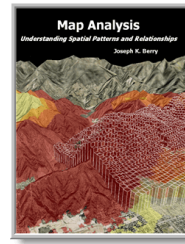


## Beyond Mapping III

# Topic 15: Deriving and Using Visual Exposure Maps



[Map Analysis](#)

Further Reading for Topic 5

[Identify and Use Visual Exposure to Create Viewshed Maps](#) — discusses basic considerations and procedures for establishing visual connectivity

[Visual Exposure is in the Eye of the Beholder](#) — describes procedures for assessing visual impact and creating simple models

[Use Exposure Maps and Fat Buttons to Assess Visual Impact](#) — investigates procedures for assessing visual exposure

[Use Maps to Assess Visual Vulnerability](#) — discusses a procedure for identifying visually vulnerable areas

[Try Vulnerability Maps to Visualize Aesthetics](#) — describes a procedure for deriving an aesthetics map based on visual exposure to pretty and ugly places

[In Search of the Elusive Image](#) — describes extended geo-query techniques for accessing images containing a location of interest

*Note:* The processing and figures discussed in this topic were derived using MapCalc™ software. See [www.innovativegis.com](http://www.innovativegis.com) to download a free MapCalc Learner version with tutorial materials for classroom and self-learning map analysis concepts and procedures.

[Click here](#) > right-click to download a printer-friendly version of this topic (.pdf).

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## Identify and Use Visual Exposure to Create Viewshed Maps

(GeoWorld, June 2001, pg. 24-25)

[\(top\)](#)

The past several columns have discussed the concept of *effective proximity* in deriving variable width buffers and travel-time movement. The procedures relax the assumption that distance is only measured as “the shortest straight line between two points.” Real world movement is rarely straight as it responds to a complex set of absolute and relative barriers. While the concept of effective proximity makes common sense, its practical expression had to wait for GIS technology.

Similarly, the measurement of *visual connectivity* is relatively new to map analysis but has always been part of a holistic perspective of a landscape. We might not be able to manually

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draw visual exposure surfaces yet the idea of noting how often locations are seen from other areas is an important ingredient in realistic planning. Within a GIS, detailed maps of visual connectivity have become a reality and are nearing commonplace use.

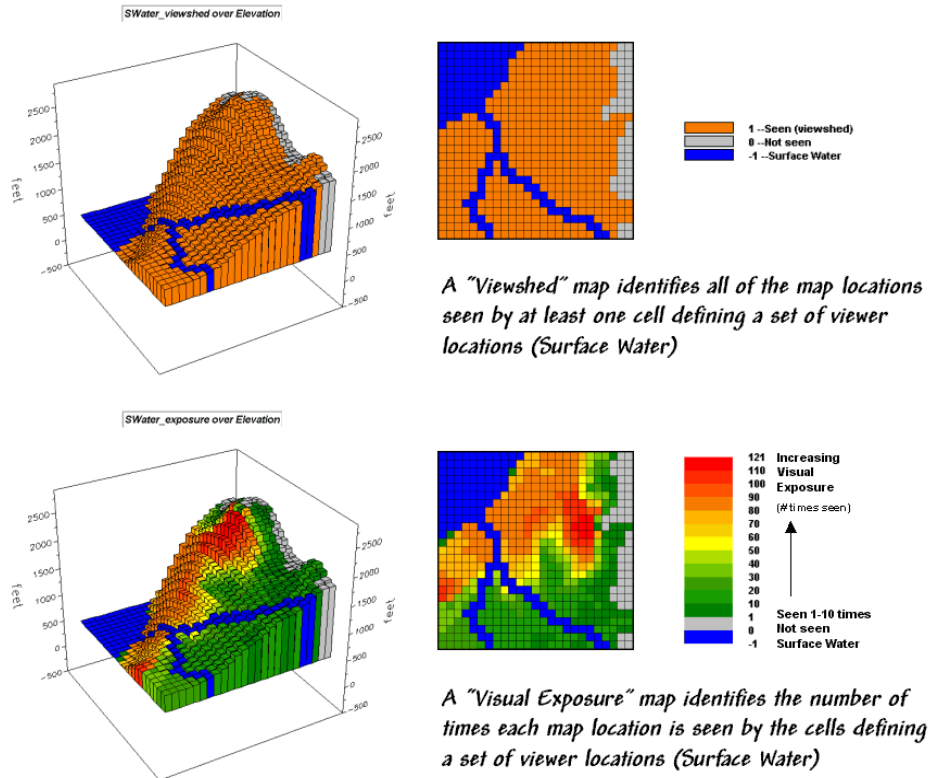


Figure 1. Viewshed of all surface water locations.

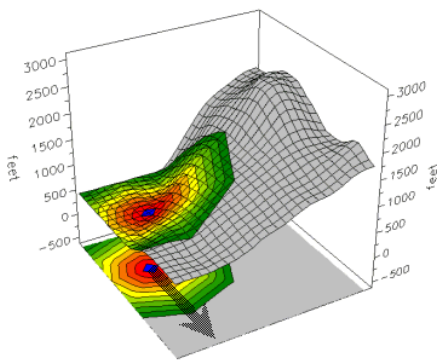
For example, the *viewshed* map shown in top portion of figure 1 identifies all the map locations that are seen (tan) by at least one cell of surface water (dark blue). The light gray locations along the right side of the map locate areas that are not visually connected to water—bum places for hikers wanting a good view of surface water while enjoying the scenery.

The bottom portion of the figure takes visual connectivity a step further by calculating the number of times each map location is seen by the “viewer” cells. In the example there are 127 water cells and one location near the top of the mountain sees 121 of them... very high *visual exposure* to water. In effect, the exposure surface “paints” the viewshed by the relative amount of exposure—green not much and red a whole lot.

So how does the computer determine visual connectivity? The procedure actually is quite simple (for a tireless computer) and is similar to the calculation of effective proximity. A series of “distance waves” radiate out from a water cell like the ripples from a rock tossed into a pond (see figure 2). As the wave propagates, the distance from the viewer cell (termed the *run*) and the difference in elevation (termed the *rise*) are calculated for the cells forming the concentric ring of a wave. If the *rise/run* ratio is greater than any of the ratios for the previous rings along a line

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from the viewer cell, that location is marked as seen. If it is smaller, the location is marked as not seen.



*Visual Connectivity is calculated by comparing the rise/run ratio along a direction- if it is greater than any of the previously calculated ratios that location is marked as seen; if not, it is marked as not seen.*

For ring #4, Rise/Run= (763-520) / (4\*328)= **.1852**

	Ring 0	1	2	3	4	5	6	7	8	9
Elevation	520 feet	556	622	695	763	818	857	911	883	877
Rise	--	36	102	175	243	298	337	391	363	357
Run	0 feet	328	656	984	1312	1640	1968	2296	2624	2952
<b>Rise/Run</b>	--	.1098	.1555	.1778	<b>.1852</b>	.1817	.1712	.1703	.1383	.1209
<i>Seen or Not Seen</i>	--	<i>Seen</i>	<i>Seen</i>	<i>Seen</i>	<i>Seen</i>	<i>Not</i>	<i>Not</i>	<i>Not</i>	<i>Not</i>	<i>Not</i>

Figure 2. Example calculations for determining visual connectivity.

In the example shown in figure 2, the rise/run ratios to the south (arrow in the figure) are successively larger for rings 1 through 4 (marked as *seen*) but not for rings 5 through 9 (marked as *not seen*). The computer does calculations for all directions from the viewer cell and marks the seen locations with a value of one. The process is repeated for all of the viewer cells defining surface water locations—127 times, once for each water cell. Locations marked with a one at least once identifies the viewshed. Visual exposure, on the other hand, simply sums the markers for the number of times each location is seen.

Now let’s complicate matters a bit. Suppose there is a dense forest with 75-foot trees that grow like “chia pet” hairs out of the elevation surface. The forest canopy height is analogous to raising the elevation surface an equal amount. But unless you’re a bird, your eyeball stays on the ground and the trees act like screens blocking your view.

The 3-D plot in figure 3 shows the effect of introducing a 75-foot forest canopy onto the elevation surface. Note the sharp walls around the water cells, particularly in the lower right corner. The view on the ground from these areas is effectively blocked. The computer “knows” this because the first ring’s rise/run ratio is very large (big rise for a small run) and is nearly impossible to beat in subsequent rings.

The consequence of the forest screens is shown in the maps on the right. The top one doesn’t consider trees, while the bottom one does. Note the big increase in the “not seen” area (gray) along the stream in the lower right where the trees serve as an effective visual barrier. If your

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motive is to hide something ugly in these areas from a hiking trail along the stream, the adjacent tree canopy is extremely important.

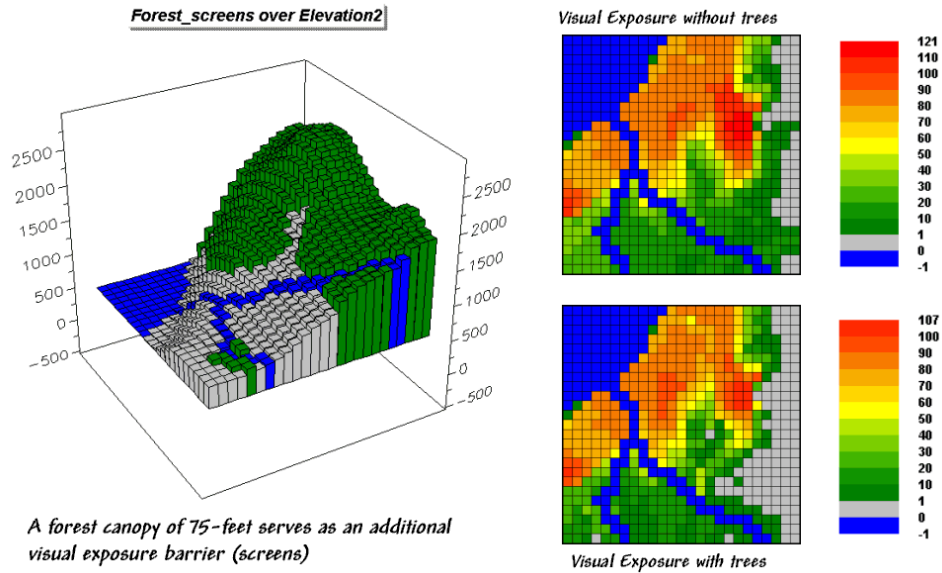


Figure 3. Introducing visual screens that block line-of-sight connections.

The ability to calculate visual connectivity has many applications. Resource managers can determine the visual impact of a proposed activity on a scenic highway. County planners can assess what is seen, and who in turn can see, a potential development. Telecommunication engineers can try different tower locations to “see” which residences and roadways are within the different service areas.

Within a GIS, users can easily simulate “what if” by changing the locations of the viewer cells and screens then comparing the visual exposure maps generated under the different scenarios—sort of like a visual impact spreadsheet. Like most things in GIS, however, “you ain’t seen nothing yet”... more on visual connectivity and its uses next month.

## Visual Exposure Is in the Eye of the Beholder

(GeoWorld, July 2001, pg. 24-25)

[\(top\)](#)

The previous section introduced some basic calculations and considerations in deriving visual exposure. An important notion was that “viewer” locations can be a point, group of points, lines or areas—any set of grid cells. In the example described last month, all of the stream and lake

cells were evaluated to identify locations seen by at least one water cell (termed a *viewshed*) or the number of water cells seeing each map location (termed *visual exposure*).

In effect, the water features are similar to the composite eye of a fly with each grid cell serving as an individual lens. The resulting map simply reports the line-of-sight connections from each lens (grid cell) to all of the other locations in a project area.

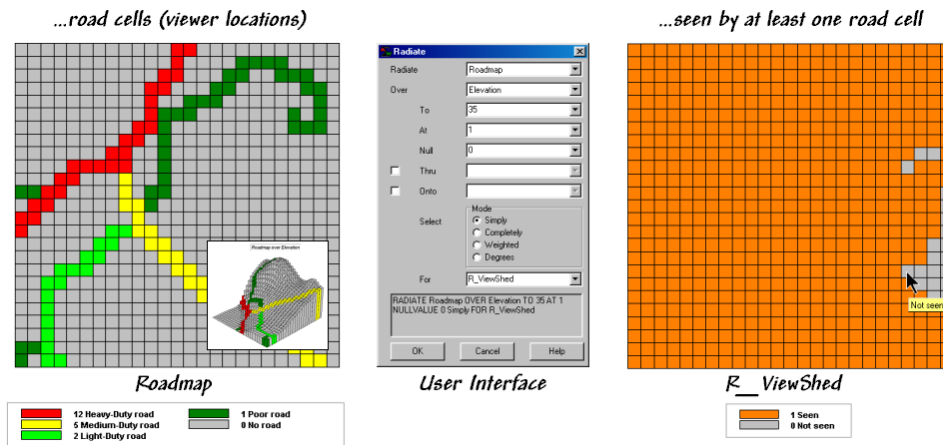


Figure 1. Identifying the “viewshed” of the road network.

Figure 1 shows a similar analysis for a road network. The cells defining the roads are shown in the map on the left with a draped display on the elevation surface as the inset. The computer “goes” to one of the road cells, “looks” everywhere over the terrain and “marks” each map location that can be seen with a value of one. The process is repeated for all of the other road cells resulting in the map on the right—a viewshed map with seen (tan), not seen (gray).

The interface in the middle of figure 1 shows how a user coerces the computer to generate a viewshed map. In the example, the command *Radiate* is specified and the *Roadmap* is selected to identify the viewer cells. The *Elevation* map is selected as the terrain surface whose ridges and valleys determine visual connectivity from each lens of the elongated eyeball. The *To 35* parameter tells the computer to look up to 35 cells away in all directions—effectively everywhere on the 25x25 cell project area. The *At 1* specification indicates that the eyeball is 1-foot over the elevation surface and the *Null 0* sets zero as the background (not a viewer cell). The *Thru* and *Onto* specifications will be discussed a little later.

As the newer generations of GIS software take hold, more and more systems are replacing their command line interfaces with dialog boxes similar to the one in the example. Clicking on the *Simply* radio button instructs the computer to create a new map specified as *R\_ViewShed*—the map displayed on the right in figure 1.

Locations on the *R\_ViewShed* map that didn’t receive any connectivity marks (value 0) are not seen from any road cell. Figure 2 shows results using different calculation modes and the resulting maps.

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The values on the *R\_VisualExposure* map were generated by clicking *Completely* to calculate the number of roads cells that “see” each location in the project area—from 0 (not seen) to 75 times seen. Generally speaking, you put ugly things where the numbers are low and pretty things where the numbers are high.

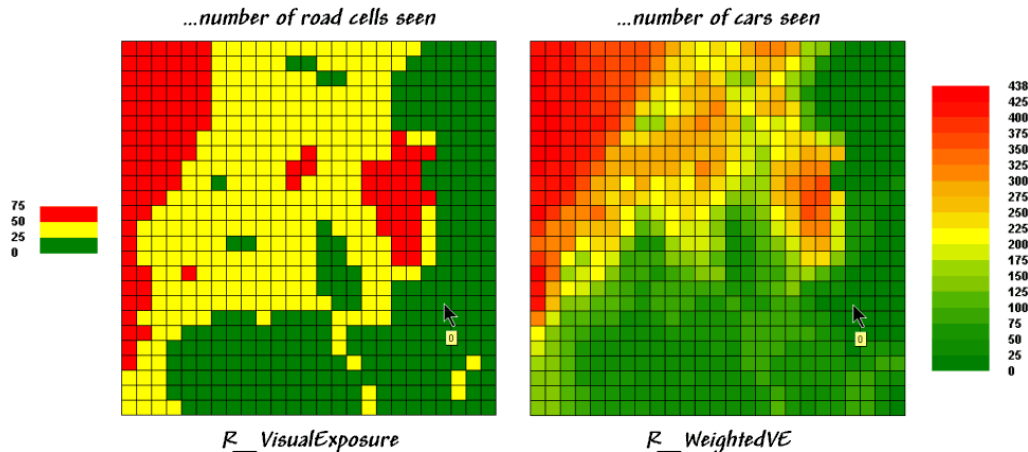


Figure 2. Calculating simple and weighted visual exposure.

But just the sum of road cells that are visually connected doesn’t always tell the whole story. Note the values defining the different types of roads on the *Roadmap* in figure 1—1 Poor road, 2 Light-duty, 5 Medium-duty, and 12 Heavy-duty. The values were craftily assigned as “relative weights” indicating the average number of cars within a 15-minute time period. It’s common sense that a road with more cars should have more influence in determining visual exposure than one with just a few cars.

The calculation mode was switched to *Weighted* to generate the *R\_WeightedVE* map displayed on the right side of figure 2. In this instance, the *Roadmap* values are summed for each map location instead of just counting how many road cells are visually connected. The resultant values indicate the relative visual exposure based on the traffic densities—viewer cells with a lot of cars having greater influence.

Now turn your attention to the *Thru* and *Onto* specifications in the example interface. The *Thru* hot-field allows the user to specify a map identifying the height of visual barriers within the area. In last month’s discussions it was used to place the 50-foot tree canopy for forested areas—the “chia pet” hairs on top of the elevation surface that blocks visual connections. The *Thru* map contains height values for all “screen” locations and effectively adds the blocking heights to the elevation values at each location—0 indicates no screen and 50 indicates a 50-foot visual barrier on top of the terrain.

The *Onto* hot-field is conceptually similar but has an important difference. It addresses tall objects, such as smoke-stacks or towers, that might be visible but not wide enough to block views. In this instance, the computer adds the “target” height when visual connectivity is being considered for a cell containing a structure but the added height isn’t considered for locations

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beyond. The effect is that the feature pops-up to see if it is seen but doesn't hang around to block the view beyond it.

Figure 3 depicts yet another way of dealing with extended features. Assume you want to assess the difference in visual impact of two proposed power line routes shown in the 3-D inset in the figure. In this instance, *Powerline1* is first selected as the viewer map (instead of *Roadmap*) and the *At* parameter is set to 50. The command is repeated for *Powerline2*.

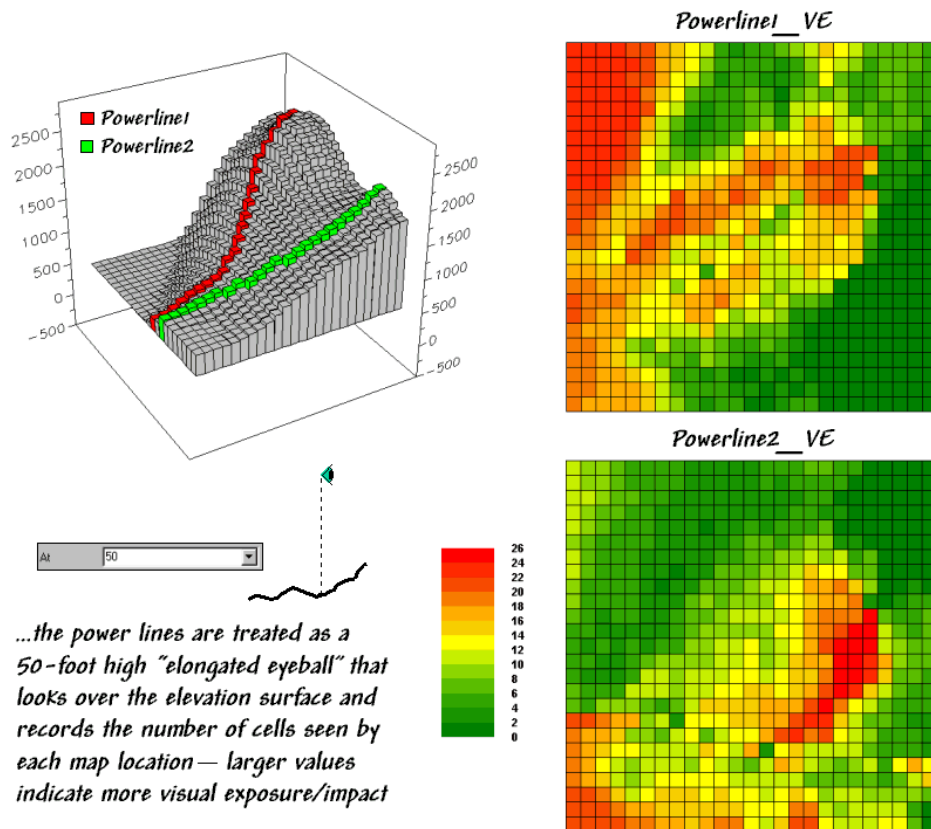


Figure 3. Determining the visual exposure/impact of alternative power line routes.

These entries identify the power line cells and their height above the ground. The *Powerline1\_VE* map shows the number of times each map location is seen by the elongated *Powerline1* eyeball. And by "line-of-sight," if the power line can see you, you can see the power line. The differences in the patterns between *Powerline1\_Ve* and *Powerline2\_VE* maps characterize the disparity in visual impact for the two routes. What if your house was in a red area on one and a green area on another? Which route would you favor?... not in my visual backyard. Next month we'll investigate a bit more into how models using visual exposure can be used in decision-making.

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# Use Exposure Maps and Fat Buttons to Assess Visual Impact

(GeoWorld, August 2001, pg. 24-25)

(top)

The last section described several considerations in deriving visual exposure maps. Approaches ranged from a simple *viewshed* (locations seen) and *visual exposure* (number of times seen) to *weighted visual exposure* (relative importance of visual connections). Extended settings discussed included *distance*, *viewer height*, *visual barrier height* and special *object height*.

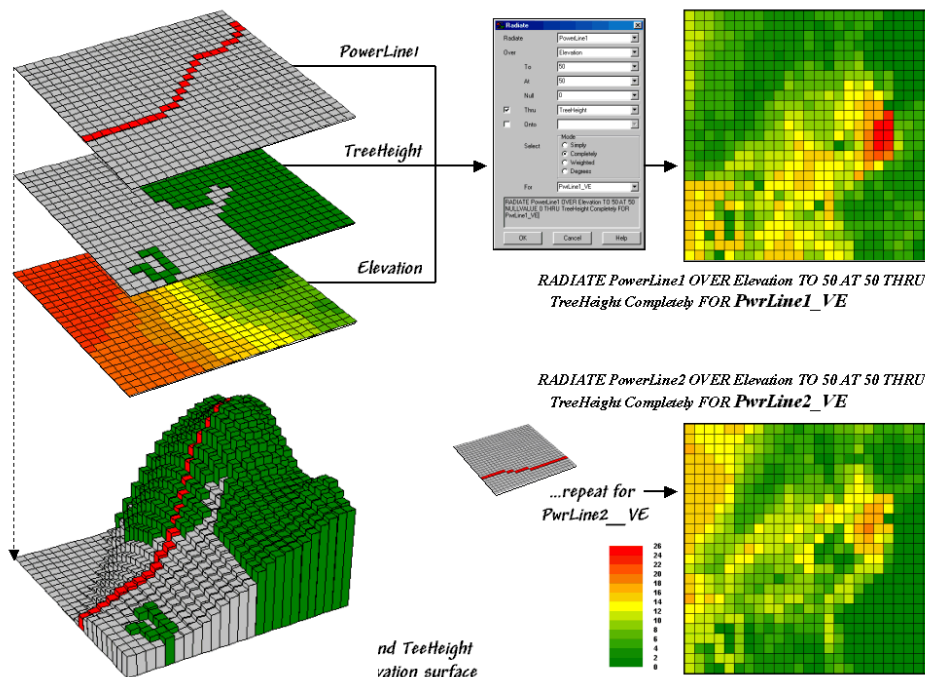


Figure 1. Calculating visual exposure for two proposed power lines.

Figure 1 rekindles the important points before tackling visual impact modeling. The maps on the left identify input information for calculating visual exposure. The *PowerLine1* map serves as an elongated eyeball, the *TreeHeight* map identifies areas with a 75-foot forest canopy that grows like “chia pet” hairs on the *Elevation* surface.

The 3-D inset is a composite display of all three input maps. The user interface shown in the middle is used to specify viewer height (*At 50*) that raises the power line 50-feet above the surface. A large distance value (*To 50*) is entered to force the calculations for all locations in the study area. Finally, the visual exposure mode is indicated (*Completely*) and a name assigned to the derived map (*PwrLine1\_VE*).

The top-left map shows the result with red tones indicating higher visual exposure. The lower-left map shows visual exposure for a second proposed power line that runs a bit more to the

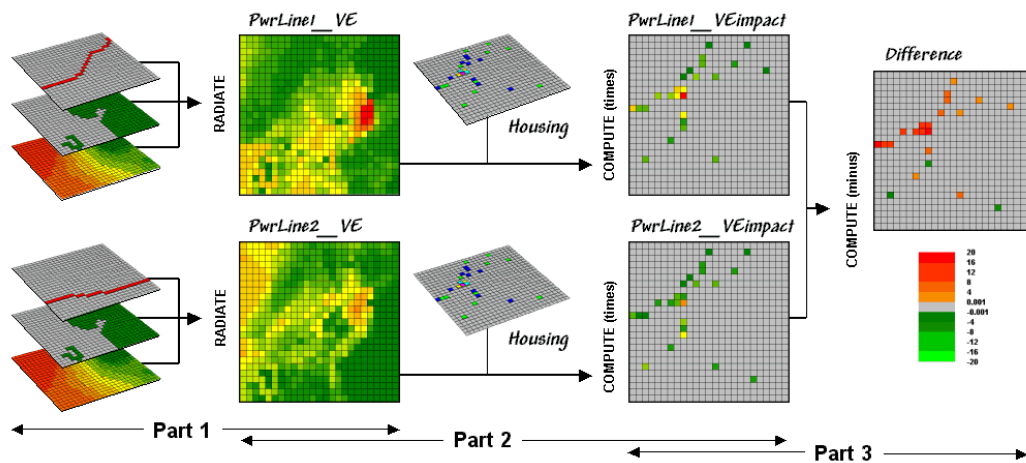
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south. It was calculated by simply changing the viewer map to *PowerLine2* and the output map to *PwrLine2\_VE*. Compare the patterns of visual exposure in the two resultant maps. Where do they have similar exposure levels? Where do they differ? Which one affects the local residents more?

This final question requires a bit more processing to nail down—locating the residential areas, “masking” their visual exposure and comparing the results. Figure 2 outlines a simple impact model for determining the exposure difference between the two proposed routes. The visual exposure maps on the left are the same as those in figure 1 and serve as the starting point for the impact model.

The *Housing* map identifies grid cells that contain at least one house. The values in the housing cells indicate how many residences occur in each cell—1 to 5 houses in this case; a 0 value indicates that no houses are present. This map is multiplied by the visual exposure maps to calculate the visual impact for both proposed routes (*PwrLine1\_VEimpact* and *PwrLine2\_VEimpact*). Note that exposure for areas without a house result in zero impact—0 times any exposure level is 0. Locations with one house report the calculated exposure level—1 times any exposure level is the same exposure level. Locations with more than one house serve as a multiplier of exposure impact—2 times any exposure level is twice the impact.



Map Analysis						
Script Edit						
Reclassify	Overlay	Distance	Neighbors	Statistical	Import/Export	Macro
NewScript						
Operation	Operation Detail	Display	Clean Up			
NOTE	Part 1 - Determine the visual exposure to both power lines for all locations...	2D	<input type="checkbox"/>			
RADIATE	RADIATE PowerLine1 OVER Elevation TO 50 AT 50 NULLVALUE 0 THRU TreeHeig...	2D	<input type="checkbox"/>			
RADIATE	RADIATE PowerLine2 OVER Elevation TO 50 AT 50 NULLVALUE 0 THRU TreeHeig...	2D	<input type="checkbox"/>			
NOTE	Part 2 - Determine the visual impact of both powerlines for housing areas...	2D	<input type="checkbox"/>			
COMPUTE	COMPUTE Housing Times PwrLine1_VE FOR PwrLine1_VEimpact	2D	<input type="checkbox"/>			
COMPUTE	COMPUTE Housing Times PwrLine2_VE FOR PwrLine2_VEimpact	2D	<input type="checkbox"/>			
NOTE	Part 3 - Computer the difference in visual impact...	2D	<input type="checkbox"/>			
COMPUTE	COMPUTE PwrLine1_VEimpact Minus PwrLine2_VEimpact FOR Difference	2D	<input type="checkbox"/>			

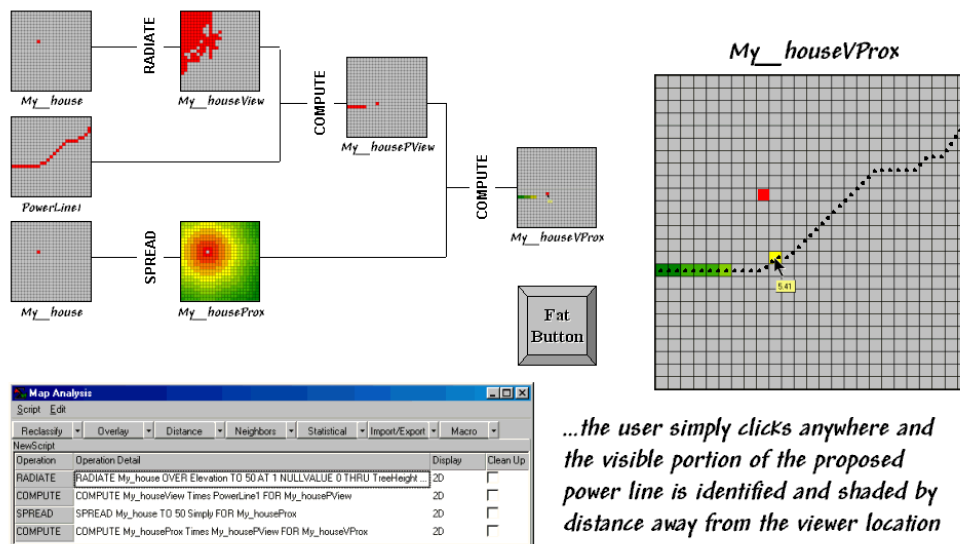
...the processing flow for determining the relative visual impact involves five command sentences (script)

Figure 2. Determining visual impact on local residents.

The final step involves comparing the two visual impact maps by simply subtracting them. The red tones on the *Difference* map identify residential locations that are impacted more by the *PowerLine1* route—the higher the value, the greater the difference in impact.

The dark red locations identify residents that are significantly more affected by route 1—expect a lot of concern about the route. On the other hand, there are only three locations that are slightly more affected by route 2 (dark green; fairly low values).

The information in the lower portion of figure 2 is critical in understanding GIS modeling. The conceptualization of a spatial problem, such as visual impact on residents, must be translated into a sequence of map analysis operations. In this instance, there are three parts— 1) visual exposure, 2) visual impact and 3) comparison. Each of the sentences in the script shown at the bottom of the figure is entered via a command dialog box similar to the one in figure 1. The script can be saved, edited and re-run at a later time or on another project area.



...the user simply clicks anywhere and the visible portion of the proposed power line is identified and shaded by distance away from the viewer location

Figure 3. Determining visible portions of a proposed power line.

The ability to save and re-run a map analysis sequence sets the stage for the current revolution in GIS technology. Figure 3 shows another simple impact model that determines the visible portion of a power line route and its distance from any location.

The flowchart shows the logical structure of the analysis and the intermediate maps generated—

- ✓ Calculate the viewshed from the selected point
- ✓ Mask the portion of the route within the viewshed
- ✓ Calculate proximity from the selected point
- ✓ Mask the proximity for just the proportion of the route

The script identifies the four sentences that solve the spatial problem. The revolution is represented by the “Fat Button” in the figure.

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Within a GIS, the *fat button* calls a command script that dutifully executes the stored commands. In this example, the user would push the fat button and the program would direct them to “click anywhere on the base map.” Once the location is set, the *My\_house* map is defined and the script is run for that location. The next thing the user would see is the final map indicating the visible portion of the route and how far away it is. Click on another location and its result is displayed.

The ability to pop-up special input interfaces and launch command scripts moves the paradigm of a “GIS Toolbox” to one of “Application-specific” solutions. With the advent of COM-object modules the entire application can be moved outside of the GIS. The bottom line is expect to see a lot of map analysis applications taking hold in places you never dreamed. Heck, they could be links within an impact statement that encourages a reader to “click anywhere on the base map” to see what you would see.

## Use Maps to Assess Visual Vulnerability

(GeoWorld, February 2003, pg. 22-23)

[\(top\)](#)

The previous sections introduced fundamental concepts and procedures used in visual analysis. As a quick review, recall that the algorithm uses a series of expanding rings to determine relative elevation differences from the viewer position to all other map locations. Elevation differences that are less than those in previous rings are not seen.

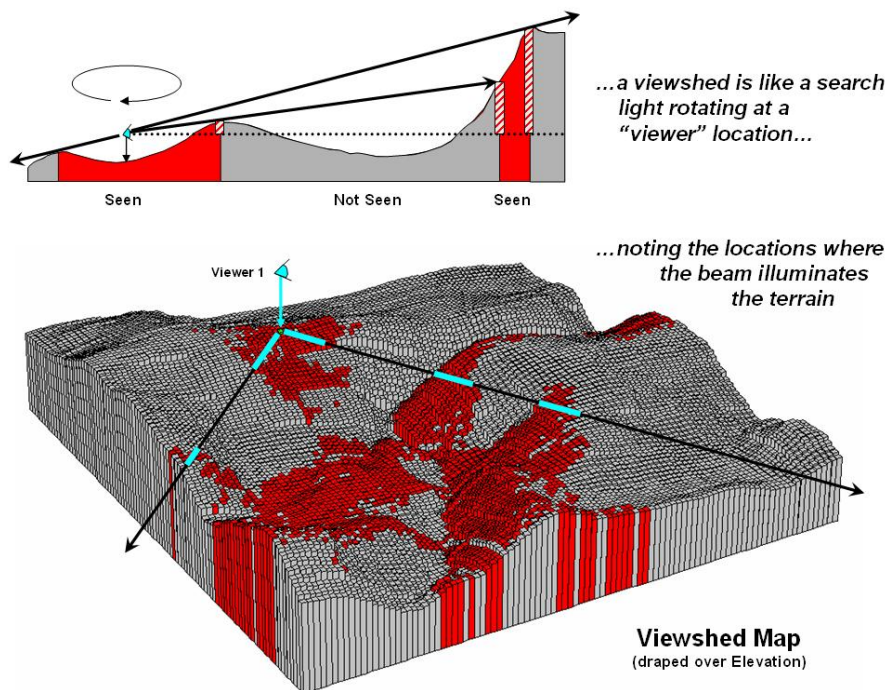


Figure 1. Calculating a viewshed.

The top portion of figure 1 illustrates the procedure. The ratio of the elevation difference (*rise* indicated as striped boxes) to the distance away (*run* indicated as the dotted line) is used to determine visual connectivity. Whenever the ratio exceeds the previous ratio, the location is marked as seen (red); when it fails it is marked as not seen (grey).

To conceptualize the procedure, imagine a searchlight illuminating portions of a landscape. As the searchlight revolves about a viewer location the lit areas identify visually connected locations. Shadowed areas identify locations that cannot be seen from the viewer (nor can they see the viewer). The result is a **viewshed map** as shown draped over the elevation surface in figure 1. Additional considerations, such as tree canopy, viewer height and view angle/distance, provide a more complete rendering of visual connectivity.

The top portion of figure 2 shows the viewsheds from three different viewer locations. Each map identifies the locations within the project area that are visually connected to the specified viewer location. Note that there appears to be considerable overlap among the “seen” (red) areas on the three maps. Also note that most of the right side of the project area isn’t seen from any of the locations (grey).

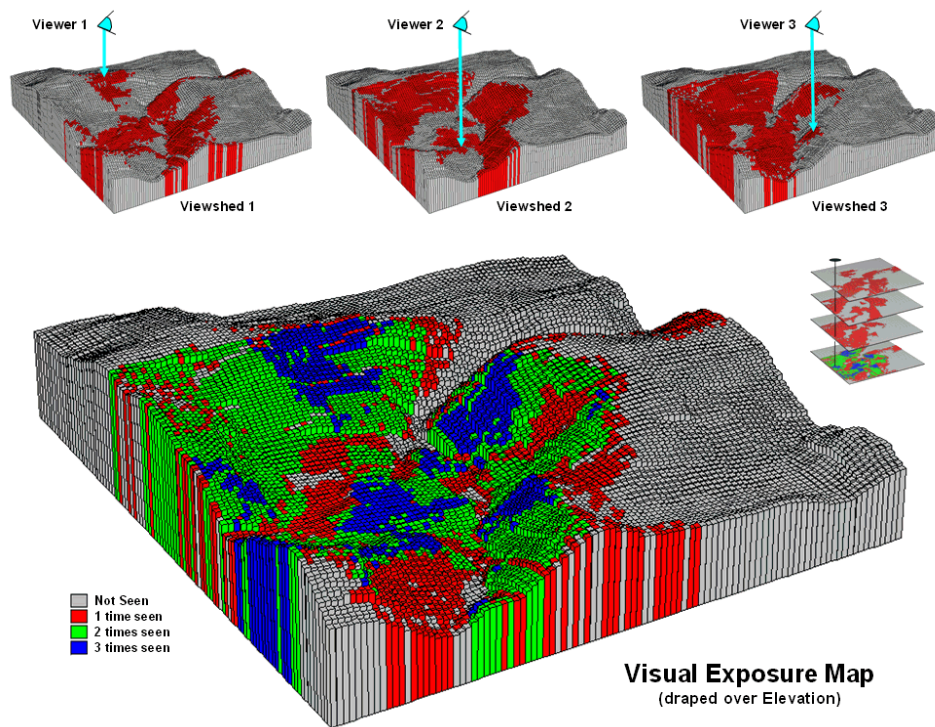


Figure 2. Calculating a visual exposure map.

A **visual exposure** map is generated by noting the number of times each location is seen from a set of viewer locations. In figure 2 this process is illustrated by adding the three viewshed maps together. The resulting visual exposure map in the bottom of the figure contains four values—0=

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not seen, 1= one time seen, 2= two times seen and 3= three times seen—forming a relative exposure scale.

The top portion of figure 3 shows the result considering the entire road network as a set of viewer locations. In addition, the different road types are weighted by the number of cars per hour. In this instance the total “number of cars” replaces the “number of times seen” for each location in the project area.

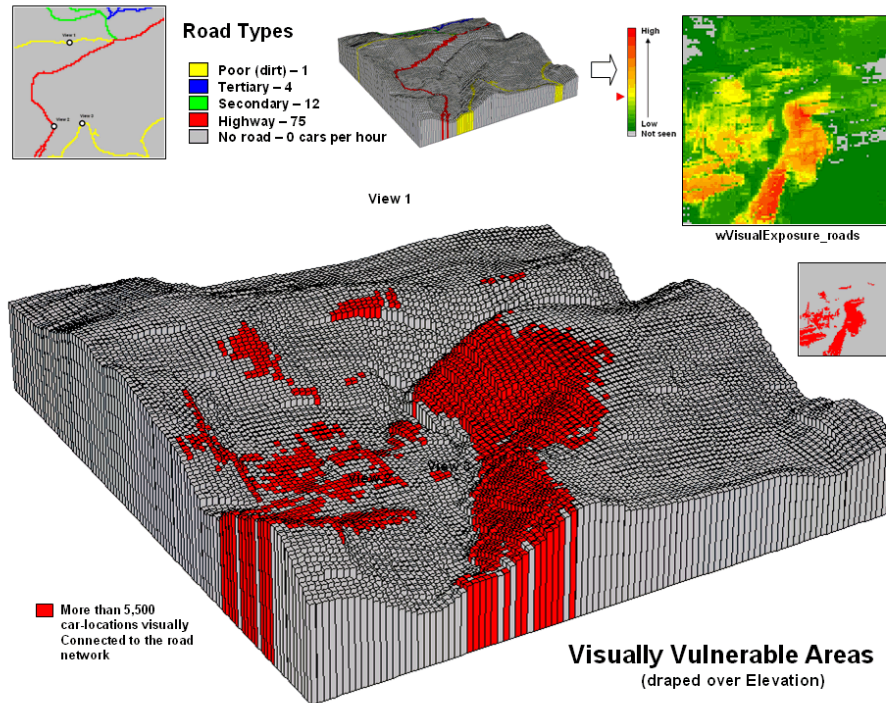


Figure 3. Calculating a visual vulnerability map.

The effect is that extra importance is given to road types having more cars yielding a *weighted visual exposure map*. The relative scale extends from 0 (not seen; grey) to 1 (one car-location visually connected; dark green) through 12,614 (lots and lots of visual exposure to cars; dark red). In turn, this map was reclassified to identify areas with high visual exposure—greater than 5,500 car-locations (yellow through red)—for a map of *visual vulnerability*.

A visual vulnerability map can be useful in planning and decision-making. To a resource planner it identifies areas that certain development alternative could be a big “eyesore.” To a backcountry developer it identifies areas whose views are dominated by roads and likely a poor choice for “serenity acres.” Before visual analysis procedures were developed, visceral visions of visual connectivity were conjured-up with knitted-brows focused on topographic maps tacked to a wall. Now detailed visual vulnerability assessments are just a couple of clicks away.

# Try Vulnerability Maps to Visualize Aesthetics

(GeoWorld, March 2003, pg. 22-23)

[\(top\)](#)

The previous section described procedures for characterizing *visual vulnerability*. The approach identified “sensitive viewer locations” then calculated the relative visual exposure to the feature for all other locations in a project area. In a sense, a feature such as a highway is treated as an elongated eyeball similar to a fly’s compound eye composed of a series of small lenses—each grid cell being analogous to a single lens.

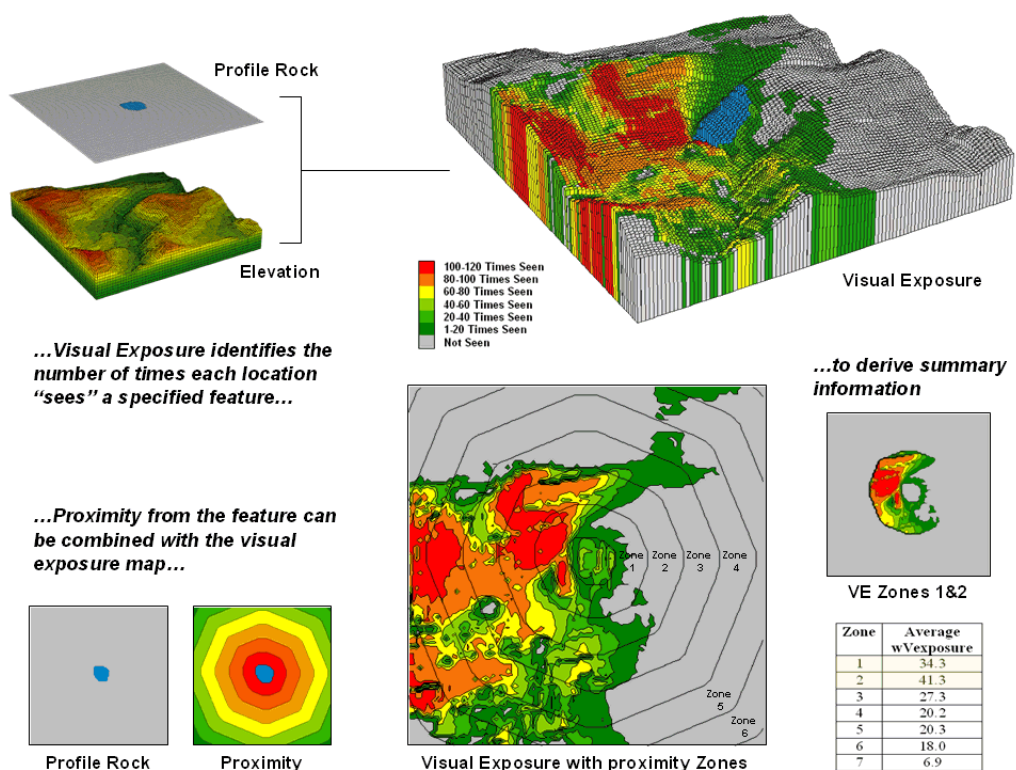


Figure 1. Visual connectivity to a map feature (Profile Rock) identifies the number of times each location sees the extended feature.

In figure 1, Profile Rock is composed of 120 grid cells positioned in the center of the project area. In determining visual exposure to Profile Rock, the computer calculates straight line connectivity from one of its cells to all other locations based on its relative position on the elevation surface. Depending on the unique configuration of the terrain some areas are marked as seen and others are not.

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The process is repeated for all of the cells defining Profile Rock and a running count of the “number of times seen” is kept for each map location. The top right inset displays the resulting visual exposure from not seen (VE= 0; grey) to the entire feature being visible (VE= 120; red). As you might suspect, a large amount of the opposing hillside has a great view of Profile Rock. The southeast plateau, on the other hand, doesn’t even know it exists.

The lower portion of figure 1 extends on the concept of visual exposure by introducing distance. It is common sense that something near you (foreground) has more visual impact than something way off in the distance (background). A proximity map from the viewer feature is generated and distance zones can be intersected with the visual exposure map (lower-right inset in figure 3). The small map on the extreme right shows visual exposure for just distance Zones 1 and 2 (600m reach). The accompanying table summarizes the average visual exposure to Profile Rock within each distance zone—much higher for Zones 1 and 2 (34.3 and 41.3) than the more distant zones (27.3 or less).

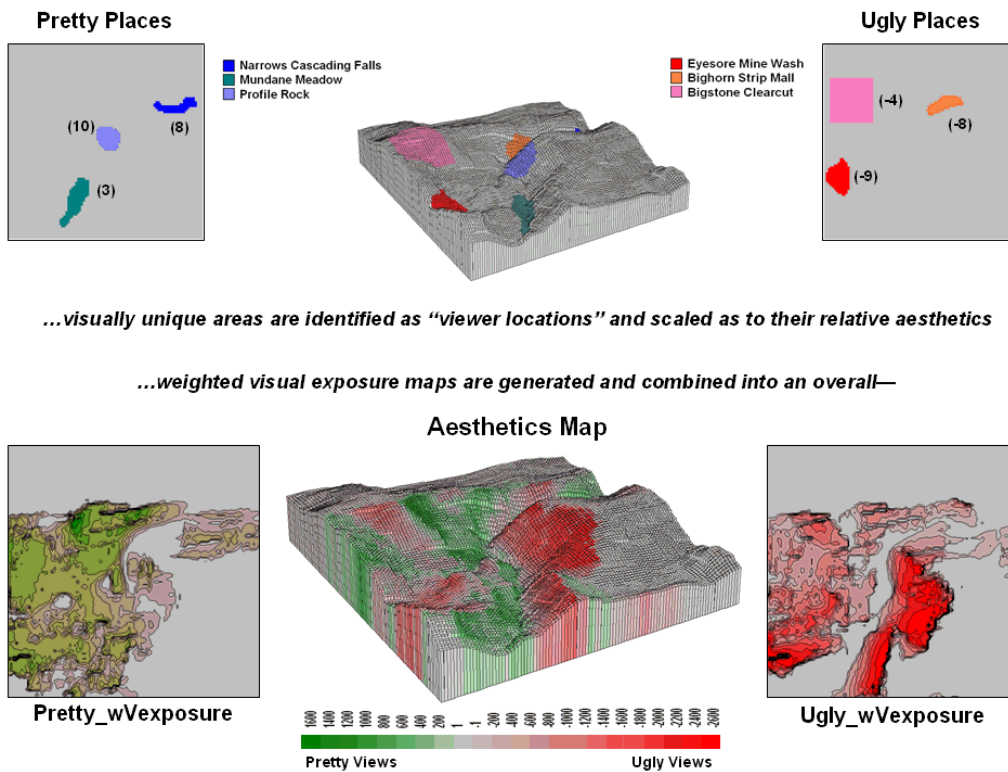


Figure 2. An aesthetic map determines the relative attractiveness of views from a location by considering the weighted visual exposure to pretty and ugly places.

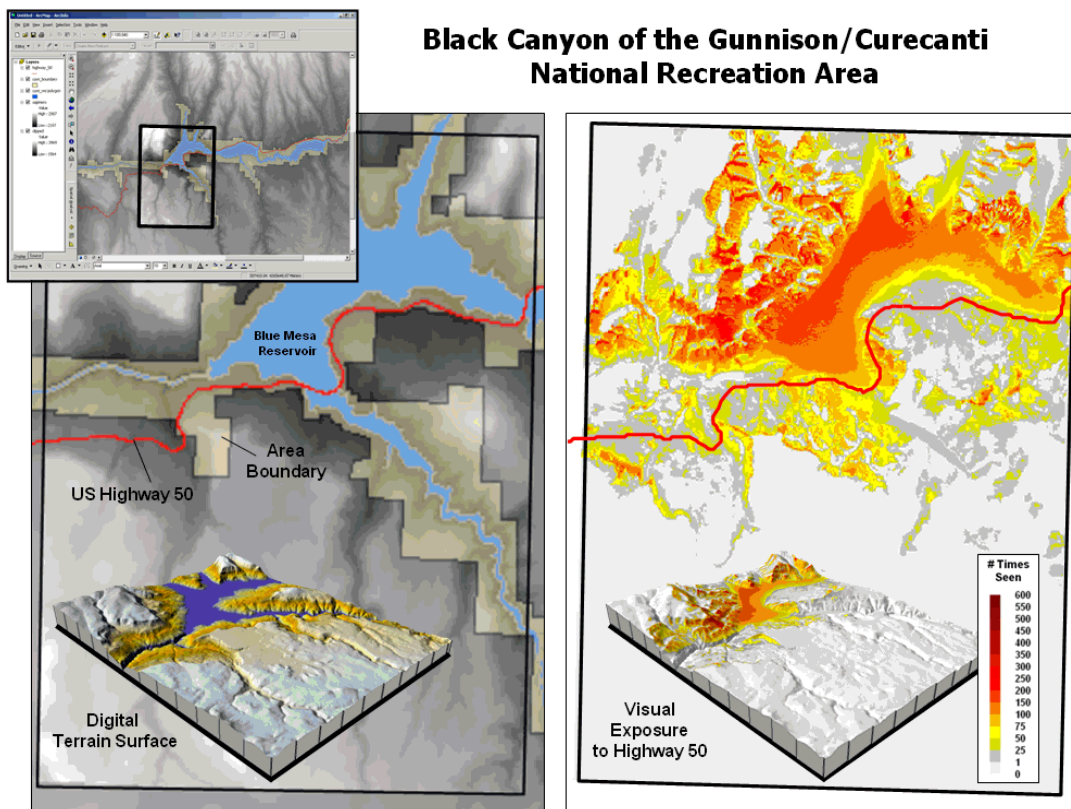
The ability to establish weighted visual exposure for features is critical in deriving an *aesthetic map*. In this application various features are scaled in terms of their relative beauty— 0 to 10 for increasing pretty places and 0 to -10 for increasing ugly places. For example, Profile Rock represents a most strikingly beautiful natural scene and therefore is assigned a “10.” However, Eyesore Mine wash is one of the ugliest places to behold so it is assigned a “-9.” In calculating

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weighted visual exposure, the aesthetic value at a viewer location is added to each location within its viewshed. The result is high positive values for locations that are connected to a lot of very pretty places; high negative values for connections to a lot very ugly places; zero, or neutral, if not connected to any pretty or ugly places or they cancel out.

The top portion of figure 2 shows the aesthetics ratings for several “pretty and ugly” features in the area as 2D plots then as draped on the terrain surface. The 2D plots in the bottom portion of the figure identify the total weighted visual exposure for connections from each map location to pretty and ugly places.

The overall aesthetic map in the center is analogous to calculating net profit—revenue (think Pretty) minus expenses (think Ugly). It reports the net aesthetics of any location in the project area by simply adding the *Pretty\_wExposure* and *Ugly\_wExposure* maps. Areas with negative values (reds) have more ugly things within their view than pretty ones and are likely poor places for a scenic trail. Positive locations (greens), on the other hand, are locations where most folks would prefer to hike.



*Figure 3. Weighted visual exposure map for an ongoing visual assessment in a national recreation area.*

Real-world applications of visual assessment are taking hold. For example, a senior honors thesis project is underway at the University of Denver by a student intern with the National Park

From the Further Reading compilation Beyond Mapping III supporting the book *Map Analysis* (Berry 2007, GeoTec Media). ©2007. All rights reserved. Permission to copy for educational use is granted.



Service (see author's note). The project will develop visual vulnerability maps from the reservoir in the center of the park and a major highway running through the park (right side of the figure 3). In addition, aesthetic maps will be generated based on visual exposure to pretty and ugly places in the park.

It seems to be a win-win situation with the student getting practical GIS experience (not to mention a lot of awesome hiking for field verification) and NPS will get cutting-edge procedures and maps they need for effective resource planning. My guess is that there is a university near you that is looking for "a few good clients" to take GIS education beyond the classroom—give them a call.

## ***In Search of the Elusive Image***

*(GeoWorld, July 2013)*

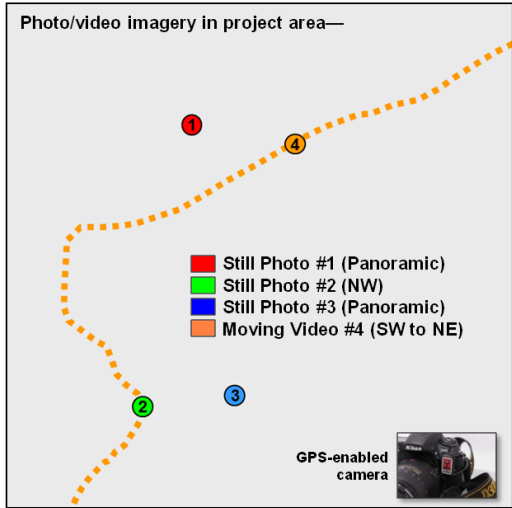
[\(top\)](#)

Last year National Geographic reported that nearly a billion photos were taken in the U.S. alone and that nearly half were captured using camera phones. Combine this with work-related imaging for public and private organizations and the number becomes staggering. So how can you find the couple of photos that image a specific location in the mountainous digital haystack?

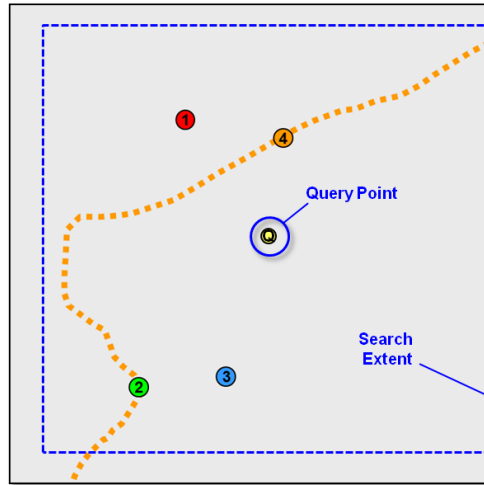
For the highly organized folks, a cryptic description and file folder scheme can be used to organize logical groupings of photos. However, the most frequently used automated search technique uses the date/time stamp in the header of every digital photo. And if a GPS-enabled camera was used, the location of an image can further refine the search. For most of us the basic techniques of *Category*, *Date/Time* and *Vicinity* are sufficient for managing and accessing a relatively small number of vacation and family photos (step 1, figure 1).

However if you are a large company or agency routinely capturing terabytes of still photos and moving videos, searching by category, date/time and earth position merely reduces the mountain of imagery to thousands possibilities that require human interpretation to complete the search. Chances are most of the candidate image locations are behind a hill or the camera was pointed in the wrong direction to have captured the point of interest. Simply knowing that the image is "near" a location doesn't mean it "sees" it.

Figure 2 outlines an approach that takes automated geo-searching a bit farther (see author's note 1). Step 2 in the figure involves calculating the *Viewshed* from the query point considering intervening terrain, cover type and the height of the camera. All of the potential images located outside of the viewshed (grey areas) are not "visually connected" to the query point, so the point of interest cannot appear in the image. These camera locations are eliminated.

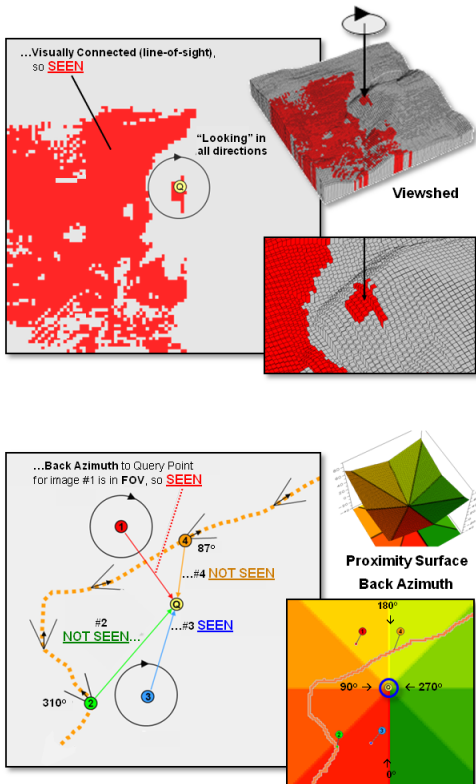


With terabytes of digital images taken every day, new database procedures are needed to **organize and search this tsunami of information**—  
 ...advanced geo-query can be a big part of the solution



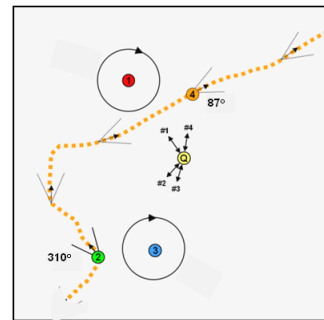
**Step 1)** The user identifies a **location of interest (Query Point)** → then specifies relevant **Category, Date/Time** and geographic **Search Extent** ...imagery not meeting the query are eliminated.

Figure 1. Geo-tagged photos and streaming video extend traditional database category and date/time searches for relevant imagery.



**Step 2)** The **Viewshed** from the query point is calculated considering intervening terrain and vegetation canopy height as visual barriers—  
 ... imagery locations not in the viewshed are eliminated.

**Step 3)** The **Viewing Direction** of the imagery is determined with respect to the direction of the camera's **Optical Axis** and **Field of View**.



**Step 4)** The **Back Azimuths** from the query point are compared to the **Viewing Direction** for all candidate imagery locations—  
 ... imagery locations not pointed toward the query point are eliminated.

Figure 2. Viewshed Analysis determines if a camera location can be seen from a location of interest and Directional Alignment determines if the camera was pointed in the right direction.

A third geo-query technique is a bit more involved and requires a directionally-aware camera (step 3 in figure 2). While a lot of GPS-enabled cameras record the position a photo was taken, few currently provide the direction/tilt/rotation of the camera when an image is taken. Specialized imaging devices, such as the three-axis gyrostabilizer mount used in aerial photography, have been available for years to continuously monitor/adjust a camera's orientation. However, pulling these bulky and expensive commercial instruments out of the sky is an impractical solution for making general use cameras directionally aware.

On the other hand, the gyroscope/accelerometers in modern smartphones primarily used in animated games routinely measure orientation, direction, angular motion and rotation of the device that can be recorded with imagery as the technology advances. All that is needed is a couple of smart programmers to corral these data into an app that will make tomorrow's smartphones even smarter and more aware of their environment to include where they are looking, as well as where they are located. Add some wheels and a propeller for motion and the smarty phone can jettison your pocket.

The final puzzle piece for fully aware imaging—lens geometry—has been in place for years embedded in a digital photo's header lines. The field of view (FOV) of a camera can be thought of as a cone projected from the lens and centered on its optical axis. Zooming-in changes the effective focal length of the lens that in turn changes the cone's angle. This results in a smaller FOV that records a smaller area of the scene in front of a camera. Exposure settings (aperture and shutter speed) control the depth of field that determines the distance range that is in focus.

The last step in advanced geo-query for imagery containing a specified location mathematically compares the direction and FOV of the optical cone to the desired location's position. A complete solution for testing the alignment involves fairly complex solid geometry calculations. However, a first order planimetric solution is well within current map analysis toolbox capabilities.

A simple proximity surface from the specified location is derived and then the azimuth for each grid location on the bowl-like surface is calculated (step 4 in figure 2). This "back azimuth" identifies the direction from each map location to the specified location of interest. Camera locations where the back azimuth is not within the FOV angle means the camera wasn't pointed in the right direction so they are eliminated.

In addition, the proximity value at a connected camera location indicates how prominent the desired location is in the imaged scene. The difference between the optical axis direction and the back azimuth indicates the location's centering in the image.

Figure 3 summarizes the advanced geo-query procedure. The user specifies the desired image category, date/time interval and geographic search extent, and then "clicks" on a location of interest. Steps 2, 3 and 4 are automatically performed to narrow down the terabytes of stored imagery to those that are within the category/date/time/vicinity specifications, within the viewshed of the location of interest and pointed toward the location of interest. A hyperlinked

list of photos and streaming video segments is returned for further visual assessment and interpretation.

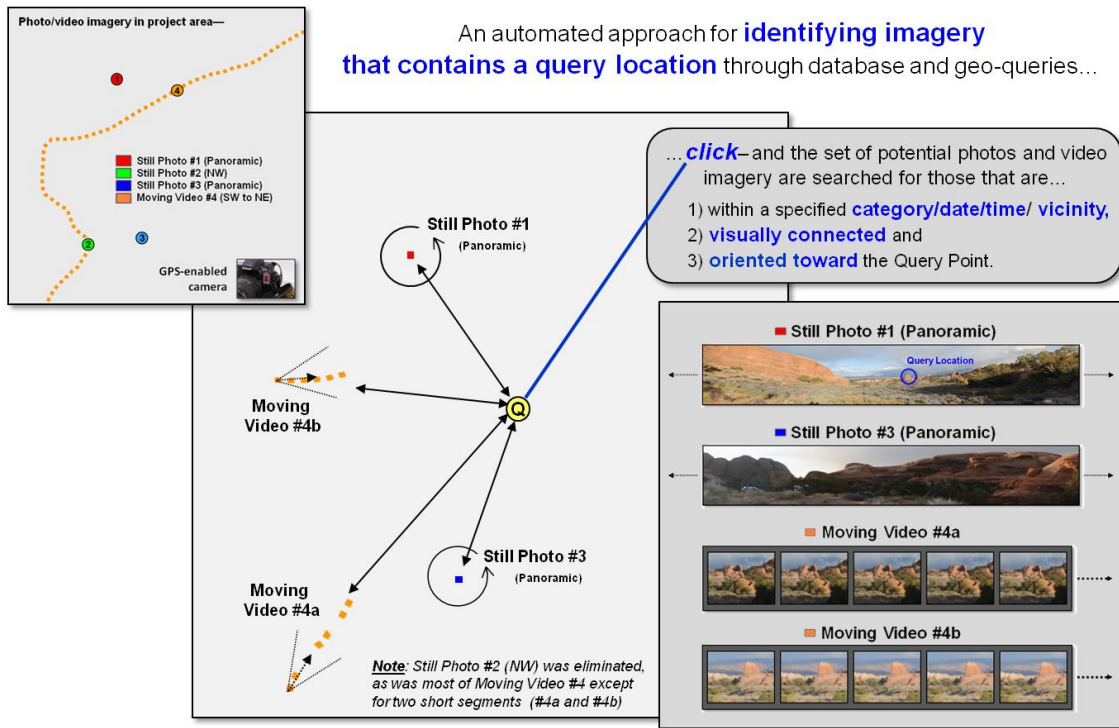


Figure 3. Advanced geo-query automatically accesses relevant nearby imagery that is line-of-sight connected and oriented toward a query point.

While full implementation of the automated processing approach awaits smarter phones/cameras (and a couple of smart programmers), portions of the approach (steps 1 and 2) are in play today. Simply eliminating all of the GPS-tagged images within a specified distance of a desired location that are outside its viewshed will significantly shrink the mountain of possibilities—tired analyst’s eyes will be forever grateful.

**Author’s Notes:** 1) The advanced geo-query approach described follows an early prototype technique developed for Red Hen Systems, Fort Collins, Colorado.

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