

**Name(s) and Affiliation of Participants:**

Alina Maas, Franz Rottensteiner, Institute of Photogrammetry and GeoInformation, Leibniz University Hannover, Nienburger Strasse 1, 30167 Hannover, Germany

e-mail: Rottensteiner@ipi.uni-hannover.de

**Procedure used for building detection:****1) Preprocessing:**

- a) **Generation of a Digital Surface Model (DSM):** We used a multi-image expansion of the OpenCV implementation (OpenCV, 2012) of semiglobal matching (Hirschmüller, 2008) with the cost function of (Birchfield & Tomasi, 1998). Dense matching was applied to all possible image pairs, and the resulting DSMs were merged to obtain a combined DSM with as few void areas due to occlusion as possible. Remaining void areas were interpolated using a method based on anisotropic diffusion.
  - b) **Generation of a true orthophoto and an NDVI image:** The DSM was the basis for computing a true orthophoto of the test sites. One raw true orthophoto was generated for each input image covering a test site. These raw true orthophotos were combined to a joint true orthophoto, for each pixel taking the median grey value of each image where the pixel is not occluded. As a result, the true orthophoto does not contain moving objects (cars). The true (CIR) orthophoto is the basis for generating the NDVI and an image  $\sigma_{\text{NDVI}}$  representing the standard deviations of the NDVI values, the latter generated by error propagation.
  - c) **Generation of a Digital Terrain Model (DTM):** A variant of the method described in (Rottensteiner et al., 2005) is used to derive a coarse approximation of the DTM. Unlike in the publication, a rank filter was used instead of morphological opening. This was necessary due to outliers in the DSM which caused the results of morphological opening to be too coarse for DTM generation to work. That is, the 5% quantile of the heights within a given window was used to define the approximate DTM height of a raster cell. Two iterations were used in all test areas, removing large buildings after the first iteration in the way described in (Rottensteiner et al., 2005).
- 2) **Building Detection:** For building detection, the method described in (Rottensteiner et al., 2005; 2007) is used. The input data are a normalised DSM (nDSM), obtained by computing the height differences between the DSM and the DTM, and the NDVI image along with its standard deviations,  $\sigma_{\text{NDVI}}$ . These data are used in raster format, sampled at 5 cm. Surface roughness was found not to be reliable enough to be used in classification, largely to the smoothing of the DSM caused by the respective smoothing terms in the dense matcher. In the pixel-wise classification based on the Dempster-Shafer theory, the models for the probability masses of the nDSM and the NDVI are set in the way described in (Rottensteiner et al., 2007), based on an estimate of the minimum building height (2.2 m to 4.5 m in the three test areas) and a parameter describing the value of the NDVI for which the related probability mass is supposed to support the hypothesis of vegetation

(set to 15% or 20% for the three test sites). The classification results were smoothed by morphologic opening followed by morphologic closing, both with square structural elements of 0.5 m side length.

- 3) **Export of Results:** The building detection results were exported as label files in the form of 8 bit palette tiff files, along with ARC/GIS world files to contain the geocoding information.

## References

- Birchfield, S., Tomasi, C., 1998. A pixel dissimilarity measure that is insensitive to image sampling. IEEE-TPAMI 20(4): 401-406.
- Hirschmüller, H., 2008. Stereo processing by semiglobal matching and mutual information. IEEE TPAMI 30(2):328-341.
- OpenCV, 2012. <http://opencv.itseez.com/modules/calib3d/doc/calib3d.html>
- Rottensteiner, F., Trinder, J., Clode, S., Kubik, K., 2007. Building detection by fusion of airborne laserscanner data and multi-spectral images: Performance evaluation and sensitivity analysis. ISPRS Journal for Photogrammetry and Remote Sensing 62(2):135-149.
- Rottensteiner, F., Trinder, J., Clode, S., Kubik, K., 2005. Using the Dempster-Shafer method for the fusion of LIDAR data and multi-spectral images for building detection. Information Fusion 6(4):283-300.