**The program package ”buildenh\_v1.0”**

The package solves the enhancement of the classification results by means of vectors. Its task is to generate a topographic map of urban areas automatically. The software is designed as a suite of various software tools. A short description of the important characteristics of the package is given in the following.

**Characteristics**

The package contains 10 main programs, numerous supporting scripts and functions, and other open-source R-packages. Its names are, e.g., ‘line\_detection.R’, ‘support\_line\_detection.R’, ‘func\_mean\_line.R’, and “EBImage”. Data and chosen parameter are also part of the package. The diagram in Figure 1 depicts the components of “buildenh v1.0”. The processing of the examples required for a few objects special solutions which are contained in additional scripts, e.g., ‘spObj\_line\_detection.R.



Figure 1. Components of the program package “buildenh”

The solution for vectorizing the raster data is based on the detection of lines. Only short pieces of lines are required to complete an object, e.g., the outline of a building’s roof. In areas where trees overlap buildings, this may become an important feature. Least-squares adjustment is carried out for lines and polygons. Display of intermediate results on top of the orthoimages is a key to obtain precise results. Checks and automatic corrections in case of errors, e.g., removal of parts from other lines, enable robust solutions. Partition of objects may also be selected. At processing, different routes are selectable for object types and methods for sequence of lines (cf. Figures 2 and 3). The decisions to be made for running different routes are based on statistics of the selected data. Explanations are within the scripts, to understand the solution and enabling extensions and adaptation to other data. Perfect rectangularity of lines is established to ensure high cartographic quality. The package will be open-source software in R comprising about 0.3 Mb. Figure 2 shows the types of objects and Figure 3 the methods for finding the sequence of lines.



Figure 2. Types of objects in the package ‘buildenh’. Upper row: 4-line rectangular (small and long), lower row: multiple rectangular lines and objects containing non-orthogonal lines.



Figure 3. Methods for finding the sequence of lines represented by their centers. Top: based on angle (α), middle: based on distance (s), bottom: based on scanning and line-following.

**Experiences**

In many tests it was found that the quality of the classification is very important for good results for the enhancement of buildings and other man-made topographic objects. A high degree of automation is achieved by proven parameters and thresholds. Interactions with orthoimage and/or graphics as background enable best results. For example, the detection of small orthogonal lines may be found by measuring of one pixel and the orientation of a roof-ridge may be derived by measuring two pixels, to ensure complete and precise results.

Unsolved problems are the mapping of objects situated on the border of two adjacent orthoimages or the mapping of objects consisting of curved lines. The package will be updated, and new versions will follow.

**Example**

In the given examples, three processing modes are available: demonstration of one object or of a group of objects, and object-wise processing. The

solution for special objects may be seen in the scripts named ‘spObj\_name of main program.R.’ Display of results on top of the orthoimage and the given reference (‘Ground truth’) is also possible (cf. Figure 4 and 5). It must be noticed that the reference is a land cover map and not a topographic map.

|  |  |
| --- | --- |
| Et billede, der indeholder tekst  Automatisk genereret beskrivelse | Et billede, der indeholder tekst  Automatisk genereret beskrivelse |

Figure 4. Enhanced buildings superimposed on orthoimage (left) and land cover map (right).