

TOWARDS ADAPTIVE IMAGE PROCESSING - AUTOMATED EXTRACTION OF RAILROAD TRACKS FROM EXTREMELY HIGH RESOLUTION AERIAL IMAGERY

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ABSTRACT:

Very high resolution ortho-imagery is a promising data source for applications such as corridor mapping and infrastructure object detection. However, automated processing of large quantities of data is still a challenging task. This is due to the spectral and thematic heterogeneity of different datasets and the given memory intensity. But automation is essential for an operational use. Thus, the aim of the present study was to develop an automated rule set for the detection of potential railroad tracks that could be applied to a large quantity of images for operational use. The essential requirements of this rule set were optimization of processing time, stability of the processes and adaptability to heterogeneous environments. We conducted this analysis on 600 ortho-images with a ground resolution of 5 cm derived from a helicopter-based platform. The study area was located in western Austria and followed the tracks of the Kufstein-Brenner railway line of the Austrian Federal Railways (Österreichische Bundesbahn, ÖBB). The environment of the tracks is extremely heterogeneous, reaching from densely populated areas to high mountain scrubland. The rule set was developed in Trimble's eCognition Developer 8.64. It is able to adapt to image brightness differences as well as scene complexity. Our results show that it is possible to develop self-adapting and robust rule sets to automate the extraction of rail tracks masks from ortho-imagery. The method yields a covering rate between 95.4 % and 97.1 %.

1. INTRODUCTION

Future tasks of image analysis will include corridor mapping, such as railroad track monitoring and surveying. The ability of workflows or rule sets to adapt to the changing environments in such imagery becomes a crucial aspect of automated extraction processes. The surroundings do not only change in their location regarding both altitude and position but also in the time of their capture. This heavily influences shadows and illumination in general. The automated extraction of objects in such images is thus challenging task. However, there is a growing demand for solutions especially regarding operational applications.

The aim of this study was to develop an approach for the fully automated detection of railroad tracks from large sets of extremely high resolution ortho-images. Furthermore, there are high demands to the procedure regarding processing time, stability, and processing quality. The resulting data is used in the subsequent spatial selection process as a railroad track mask to classify simultaneously acquired LiDAR data as a basis for further object extraction.

The demand for geospatial information in the public transportation sector is rapidly growing. The updating of existing datasets or information systems and the digital implementation of objects have become of crucial importance. Such information is needed by railroad companies both for internal planning and for complying with international standards especially regarding railroad safety. Until now the gathering of such information was a domain of terrestrial surveying. However, the retrieval of required information is costly and there is a growing demand for alternative methods.

Conventional methods of pixel-based image analysis only use spectral signatures for the classification process. But for high resolution imagery such methods are not suitable since the level of detail is too high to rely purely on spectral signatures in order to distinguish target classes from each other (Neubert, 2006; Hay and Castilla, 2008; Blaschke, 2010). Thus, the geographic object-based image analysis approach (GEOBIA) was applied in this study. The effectiveness of this new method has been proved in numerous studies (Blaschke, 2010). Baatz et al. (2008) extended the concept of OBIA to object-oriented image analysis (OOIA). Within this concept defined classes are not fixed anymore; furthermore, they allow for an iterative process to yield an optimal result. Such a procedure is especially suited for object extraction and has been successfully applied for tree crown delineation by Baatz et al. (2008). Due to the high heterogeneity of the used imagery the approach was implemented here. Until now self-adapting rule sets are not yet widely used (e.g. Costa et al., 2008) but offer excellent possibilities for the processing of large and heterogeneous datasets.

2. METHODOLOGY

2.1 Input Data

The research was performed on ortho-imagery with an extremely high resolution of 5 cm derived by a helicopter-based platform (Figure 1). The term extremely high resolution is used according to Möller (2002) for images with a ground resolution below 10 cm.

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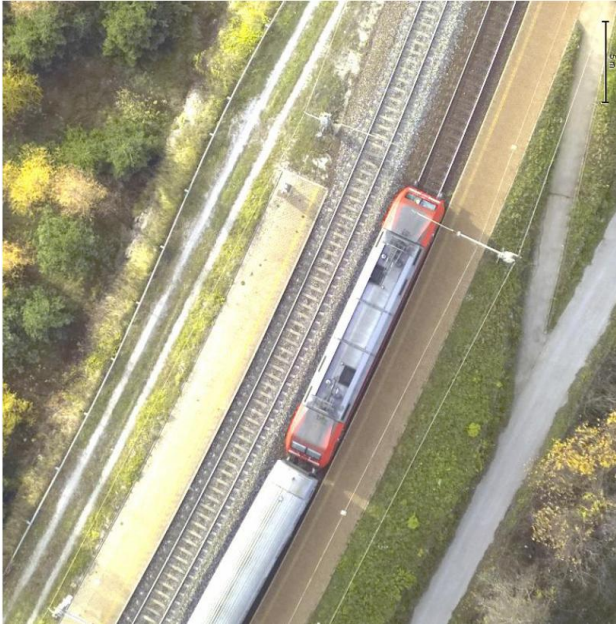


Figure 1. Sample subset of the used high-detailed aerial ortho-imagery with 5 cm ground resolution

The platform was equipped with a Rollei AIC modular LS (H25) photogrammetric camera and an IMAR INAV_FJR-001 inertial measuring system. For a simultaneous acquisition of laser point data a Riegl LMS-Q560 laser scanner was also part of the platform. The helicopter was flying at an approximate height of 200 m above ground level to yield extremely high resolution imagery and point density. More than 600 image tiles of 250 m grid size (5,000 x 5,000 pixels) and a data volume of approximately 75 MB each had to be processed.

The only ancillary data used in the extraction process was the flight path (trajectory) for a coarse delineation of the search area for railroad tracks. The resulting railroad track mask is used to select LiDAR data for a subsequent object extraction. This part of the workflow is described in Beger et al. (2011) and thus not included in this paper. A scheme of the procedure including the input and output data is given in Figure 2.

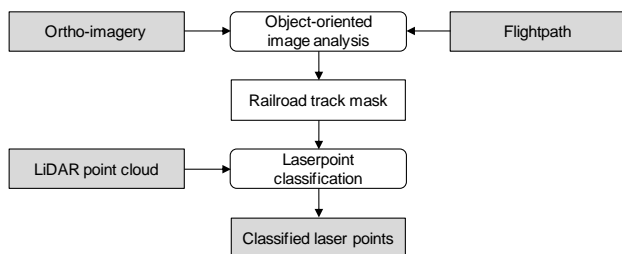


Figure 2. Schematic overview of the procedure for the automated extraction of railroad tracks

2.2 Study area

The study area follows the tracks of the Kufstein-Brenner railway line in western Austria belonging to the network of the Austrian Federal Railways (Österreichische Bundesbahn, ÖBB).

The surrounding of the tracks is extremely heterogeneous, reaching from densely populated areas to high mountain scrubland. Furthermore, due to cloud cover and sun position, general illumination and shading of the landscape is very variable.

2.3 Methodical Approach

To guarantee optimal detection results, a rule set has to be able to adapt to the specifications of each image in a set. This can be achieved through an analysis of image parameters and the setting of variable values before a scene is processed. The work was implemented with Cognition Network Language (CNL) in Trimble's eCognition Developer 8.64. The design of the approach features self-adapting algorithms within process trees with the adaptability to heterogeneous images scenes. Three consecutive segmentation steps were performed. First, an overall area of interest was detected through chessboard segmentation. Second, quad-tree segmentation was performed in order to reduce the size of the already selected area of interest. Finally, a multi-resolution segmentation was performed. The formed segments were classified into potential rails or discarded. The entire process was implemented in a single rule set (Figure 3).

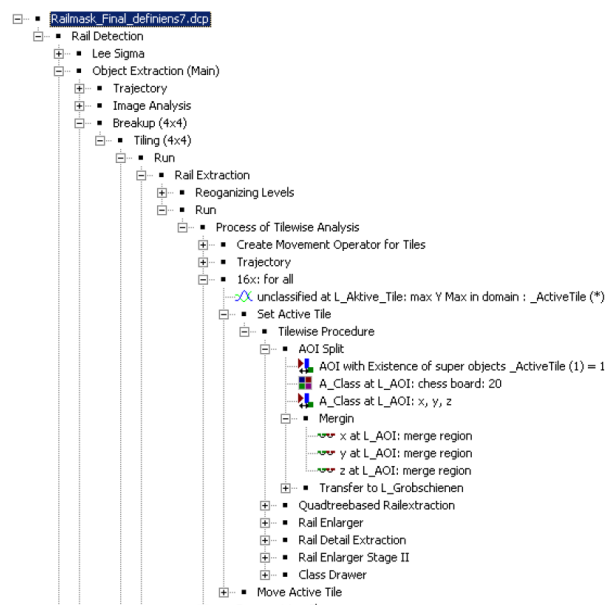


Figure 3. Subset of the developed rule set for the automated extraction of railroad tracks

Edge layer: Before the segmentation procedure, an additional data layer was generated using a Lee sigma filter that contains edge information. This process allows a fast operation compared to other filter algorithms. In this edge layer railroad tracks appear as bright linear edges (Figure 4).

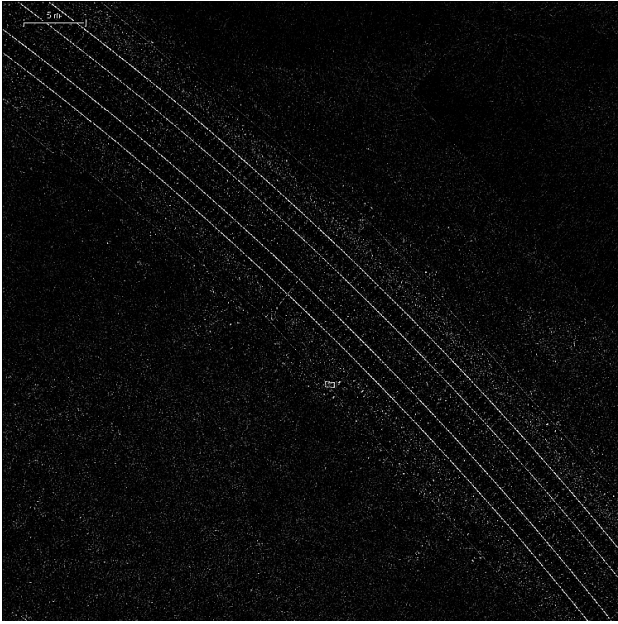


Figure 4. Representation of the Lee sigma edge layer for a subset of the investigation area

Chess-board segmentation: The flight trajectory of the helicopter which follows the course of the tracks roughly was buffered by 20 m. Subsequently, each image was segmented into squared tiles (4 x 4 m) using the chess-board segmentation algorithm. All tiles intersecting the buffered flight path were selected. Since the railroad track areas are clearly visible in the edge layer the tiles with an edge layer value above a certain threshold were considered as area of interest (AOI) for the next iterative step (Figure 5). Through this step the area and thus the amount of data for further processing was minimized.



Figure 5. Area of interest (green) for the further extraction of railroad tracks

Quad-tree segmentation: The AOI was further processed using the quad-tree segmentation algorithm. Quad-trees are generated according the homogeneity of enclosed pixels with a maximum size defined by the scale parameter. The high performance regarding the processing time is advantageous.

Since illumination heterogeneities caused by object shadows, changed flight conditions or mosaicking of image tiles were considered in this step. Therefore, the AOI was segmented into squares of 50 cm side length. These squares were classified into bright, average or dark areas.

The quad-tree segmentation was performed using the same scale parameter for each of these classes based on the pixel values of the Lee sigma edge layer. If the quad-trees corresponded to the given mean edge layer value, they were classified as a member of crude railroad tracks.

In addition the AOI was used for the further adaptation of the remaining rule set. Thus, an initial segmentation was applied to determine the scene complexity by counting the number of created segments. This number depends heavily on the environment of the railroad tracks, the position of the tracks within the image and the possible existence of train stations. Thus, this number could be used to adapt the following algorithms to the conditions of the scene. Based on the result the image was either processed as a whole, split into four tiles (Figure 6) or into 16 tiles (Figure 7). The tile-wise processing avoids a memory overflow through exceeding the addressing limit, guarantees stability and processing time optimization.



Figure 6. Initial splitting of a single image into four sub-tiles in case of heterogeneous scene content

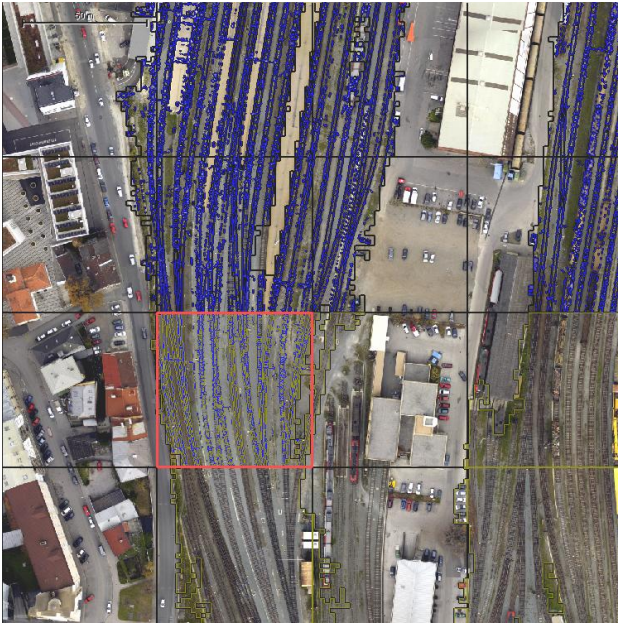


Figure 7. Subsequent splitting of scenes into 16 sub-tiles when highly complex urban structures or railway stations occur

Multi-resolution segmentation: In the next iterative step a multi-resolution segmentation is performed on the preceding classification results. This segmentation was applied on a fine scale with a scale factor of 10 to detect the narrow tracks. The edge layer was weighted with the maximum, whereas the RGB bands have been used with a weighting of 20 % only. This represents the higher importance of the edge layer, which is likely to represent railroad tracks, in forming of segments. The compactness criterion was set to a low value to allow for the extraction of elongated objects. Thus, railroad tracks cause the algorithm to form long and connected segments.

The area/perimeter ratio of the segments of was used to further improve the classification results. All objects with a low area/perimeter ratio and a higher Lee sigma value were classified railroad tracks. For further processing the resulting railroad track mask was exported as shape file.

3. RESULTS

Our developed rule set processed all images without interruptions. It adapted automatically to brightness of the image tiles. According to scene complexity the algorithm splits images in sub-tiles and delivers results that have been successfully used in further processing steps. Image scenes with very consistent track surroundings are processed without splitting the image. In this case, processing time is about 2 minutes. More heterogeneous tiles are split into four sub-tiles (Figure 6) which are processed in succession within 4 to 8 minutes each. Images with highly complex urban structures or railway stations are further split into 16 sub-tiles (Figure 7). The processing time is 10 to 15 minutes.

The obtained result is a polygon shape file covering the railroad tracks of the investigation area (Figure 8). Our results show that adaptive rule sets in object-based image analysis can fully automate the processing of large and heterogeneous data sets.

The detection accuracy is high although leading to more artefacts. But these misclassified track areas can be removed in the subsequent processing steps. Two control areas with about 17,000 m of tracks each have been chosen to evaluate the quality of the approach. The quality assessment was only able to be performed using the resulting railroad track axis after LiDAR data classification and the subsequent extraction process. A covering rate of 95.4 % and 97.1 % respectively could be achieved in total. The quality is higher for open tracks 96.8 % and 98.3 % resp. compared to train station areas 92.4 % and 94.2 %.



Figure 8. Detection results: Area of interest (grey) and final delineated railroad tracks (blue)

4. CONCLUSION

The study showed that it is possible to extract features from large or numerous data sets in an automated way and with high quality. The results are the basis for the further detailed extraction of railway infrastructure objects using LiDAR data (Beger et al., 2011).

Future research will focus on the improvement of the analysis of scene characteristics.

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