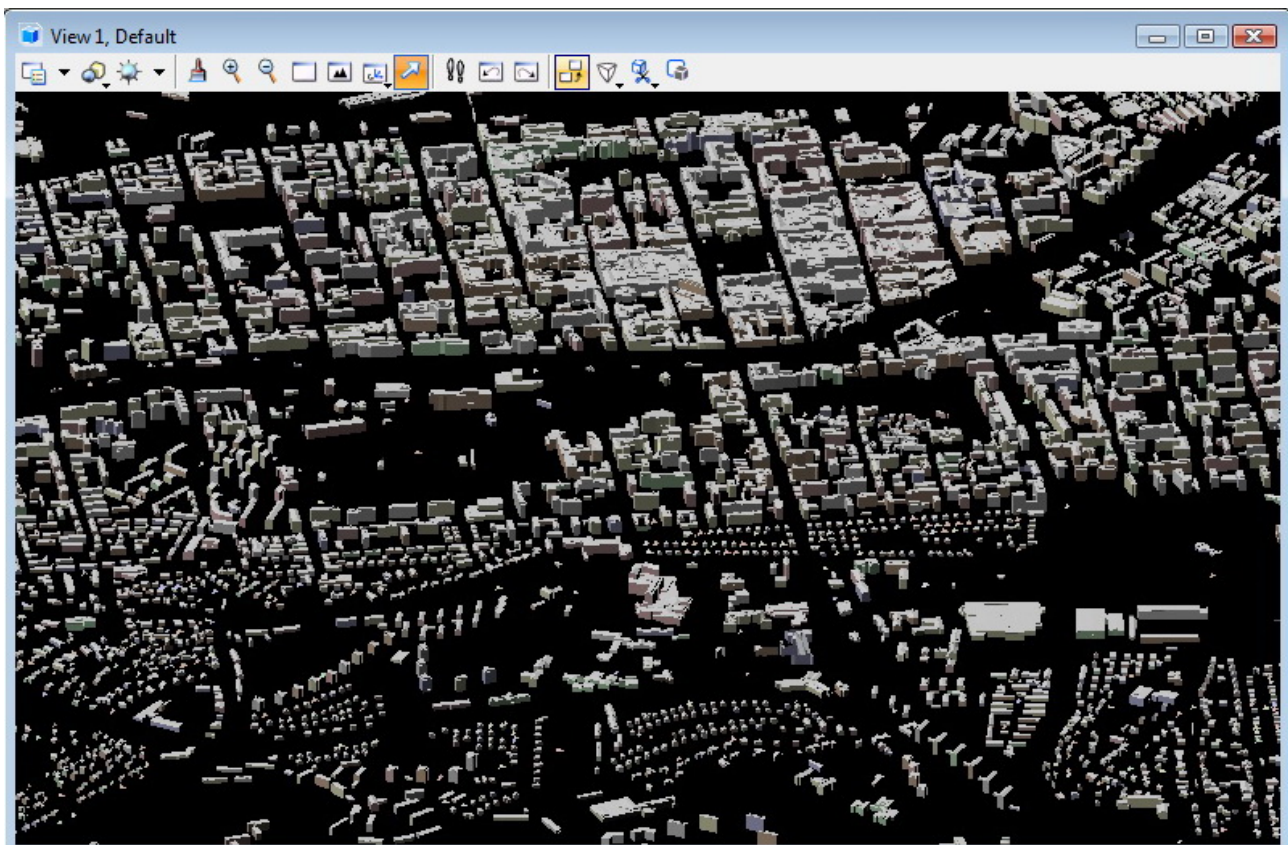
EDITING

Once the building vectorization has been done each building has got its unique identifier. There is a tool to review each building and see if it meets the conditions or if it needs to be edited. There is a set of tools to adjust the roof edges or edit details. Aerial images with accurate camera xyz positions and orientations support this process greatly. As laser data provides known equations for roof planes, one can measure edge positions from a single image. This measurement method is often called monoscopic measurement.

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CONCLUSIONS

It is possible to automatically produce vectorized building models from laser scanned point clouds. Laser point density has a major effect on the accuracy of the automatically generated models. The higher the point density the better and more accurate models can be produced. Low density point clouds (<2 points/ m²) produce good models of large buildings but there are problems with small buildings. Medimum density point clouds (2-10 points / m²) already produce good models and with high density point clouds (> 10 points / m²) we can produce very accurate and high detail building models.

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