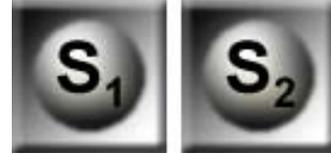


NAME: Directional Slope 1.2a

Aka: dir_slope.avx

Last modified: October 6, 2006



TOPICS: Slope Direction Angle Bearing

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DESCRIPTION: This extension generates a grid of estimated slope values, where the slope is measured in specified directions. This differs from the standard slope value which estimates the absolute slope in the steepest direction.

Results: Produces a grid of slope values in either Percent or Degrees.

REQUIRES: Spatial Analyst, plus a projected grid of elevation values. The elevation units must be the same as the coordinate system units. If your elevation grid is unprojected and you do not have access to ArcInfo Grid Projection utilities, you can use the author's Grid Projector extension to project your grid (see http://www.jennessent.com/arcview/grid_theme_projector.htm).

This extension also requires that the file "avdlog.dll" be present in the ArcView/BIN32 directory (or \$AVBIN/avdlog.dll) and that the Dialog Designer extension be located in your ArcView/ext32 directory, which they usually are if you're running AV 3.1 or better. The Dialog Designer doesn't have to be loaded; it just has to be available. If you are running AV 3.0a, you can download the appropriate files for free from ESRI at:

<http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.viewPatch&PID=25&MetalD=483>

REVISIONS: Version 1.2a: Minor update, adds a function to check scripts if extension crashes.

Recommended Citation Format: For those who wish to cite this extension, the author recommends something similar to:

Jenness, J. 2006. Directional Slope (dir_slope.avx) extension for ArcView 3.x, v. 1.2a. Jenness Enterprises. Available at: http://www.jennessent.com/arcview/dir_slopes.htm.

Please let me know if you cite this extension in a publication (jeffj@jennessent.com). I will update the citation list to include any publications that I am told about.

Table of Contents

GENERAL INSTRUCTIONS:	2
CALCULATING SLOPE IN CARDINAL DIRECTIONS:	3
CALCULATING SLOPE IN ANY DIRECTION:.....	5
HOW THIS EXTENSION CALCULATES SLOPE:	7
REFERENCES	11
TROUBLESHOOTING	11

General Instructions:

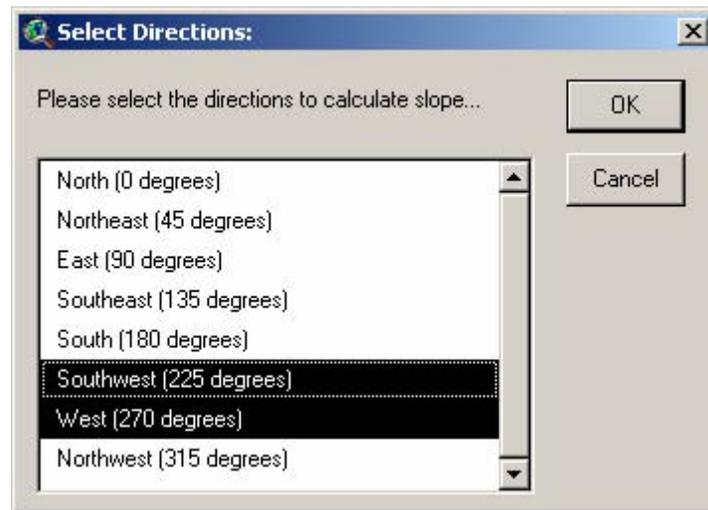
- 1) Begin by placing the "**dir_slope.avx**" file into the ArcView extensions directory (../Av_gis30/Arcview/ext32/).
- 2) After starting ArcView, load the extension by clicking on **File --> Extensions...**, scrolling down through the list of available extensions, and then clicking on the checkbox next to the extension called "**Directional Slope.**"
- 3) The extension will add two buttons to your View. These buttons will only be enabled if you have a single grid theme active in your view. The slope calculations will be done on the active grid, and the extension assumes this is a grid of elevation values in which the elevation units are the same as the X- and Y-Coordinate units (i.e. the grid must be projected). If your elevation grid is unprojected and you do not have access to ArcInfo Grid Projection utilities, you can use the author's Grid Projector extension to project your grid (see http://www.jennessent.com/arcview/grid_theme_projector.htm).
 - a.  This button calculates slope in the cardinal directions North, Northeast, East, Southeast, South, Southwest, West and Northwest. Slope values may be calculated in either Degrees or Percent.
 - b.  This button calculates slope in a single specified direction and can use any compass bearing. Slope values may be calculated in either Degrees or Percent.

IMPORTANT: There are many ways to calculate slope based on different assumptions of what the slope should represent. The method presented here makes intuitive sense to the author, but please review the methods section ([How this extension calculates slope](#), p. 7), to judge for yourself whether this method is appropriate for your analysis.

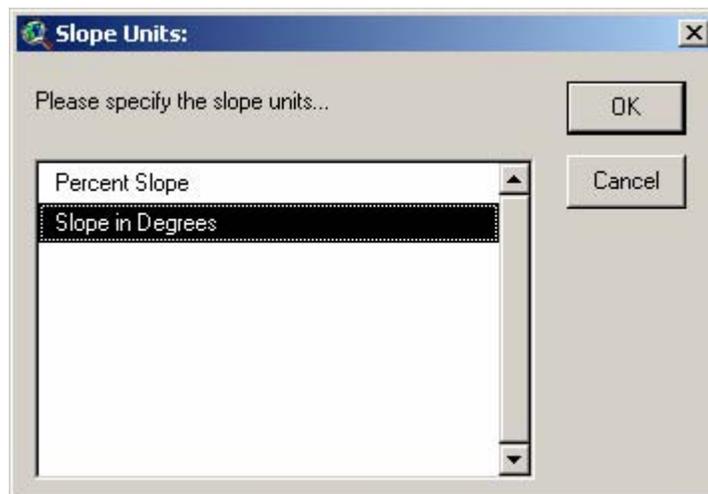
Calculating Slope in Cardinal Directions:

This function will calculate the slopes in any or all of the 8 cardinal directions *North, Northeast, East, Southeast, South, Southwest, West* and *Northwest*. Slope values may be calculated in either Degrees or Percent.

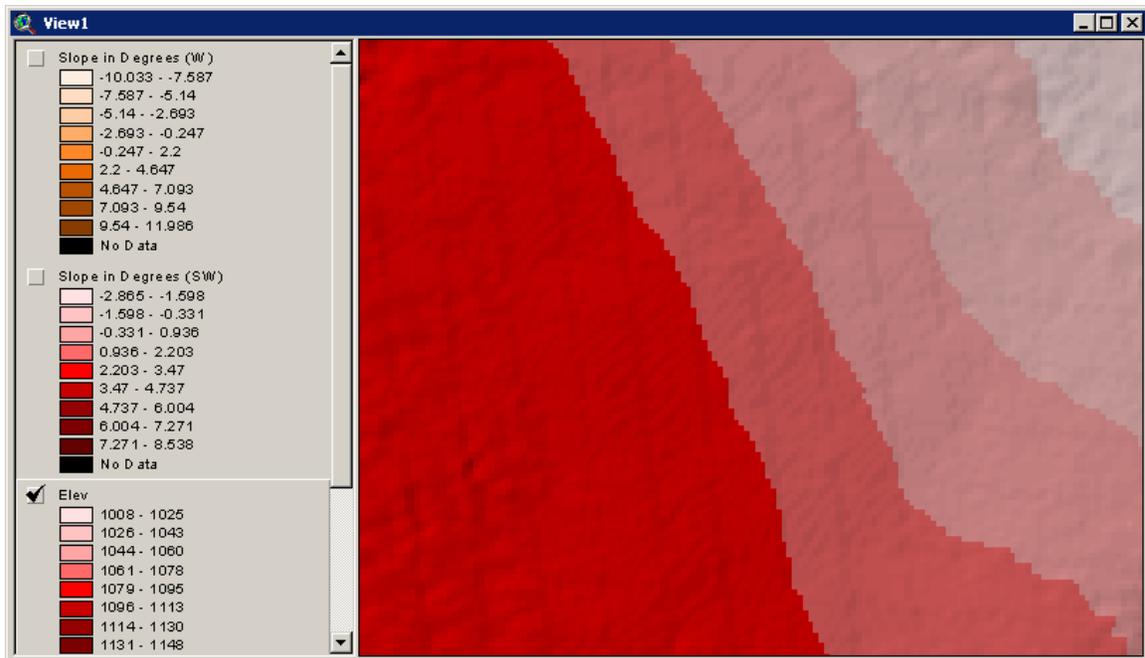
First select your elevation grid and click the  button. You will first be asked which cardinal directions to use:



Select as many directions as you want by holding down the [Shift] key, then click "OK". Next, specify whether you want slope values in Percent or Degrees, or both:

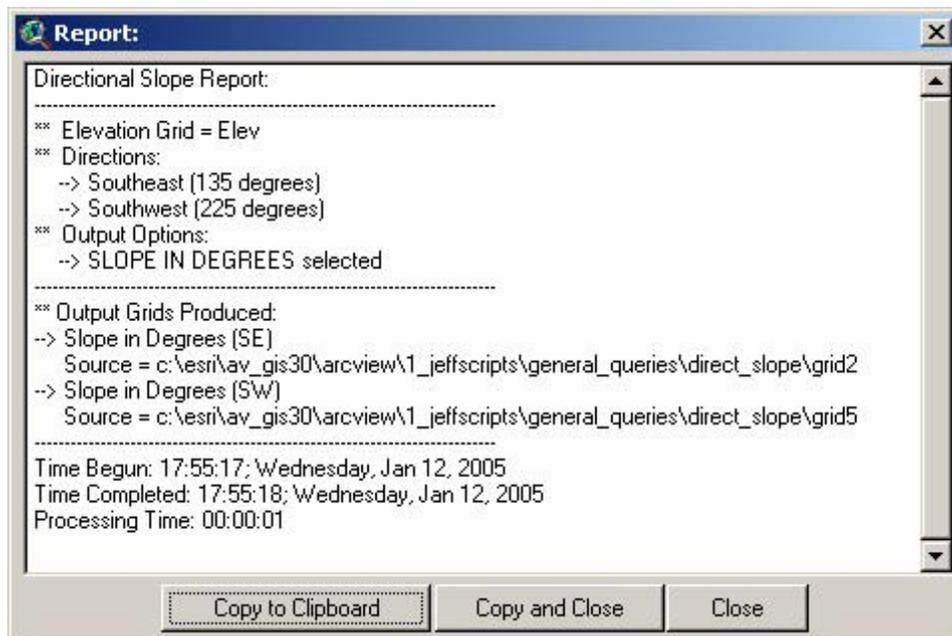


Make your selection, click "OK", and the extension will create the specified grids and add them to your view.



NOTE: These grids are temporary, so they will be deleted from the hard drive if they are deleted from the view. These grids will become permanent if you save the project, or click "Save Dataset" or "Convert to Grid" in the view Theme menu.

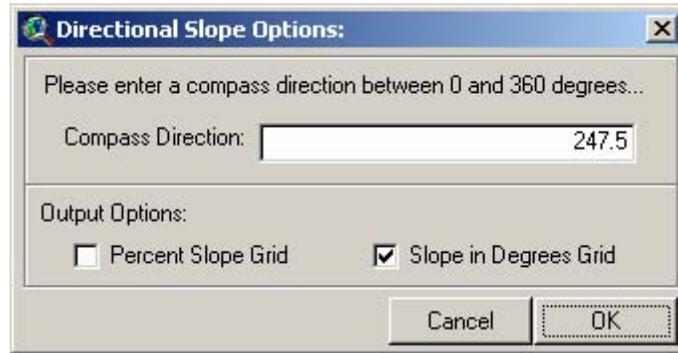
The extension will also generate a short report describing what it did:



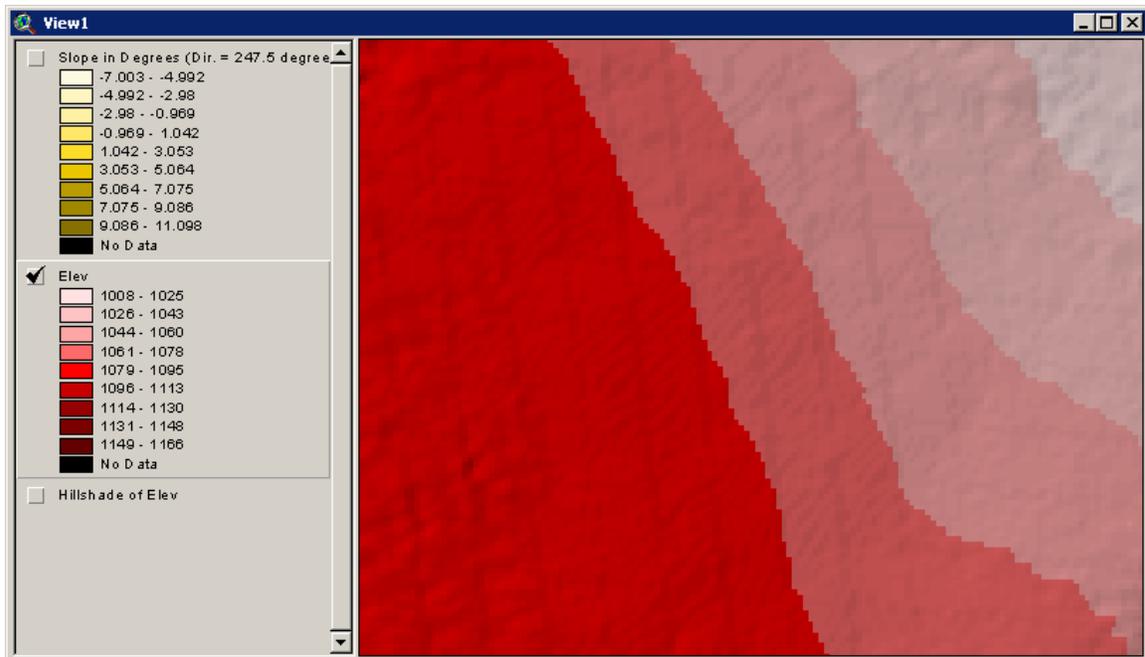
Calculating Slope in Any Direction:

This function will calculate the slope in a single specified direction and can use any compass bearing. Slope values may be calculated in either Degrees or Percent.

First select your elevation grid and click the  button. You will be asked what direction to calculate use and whether you want your output in Degrees or Percent:

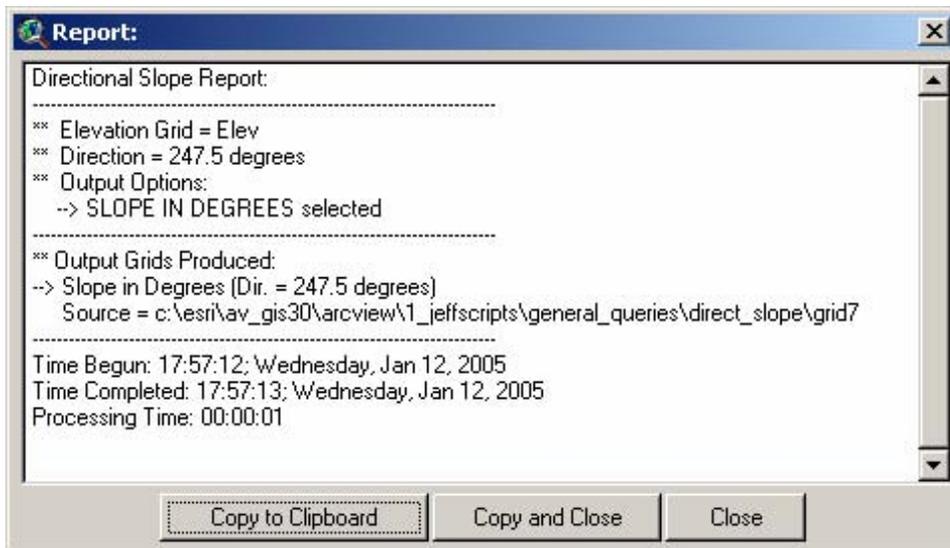


Click "OK" and the extension will add the grid(s) to your view:



NOTE: This grid is temporary, so it will be deleted from the hard drive if it is deleted from the view. The grid will become permanent if you save the project, or click "Save Dataset" or "Convert to Grid" in the view Theme menu.

The extension will also generate a short report describing what it did:



How this extension calculates slope:

The slope of a cell is generally defined as the absolute value of the slope in the steepest direction. For example, given a simple elevation grid with 9 cells labeled A – I,

A	B	C
D	E	F
G	H	I

several algorithms are available to calculate the slope of cell E based on some combination of the elevation value in that cell and the 8 adjacent cells. In an early example, Evans (1972) describes and discusses several terrain measures developed by W. R. Tobler, in which the slope (or gradient) is defined as the 1st derivative of the landscape surface, and calculated as:

$$\text{Gradient} = \frac{\sqrt{(Z_{i,j+1} - Z_{i,j-1})^2 + (Z_{i-1,j} - Z_{i+1,j})^2}}{2d} \quad (\text{Evans 1972, p. 52})$$

where $Z_{i,j+1}$ = Cell B

$Z_{i,j-1}$ = Cell H

$Z_{i-1,j}$ = Cell D

$Z_{i+1,j}$ = Cell F

d = Cell Size

ESRI software uses the algorithm described by Burrough and McDonnell (1998, p. 190-193; see also <http://support.esri.com/index.cfm?fa=knowledgebase.techarticles.articleShow&d=21345>):

$$\% \text{ Slope} = \sqrt{\Delta Z_x^2 + \Delta Z_y^2}$$

$$\text{where } \Delta Z_x^2 = \frac{(A + 2D + G) - (C + 2F + I)}{8(\text{cell size})}$$

$$\text{where } \Delta Z_y^2 = \frac{(A + 2B + C) - (G + 2H + I)}{8(\text{cell size})}$$

In general:

$$\text{Slope in Degrees} = \text{Arctan}(\% \text{ Slope}) \frac{180}{\pi}$$

Kevin Jones provides an excellent discussion and comparison of 8 slope algorithms (Jones 1998), ranking them in order of accuracy when applied to two complex surfaces in which the true slopes are known. The ESRI algorithm, described as Horn's method in Jones' paper, ranked 2nd in accuracy on one surface and 3rd on another surface.

Interestingly, Hodgson (1995) describes how most slope and aspect algorithms generate values reflecting an area 1.6 to 2 times the size of the actual cell, which implies that operations that rely on both cell size and slope or aspect may be unduly influenced by adjacent cells. For example, it would seem reasonable to use the cell size, slope and aspect of a cell to estimate the surface area in that cell (see Berry [2002] for a good description of this method), but Hodgson's findings suggest that alternative methods may be more appropriate (one possibility is described by Jenness [2004]).

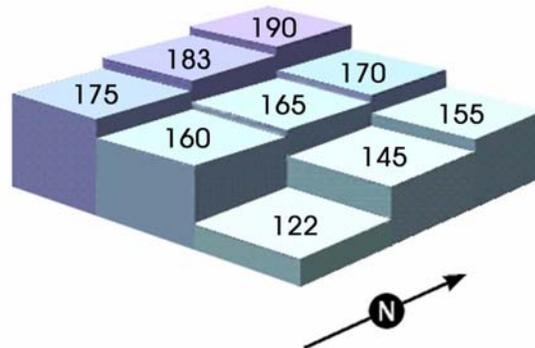
This extension takes a reasonably simple (and possibly simplistic) approach to estimate the slope of a cell in a particular direction. It assumes that the elevation values for all cells are reasonable estimates of the elevation at the centerpoints of the cells. Slopes are calculated from the vertical and horizontal distances between the centerpoint of the focal cell and the centerpoint of the adjacent cell in the direction specified. If the direction is not a cardinal direction, then the slope is calculated from the focal cell centerpoint to an interpolated point between 2 adjacent cell centerpoints.

$$\% \text{ Slope} = \frac{\text{Vertical Distance}}{\text{Horizontal Distance}}$$

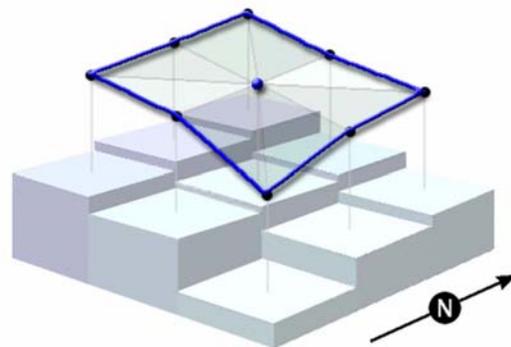
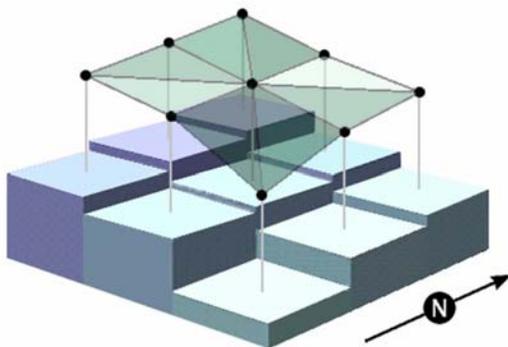
$$\text{Degrees Slope} = \text{Arctan}(\% \text{ Slope}) \frac{180}{\pi}$$

To illustrate this, consider a sample elevation grid. The focal cell and the 8 adjacent cells can be pictured as a set of adjacent columns, each rising to the cell elevation value:

210	190	170	155	140	135
204	183	165	145	125	120
200	175	160	122	110	100
208	187	165	150	126	120

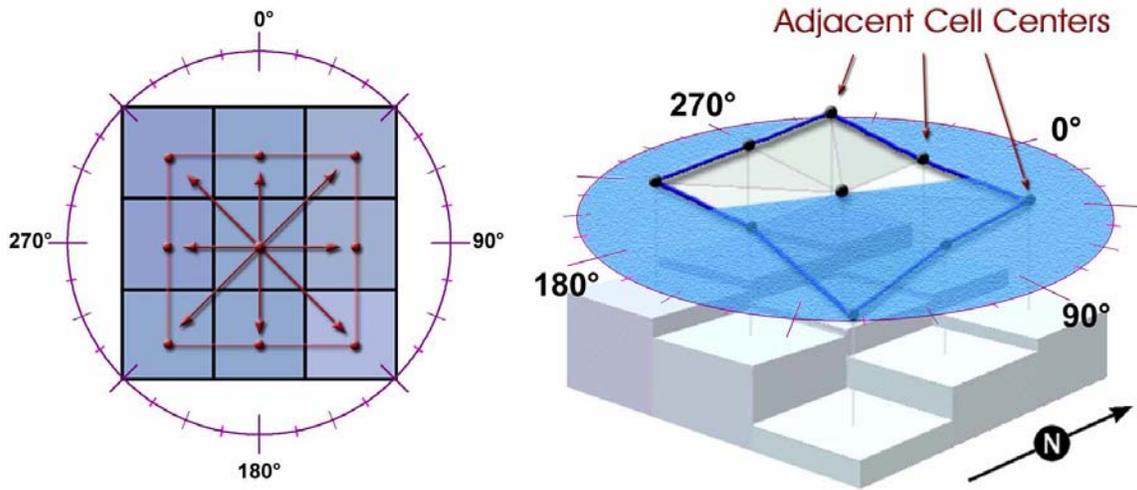


We are interested in the elevation value of the focal cell centerpoint, plus the elevation values along the ring connecting the 8 adjacent cell centerpoints.

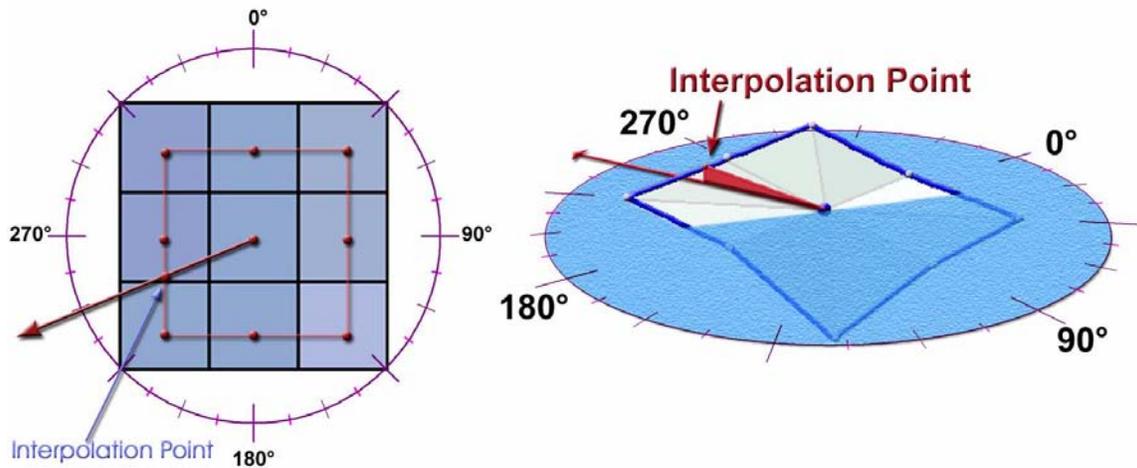


This extension calculates the directional slope of the focal cell by drawing a line out from the focal centerpoint in the specified direction, and intersecting that line with ring illustrated above. If the

direction is one of the 8 cardinal directions, then the intersection point is the cell center of the adjacent cell.



If the line goes in a direction other than one of the cardinal directions, then we need to interpolate the elevation at the point in which bearing intersects the ring. For example, the bearing 247.5° would intersect the ring somewhere between the cell centerpoints of the cells to the West and Southwest:



Using a bit of trigonometry, we can determine that the intersection point is 58.6% of the way along the line connecting the SW centerpoint to the W centerpoint. Therefore, the interpolated elevation at that point would be $(0.586 \times [\text{elevation at W}]) + (0.414 \times [\text{elevation at SW}])$.

Using the sample grid above, the slope calculations would go as follows:

$$\begin{aligned}
&\text{Focal Cell Elevation} = 165 \\
&\text{Interpolation Point Elevation} = (183 \times 0.586) + (175 \times 0.414) \\
&\qquad\qquad\qquad = 179.688 \\
&\text{if Cell Size} = 30, \text{ then Horizontal Distance} = 32.472 \\
&\qquad\qquad\qquad \text{Vertical Distance} = |165 - 179.688| \\
&\qquad\qquad\qquad = 14.688 \\
&\qquad\qquad\qquad \% \text{ Slope} = \frac{14.688}{32.472} \\
&\qquad\qquad\qquad = 0.452 \\
&\text{Degrees Slope} = \text{Arctan}(0.452) \frac{180}{\pi} = 24.34^\circ
\end{aligned}$$

IMPORTANT: One thing to note about this method is that the distance between points changes depending on the direction. At the most extreme, the distance from the focal cell centerpoint to centerpoints in diagonal directions (NE, SE, SW and NW) is 1.414 times the distance to centerpoints in straight directions (N, E, S, and W). This may have important implications for your analysis because slopes tend to become shallower over larger distances, and therefore slopes to the N, E, S and W will tend to be slightly steeper than slopes to the NE, SE, SW and NW.

This method does have the advantage, though, of producing slope estimates based on the least amount of interpolated data. In other words, the best data we have regarding the elevations around a grid cell are the elevation values in the 8 adjacent grid cells, and each of these grid cells should be equally likely to have a correct elevation value. If the elevation value of a grid cell is most likely to be found at the cell centerpoint (which should be the case if all cells are averaged), then the square-shaped ring connecting those 8 cell centerpoints should represent a line of least-interpolated values, and therefore the most reliable source to calculate slope. Slopes along cardinal directions to the exact cell centerpoints of adjacent cells are not interpolated at all (except to the degree that the original grid was interpolated).

If it is important to estimate directional slope in a way that all directions are based on the same horizontal distance, then the best solution would likely be to use the methods described above, except using a circular ring with *Radius = Cell Size* instead of a square ring. In this case the bearings to the North, South, East and West would be identical to the method described above, but all other elevation points should be interpolated from the 4 closest cells to the interpolation point.

References

- Berry, J. K. 2002. Use surface area for realistic calculations. *Geoworld* 15(9):20-1.
- Burrough, P. A. and R. McDonnell. 1998. *Principals of Geographical Information Systems*. Oxford University Press.
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- Hodgson, M. E. 1995. What cell size does the computed slope/aspect angle represent? *Photogrammetric Engineering & Remote Sensing* 61:513-517.
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- Jones, K. H. 1998. A comparison of two approaches to ranking algorithms used to compute hill slopes. *Geoinformatica* 1:3, 235-256. Kluwer Academic Publishers, Boston.
- Wang, K., and C-P. Lo. 1999. An assessment of the accuracy of triangulated irregular networks (TINs) and lattices in ARC/INFO. *Transactions in GIS* 3(2):161-174
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Troubleshooting

If you encounter some strange crash, please click the menu item “Check Directional Slope Scripts” in either the View or Project Help menu. Click this as soon as you are able to following the crash. With any luck, that function will generate a report with enough information for the author to find and fix the problem.

Enjoy! Please contact the author if you have problems or find bugs.

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Updates to this extension and an on-line version of this manual are available at

http://www.jennessent.com/arcview/dir_slopes.htm

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