GIS MODELING AND APPLICATION ISSUES
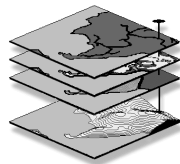
GeoTec Conference
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presentation by

Joseph K. Berry

"GIS Modeling is technical Oz. You're hit with a tornado of new concepts, then come back to yourself a short time later wondering what on earth all those crazy things meant"

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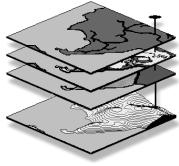
SITUATION *Most desktop mapping and GIS applications have focused on mapping and spatial data management responding to inventory assessments of "Where Is What" (geo-query of mapped data). GIS modeling provides new tools and processing structures for incorporating spatial relationships that address "Why and So What" in a decision-making context (map analysis and modeling). This extension of descriptive to prescriptive mapping involves entirely new spatial reasoning concepts and procedures that are not reflected in our paper map legacy.*

WORKSHOP DESCRIPTION *This intermediate level workshop presents basic concepts, procedures and applications of GIS modeling emphasizing natural resources and environmental management applications. The concepts presented are reinforced through several practical exercises. The first portion of the workshop establishes the concept of "maps as data" by introducing basic data structure issues impacting spatial analysis capabilities. The discussion focuses on individual operations, such as, map comparison, effective distance, optimal paths, visual exposure, roving windows and shape/pattern indices that are used in modeling spatial relationships. The next portion of the workshop discuses issues surrounding spatial interpolation of point data and spatial data mining techniques to discover relationships within and among maps. These concepts are presented within practical contexts for a basic understanding of the procedures and their utility. The final portion describes the concepts, procedures and considerations of a generalized GIS modeling framework required for sound application models, as well as providing a glimpse of trends and future directions in GIS technology.*

WHO SHOULD ATTEND *Managers and GIS specialists who are currently involved in the development of systems that use and analyze spatial data should attend. This is an intermediate-level workshop and prior GIS experience and familiarity with basic statistical concepts are recommended.*

WORKSHOP TOPICS

Topic #1, Spatial Analysis— *discusses data considerations and individual spatial analysis operations emphasizing grid-based techniques, such as shape/pattern indices, effective distance, optimal path connectivity, visual exposure, and roving windows. Maps as Data (Ex#1– Map Analysis Framework); Map-ematics (Ex#2– Example of a Simple GIS Model); Data Issues; Reclassifying and Overlaying Maps (Ex#3–R&O Techniques); Measuring Distance and Connectivity (Ex#4– Distance Techniques); Neighborhood Characterization (Ex#5– Neighborhood Techniques)*

Topics #2 and #3, Spatial Statistics (Surface Modeling & Spatial Data Mining)— *establishes the fundamental concepts and procedures used in spatial interpolation and analyzing relationships within and among mapped data. Surface Modeling (Ex#6a– Spatial Interpolation); Spatial Data Mining (Ex#6b– Investigating Spatial Relationships))*

Topic #4, GIS Modeling— *describes procedures involved in constructing sound application models and suggests future directions in GIS technology. Model Development and Execution (Ex#7– Suitability Modeling); Spatial Reasoning and Dialogue*

ABOUT THE INSTRUCTOR
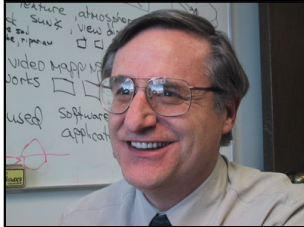
Dr. Joseph K. Berry is the Principal of Berry and Associates // Spatial Information Systems, consultants and software developers in Geographic Information Systems (GIS) technology since 1986. Also he serves as a Special Faculty member at Colorado State University and the Keck Scholar in Geosciences at the University of Denver. He is the author of the "Beyond Mapping" column for GeoWorld and has written over two hundred papers on the analytic capabilities of GIS. He is the author of the popular books Beyond Mapping and Spatial Reasoning and is involved in the development of the MapCalc software system for grid-based map analysis. He holds a B.S. degree in forestry, a M.S. degree in business management emphasizing operations research and finance, and a Ph.D. emphasizing remote sensing and land use planning.

SOFTWARE USED IN THE WORKSHOP

The workshop uses MapCalc and Surfer software systems for demonstrations and exercises. The **MapCalc** *software by Red Hen Systems has extensive capabilities in spatial analysis and modeling. The MapCalc Learner version with the workshop CD is constrained to a 100x100 grid configuration (10,000 grid cells) and some of Surfer's output features are constrained in the tutorial version. The* **Surfer** *system by Golden Software provides extended capabilities in surface modeling and 3-D graphics. The Surfer Demo version with the workshop CD constrains saving and printing of plots. Both software systems have data exchange tools and accept data for creating your own databases. More information at…*
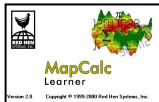
www.redhensystems.com/mapcalc/

www.goldensoftware.com

Workshop Notes

*Joseph K. Berry, email **jberry@innovativegis.com**, website **www.innovativegis.com/basis***

Map Analysis *hardcopy book and CD from GeoTec Media available from…*
    ***http://www.geoplace.com/ME2/Default.asp**, select "Bookstore"*

Beyond Mapping III *online book posted at…*
    ***www.innovativegis.com/basis**/, select "Beyond Mapping III"*

Example Applications *posted at…*
    ***www.innovativegis.com/basis**/, select "Example Applications"*

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Cartography– manual map drafting (paper map legacy for thousands of years)
Computer Mapping– automates the cartographic process (70s)
Spatial Database Management– links computer mapping techniques with traditional database capabilities (80s)
GIS Modeling and Analysis– representation of relationships within and among mapped data (90s)…

- ✔ *Surface Modeling*– maps the spatial distribution of a set of point sampled data,
- ✔ *Spatial Data Mining*– characterizes the "numerical" relationships among mapped data and develops predictive models,
- ✔ *Spatial Analysis*– derives new information based on "contextual" relationships among mapped data, and
- ✔ *GIS Modeling*– logical processing of spatial information to characterize a system or solve a problem.

*(See Beyond Mapping III online book, "**Topic 4**" and "**Topic 27**" for more information)*

Raster refers to image display (map values represent the color assigned to each dot; e.g., scanned topographic maps–DRGs or aerial photos–DOQs) while **Grid** refers to map analysis (map values have all of the rights, privileges and responsibilities of a map-*ematics*).

Grid data structure the *Analysis Frame* provides consistent "parceling" needed for map analysis and extends points, lines and areas to *Map Surfaces.*
*(See Example Applications, "**Short Video Demos**" for more information)*

Surface Contouring options include *# of Ranges*, *Calculation Method* (e.g., Equal Ranges with same range for each interval and Equal Count with same number of cells for each interval) and *Color Pallet/Ramp* selection.

Grid Display Types are *Lattice* that forms a smooth "wireframe" by connecting cell centroids with lines whose lengths are a function of elevation differences and *Grid* that forms extruded grids whose heights are a function of elevation differences.
*(See Example Applications, "**Display Types**" for more information)*

Grid Data Types are characterized by their *Numeric Distribution* (independent integers versus range of values) and their *Geographic Distribution* (abrupt boundaries versus gradient). A *Discrete* map has values that simply represent categories (e.g., a Cover type map) that form sharp abrupt boundaries) whereas a *Continuous* map has values that represent a spatial gradient (e.g., a slope map).
*(See Example Applications, "**Data Types**" for more information)*

Spatial Analysis investigates the "contextual" relationships in mapped data…
- **Reclassifying Maps**– New map values are a function of the values on a single existing map… no new spatial information is created
- **Overlaying Maps**– New map values are a function of the values on two or more existing maps… new spatial information is created
- **Measuring Distance**– New map values are a function of the simple or weighted distance or connectivity among map features
- **Summarizing Neighbors**– New map values are a function of the values within the vicinity of a location on an existing map.

(See Beyond Mapping III online book, "Topic 24" for more information)

Reclassifying and Overlaying Maps– reclassifying operations involve the reassignment of the values of an existing map as a function of its initial value, position, size, shape or contiguity of the spatial configuration associated with each map category; overlay operations involve the creation of a new map where the value assigned to every location is computed as a function of the independent values associated with that location on two or more maps (point-by-point, region-wide and map-wide)
(See Beyond Mapping III online book, "Topic 22" for more information)

Measuring Distance and Connectivity– the concept of *Distance* as the "shortest straight line between two points" is expanded to *Proximity* by relaxing the assumption of only "two points" then expanded to *Movement* by relaxing the assumption of "straight-line" connectivity.
(See Beyond Mapping III online book, "Topic 13," "Topic 14" and "Topic 25" for more information)
(See Example Applications, "Determining Proximity" and "Creating an Up-Hill Road Buffer")

Calculating Visual Exposure– a *Viewshed* identifies all locations that can be seen from a view point(s) while *Visual Exposure* develops a relative scale indicating the number of times each location is seen from a set of viewer points (e.g., a road network).
(See Beyond Mapping III online book, "Topic 15" for more information)
(See Example Applications, "Determining Visual Exposure" and "Modeling Visual Exposure)

Summarizing Neighbors– a *Diversity Map* indicates how many different types, a *Roughness Map* identifies the variation in slope values, and a *Density Map* reports the total value within a specified distance of each grid location.
(See Beyond Mapping III online book, "Topic 11"and "Topic 26" for more information)
(See Example Applications, "Assessing Covertype Diversity")

Surface Modeling maps the spatial distribution and pattern of point data…
- ✓ **Map Generalization**– characterizes spatial trends (e.g., titled plane) by considering all of the samples at once as it fits a surface,
- ✓ **Spatial Interpolation**– derives spatial distributions (e.g., IDW, Krig) by considering small, localized set of samples throughout the map area (roving window), and
- ✓ **Other**– roving window and facets (e.g., density surface; tessellation)
(See Beyond Mapping III online book, "Topic 2", "Topic 3" and "Topic 8" for more information)

Spatial Data Mining investigates the "numerical" relationships in mapped data…
- ✓ **Descriptive**– calculates aggregate statistics (e.g., average/stdev, similarity, clustering) that summarize mapped data,

✔ **Predictive**– develops relationships among maps (e.g., regression) that can be used to forecast characteristics or conditions at other locations or times, and

✔ **Prescriptive**– uses descriptive and predictive information to optimize appropriate actions.

*(See <u>Beyond Mapping III</u> online book, "**Topic 7**", "**Topic 10**" and "**Topic 16**" for more information)*

GIS Models come in three basic types…

✔ **Suitability Models**– based on logically sequenced decision criteria similar to a recipe (e.g, animal, shopper and pipeline "habitat")…

- o **Binary Model**– identifies areas that are acceptable based on combining binary maps (0 and 1),
- o **Ranking Model**– develops a ranking of areas based on the number of criteria that are acceptable (0 to 3), and
- o **Rating Model**– develops a "goodness" scale (0 to 9 best) and calculates the average rating for each grid cell.

✔ **Statistical Models**– based on numerical relationships (e.g., crop yield), and

✔ **Process Models**– based on physical (e.g., erosion potential)

*(See <u>Beyond Mapping III</u> online book, "**Topic 17**", "**Topic 19**", "**Topic 20**" and "**Topic 23**" for more information)*

Capturing and Communicating Model Logic– a flowchart is used where boxes

represent maps and lines represent analytical operations to identify the processing steps linking command scripts to mapped data.

*(See <u>Beyond Mapping III</u> online book, "**Topic 21**" for more information)*

Data Conversion investigates vector to/from raster data exchange…

✔ **V to R**– burning the points, lines and areas into the grid (fat, thin and split),

✔ **R to V**– connecting grid centroids, sides and edges (line smoothing), and

✔ **Pseudo Grid**– each grid cell is stored as a polygon

*(See <u>Beyond Mapping III</u> online book, "**Topic 18**" for more information)*
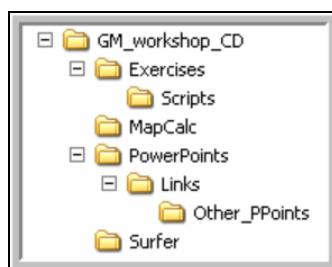
Lecture Notes

Part 1 – Introduction and Data Considerations

Part 2 – Concepts and Techniques in Spatial Analysis

**Part 3 – Uncovering Spatial Relationships through
Surface Modeling and Spatial Data Mining**

Part 4 – Developing Spatial Reasoning Skills and GIS Models

PowerPoint side sets are included on the companion Workshop CD in the **\PowerPoints** folder

Exercises

Exercise #1 – Map Analysis Framework

Exercise #2 – Example of a Simple GIS Model
Erosion Potential Model

Exercise #3 – Reclassify and Overlay Techniques
Habitat Suitability Model

Exercise #4 – Measuring Distance and Connectivity

Exercise #5 – Characterizing Spatial Neighborhoods
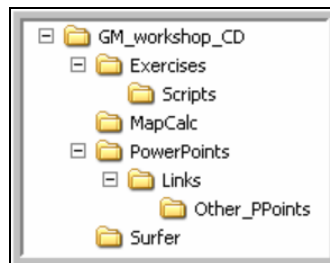
Exercise #6 – Spatial Interpolation Techniques

Exercise #7 – Gaining GIS Modeling Experience
Campground Suitability Model
Electrical Transmission Line Routing Model

Exercise #8 – Data Exchange Procedures

Software, Databases and Word file containing the exercises
are included on the Workshop CD in the **\Exercises** folder

Further Reading

See the **Workshop CD** for background readings, hands-on exercises and other supplemental materials including copies of the PowerPoint slide sets used in the lecture section. The references in the lecture slides refer to online materials including:

- Beyond Mapping III at http://www.innovativegis.com/basis/MapAnalysis/Default.html
- Example Applications at http://www.innovativegis.com/basis/Senarios/Default.html

…and direct links to other online materials. The references are automatically linked when viewing the PowerPoint lecture slides from the special workshop CD.
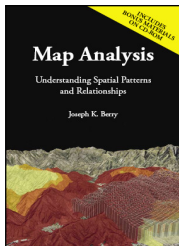
Map Analysis: *Understanding Spatial Patterns and Relationships*
by Joseph K. Berry (1993, GeoTec Media)

Map Analysis is organized into 10 topics leading the reader from an understanding of the fundamental nature of mapped data through a series of procedures used in deriving, analyzing and applying spatial information. Includes CD-ROM with software for hands-on experience. $45.00

Beyond Mapping: *Concepts, Algorithms and Issues in GIS*
by Joseph K. Berry (1993, John Wiley Publishers, www.wiley.com)

Beyond Mapping explores the basic concepts of map analysis and discusses emerging issues as GIS moves from the realm of research to widespread applications. The book is structured so the reader first can examine the broad issues and then delve into more detail. $60.00
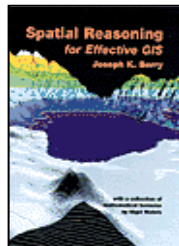
Spatial Reasoning for Effective GIS
by Joseph K. Berry (1995, John Wiley Publishers, www.wiley.com)

Spatial Reasoning explores the basic concepts of map analysis and discusses emerging issues as GIS moves from the realm of research to widespread applications. It is an incisive book describing the expansion of geographic technology from maps that simply tell us "Where is what" to systems that help us decide "So what?" $60.00

*These books, based on Joe Berry's popular "Beyond Mapping" columns in GeoWorld magazine, discuss the new breed of map analysis tools and how they can be used to better characterize and communicate spatial relationships. Both books can be purchased online from **www.wiley.com** and www.amazon.com.*

*…all of the books are supported by **MapCalc Learner software** (US$ 21.95) for hands-on experience with the concepts and procedures used in grid-based GIS Modeling…*

www.redhensystems.com/mapcalc, *select "MapCalc" software*

Workshop CD

The **GIS Modeling and Application Issues Workshop CD** contains four folders…

\PowerPoints folder— contains the PowerPoint slide sets used in the workshop.

- **GM_Part1.ppt** – click on this link and select **Open** to view directly or **Save** to transfer to your computer.
- **GM_Part2.ppt** – click on this link and select **Open** to view directly or **Save** to transfer to your computer.
- **GM_Part3.ppt** – click on this link and select **Open** to view directly or **Save** to transfer to your computer.
- **GM_Part4.ppt** – click on this link and select **Open** to view directly or **Save** to transfer to your computer.
- **\Links** – this sub-folder contains the additional PowerPoint slide sets. If you copy the PowerPoints to your hard drive for better performance, this folder must be **manually copied** into the <u>same folder with the workshop PowerPoints</u> to retain the relative links embedded in the slide sets.

\MapCalc folder— contains the MapCalc Learner evaluation software and tutorials…

- **Mapcalc_learner.exe** – click on this link and select Open. Follow the onscreen installation instructions. It is recommended that you accept the default specifications as the exercise write-ups assume this installation location.
- **\MapCalc_Tutorials\MapCalc_tutorials.pdf** – click on this link to access the MapCalc Tutorials. You must have Adobe Reader installed to view.
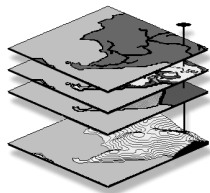
\Surfer folder— contains the Surfer Demo software and tutorials…

- **s8demo.exe** – click on this link and select Open. Follow the onscreen installation instructions. It is recommended that you accept the default specifications as the exercise write-ups assume this installation location.
- **\Surfer_Tutorial\Surfer_tutorial.pdf** – click on this link to access the Surfer Tutorials. You must have Adobe Reader installed to view.

    *To access Surfer, press **Start→ Programs→ Golden Software→ Surfer 8 Demo** (click on the banner screen to dismiss) and follow the instructions in the exercises.*

\Exercises folder— contains the set of demonstration exercises (for MapCalc and Surfer) used in the workshop.

- **GM_Exercises.doc** – click on this link to access a Word version of the workshop exercises.
- *Note:* the MapCalc scripts for the exercises are in the **\Exercises\Scripts** folder. Once you have installed MapCalc Learner, copy the contents of this folder to the folder containing the MapCalc Data…
    C:\Program Files\Red Hen Farming\MapCalc\MapCalc Data\Scripts folder (default location)