OBJECT EXTRACTION AT AIRPORT SITES USING DTMs/DSMs AND MULTISPECTRAL IMAGE ANALYSIS

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ABSTRACT

The automatic detection and 3D modeling of objects at airports is an important issue for the EU FP6 project PEGASE. PEGASE is a feasibility study of a new 24/7 navigation system, which could either replace or complement existing systems and would allow a three dimensional truly autonomous aircraft landing and take-off primarily for airplanes and secondary for helicopters. This new navigation system relies on three key technologies:

• The specification and acquisition of a reliable geospatial reference database of the airports.
• Various sensors onboard the aircraft that perform a real-time extraction of relevant features from the data.
• Innovative correlation techniques between the above features and the onboard reference database to determine the location of the aircraft and plan its future trajectory for safe landing or take-off.

In this work, we focus on the first topic. Since often existing data for airports have not the necessary accuracy, resolution and/or currency, we need to develop automated methods for generating them.

1. INTRODUCTION

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2. INPUT DATA

We have worked on the area of Zurich airport. The available data for this region are:

- Vector map
- Color and CIR image data
- Orthophotos
- LIDAR DSM/DTM raw point cloud
- LIDAR DSM/DTM GRID surface model data

2.1 Vector data:

The vector map has 20 cm horizontal accuracy. It has been produced using semi-automated measurement of buildings and other objects (poles, towers, etc.) from stereo aerial images using CC-Modeler.

2.2 Image data:

Color and CIR (color infrared) image data have been used for generation of DSM and multispectral classification process. Metadata of images can be seen in Table 1.

Film	Color and IR
Camera Type	Frame
Focal Length	303.811 mm.
Scale	1:10'150 (color) / 1: 6'000 (IR)
Endlap	70%
Sidelap	26%
Scan resolution	20 micron

Table 1.Image data description

Orthophoto of the airport region has been produced using an image matching DSM (see below) with 1m resolution.

2.3 LIDAR Data:

LIDAR DTM-AV and DSM point cloud data have been used for extraction of objects process. The process can be seen at the section 4. The DSM-AV point cloud includes all lidar points with 4 echoes per pulse. The DTM-AV data includes only points on the ground, so it has holes at building positions, and less density at tree positions. The altimetric precision (one standard deviation) of both models is 0.5 m, and 1.5 m at vegetation and buildings. The density is approximately 1 point by 2 m^2. The GRID DSM and DTM have a grid spacing of 2m

and same accuracy specifications as the point cloud models. They represent the visible and terrain surface respectively.

3. OBJECT EXTRACTION FROM DIGITAL SURFACE MODELS

3.1 Extraction of buildings using SCOP++

SCOP++ software derives from a point cloud a DTM and DSM and classifies the original points using a hierarchical method. In each hierarchy level, robust interpolation for the classification of the points and the surface derivation is done. SCOP++ performs filtering of airborne laser scanning data for automatic classification of the raw point cloud into terrain and off-terrain points, i.e. for extracting the true ground points for further DTM processing. It uses efficient robust interpolation techniques with flexible adaptation to terrain type and terrain coverage. The package has user-controlled hierarchical process using point cloud pyramids and elimination of gross errors (Kraus et al., 1998, Pfeifer et al., 1998).

We applied the automatic LIDAR classification tool and it performed the separation process as building, vegetation and ground points for the DSM raw lidar point cloud (Fig. 1) .
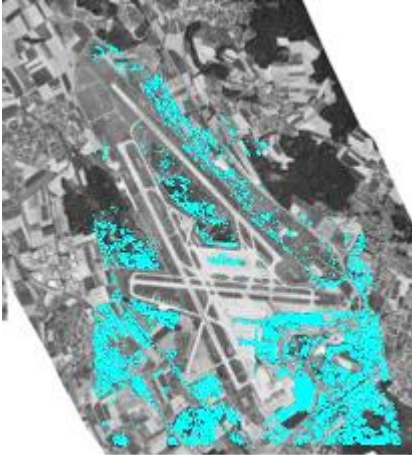

Figure 1. First results for buildings on reference orthophoto

For refining of results, the DTMaster programme has been used. This software gives the opportunity to improve the result quality using orthophotos overlapping with the point classes. Manually selected points can be easily moved to another class (vegetation, ground) or be deleted interactively. Final building points have been refined and the result can be seen in Fig. 2.
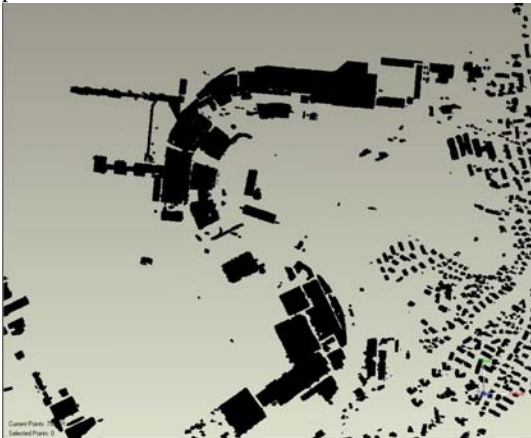

Figure 2. Results from SCOP++/DTMaster

The result of classification process is partly unknown and we tried to develop additional procedures for extraction of buildings and trees.

3.2 DSM generation using image matching

At the Institute of Geodesy and Photogrammetry, ETH Zurich, a full suite of new algorithms and the software package SAT-PP (Satellite Image Precision Processing) have been developed for the precision processing of high-resolution satellite and aerial image data. The software features include: GCP measurements, image georeferencing with RPC approach and other sensor models, DSM generation with advanced matching techniques, orthoimage generation, semi-automated feature extraction etc. (Gruen et al., 2005). The mathematical description of the sensor model and block adjustment developed in SAT-PP is given in Baltsavias et al. (2005) and Gruen et al. (2005).

11 aerial images of the area have been used as input. The matching approach used a coarse to fine hierarchical solution with a combination of multi image matching algorithms and automatic quality control.

In order to reduce the effects of the radiometric problems such as strong bright and dark regions and to optimize the images for subsequent feature extraction and image matching, a preprocessing method, which combines an adaptive smoothing filter and the Wallis filter, was developed. Firstly, an adaptive smoothing filter is applied to reduce the noise level and to sharpen edges and preserve even fine details such as corners and line end-points. Next, the Wallis filter is applied to enhance and sharpen the already existing texture patterns. After the image preprocessing, the image pyramid is generated starting from the original resolution images. Three additional pyramid levels are generated, each with a reduced resolution by factor 3 from the previous level.

After pre-processing of the original images and production of image pyramids, the matches of three kinds of features (feature points, grid points and edges) in the original resolution images were found, progressively starting from low-density features on the lower resolution levels of the image pyramid. Seed points were selected by stereo-measurement technique. Finally, we generated an interpolated regular DSM with 2 m resolution for the airport area (Fig. 3).

Figure 3. Matching DSM for Zurich Airport

3.3 Extraction of vegetation areas using multispectral classification and DSM

A CIR orthophoto was produced using the matching DSM for high vegetation extraction (Fig. 4). When calculating a DSM from aerial images, trees produce the same effect as buildings, showing up as features above ground (Niederöst, 2001). Applying classification process using the orthophoto gives the

tree region. We applied this process on a small part of the airport site.
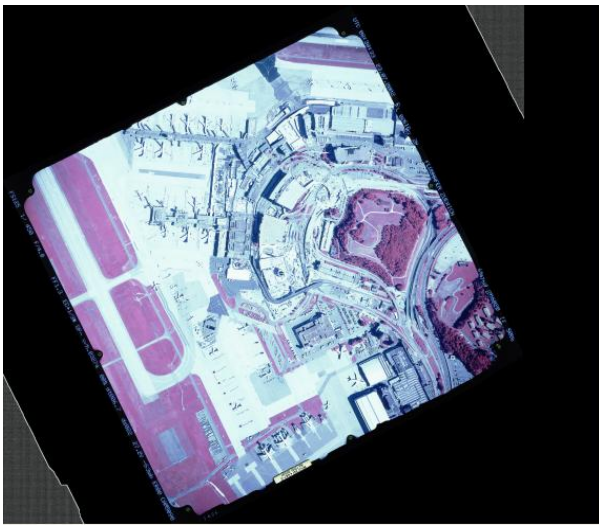

Figure 4. Orthophoto

We used supervised classification which uses NDVI analysis as a tradditional vegetation method. The spectral characteristics of vegetation can help to seperate it from other objects. Near infrared(NIR), red(R) and green (G) channels were used to classify vegetation areas using the normalised vegetation index given as NDVI = (IR-R)/(IR+R). It takes values between [-1;1]. Our main target classes for airports are open grass, high vegetation (trees), man-made objects (mainly buildings, roads, poles). Here, we focused to extract mainly trees using multispectral information.
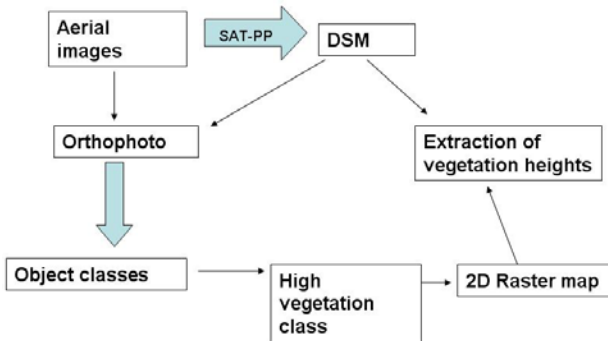

Figure 5. Workflow of vegetation extraction

The training areas were selected manually using AOI tools with the ERDAS Imagine commercial software. Automatic supervised classification produced 3 classes: open grass, trees and man-made structures (see Fig. 6).
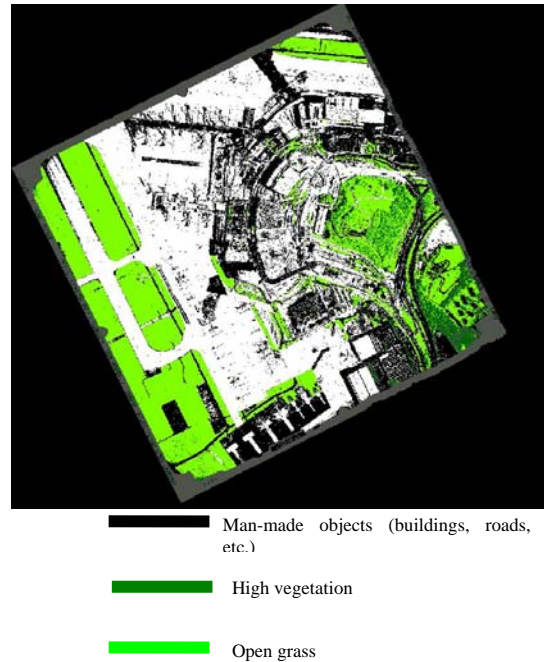

Figure 6. Classification result for vegetation extraction.

The region which was classified as high vegetation, was converted to a 2D raster map with 1m resolution, using pattern recognition and image processing techniques. Tree heights were interpolated in the DSM (Fig. 7). The workflow of the extraction process can be seen in Figure 5.

Figure 7. Extracted vegetation and digital surface model

3.4 Extraction of objects using existing vector maps and DSM

In the past, many researchers studied the extraction of objects using existing plans. Haala et al. (1998), Brenner (2000), Vosselman and Dijkman (2001), Hofmann et al. (2002), Hofmann (2004), Vosselman (2003), Koch (2004), Overby et al. (2004), Stoter and Oosterom (2004) used 2D maps as prior information for extracting buildings by using LIDAR data. Haala et al. (1998) described a method that combines height data provided by airborne laser scanning and existing ground plans of buildings in order to enable an automatic data capture by the integration of these different types of information. Vosselman and Dijkman (2001) focused on the extraction of the roof faces and the generation of 3D building models by

combining the extracted roof faces with the ground plans. Hofmann et al. (2002) transformed laser data into raster format, in order to extract buildings from laser data. Vosselman (2003) described several algorithms and procedures developed for the 3D reconstruction of streets and trees from airborne laser altimetry data in combination with a cadastral map. Overby et al. (2004) generated roof polygons using airborne laser scanning and ground plans (footprints) extracted from technical feature maps and applied plane extraction by a 3D Hough transform.

We used the existing vector map and converted the building polygons to a 2D raster map (Fig.8).
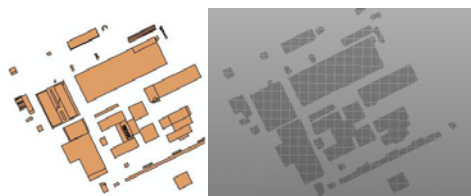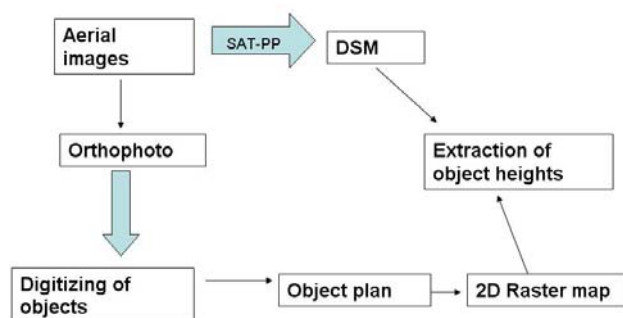

Figure 8. Object polygons to 2D raster map

Figure 9.Extraction of objects using object vector maps

The height for the 2D building points (see Fig.9) was interpolated from the DSM (Fig.10).

Figure 10.Extraction of buildings and DSM

4. EXTRACTION OF OBJECTS USING DENSITY CALCULATION OF LIDAR DATA

When no prior existing data are available, exploring other methods for detection of objects can be useful. One of these methods is using the density information of LIDAR based DTM and DSM. As input data, we use the raw lidar data and multispectral aerial images from the Zurich airport. They include 2 datasets acquired with leaves off: a) terrain-only points (DTM-AV) (see Fig. 11), b) all points with 4 echoes per pulse (DSM-AV). Thus, the last dataset shows the structure of trees (see Fig. 12).
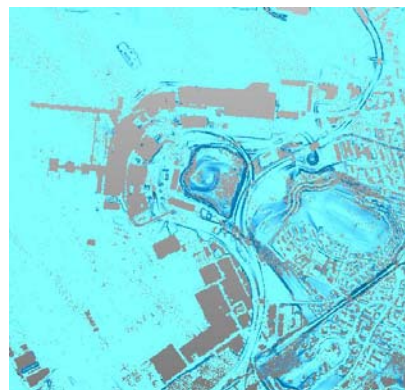

Figure 11. DTM-AV Data for the Zurich Airport, holes in the data points mainly at buildings

Using high-resolution LIDAR data, it is not only possible to detect buildings and their approximate outlines, but also to extract planar roof faces and, thus, to create models of the roof structure. With decreasing resolution, it becomes more difficult to correctly detect buildings in LIDAR data, especially in residential areas characterised by detached houses (Rottensteiner et al., 2003).

Figure 12. Profile tree view from LIDAR DSM raw data

We tried to develop an own method for detecting buildings, using the multiple echoes for each pulse, and the 3D nature and higher point density of lidar point clouds with trees. Buildings can be detected from the DTM-AV raw dataset using the fact that there are no measurements at their planimetric position. Indication of trees can be used, by using the image classification results as a mask and using the raw DTM-AV data. Using the same mask, with the raw DSM-AV data, will show that at tree areas , the point density is much higher than at open terrain or buildings, so this indicator could be used.

4.1 Calculation of point density

This algorithm calculates total number of points in $2m^2$ area squares of the DTM-AV data. The number of points in per $2m^2$ was reported to a file (Table 2).

This file contains three columns. Two columns show the searched position and one column presents the total number of points.

Number of points	X	Y
10	679332	234366
6	679332	234368
2	679332	234370
0	679332	234372
.	.	.
.	.	.

Table 2. Density report

X and Y columns present the 2m range scale. For example if there is a value as 679332, it presents a 2m range between 679330-679332 values.

4.2 Extraction process

Another algorithm searches the no-point areas using the above density report file and extracts these areas from the DSM. Firstly, the code searches the columns of "number of points" and if the value is 0, then it extracts the corresponding range area from digital surface model.
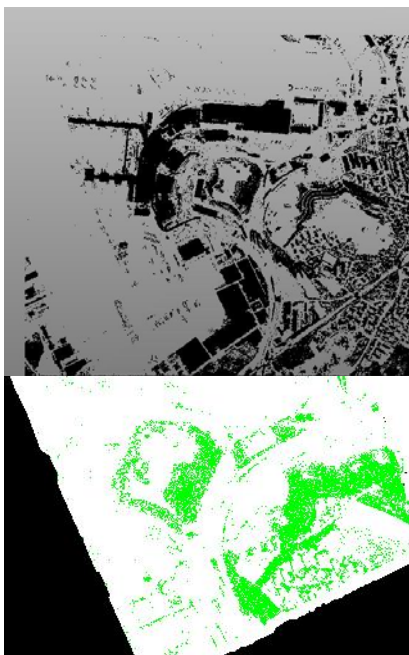

Figure 13. Extracted objects (top) and vegetation mask (bottom)

First results show mainly buildings and secondly high trees and some objects (airplanes, cars, etc.). Using the classification mask with this the result can provide the elimination of tree points from other points (Fig. 13).
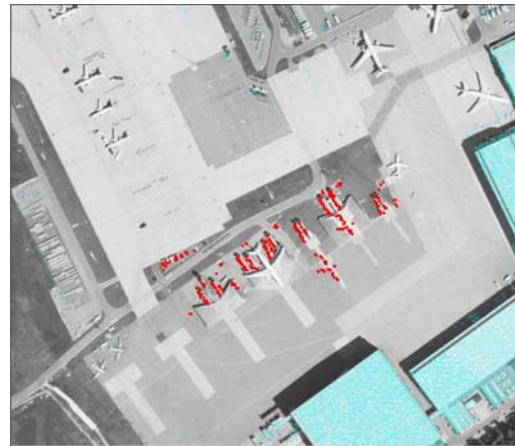

Figure 14. Selected other-than-building object points (e.g. airplanes)

The final result was improved using DTMaster software with manual elimination of tree points, airplanes etc. (Fig. 14-15).
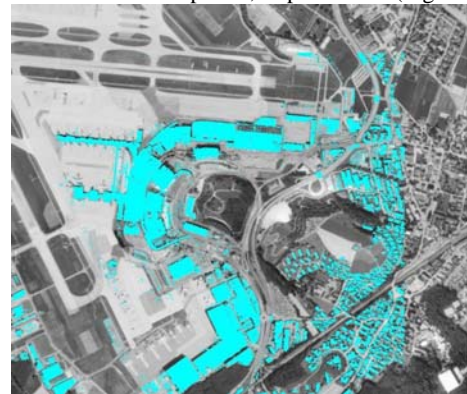

Figure 15. Final extracted building points

4.3 Performance evaluation

We compared the results from SCOP++ processing and density calculation process (Figures 16 and 17). Because of the low density of the DTM-AV data, small buildings were not detected as well as with the SCOP++/DTM edit package classification. Large airport buildings could be extracted equally well as with the other methods.
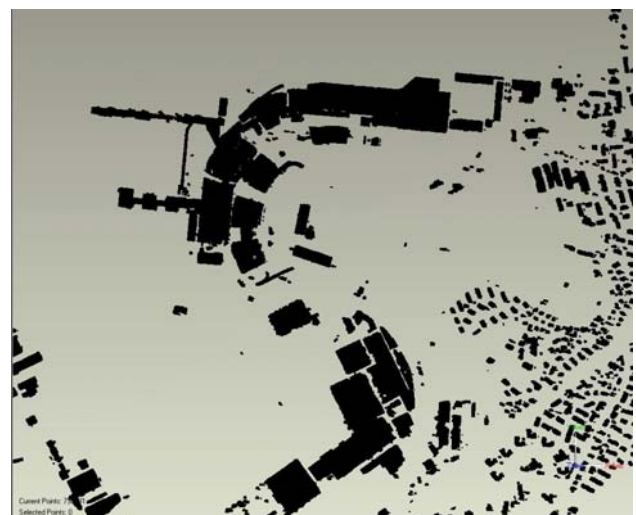

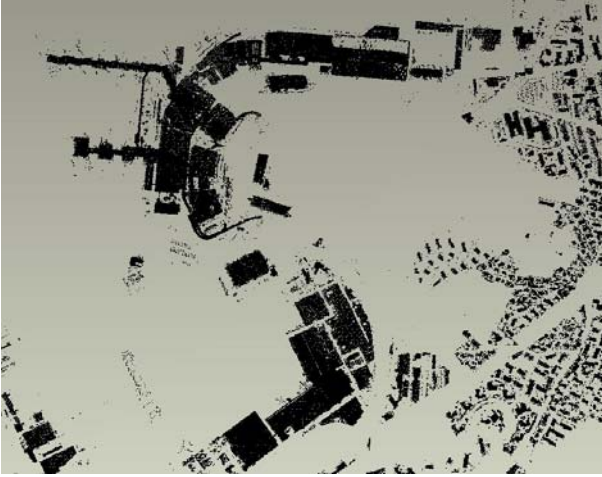Figure 16. Results from SCOP++/DTMaster

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Figure 17.Results from density calculation

If we compare the results from the rasterised vector maps and the SCOP LIDAR/ DTM edit package, we can see that the results are very similar (Fig. 18).
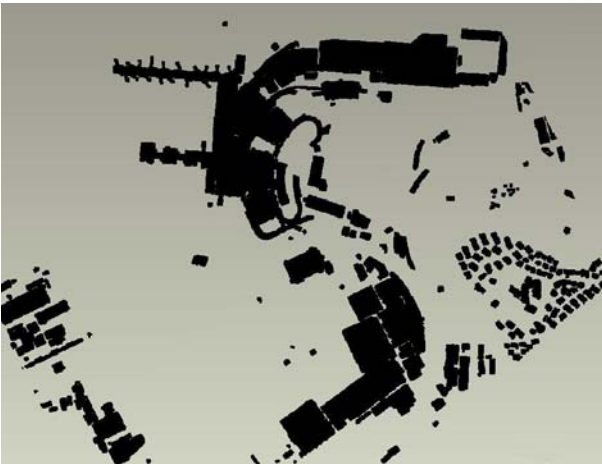

Figure 18. Results from the rasterised vector maps

5. CONCLUSIONS

We have presented four methods for object extraction for airport sites. These methods are using commercial LIDAR processing software, multispectral classification using orthophotos, calculation of point density of DTM-AV and rasterised vector maps. When LIDAR DTM-AV and DSM data are available and if commercial software like SCOP is unavailable, point density of raw DTM and DSM data can be used mainly for large object extraction. When LIDAR data is unavailable, DSMs can be generated using multi-image matching methods (e.g. SAT-PP software). The use of multiple cues, especially multispectral information, point density, DSM, 2D location of reference data support the building extraction result. Future work will include the combination of these various cues, and quantitative evaluation using the existing reference data.

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