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Implementing the automatic extraction of ridge and valley axes using the PPA algorithm in Grass GIS

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Abstract

The profile recognition and polygon breaking (PPA) algorithm allows to extract the ridge and valley axes automatically over wide areas maps. The algorithm simulates the human thinking in the line drawing process. First a process of profile recognition takes all the points close to the possible axes and connects them as a belt of closed polygons. The polygons are then broken into a continuous line and a smoothing algorithm adjusts the line. The algorithm, originally coded in Fortran, has been adapted to be used for raster analysis in Grass. The module takes a raster map, typically a DEM, and outputs a vector file representing the ridge or the valley axes. Various testings show the features of the algorithm and the implementation into Grass GIS.

1 Introduction

The automatic extraction techniques of linear or curvilinear features from 2-dimensional maps have been in great demand by many map interpreters for decades. In 1990s, some algorithms had been developed under this demand [2, 4, 5]. The two remaining problems of this issue are: 1) how to keep the linear features be continuous when the targets are occasionally vague, and 2) how to handle the complicate branch lines properly and completely. In this task, we prove that Profile recognition and Polygon breaking Algorithm (PPA), which was developed by Chang et al. [1], can solve these two problems quite properly and reasonably.

With the Profile Recognition Algorithm in PPA, the possible target point of ridge axis is made centre of a variable length of profile switched in all the possible directions (N-S, NE-SW, E-W and NW-SE). If at least a lower point along a profile is found, the central point is considered as a target. In this way also points that are not locally maximum are included as target points. The advantage of this fuzzy treatment is that it guarantees the ridge or valley axes will not be interrupted by occasionally small-scale flat bottoms or flat tops of ridges or valleys. Thus, the linear continuity based on a wider area can be saved. Moreover, the lengths of profile are variable; it can be adjusted to just longer than the ambiguous features to overcome the threat of discontinuity.

After the Profile Recognition Process, a Target Connection Process will register each target's connection state with its 8 neighbours in the grid, which makes the target as one end of at most 8 segments. It is inevitable that many segments are actually crossed to each other, which creates many unreasonable branch points. When this happens, the less important segment, like a lower elevation segment in the case of ridge extraction, is cancelled.

After the Target Connection process, the possible segment groups of linear features result in bunch of closed polygons. These polygons are broken into dendritic line patterns by repeatedly eliminating the least important segment among each closed polygon (the lowest one in the case of ridge recognition), which is called Polygon Breaking Process. The details of this process can be referred to the original work of Chang [1].

After the Polygon Breaking Process, the Branch Reduction Process can moderately cut down some ambiguous or unimportant ends of complex branches; the Line Smoothing Process can soften the angles of segments' connection. The two processes are basically optional. However, since the Profile Recognition had somehow exaggerated the extent

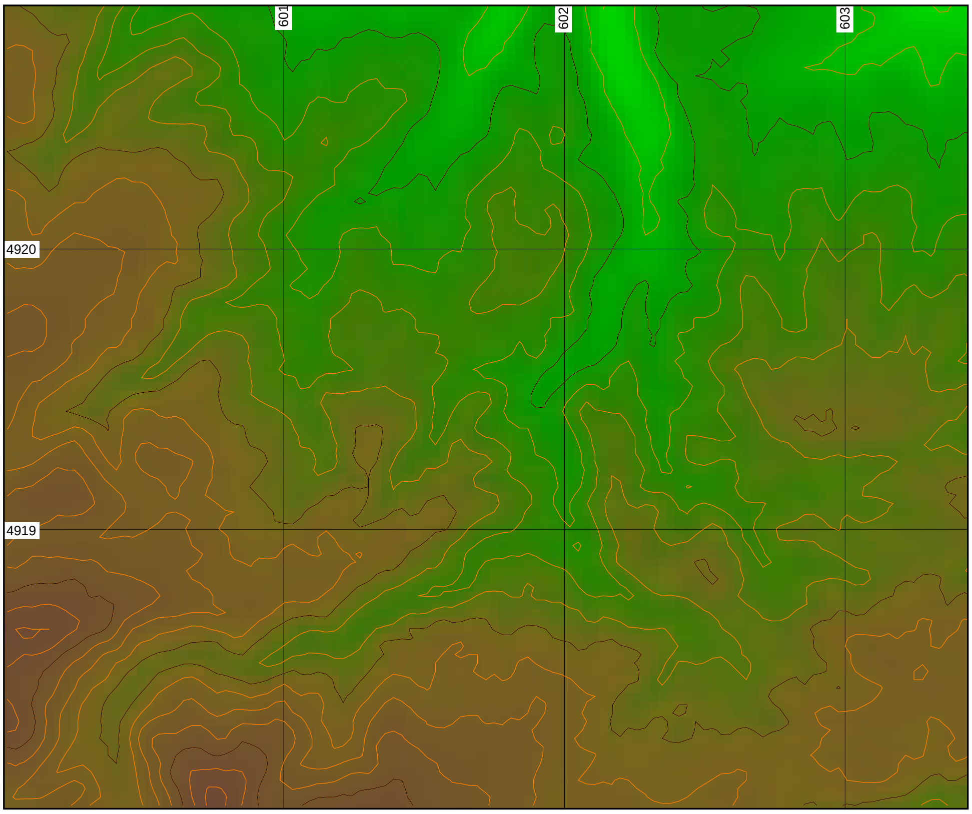

Figure 1: DEM from a subregion of Spearfish dataset. UTM coordinates are reported in kilometers

of linear feature, it is more recommended to execute the Branch Reduction at least half the length of the profile. In the other hand, the Line Smoothing is basically a position interpolation process based on elevation. Its effect is evident especially when grid intervals are large.

2 The PPA algorithm in Grass

The PPA algorithm has been coded in Fortran77 by Chang [1] in 1998. Modification to the code has been made exclusively on the IO procedures in order to get code reading command line arguments and to produce an ASCII Grass vector file [3]. The interface to Grass is made through a shell script that makes possible to select the raster input map and the vector output (`g.ask` module). The ASCII Grass vector file is then transformed to a binary one within the script through `v.in.ascii` module, and passed to `v.in.support`.

The authors think that `r.ppa` would be a good name for the module.

3 The `r.ppa` module

The map in figure 1 represents a portion of Digital Elevation Model DEM coming from the freely available Spearfish dataset[1]. The projection is UTM zone 13 and the reference ellipsoid is WGS84. The Dem resolution is 30 meters. The region displayed is dimensioned so to have a 95x115 bidimensional dataset. The elevation range is from 1223 meters (brightest green) to 1559 meters (darkest brown). Isolines with an equidistance of 25 meters are reported in brown while for the black isolines equidistance is 100 meters.

Calling `r.ppa` module within Grass GIS environment will ask the user for raster map to be analysed, the vector file to be generated and the specific PPA parameters: the type of analysis (the extraction of valleys or ridges axes), the algorithm grid resolution, and the profile length (in number of points on the algorithm grid).

[1]Spearfish dataset together with other free data sources is available at `http://grass.itc.it/data.html` Grass site or other Grass mirror site

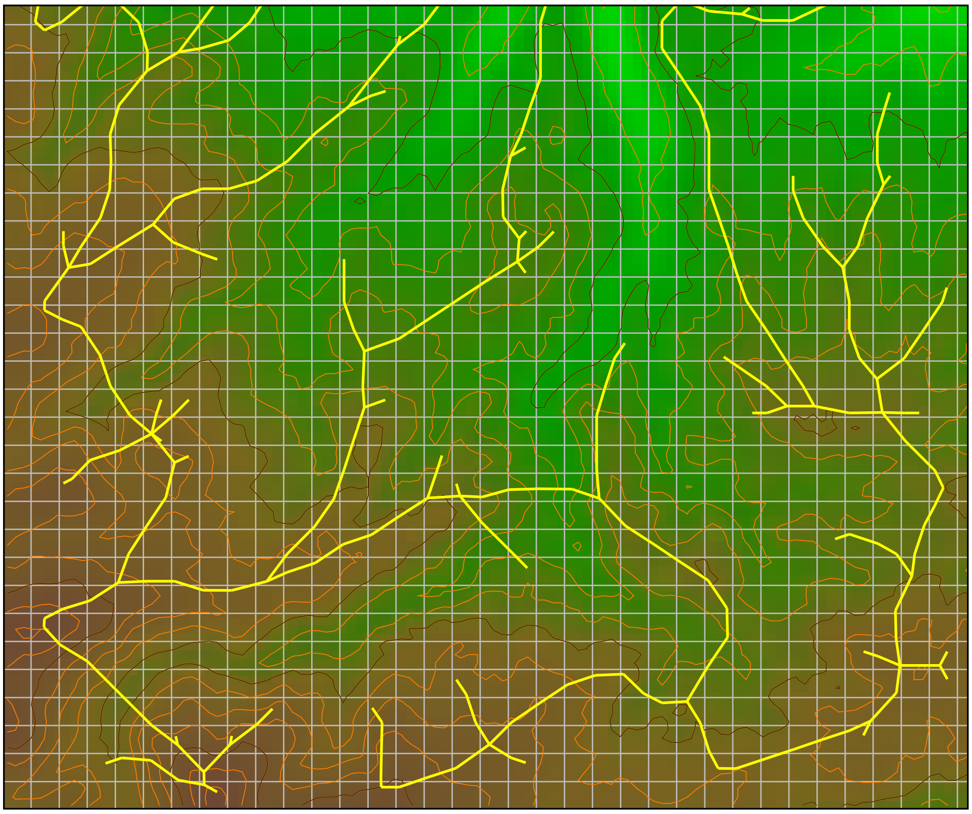

Figure 2: The PPA algorithm applied to Spearfish DEM

The extraction of ridges axis is shown in figure 2. The DEM is overlayed by `r.ppa` vector output (in yellow) obtained on a 100x100 meters grid (the grey grid) with a profile length of 5. Analysis is made on a wider (about half the profile length will suffice) region to avoid influence of DEM's boundaries.

Varying the parameters brings different results, a good combination in the case of the study area is to get a 50x50 grid and a profile length of 10. The yellow vectors in figure 3 are the results of automatic extraction of ridge axis.

Figure 4 shows the extraction of valley axes (white vectors) with the same parameters used above.

4 Conclusions

The ppa algorithm is so included in Grass GIS through `r.ppa` module. The original Fortran source code has not been modified apart for `IO` and to get command line arguments.

At the moment of writing this paper the module is working, so, after the creation of a manual page, it could be distributed internally of Grass or as external module.

Though `f2c` produces a working C version of the code, manual translation is needed to maintain good code readability. In the C version there will be the opportunity to call Grass raster libraries directly form the code.

Although the PPA is used only for ridge and valley axes extraction in this paper, it is also possible to apply on many other kinds of linear features.

The key point is how to define the target point in the Profile Recognition Process. For example, on a satellite image, the color contrast between the sea and land can be used as parameters or formula to define targets, therefore to delineate the shorelines. Some of such works have been done by the author Chang in Taiwan, including the lineation of continental shelf breaks, shorelines picking and seismic skeleton of the Ground Penetration Radar (GPR) profiles.

Future development are up to the Grass users needs. Since ppa algotithm treats heights, it would be very interesting to make `r.ppa` supporting the creation of 3D vector layers that are being implemented in Grass v.5.1 and will be available in the future stable releases as Grass v.5.2.

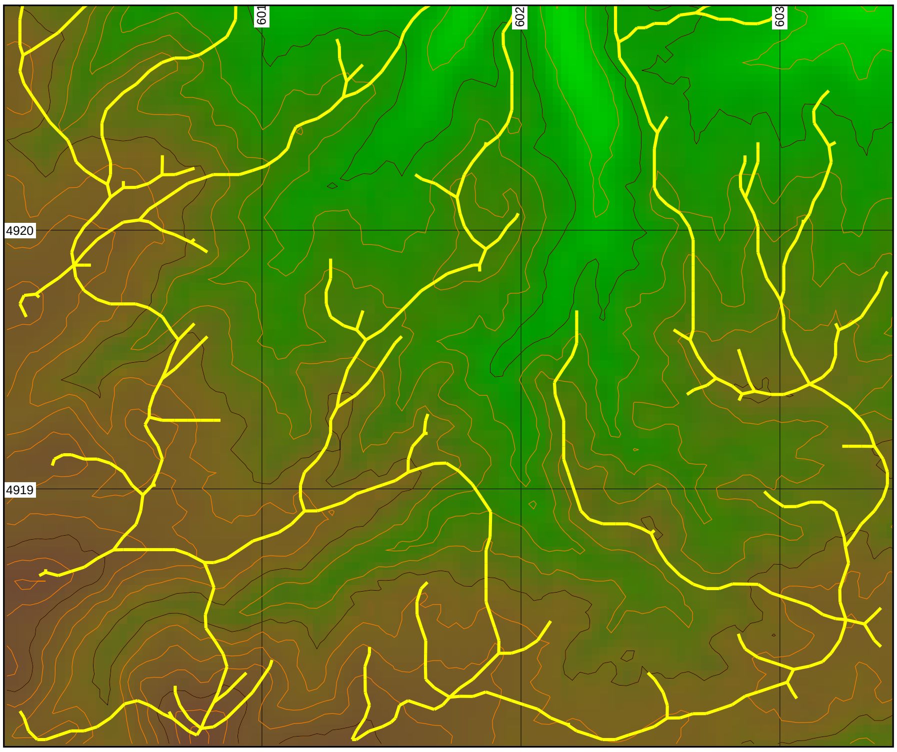

Figure 3: Automatic extraction of ridge axis

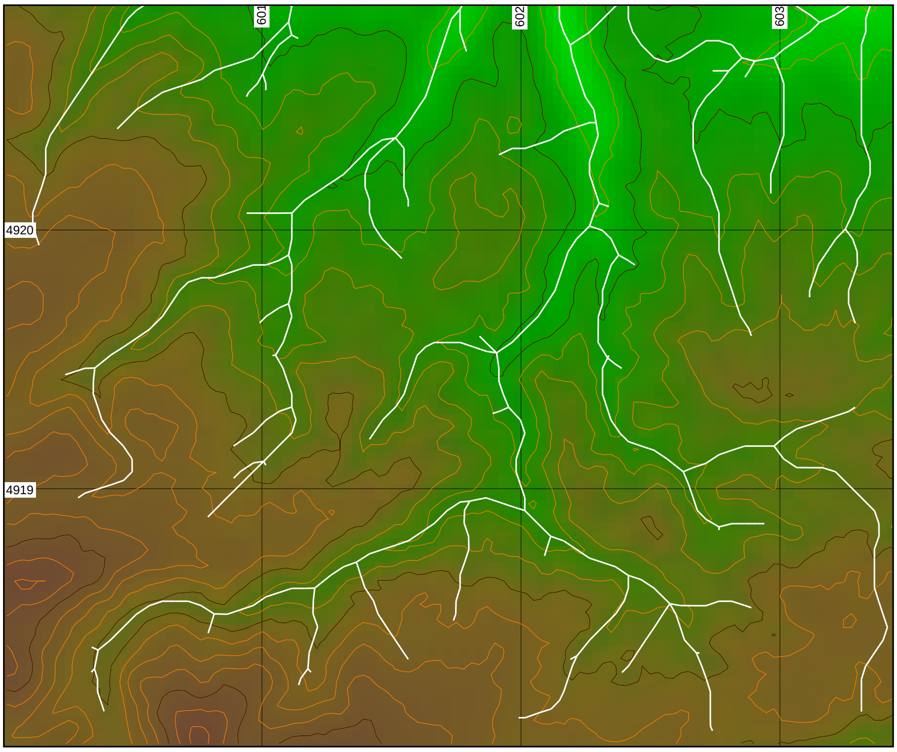

Figure 4: Automatic extraction of valley axes

Feedback on the algorithm and the Grass implementation will be very apreciated by the authors, that look forward to see if and how `r.ppa` will help in solving specific scientific problems.

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