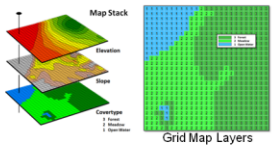
Draft3, April 2012

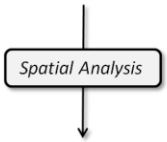
Math/Stat Classification of Spatial Analysis and Spatial Statistics Operations

for MapCalc software distributed by Berry & Associates // Spatial Information Systems

Spatial Analysis Operations *(Geographic Context)*

GIS as "Technological Tool" (*Where* is *What*) vs. "**Analytical Tool**" (*Why, So What* and *What if*)





GIS Perspective:

Reclassify *(Position, Value, Size, Shape, Contiguity)*
Overlay *(Location-specific, Region-wide, Map-wide)*
Distance *(Distance, Proximity, Movement, Optimal Path, Visual Exposure)*
Neighbors *(Characterizing Surface Configuration, Summarizing Values)*

Map Analysis Toolbox

Mathematical Perspective:

Basic GridMath & Map Algebra *(+ - * /)*
Advanced GridMath *(Math, Trig, Logical Functions)*
Map Calculus *(Spatial Derivative, Spatial Integral)*
Map Geometry *(Euclidian Proximity, Narrowness, Effective Proximity)*
Plane Geometry Connectivity *(Optimal Path, Optimal Path Density)*
Solid Geometry Connectivity *(Viewshed, Visual Exposure)*
✓ ***Unique Map Analytics*** *(Contiguity, Size/Shape/Integrity, Masking, Profile)*

Alternative frameworks for quantitative map analysis involving Spatial Analysis of geographic context within and among map layers.

Spatial Analysis Operations — Mathematical Perspective

…of Grid-based Map Analysis and Modeling Operations

…for BASIS ***MapCalc Software***

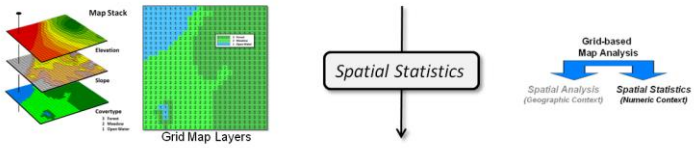
Mathematical Concepts	MapCalc Operation	Comments
Basic and Advanced GridMath & Map Algebra *(+ - * / and Math, Trig, Logical Functions):*		
	Compute *(two or more map layers)*	**Compute** creates a map as the mathematical or statistical function of two or more maps or constants.
	Calculate *(two or more map layers)*	**Calculate** is a manual equation editor that expands upon the more automated Compute function. Calculate helps you build equations by letting you choose the individual elements from the menus. Alternatively, you can type the entire equation into the blank. There is no limit to the length of an equation. Use parentheses and brackets as needed to specify order of operations. Computational operations include: • Operators - basic mathematical operations, i.e., sum, difference • Common - mathematical functions, i.e., exponent, square root • Logical - relational operators, i.e., and, or • Grid - statistical functions, i.e., maximum, minimum • Trig - trigonometric functions, i.e., sine, tangent
Map Calculus *(Spatial Derivative, Spatial Integral):*		

	***Neighbors:* Slope** *(single map layer)*	**Slope** creates a map indicating the rate of change (1st derivative) along a continuous surface. Most often slope is determined for terrain elevation data. However, a first derivative or slope map can be generated for any data that forms a continuous distribution in geographic space.
	***Neighbors:* Orient** *(single map layer)*	**Orient** produces a map of aspects or azimuths along a surface map. Note: The Orient function determines the direction of the rate of change throughout a map. Most often slope is determined for terrain elevation data. However, a first derivative or slope map can be generated for any data that forms a continuous distribution in geographic space.
	***Overlay:* Composite** *(discrete templateMap and continuous dataMap layers)*	**Composite** creates a map summarizing values from a data map which coincide with the categories of a template map. Composite Total calculates the total value (dataMap) for all map locations within specified regions (templateMap) under a surface in a manner that is analogous to the traditional integral calculating the area under a curve.
Map Geometry *(Euclidian Proximity, Narrowness, Effective Proximity):*		
	***Distance:* Spread** *(single map layer for simple Euclidean distance)* *(Friction map layer required for effective distance)* *(Guiding surface layer required for uphill/downhill constrained movement)*	**Spread** creates a map indicating the shortest simple Euclidean or effective distance from all cells with non-zero values to other map locations. The measurement can be affected by the nature of the movement, and by the conditions in which the movement takes place (absolute and relative barriers). For example, a lake acts as an absolute barrier to a non-swimmer, so it has to be circumvented. A steep, densely-forested area represents a relative barrier that slows down a hiker. In addition to absolute and relative barriers, Spread can be constrained to flow like water, uphill or downhill over a surface. These guides are not constrained to terrain conditions, but can represent up and down wind by similar movement over a barometric surface.
	***Distance:* Span** *(single discrete map layer)*	**Span** creates a map indicating narrowness within all non-zero areas on a map. A narrowness value is assigned to each cell that is equal to the length (in grid spaces) of the shortest line connecting opposing edges of the feature.
Plane Geometry Connectivity *(Optimal Path, Optimal Path Density):*		
	***Distance:* Stream** *(surfaceMap and sourceMap layers)*	**Stream** creates a map identifying the steepest, or optimal, path along a surface. If the surface map depicts terrain elevation, the optimal path is the one with the least friction in which water would follow. If the surface is an accumulated distance map, such as a travel-time map, the path is the shortest, but not necessarily straight line connecting the target cell to the bottom of the surface. This route represents the quickest path between the two locations. If the surface is an accumulated cost surface, the path is the least-cost route.
	***Distance:* Drain** *(surfaceMap and sourceMap layers required for unweighted accumulation flows)* *(Weighting values assigned to sourceMap locations are required for weighted accumulation flows)*	**Drain** creates a map indicating the number of steepest paths (optimal path density) from a set of locations along a surface. It calculates all downhill paths extending from a starting location specified on one map (sourceMap) over a three-dimensional surface (surfaceMap). The surface map may be a topographic surface map, a cost surface map, or any other map in which the cell values are represented as height. This function differs from the Stream function, in that paths are calculated from all target cells rather than just a single cell.
Solid Geometry Connectivity *(Viewshed, Visual Exposure):*		
	***Distance:* Radiate** *(surfaceMap and viewersMap layers required for viewshed and visual exposure calculation)* *(Weighting values assigned to viewersMap locations are required for weighted visual exposure) (screen_heightMap needed for added visual barriers rising above the surface)* *(target_heightMap required for potentially visible features rising above the surface)*	**Radiate** creates a viewshed map indicating areas that are visible from locations on the viewersMap. It can be used to identify all the cells that can be seen from a single location, or groups of locations. All cells in the viewshed are on an unobstructed line of sight between them and cells on the viewersMap. If any portion of a cell can be seen, then the entire cell is marked as seen. The visual connection can be modified by cell position on a topological surface (elevation), viewer height on the surface (for instance, view from a fire tower), effects of visual screens such as trees, and height of special objects such as smokestacks.

Unique Map Analytics *(Reclassify, Contiguity, Size/Shape/Integrity, Masking, Profile):*		
	Reclassify: **Renumber** *(Single discrete or continuous map layer)*	**Renumber** assigns new values to the category values of an existing map. It is one of the most frequently used operations in MapCalc as it prepares maps for subsequent processing. Renumbering can be made to individual values, or to a range of existing values. The function is used to create new maps out of old maps with the same spatial distribution of categories but with different values.
	Overlay: **Intersect** *(two discrete map layers)*	**Intersect** creates a map that assigns new values to pairwise combinations of values on two maps. The operation compares values at the corresponding cell location of two existing maps. If a specified pair of values is found, it assigns a new value to the location.
	Reclassify: **Clump** *(single discrete map layer)*	**Clump** uniquely identifies groups of cells with the same value, but geographically separated. It is most often used to identify contiguous parcels of the same condition on a map.
	Reclassify: **Size** *(single discrete map layer)*	**Size** assigns new values according to the size of the area associated with each map category. It calculates the area for entire categories (map values) which are often composed of numerous separate groupings. Use Clump, then Size to determine the area of individual groups of the same category.
	Reclassify: **Configure** *(single discrete map layer)*	**Configure** assigns new values characterizing the shape and integrity of the area associated with each map category. Two types of shape assessments are used: boundary configuration and spatial integrity. Boundary configuration uses relationships between the perimeter and area of features. Spatial Integrity characterizes the “intactness” of the area associated with each map category based on the number holes and fragments.
	Overlay: **Cover** *(two or more map layers)*	**Cover** creates a new map where values of the top map replace the values on the bottom map, or stack of maps. In other words, it is used to combine maps such that the categories of the top map overlay take precedence over the values on any map beneath it. This masking procedure is similar to overlaying several maps on a light-table, except numbers are substituted for opaque map colors.
	Neighbors: **Profile** *(surfaceMap layer required for profile calculation)*	**Profile** characterizes the cross-sectional profile along a continuous surface. The profile process is similar to slicing a loaf of bread, then holding up each slice. As you look at the side of a slice, its top crust forms a line, termed the surface's profile. The up and down pattern of the profile line is summarized by the Profile function. It creates a new map by assigning a value to each cell based on the inclination of a line through it and two diametrically opposed neighbor cells.

Spatial Statistics Operations *(Numeric Context)*

GIS as "Technological Tool" (*Where* is *What*) vs. "**Analytical Tool**" (*Why, So What* and *What if*)



GIS Perspective:

Surface Modeling *(Density Analysis, Spatial Interpolation, Map Generalization)*
Spatial Data Mining *(Descriptive, Predictive, Prescriptive)*

Map Analysis Toolbox

Statistical Perspective:

Basic Descriptive Statistics *(Min, Max, Median, Mean, StDev, etc.)*
Basic Classification *(Reclassify, Contouring, Normalization)*
Map Comparison *(Joint Coincidence, Statistical Tests)*
✓ ***Unique Map Statistics*** *(Roving Window and Regional Summaries)*
✓ ***Surface Modeling*** *(Density Analysis, Spatial Interpolation)*
Advanced Classification *(Map Similarity, Maximum Likelihood, Clustering)*
Predictive Statistics *(Map Correlation/Regression, Data Mining Engines)*

Alternative frameworks for quantitative map analysis involving Spatial Statistics of numerical context within and among map layers.

Spatial Statistics Operations — Statistical Perspective

…of Grid-based Map Analysis and Modeling Operations

…for BASIS ***MapCalc Software***

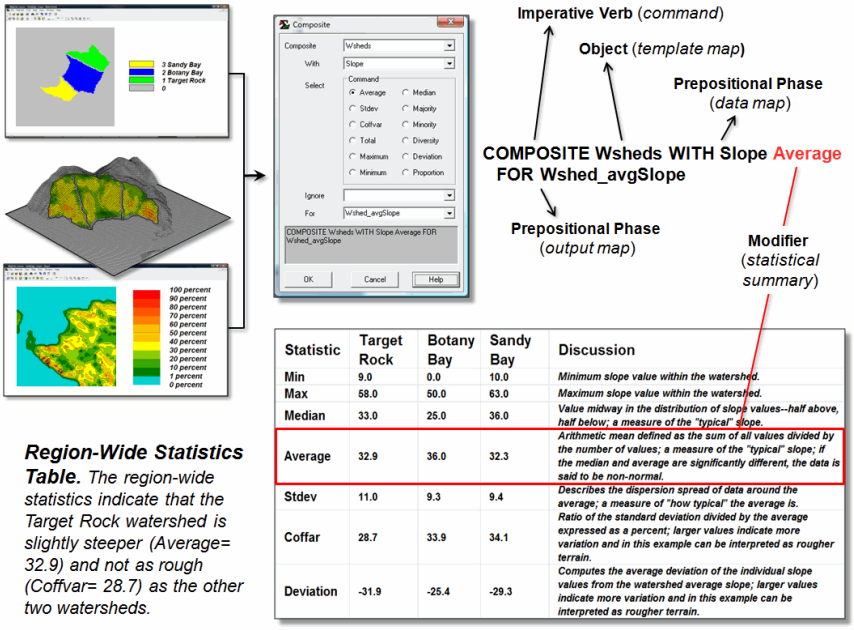
Statistical Concepts	MapCalc Operation	Comments
Basic Descriptive Statistics *(Min, Max, Median, Mean, StDev):*		
	Spatial Data Mining: **Shading Manager Table** *(single map layer)*	**SM Table** for each map layer contains Minimum, Maximum,Range, Mean, Median, StDev, Variance, Total Gridded Area, Histogram, Frequency Counts by classified intervals (Equal Ranges, Equal Count, +/- StDev and User Defined).
	Spatial Data Mining: **Analyze** *(two or more map layers)*	**Analyze** creates a map of the simple or weighted average, standard deviation, coefficient of variation and several other descriptive statistics for two or more maps. It is most frequently used to compute the arithmetic average of several maps.
Basic Classification *(Reclassify, Contour, Normalization):*		
	Reclassify: **Renumber** *(single map layer)*	**Renumber** assigns new values to the category values of an existing map. It is one of the most frequently used operations in MapCalc as it prepares maps for subsequent processing. Renumbering can be made to individual values, or to a range of existing values. The function is used to create new maps out of old maps with the same spatial distribution of categories but with different values.
	Reclassify: **Slice** *(single map layer)*	**Slice** divides the range of values on a map into a specified number of evenly spaced intervals (contours).
	Overlay: **Calculate** *(single map layer)*	**Calculate** is used to normalize a map layer using standard normalization equations such as percent of a specified Goal, specified value Range, or Standard Normal Variable— – *Norm_Goal* = (mapValue / Goal_value) * 100 – *Norm_Range* = ((mapValue – mapMin) * rangeMax) / (mapMax – mapMin) + rangeMin – *Norm_SNV* = ((mapValue - mean) / StDev) * 100 where mapValue is the map layer variable to be normalized and all other terms are constant values.

Map Comparison *(Joint Coincidence, Statistical Tests):*		
	Overlay: **Compare** *(two map layers)*	**Compare** creates a summary table of various comparison statistics between two maps.
	Overlay: **Crosstab** *(two map layers)*	**Crosstab** generates a spatial coincidence table of the relative occurrences of the categories of two maps, and the result is output to a text file.
Unique Map Statistics *(Roving Window and Regional Summaries):*		
	Neighbors: **Scan** *(single map layer)*	**Scan** is a localized summary operation that creates a map summarizing the values that occur within the vicinity of each cell. A user-defined Scan window is moved over the data map, and each map location is assigned a value summarizing the cell values within the window. Summary statistics include Average, StDev, Coffvar, Total, Maximum, Minimum, Median, Majority, Minority, Diversity, Deviation, and Proportion.
	Overlay: **Composite** *(two map layers)*	**Composite** creates a map summarizing values from a data map which coincide with the categories of a template map. Summary statistics include Average, StDev, Coffvar, Total, Maximum, Minimum, Median, Majority, Minority, Diversity, Deviation, and Proportion.
Surface Modeling *(Density Analysis, Spatial Interpolation):*		
	Surface Modeling: **Scan** *(single map layer)*	**Scan** is a localized summary operation that creates a map summarizing the values that occur within the vicinity of each cell. In creating a density map the “Total” number occurrences within a specified reach is assigned to each map location.
	Surface Modeling: **Interpolate** *(single map layer)*	**Interpolate** creates a continuous surface from point data by performing a nearest neighbor analysis to fill in missing values on a map. Interpolated values may be determined by weighted nearest-neighbor or discrete interpolation.
Advanced Classification *(Map Similarity, Maximum Likelihood, Clustering):*		
	Spatial Data Mining: **Cluster** *(two or more map layers)*	**Cluster** is used to identify areas with similar characteristics on a set of map layers. The procedure in effect spears a set of values through a stack of map layers, and then investigates the data pattern formed by values to determine other locations that are most similar. For example a location with values 100, 100, 100 for three map layers would be more similar to another location with values 98, 96, 97 than to a location with values 15, 12, 17.
	Spatial Data Mining: **Relate** *(two or more map layers)*	**Relate** is used to quantify the similarity of a map to an evaluation data pattern, or set of comparison values. A map of similarity is generated that contains values from zero (least similar data pattern) to 100 (identical data pattern).
Predictive Statistics *(Map Correlation/Regression, Data Mining Engines):*		
	Spatial Data Mining: **Correlate** *(two or more map layers)*	**Correlate** derives a correlation matrix from a stack of maps.
	Spatial Data Mining: **Regress** *(two or more map layers)*	**Regress** performs linear regression analysis by using the "least squares" method to fit a line through a set of data points in multiple maps. Each grid location identifies a series of values. You can analyze how a single map (the dependent variable) is affected by the values of one or more other maps (independent variables).

MapCalc has 27 analytical operations in 5 categories for performing map analysis and modeling. The above listings identify the analytical tools with traditional math/stat categories in quantitative analysis. The listing below identifies non-analytical support tools (highlighted in grey) involved with specialized applications, raster layer management, conversion, editing, selection, tabular summary or display (housekeeping).

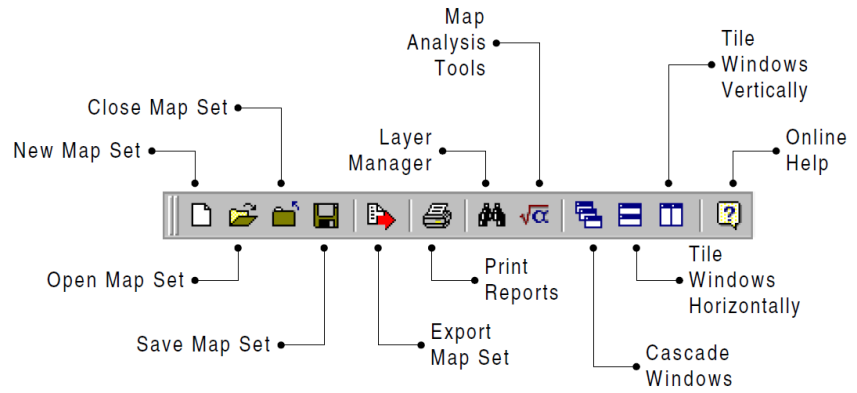
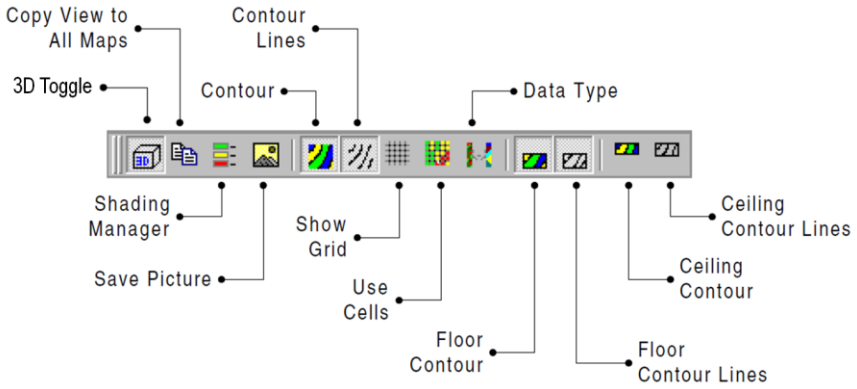
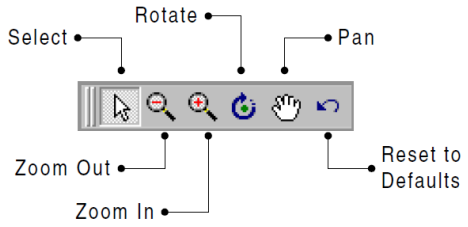
Posted at— http://www.innovativegis.com/basis/MapCalc/MapCalc_User_Guide.pdf

MapCalc Operations: (non-analytical tools highlighted in grey)

Category	Operation
Reclassify	Clump • Configure • Renumber • Size • Slice
Overlay	Calculate • Composite • Compute • Cover • Crosstab • Intersect
Distance	Drain • Radiate • Span • Spread • Stream
Neighbors	Interpolate • Orient • Profile • Scan • Slope
Statistics	Analyze • Cluster • Compare • Correlate • Regress • Relate
Graphical User Interface creating a grammatically correct sentence	
File Menu	New • Open • Close • Save • Save As… • Export Map Set • Send to MapInfo • Send to Surfer • Print • Last Opened Files • Exit
Map Set Menu	Manage Layers • Map Analysis • Create Graph • Add New Layers
Graph Menu	Properties • Reset View • Regression Line • Save Picture As… • Close Graph *Note: This menu is available when a graph (scatter plot or histogram) is open. You can access menu options marked below with an asterisk (*) by right-clicking on a map to activate a Shortcut menu.*

Region-Wide Statistics Table. *The region-wide statistics indicate that the Target Rock watershed is slightly steeper (Average= 32.9) and not as rough (Coffvar= 28.7) as the other two watersheds.*

Statistic	Target Rock	Botany Bay	Sandy Bay	Discussion
Min	9.0	0.0	10.0	*Minimum slope value within the watershed.*
Max	58.0	50.0	63.0	*Maximum slope value within the watershed.*
Median	33.0	25.0	36.0	*Value midway in the distribution of slope values--half above, half below; a measure of the "typical" slope.*
Average	32.9	36.0	32.3	*Arithmetic mean defined as the sum of all values divided by the number of values; a measure of the "typical" slope; if the median and average are significantly different, the data is said to be non-normal.*
Stdev	11.0	9.3	9.4	*Describes the dispersion spread of data around the average; a measure of "how typical" the average is.*
Coffar	28.7	33.9	34.1	*Ratio of the standard deviation divided by the average expressed as a percent; larger values indicate more variation and in this example can be interpreted as rougher terrain.*
Deviation	-31.9	-25.4	-29.3	*Computes the average deviation of the individual slope values from the watershed average slope; larger values indicate more variation and in this example can be interpreted as rougher terrain.*

Tools Menu	Select • Zoom In • Zoom Out • Rotate • Move
Map Menu	Layer • Floor & Ceiling • Legend • Overlay • 3D Toggle • Shading Manager • Reset View • Copy View • Print • Save Picture As... • Close Map
View Menu	Options • Toolbars • Data Inspection • Status Bar
Window Menu	Close • Close All • Arrangement Options • Selection List
Help Menu	About • Contents and Index • Register Software
Quick Access Toolbars (buttons)	 Main Toolbar  Map Toolbar  Tools Toolbar