Relief Visualization Toolbox, ver. 1.3

Manual

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When using the toolbox, please cite:

Kokalj, Žiga, Klemen Zakšek and Krištof Oštir. 2011. Application of Sky-View Factor for the Visualization of Historic Landscape Features in Lidar-Derived Relief Models. *Antiquity* 85 (327): 263–273.

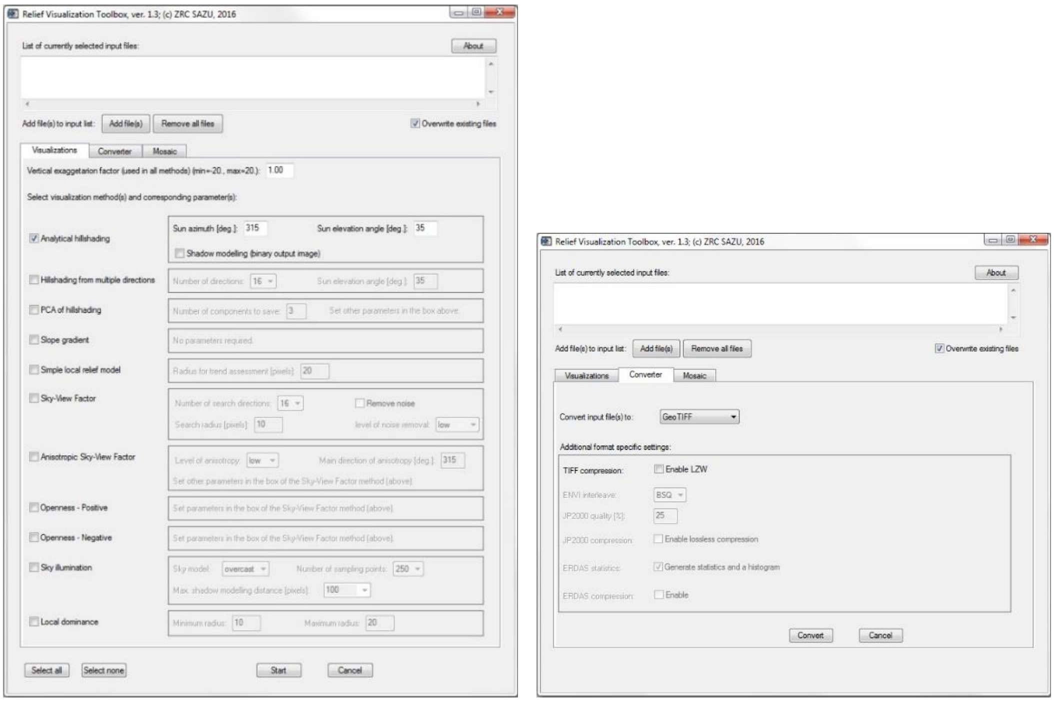
Zakšek, Klemen, Krištof Oštir and Žiga Kokalj. 2011. Sky-View Factor as a Relief Visualization Technique. *Remote Sensing* 3: 398–415.

General information

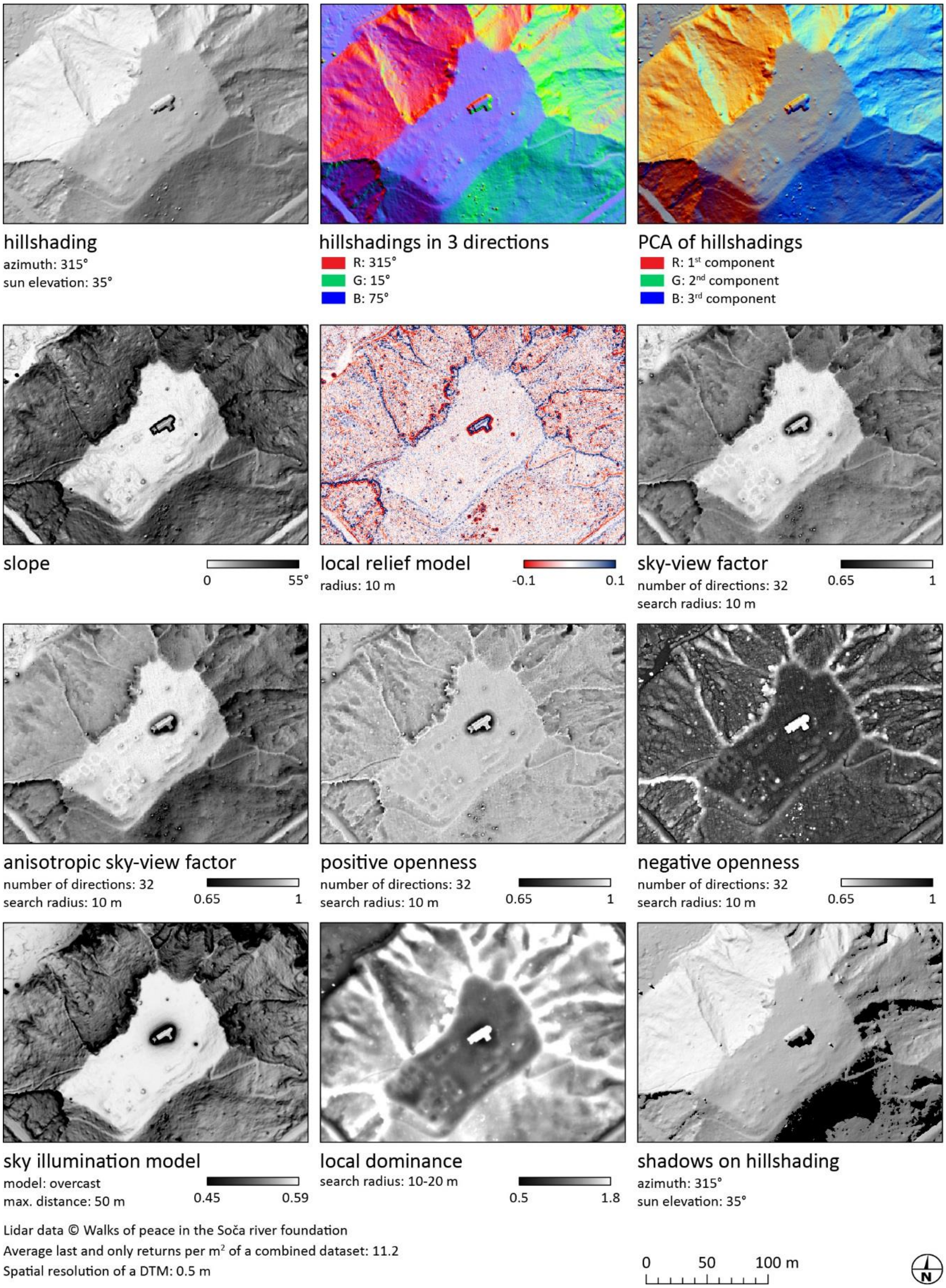
This software was produced to help scientists visualize raster elevation model datasets. We have narrowed down the selection to include techniques that have proven to be effective for the identification of small scale features. Default settings therefore assume working with high resolution digital elevation models, derived from airborne laser scanning missions (lidar). Despite this, the techniques can also be used for different other purposes. Sky-view factor, for example, can be efficiently used in numerous studies where digital elevation model visualizations and automatic feature extraction techniques are indispensable, *e.g.* in geography, geomorphology, cartography, hydrology, glaciology, forestry and disaster management. It can be used even in engineering applications, such as predicting the availability of the GPS signal in urban areas.

For a more detailed description of the visualization methods see the references given at each method, and a comparative paper describing them (*e.g.* Kokalj et al. 2013).

The tool also supports elevation raster file data conversion. It is possible to convert all frequently used single band raster formats into GeoTIFF, ASCII gridded XYZ, Erdas Imagine file and ENVI file formats.



RVT tool GUI for computation of different visualizations (left) and a single band raster data converter (right).



Visualization techniques showing St. Helena church and its immediate surroundings. St. Helena is a known yet un-researched archaeological site west of Kobarid, Slovenia, believed to be a late Roman camp.

Online resource

http://iaps.zrc-sazu.si/en/rvt

Check for updates from time to time. Please report any bugs and suggestions for improvements.

Version

Version: 1.3, September 2016

Name of the standalone package: RVT_1.3_Win64.zip (works independently).

For changes see version history at the bottom.

Installation

No installation is required. Unzip the package RVT_1.3 to any folder and run the exe file.

Input and output files

Input file(s): one or several digital elevation model file(s) in GeoTIFF format or any GDAL (GDAL Development Team 2014) supported format (*e.g.* GeoTIFF, generic binary file, Erdas Imagine file, ENVI file, Arc/Info ASCII Grid, ASCII gridded XYZ, JPEG2000…). If your extension is not listed on the Add files menu, change the format filter to *.*. Input files can come from multiple folders and can be of different formats. You can copy-paste the file list into the input window or manually type in the files. Each path/filename has to be in a separate line. For ASCII gridded XYZ input files the software assumes that units are meters and that coordinates have even spacing, therefore, it will not convert ungridded XYZ data, *e.g.* last return lidar data.

Output file formats for data format conversion: GeoTIFF, ASCII gridded XYZ, Erdas Imagine file or ENVI file.

Output files for visualizations: a pair of GeoTIFFs per each selected visualization:

- a calculated 32-bit result, and
- a simplified 8-bit result, optimized for non-GIS software.

All output files are written into the folder of the input file. Output file names for visualizations are composed of the input file name, and suffixes describing the selected method and processing parameters. Format conversion only changes the file extension. *N.B.* If output files already exist, the tool replaces them without warning! It is possible to disable this if you uncheck the option.

Each execution of the program generates a processing log file per input file that includes a list of performed visualization methods and parameters used, output file names, possible warnings, and other metadata. The log file is named input_file_name_process_log_yyyy-mm-dd-hh-mm-ss.txt.

Simplified 8-bit GeoTIFF files are prepared for displaying the results in non-GIS software, *e.g.* by Windows Photo Viewer or by Preview for Mac users. Each 8-bit visualization uses its own histogram stretch, as described in the table below. The histogram stretch with a cut-off does not work when there are more than 2% extreme values such as no-data values or outliers (*e.g.* 0 value borders, “birds”, “clouds”…) – the 8-bit image is grey. You can visualize the results by applying a manual stretch (about -0.1 to 0.1 m for SLRM for example) to the original results.

	Name suffix	Histogram stretch type	Min, max	Note
Analytical hillshading	HS	linear stretch	0, 1	
Hillshading from multiple directions	MULTI-HS	linear stretch	0, 1	Red 315°, Green 15°, Blue 75°.
PCA of hillshading	PCA	histogram equalization	2% cut-off	
Slope gradient	SLOPE	linear stretch	0°, 51°	inverted greyscale bar
Simple local relief model	SLRM	histogram equalization	2% cut-off	
Sky-view factor	SVF	linear stretch	0.6375, 1	

Anisotropic sky-view factor	SVF-A	histogram equalization	2% cut-off
Openness – positive	OPEN-POS	linear stretch	60°, 95°
Openness – negative	OPEN-NEG	linear stretch	60°, 95°
Sky illumination model	SIM	linear stretch	0.25% cut-off at minimum
Local dominance	LD	linear stretch	0.5, 1.8

As with all spatial calculations that consider neighbourhood, edge pixels do not have correct values. The size of the incorrect edge depends on the neighbourhood size; *e.g.* when openness is calculated with search radius of 10 pixels, 10 edge pixels have incorrect values.

Methods and parameters

To ease the usage of the toolbox the number of input parameters required for each visualization technique is kept to a minimum.

If you select a parameter beyond the allowed interval (min … max), the parameter is adjusted (trimmed) to fit into the interval, and a corresponding warning is written in the log text file.

Vertical exaggeration is the common parameter that influences all techniques. You can set it higher than the default 1, if you need more contrast in the results; *e.g.* set it to 3 if the terrain is very flat, or 20 if you use very detailed models, derived with structure-from-motion.

	Default value	Allowed values min … max	Most useful values	Note
Vertical exaggeration factor	1	-1000 … 1000	0.5 … 3	No exaggeration = 1. For flat relief use > 1. Use < 1 and > 0 if your terrain data has been converted to integer (whole) values (*e.g.* use 0.001 if units are mm). For calculations on inverted relief use negative values.

Analytical hill-shading is straightforward to interpret even by non-experts and without training. However direct illumination restricts the visualization in dark shades and brightly lit areas, where no or very little detail can be perceived. A single light beam also fails to reveal linear structures that lie parallel to it which can be problematic in some applications, especially in archaeology.

	Default value	Allowed values min … max	Most useful values	Note
Sun azimuth [°]	315	0 … 360	0 … 90, 270 … 360	0 is North and 90 is East. Values from southern hemisphere (90 … 270) display inverted shaded relief.
Sun elevation angle [°]	35	0 … 90	5 … 45	Use small values (5, 10) for flat terrain and higher values (45) for steep terrain.

Analytical hillshading can be calculated in **multiple directions** that are equally distributed between 0° and 360°. 0° is always in band 1, followed by azimuths in clockwise direction, *e.g.* 45° in band 2, 90° in band 3 … 315° in band 8, for calculation in 8 directions. The 8-bit image is a result of calculation in three directions, separated by 60° (315° in the red band, 15° in the green band, 75° in the blue band).

	Default value	Allowed values min … max	Most useful values	Note

Number of directions	16	4 …360	8, 16, 32, 36	The drop down menu is editable, so any number in the allowed range can be inserted. However, it is not very useful to go much beyond 16 directions, due to high autocorrelation.
Sun elevation angle [°]	35	0 … 75	5 … 45	Use small values (5, 10) for flat terrain and higher values (45) for steep terrain.

Principal Components Analysis (PCA) is a mathematical procedure that summarizes the information of correlated data; hillshaded images from multiple directions in this case. The method does not provide consistent results with different datasets. Some common examples of displaying the components are:

- a combination of the first and second principal components, transparently overlaid,
- a false colour composite image (RGB) of the first three components, or
- displaying the third component on its own with high histogram stretch and clipping.

The 8-bit image shows the first three components as an RGB image (1st component in the red band, 2nd in the green band, 3rd in the blue band).

Other parameters are set at the hillshading from multiple directions method box (see above).

	Default value	Allowed values min … max	Most useful value	Note
Number of components to save	3	1 … (number of directions-1)	3	The first three components usually hold more than 99% of the information of the original hillshaded images. The rest is “noise”. But sometimes you are interested in it, because it presents something uncommon.

Slope gradient represents the maximum rate of change between each cell and its neighbours and can be calculated either as degree of slope (as in this tool) or as percentage of slope. If presented in an inverted greyscale (steep slopes are darker), slope severity retains a very plastic representation of morphology. However, additional information is needed to distinguish between positive/convex (*e.g.* banks) and negative/concave (*e.g.* ditches) features since slopes of the same gradient (regardless of rising or falling) are presented with the same colour. The method requires no parameters.

Local relief modelling removes the large scale morphological elements (hills, valleys…) from data so only small scale features remain (*e.g.* archaeology). This version of the tool uses a simplified process – the trend is computed by a simple mean filter and a trend removed model is produced directly by subtracting the filtered model from the original. For a more complex method see Hesse (2010) and LiVT (Hesse 2013).

	Default value	Allowed values min … max	Most useful values	Note
Radius for trend assessment [px]	20	5 … 50	10 … 50	Radius should be a bit more than half the size of the features you are interested in.

Sky-view factor is a proxy for diffuse illumination and measures the proportion of the sky visible from a given point. Locally flat terrain, ridges and earthworks (*e.g.* building walls, cultivation ridges, burial mounds) which receive more illumination are highlighted and appear in light to white colours on a SVF image, while depressions (*e.g.* trenches, moats, ploughing furrows, mining pits) are dark because they receive less illumination (Zakšek et al. 2011).

The option to remove noise does not consider nearest pixels in the calculation. This diminishes small variations that are usually a result of data collection and processing, and are seen as “salt and pepper effect” on a sky-view factor or openness image.

	Default value	Allowed values min … max	Most useful values	Note
Number of search directions	8	4 … 360	8 … 36	Computational time increases as a linear function of number of search directions. 16 is optimal for most applications. The drop down menu is editable, so any number in the allowed range can be inserted.
Search radius [px]	10	1 … 100	5 … 50	Use small search radius (5-10 m; i.e. 5-20 pixels) if you are interested in small features, *e.g.* archaeology.
Remove noise	none	low … high	low	low: first 10% pixels (1 pixel if r <= 10) medium: first 20% pixels (2 pixels if 5 < r <=10) high: first 40% pixels (4 pixels if r <=10)

Anisotropic sky-view factor assumes that the sky is brighter in some directions than in others. The weights are based on the cosine function of half angle (Zakšek et al. 2012). There are three parameters that typically have to be set – the azimuth of the highest weight, the exponent defining the gradient from maximal to minimal weight, and the minimal possible weight. The exponent and minimal weight define the level of anisotropy – the greater the exponent and the smaller the minimal weight – the stronger the effect. This has been simplified to the low and high anisotropy levels where the minimal possible weights are 0.4 and 0.1, and the exponents are 4 and 8 respectively.

Other parameters are set at the sky-view factor method box (see above).

	Default value	Allowed values min … max	Most useful value	Note
Anisotropy level	low	low, high	low	“How much the relief perception is enhanced.”
Main direction of anisotropy [°]	315	0 … 360	315	0 is North and 90 is East. 315 presents usual direction for shaded relief.

Openness is also a proxy for diffuse illumination and is based on an estimation of a mean horizon elevation angle within a defined search radius. The mean value of all zenith angles gives **positive openness**, while the mean nadir value gives **negative openness**. Positive openness is similar to sky-view factor, with a more “flattened feel”, while negative openness gives additional information on convex features (Yokoyama et al. 2002). Because it is direction and shading independent and removes general topography, it is useful for automatic feature recognition.

Parameters are set at sky-view factor method box (see above).

Sky illumination models quantitatively represent natural luminance of the sky under various atmospheric conditions (Kennelly and Stewart 2014). **Uniform** and **overcast** sky models are implemented as they both disregard directional shadowing effects. Mode details in shadows can be seen using the overcast sky model. Calculations last much longer than for other visualizations, especially with large maximum shadow modelling distances.

	Default value	Allowed values min … max	Most useful values	Note
Sky model	overcast	overcast, uniform	overcast	Different weights are assigned to calculation points. All weights are equal for uniform sky model while weights increase towards the zenith for the overcast model.
Number of sampling points	250	250 or 500	250	Defines how smooth is the resulting image. The difference is minimal.

Maximum shadow modelling distance [px]	100	5 … unlimited	100 … 500	The maximum distance to which shadows of objects are calculated.

Local dominance visualisation of a DEM shows how dominant an observer standing above a certain pixel would be for a local surrounding area (Hesse 2016). Dominance is higher for points on local protrusions as well as on slopes, and lower for points in local depressions. It is well suited for very subtle positive relief features such as former field boundaries or heavily eroded burial mounds, but also delivers very good results for topographic depressions such as dolines, mining traces, and hollow ways.

	Default value	Allowed values min … max	Most useful values	Note
Minimum radius [px]	10		5 … 20	Minimum radius should be a bit more than half the size of the features you are interested in.
Maximum radius [px]	20		10 … 50	Maximum radius should be a bit more than the size of the features you are interested in.

Mosaicking

RVT supports mosaicking of multiple files, *e.g.* tiled lidar elevation models. The method is simple and not many checks are performed, but works well if data are reasonable, *i.e.* if all the files have the same projection, resolution, square pixels *etc.* The result is written in the same location and has the same name as the first input file with a _mosaic suffix. All the input files are converted to GeoTIFFs.

Settings file

Default settings can be changed in the default_settings.txt file in the RVT_1.3_Win64\settings directory. Computation of a visualization is turned on if its name is followed by 1 and off if it is followed by 0, *e.g.* hillshading = 1, multiple_hillshading = 0. For the meaning of other settings see descriptions and tables at individual visualizations above.

Processing without a GUI

RVT checks for filenames with paths in the process_files.txt file in the RVT_1.3_Win64\settings directory. If any filenames are found, the GUI does not show, and all the files are processed with the settings from the settings file. The filenames should be listed in rows; see below for example.

```
D:\Podatki\Lidar\Rence\rence_DEM_05m.tif
D:\Podatki\Lidar\Germany\Hugelsheim_DTM_1m.asc
D:\Documents\Papers\2016 Lidar visualization guidelines\data\Maiden_castle_DSM_05m.tif
D:\Documents\Papers\2016 Lidar visualization guidelines\data\Odolina_dem_1m.tif
C:\Test\Manhattan_DSM_1m_avg.xyz
```

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This software is distributed without any warranty and without even the implied warranty of merchantability or fitness for a particular purpose.

Known issues

IDL running on Windows can encounter problems with large arrays (depending on the amount of physical RAM, limitations of the operating system and memory fragmentation; see documentation on Exelis VIS web pages). To help overcome this issue the SVF and openness based methods use tiling. The tiles are maximum 5 megapixels large (*e.g.* 2500 by 2000 pixels). A buffer size is determined from selected visualization parameters.

The software can crash when processing large DEMs on a lot of shading directions as a result of a limitation of GeoTIFF file size.

RVT can only process single band files.

Version history

Version 1.3, September 2016

- Added support for automatic processing without GUI.
- Local dominance modelling.

Version 1.2, August 2015

- Added support for overcast and uniform sky illumination modelling.
- Settings can be read from a txt file and last used settings are saved temporarily.
- It is now possible to mosaic multiple files.
- SLRM calculation was changed from Gaussian averaging to a simple mean.

Version: 1.1, October 2014

- Added support for processing of multiple files.
- The tool now reads different file formats and can convert them to GeoTIFF, ASCII gridded XYZ, Erdas Imagine file or ENVI file.

Version: 1.0, November 2013

- Nine relief visualisation methods implemented: hillshading, hillshading from multiple directions, PCA of hillshading, slope gradient, simple local relief model, sky-view factor, anisotropic sky-view factor, positive and negative openness implemented.

References

GDAL Development Team. 2014. *GDAL - Geospatial Data Abstraction Library*. Windows (version 1.11.0). Open Source Geospatial Foundation.

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Yokoyama, Ryuzo, MIchlo ShIrasawa and Richard J. Pike. 2002. Visualizing Topography by Openness: A New Application of Image Processing to Digital Elevation Models. *Photogrammetric Engineering and Remote Sensing* 68: 251–266.

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