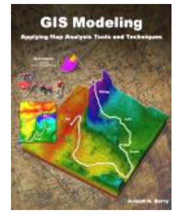
Topic 3 – *Extending Terrain Analysis Procedures (Further Reading)*



GIS Modeling book

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Shedding Light on Terrain Analysis

(GeoWorld, may 2008)

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A lot of GIS is straightforward and mimics our boy/girl scout days wrestling with paper maps. We learned that North is at the top (at least for us in the northern latitudes) and red roads and blue streams wind their way around green globs of forested areas. However, the brown concentric rings presented a bit more of a conceptual challenge.

When the contour lines formed a fairly small circle it was likely a hilltop; or a depression, if the line sprouted whiskers. Sharp "V-shaped" contour lines pointed upstream when a blue line was present; and somewhat rounded V's pointed downhill along a ridge. Once these and a few other subtle nuances were mastered and you survived a day or so in the woods, a merit badge and sense power over geography was attained.

Your computer is devoid of such a nostalgic experience. All it sees are organized sets of colorless numbers. In the case of vector systems, these number sets identify lines defining discrete spatial features in a manner fairly analogous to traditional mapping. On the surface, direction measurement fundamentals remain the same and your fond memory of the 0-360^o markings around a compass ring holds for most GIS mapping applications.

The upper-left portion of figure 1 unfolds the compass ring into a continuum of azimuth from 0^o (north) to 360^o (north). Whoa …you mean north is at both ends of the continuum? As azimuth increases, it becomes less north-like for awhile and then more north-like until 0 = 360. Now that's enough to really mess-up a numeric bean-counter like a computer. Actually, azimuthal direction is termed a discontinuous number set as it wraps around on itself (spiral in the top-right side of figure 1).

The lower scales in figure 1 transform direction into a more stable continuous number set that indicates the relative alignment with a specified direction. A *Facing Angle* utilizes the concept of a back azimuth to indicate an orientation as different as it gets—180^o is completely opposite; and 0^o is exactly the same direction.

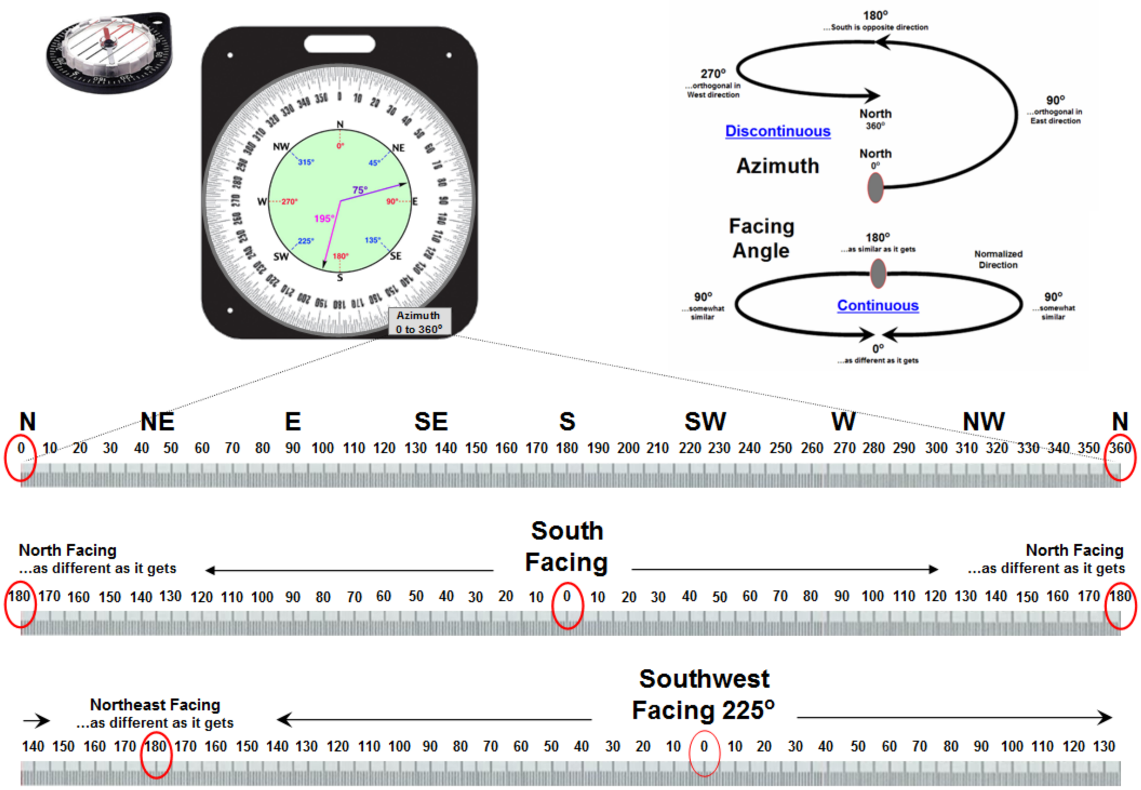

Figure 1. Azimuth is a discontinuous numeric scale as it wraps around on itself; Facing Angle is a continuous gradient indicating relative alignment with a specified direction.

For a south facing location the continuum starts at 0 (South) and progresses "less south-like" in both the East and West directions until the orientation "is 180 degrees off" at due North. The importance of the consistency of this continuous scale might be lost on humans, but it means the world to a computer attempting to statistically analyze a set of directional data. The procedure normalizes terrain data for any given facing angle into a consistent scale of 0 to 180 indicating the degree of orientation similarly throughout an entire project area.

Figure 2 summarizes the geometry between Azimuth and Facing angles. Also it introduces the concept of a *Horizontal* angle that takes direction from 2D planar to 3D solid geometry. The "Hillshade" map of Mount St. Helens on the right shows the relative brightness of the terrain assuming a sun position from 225^o azimuth (SSW) and 35^o above the horizon; the brightest areas directly face the sun.

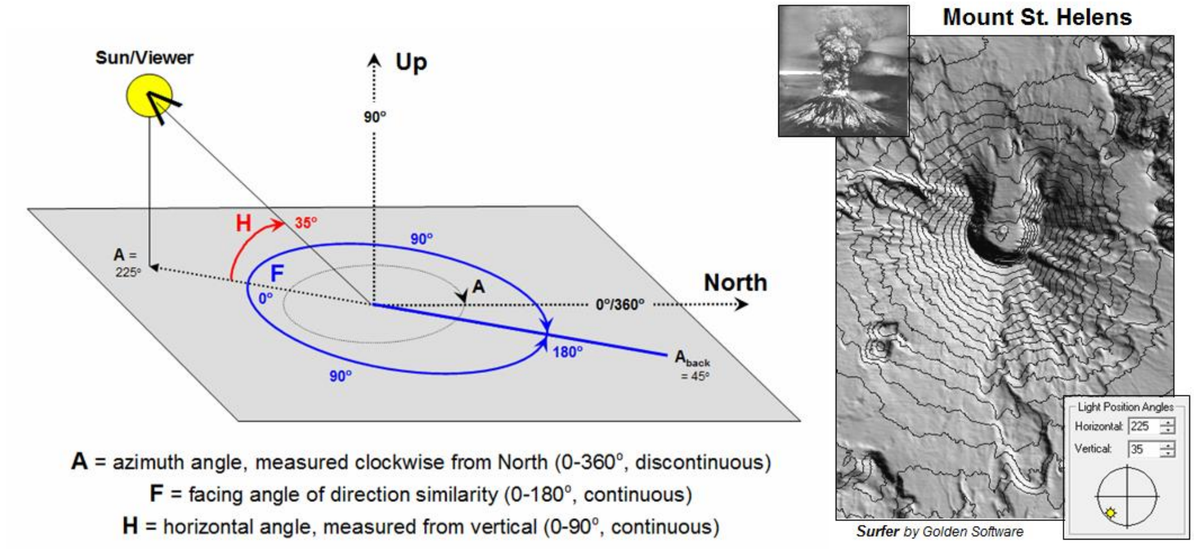

Figure 2. A Hillshade map identifies the relative brightness at every grid location in a project area.

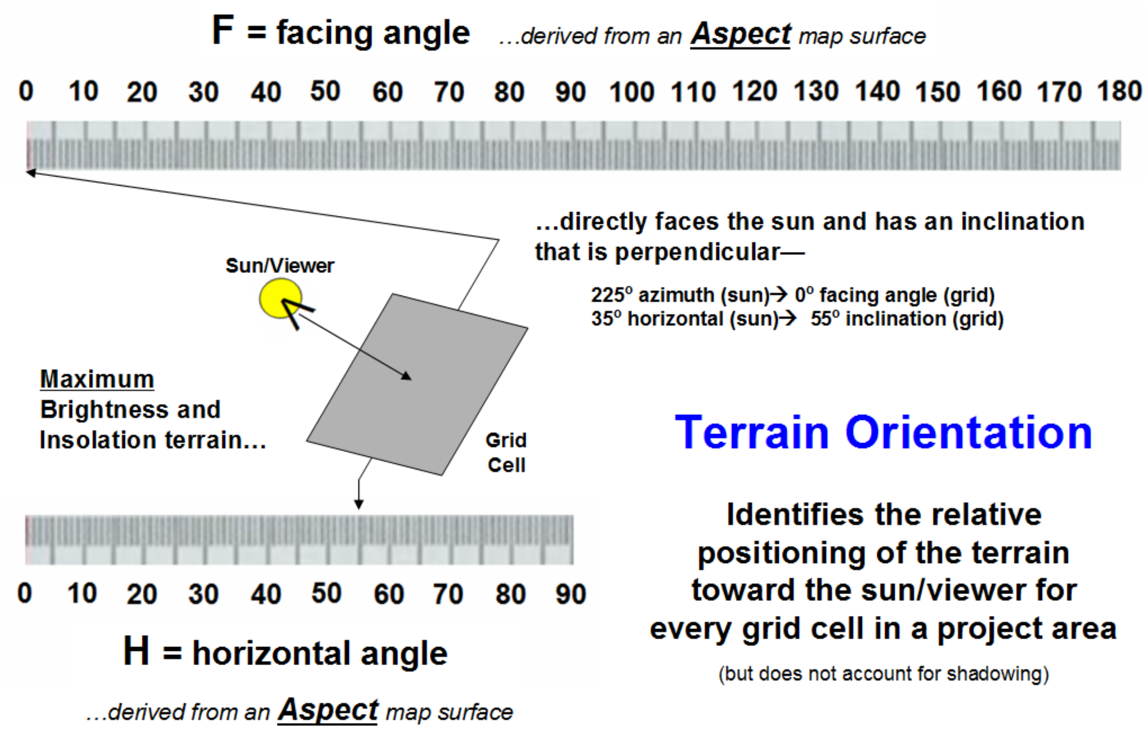

Figure 3. Terrain orientation combines azimuthal and horizontal angles for each grid cell facet.

Figure 3 expresses the relationship between the azimuth and horizontal angle gradients derived from aspect and slope maps. Each grid cell (30x30 meters in this example) can be thought of as a tilted plane in three-dimensional space. In the case of the brightest location, it identifies a grid cell that is perpendicular to the sun—like a contented lizard or sunbather positioned to absorb the most rays. All other possible orientations of the grid cell facets are some combination of the facing and horizontal angle gradients.

However, the "superstar *map*-ematicians" among us know that things are a bit more complex than an independent peek at each grid cell. A grid cell could be directly oriented toward the sun but on a small hill in the shadow of a much larger hill. To account for the surrounding terrain configuration one needs to solve the angles using solid geometry algorithms involving direction cosines to connect the grid cell to the sun and test if there is any intervening terrain blocking connection.

So what's the take-home from all this discussion? Actually three points should stand out. First, that GIS technology encompasses our paper map thinking (e.g., discontinuous azimuthal direction), but the digital map enables us to go beyond mapping. Secondly, that a map is an organized set of numbers first, and a picture later; we must understand the nature of the data (e.g., continuous facing angle) to fully capitalize on the potential of map analysis.

Finally, the new map-*ematical* expression of maps supports radically new applications. For example, one can integrate a series of brightness maps over a day for a map of solar influx (insolation) that drives a wealth of spatial systems from wildlife habitat to global warming. In addition, these data can be statistically analyzed for insight into spatial patterns, relationships and dependencies that were beyond discovery a few years ago. In short, GIS is ushering in a new era of decision-making, not simply keeping track of where is what.

Author's Note: *related discussion on Terrain Analysis is in Topic 6, Summarizing Neighbors in the book Map Analysis (Berry, 2007; GeoTec Media,* ***www.geoplace.com/books/MapAnalysis****) and Topic 11 in the online Beyond Mapping III compilation (****www.innovativegis.com/basis/MapAnalysis****).*

Correction: *the following letter (5/25/08) outlined some concerns about the discussion of Azimuth.*

Joseph— in the many years of Beyond Mapping I've never had a serious disagreement. In the May column it seems as though your slant on angles is a bit off course. I'm no map-ematician but azimuth is not discontinuous; rather it is a cyclic attribute type that continuously wraps around (and around). If we thought of phase angles as discontinuous we would have a hard time using sines and cosines to compute mean wind directions slope aspects or buoy longitudes east of New Zealand.

You say too that the brightest areas in a hillshade image face the sun. Those slopes that exactly face the sun reflect light back to the sun's incident angle, not the viewer. When the angle of incidence from surfaces is oblique to the sun angle it causes the angle of reflection to return to the viewer "overhead" the surface is brightest.

One more thing if you will allow me. Your Mount St. Helens is lit from 225 degrees, putting the "shadows" to the north-east. This violates the remote sensing custom of putting the "shadows" to the south-east to avoid the terrain inversion phenomenon that results from the pseudoscopic effect. Many folks will see your Mt. St. Helens, as a depression with a small Mound St. Helens at the bottom. That of course is why the Surfer default is 335 degrees.

Best wishes**, Peter H. Dana**, Ph.D., Research Fellow and Lecturer, Department of Geography, University of Texas at Austin, pdana@mail.utexas.edu

Peter— right on … excellent points well taken. Azimuth is not "discontinuous" and your classification of "cyclical" is a good one. The bottom line is that azimuth isn't your normal numerical gradient and being a bit whacko one can't simply utilize raw azimuth values in spatial data mining.

My use of the term "brightest areas" was misleading …I was referring to surface illumination intensity (amount of sunlight impacting a location as contained in the facing angle) not the relative brightness in the image which is dependent on viewer angle as well as solar angle as compounded by the unique lay of the terrain.

Your recounting of the imaging interpretation rule also holds true for interpreting the graphic. My point however was less on the interpretation of the map graphic as on the ability to track solar insolation …mapped data versus visualization. The bottom line is that I am delighted that someone out there actually reads the column, particularly with your level of interest and expertise. The dialog is much appreciated and I stand corrected. Thank you. Joe

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