Influence of Spurious Pit Removal Methods from SRTM on River Network Positioning

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1. Introduction

Digital elevation models (DEMs) provide us with a digital representation of the continuous land surface. DEMs often contain depressions that result in areas described as having no drainage, referred to as sinks or pits. These depressions disrupt the drainage surface, which preclude routing of flow over the surface. Sinks arise when a connected component of pixels occurring at the same elevation level is surrounded by pixels of higher elevation, or when two cells flow into each other resulting in a flow loop, or the inability for flow to exit a cell and be routed through the grid. Hydrologic parameters derived from DEMs, such as flow accumulation, flow direction, upslope contributing area and river network detection require sinks to be removed (Maune, 2001). Naturally occurring sinks in elevation data with a grid cell size of $100m^2$ or larger are rare in terrains modelled by fluvial erosion processes. They could occur more frequently in glaciated or karst topographies. Various algorithms have been proposed to detect and remove surface depressions, such as elevation-smoothing method (Mark 1984), depression-filling algorithms (Jenson and Domingue, 1988; Soille and Ansoult, 1990; Tarboton et al., 1991), breaching (Martz and Garbrecht, 1998) carving method (Soille et al., 2003) or hybrid method combining carving and depression filling (Soille, 2004). For a detailed review it is possible to refer to e.g. Reuter et al. (2008) or Wang and Liu (2006). Lindsay and Creed (2005) compared the performance of different algorithms on various slope classes and landforms using a very high resolution dataset. However there is few information on the influence of the various algorithms on the accuracy of the positioning of the extracted networks. The aim of this study was to assess the effects of three pit removal methods on the position of river networks extracted from the SRTM dataset.

2. Test Area and DEM Processing

The area used for the test is situated in the Rhine basin with a size of approximately 120 km^2, with a variety of land uses and morphological characteristics (Fig. 1). It is a subcatchment of river Ruwer with very limited artificial channels, counting for less then 1% of the whole network.

The considered SRTM dataset (Jarvis et al., 2006) has an original resolution of 3 arc-seconds. The SRTM digital elevation data were originally produced by NASA. The dataset used was further processed from the original NASA DEMs to fill in no-data voids (Jarvis et al., 2006). The processing included: (i) the support for auxiliary information, (ii) the use of a void region specific processing over a tile based processing, and (iii) use

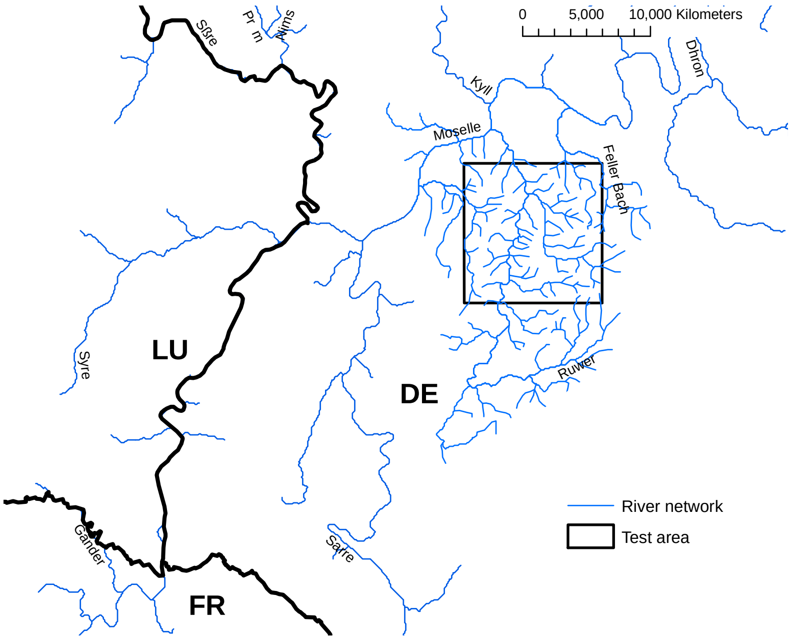
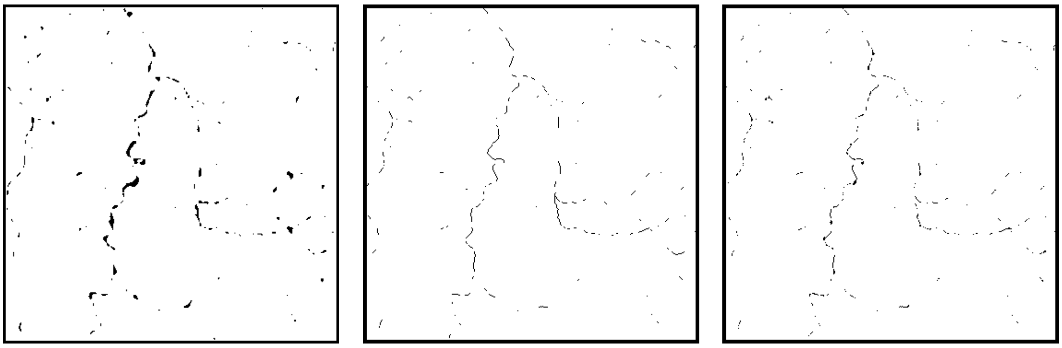


Figure 1: Test area. DE for Germany, FR for France and LU for Luxembourg

of SWDB V2 water body database. The dataset was mosaicked for the available scenes, and projected to the ETRS89-LAEA projection (Annoni et al., 2003). The methods used for pit filling and generating flowing surfaces were:

1. **Filling algorithm (F1)**. A sink is filled in an iterative two steps procedure: (i) to identify local minima, and (ii) to fill them from the bottom to the top by exploring the neighbourhood to find the pour points (Jenson and Domingue, 1988; Tarboton et al., 1991). Mathematical morphology offers a suitable framework for the development of efficient pit filling procedures even in the presence of composite pits and natural depressions (Soille and Ansoult, 1990).
2. **Carving (F2)**. The carving method (Soille et al., 2003) relies on a flooding simulation. The sinks are not filled, but the terrain is carved to make pits flowing further down, i.e. carving decreases the elevation of pixels occurring along a path starting from lower elevation pixels. All spurious minima of the input DEM are identified. If the terrain does not contain any significant natural depression all minima connected to the image border are used as outlets.
3. **Optimal hybrid (F3)**. The optimal approach combines morphological pit filling and carving (Soille, 2004) in order to reduce the sum of the differences in elevation between the original DEM and the elaborated one. In the combined approach sinks are filled up to a certain level and then carving proceeds from that level. The level is set to: i) minimise the sum of the heights differences between the input and the output depressionless DEM; or ii) minimise the number of modified pixels.

The number of pixels modified by each considered method is summarised in Table 1. Carving (F2) and optimal hybrid (F3) modified less pixels than the plain filling method. These results are reflected also in the sum of the elevation differences between the in-



(a) F1 (b) F2 (c) F3

Figure 2: Spurious pit removal methods: mask of the modified pixels.

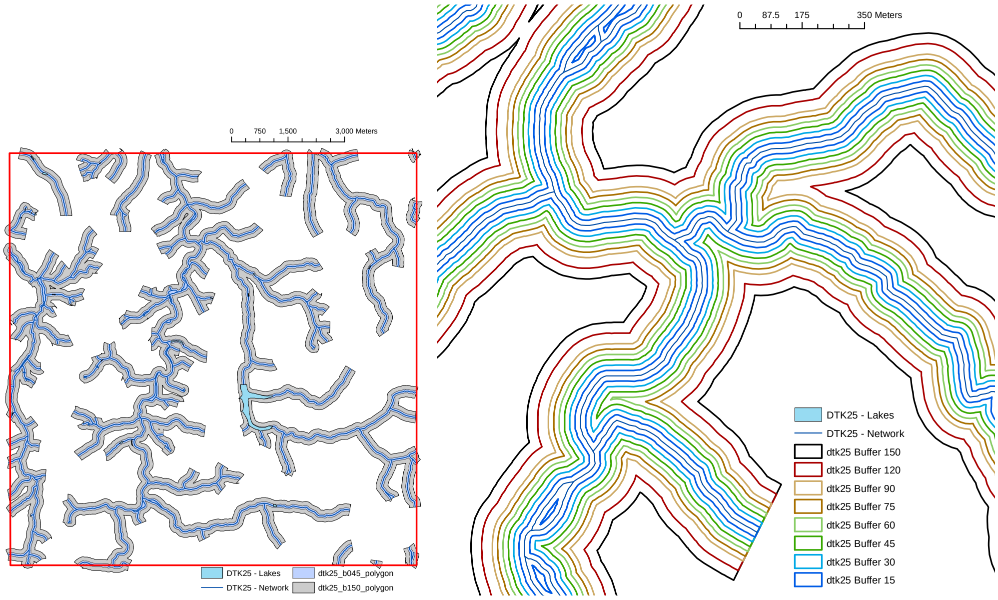
	Number pixels	% modified pixels	Sum of elevation differences (m)
F1	3303	2.52	712400
F2	2023	1.54	592809
F3	2025	1.54	564015

Table 1: Spurious pit removal methods: summary statistics.

put and the modified dataset when suppressing all pits, minimised by the optimal hybrid method (Soille, 2004). Most of the spurious pits were located at the bottom of the valleys, where the main sections of the rivers network are to be located (Fig. 2).

The river network used as reference was extracted from the German digital topographic maps (DTK5) for the Rheinland-Pfalz region, an independent dataset at very high resolution. The widest stream section is 20 metres large, below the pixel size of the SRTM dataset. Several buffer areas were created around the river network at distance multiple of 15m (Fig. 3).

The SRTM river networks were defined as all cells with a flow accumulation value higher then a certain threshold. Flow direction and flow accumulation values were calculated using the D8 (Fairfield and Leymarie, 1991).The spatial positioning of the extracted river networks was assessed by calculating the number of pixels of the networks falling in the different buffer areas normalised by the total number of pixels for each network.



(a) Buffered reference river network (b) Zoom on buffered network

Figure 3: Buffering in the test area

3. Preliminary Results

The preliminary results for SRTM are presented in Fig. 4. Only less then 20% of the pixels of the extracted river networks are contained on the smallest buffer size. The values are then regularly growing up to a maximum of 75%. The river network extracted form the dataset filled with optimal carving (F3) is the closest to the ground truth network.

In Fig. 5 are presented some preliminary results for the Strahler order level obtained from networks extracted with D8 method. The curves have similar trends with F3 method reaching higher results. The figures underline the higher uncertainty in the position of network segments with lower Strahler order. Further analysis and computations are envisaged for breaking the results for slope classes and other land parameters, such as land use or morphological features. The comparison of different datasets in the same area would be carried out in order to highlight possible difference due to resolution, DEM preparation and error structure of the dataset.

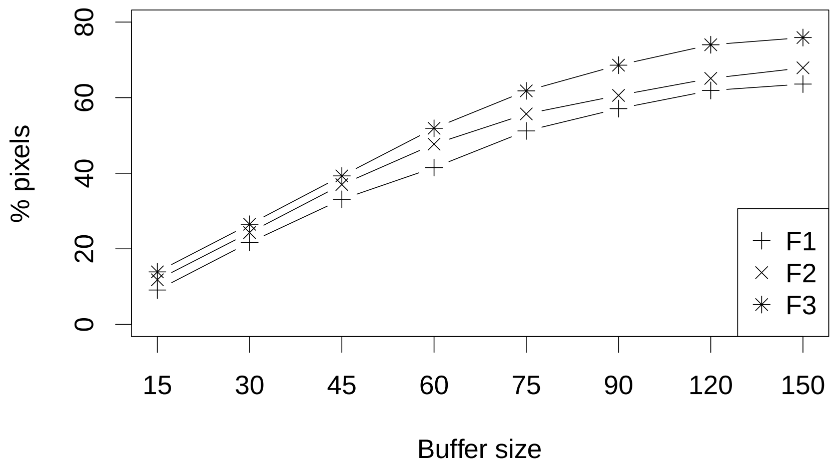
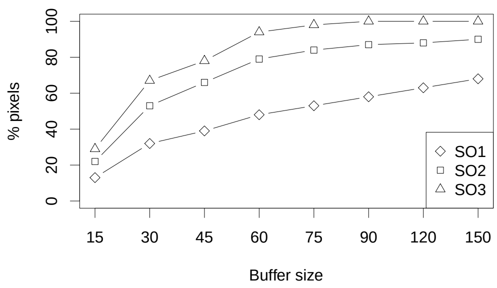
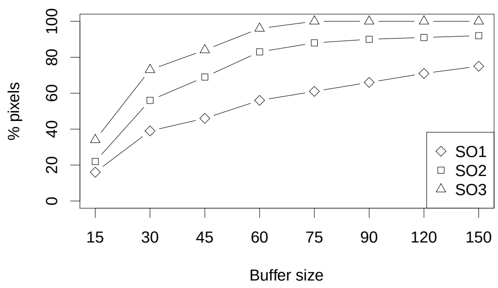


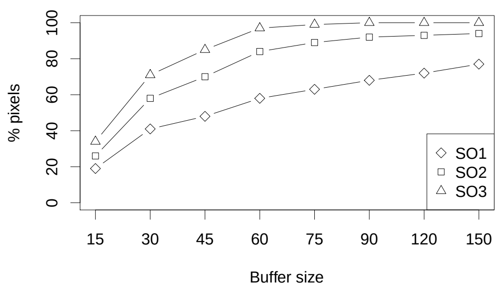
Figure 4: Filling algorithms and percent of pixels in the different buffer areas. The size of buffers are in meters for each side of the reference network.



(a) F1



(b) F2



(c) F3

Figure 5: Filling algorithms and percent of pixels in the different buffer areas for Strahler orders.

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