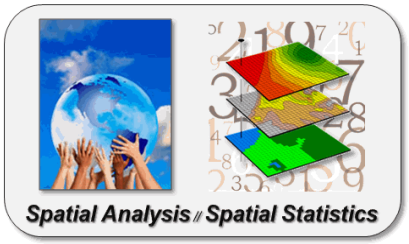
*Spatial*STEM:

A Mathematical/Statistical Framework for Understanding and Communicating Map Analysis and Modeling



Part 4) **Future Directions**. Most GIS technology has deep roots in manual mapping and geo-query procedures involving discrete spatial objects— **continuous mapped data promises a future that moves well beyond mapping**. The current cycle of innovation is focused on *hexagonal/dodecahedral* grid representation and implementation of a latitude/longitude-based *universal spatial database key* which are poised to change how we conceptualize, visualize, process and analyze spatial data.

This PowerPoint with notes and online links to further reading is posted at

www.innovativegis.com/basis/Workshops/NGA2015/

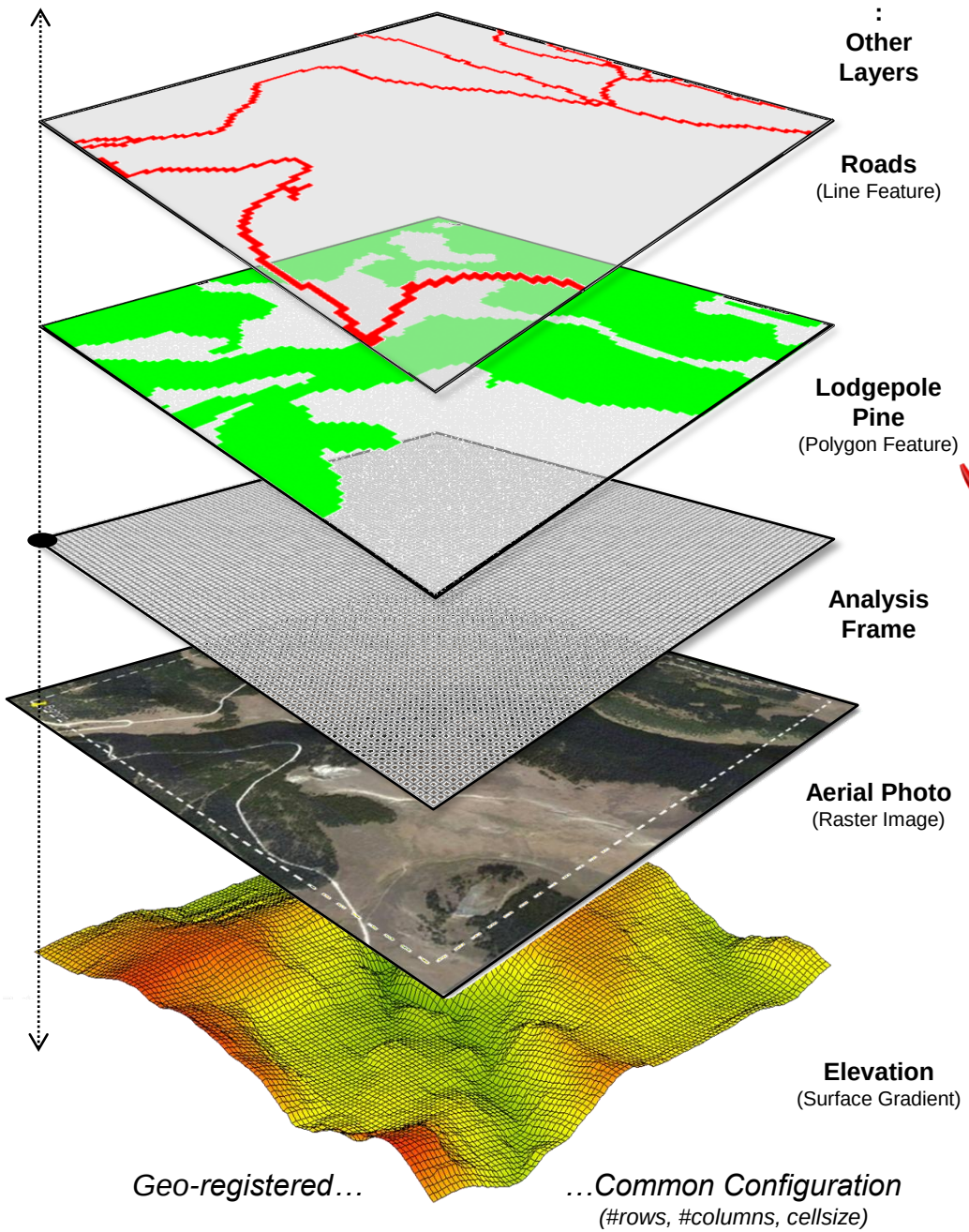
Presented by

Joseph K. Berry

Adjunct Faculty in Geosciences, Department of Geography, University of Denver
Adjunct Faculty in Natural Resources, Warner College of Natural Resources, Colorado State University
Principal, Berry & Associates // Spatial Information Systems

Email: jberry@innovativegis.com — Website: www.innovativegis.com/basis

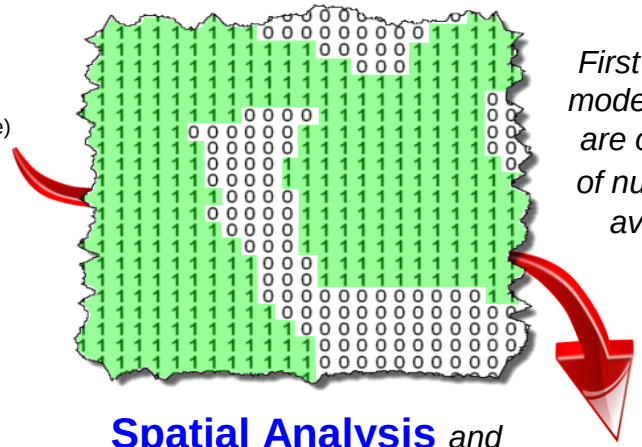
Grid-based Data Organization *(for Contextual and Numerical analysis of mapped data)*



Map Stack of Grid Map Layers

A **Grid Map Layer** *consists of a matrix of numbers with a value indicating the characteristic or condition at each grid cell location– forming a geo-registered/configured* **Map Stack**.

Matrix of Numbers



*First and foremost, modern digital maps are organized sets of numbers (***data***) available for…*

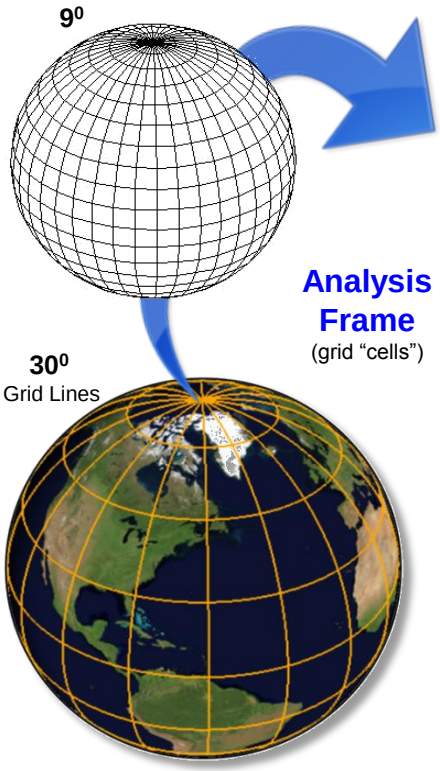
Spatial Analysis *and* **Spatial Statistics**
using "map-ematical" operations to ***quantitatively analyze*** *mapped data for a better understand of geographic patterns and relationships.*

*…pictures later (***graphics***)*

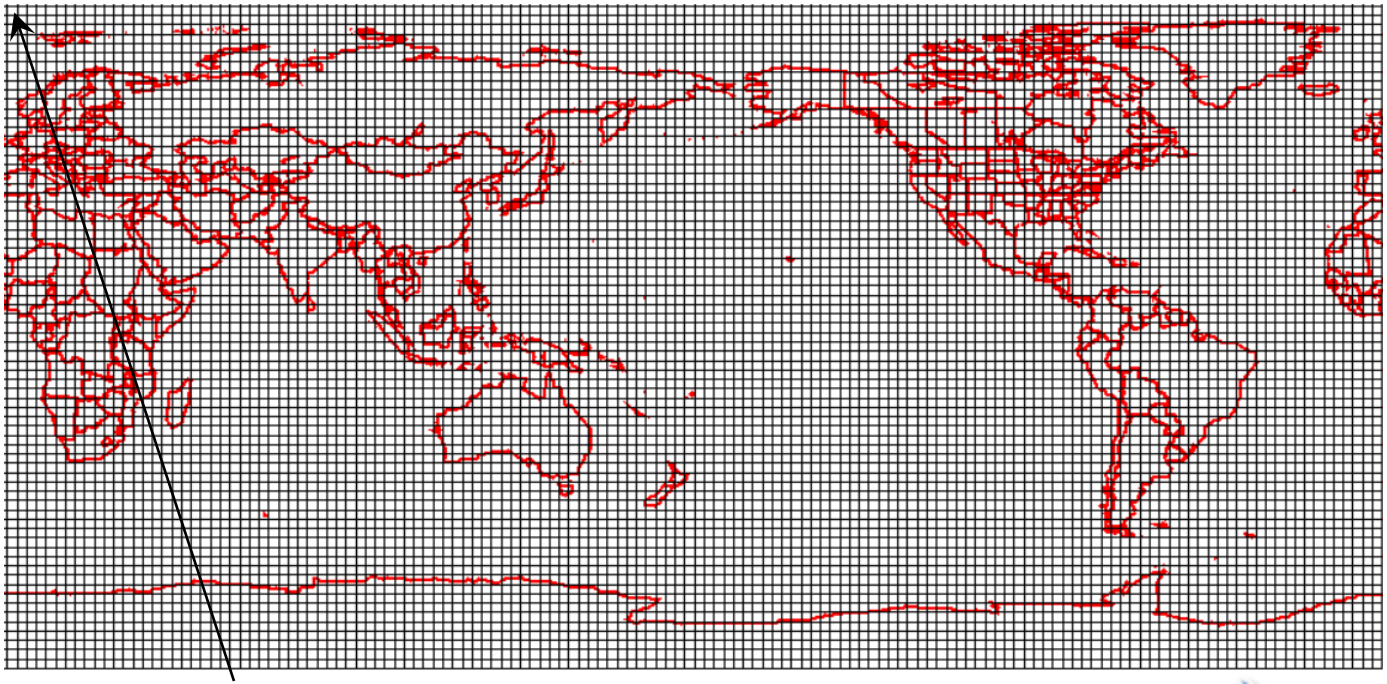
Pine Layer draped over 3D Elevation Surface

(Berry)

Grid-based Map Data Structure *(geo-registered matrix of map values)*



2.5⁰ Latitude/Longitude Grid (140mi grid cell size)



Coordinate of first grid cell is 90⁰ N 0⁰ E

#Rows= 73 #Columns= 144 = 10,512 grid cells

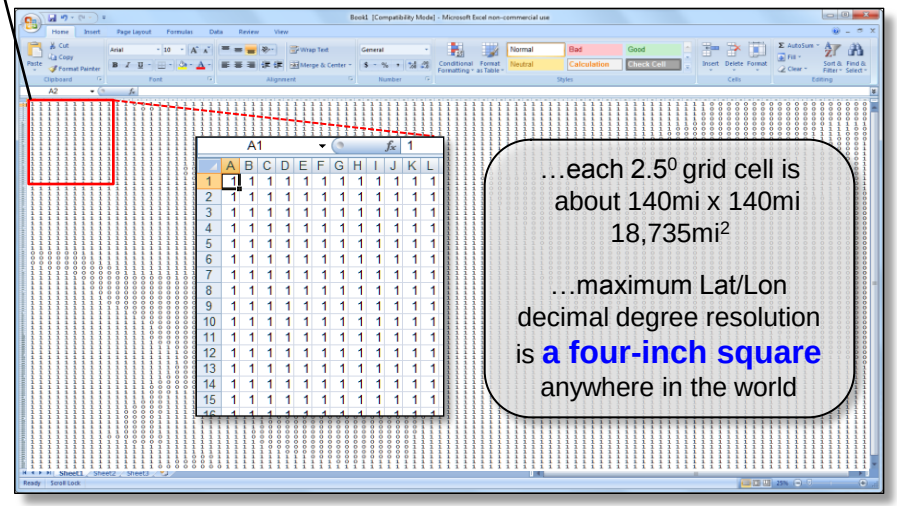
↳ The **Latitude/Longitude** grid forms a continuous surface for geographic referencing where each **grid cell** represents a given portion of the earth' surface.

The easiest way to conceptualize a grid map is as an Excel spreadsheet with each **cell** in the table corresponding to a Lat/Lon grid space (*location*) and each **value** in a cell representing the characteristic or condition (*information*) of a mapped variable occurring at that location. →

…the bottom line is that…

*All **spatial topology** is inherent in the grid.*

Conceptual Spreadsheet (73 x 144)



Lat/Lon

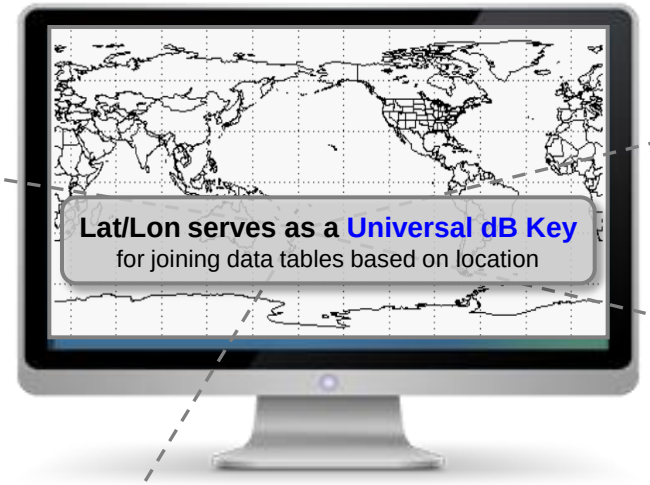
…from Lat/Lon

"crosshairs to grid cells"

that contain map **values** indicating characteristics or conditions at each grid location

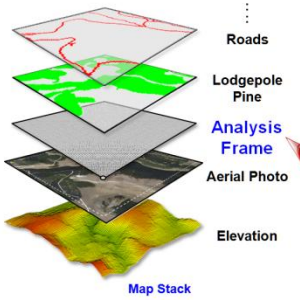
(Berry)

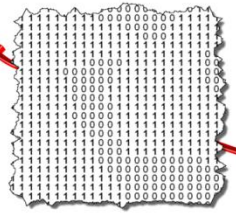
Universal Database Key *(moving Lat/Lon from crosshairs to grid cells)*



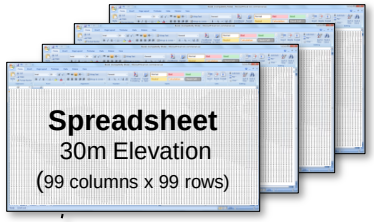
Spatially Keyed
data in the cloud

…**Spatially Keyed** data in the cloud are downloaded and configured to the **Analysis Frame** defining the **Map Stack**





Conceptual Organization



Wyoming's Bighorn Mts.

RDBMS Organization

2D Matrix→ 1D Field

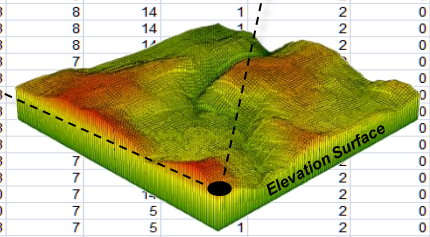
Keystone Concept

"Where"

Geographic Space | **Grid Space** | **Database Table**

Lat	Lon	Col	Row	Elevation	Slope	Veg_type	Bedrock	Covertype	Rock_type	Surf_geology	Locations	CostDist_prox	Euclidean_p
0.000134989	0.000134989	1	1	2492	6.42575	13	8	14	1	2	0	500	53.1
0.000134989	0.000404968	1	2	2490	10.065	13	8	14	1	2	0	500	52.1
0.000134989	0.000674946	1	3	2489	8.74816	13	8	14	1	2	0	500	51.1
0.000134989	0.000944924	1	4	2487	8.57436	13	8	14	1	2	0	500	50.1
0.000134989	0.001214903	1	5	2487	6.94267	13	7	14	1	2	0	500	49.1
0.000134989	0.001484881	1	6	2484	8.24707	13	7	14	1	2	0	500	48.1
0.000134989	0.001754860	1	7	2481	8.83946	13	7	14	1	2	0	500	47.1
0.000134989	0.002024838	1	8	2479	7.89355	13	7	14	1	2	0	500	46.1
0.000134989	0.002294817	1	9	2472	10.7096	13	7	14	1	2	0	500	45.1
0.000134989	0.002564795	1	10	2467	9.73483	13	7	14	1	2	0	500	44.1
0.000134989	0.002834773	1	11	2459	11.6533	13	7	14	1	2	0	500	43.1
0.000134989	0.003104752	1	12	2453	11.451	13	7	14	1	2	0	500	42.1
0.000134989	0.003374730	1	13	2442	13.4447	0	7	14	1	2	0	500	41.1
0.000134989	0.003644708	1	14	2437	9.6861	0	7	5	1	2	0	49.2843	40.1
0.000134989	0.003914687	1	15	2428	11.1091	3	7	5	1	2	0	500	39.1
0.000134989	0.004184665	1	16	2421	9.01929	3	7	7	1	2	0	500	38.1
0.000134989	0.004454644	1	17	2415	8.63434	3	7	7	1	2	0	42.6274	37.1
0.000134989	0.004724622	1	18	2407	8.06603	3	7	7	1	2	0	500	36.1
0.000134989	0.004994600	1	19	2406	3.06676	3	7	7	1	2	0	500	35.1
0.000134989	0.005264579	1	20	2403	3.048	3	7	7	1	2	0	500	34.1
0.000134989	0.005534557	1	21	2400	2.42448	3	7	7	1	2	0	500	33.1
0.000134989	0.005804536	1	22	2404	4.58453	16	7	14	1	1	0	33.799	32.1
0.000134989	0.006074514	1	23	2409	3.80529	16	7	14	1	1	0	32.799	31.1
0.000134989	0.006344492	1	24	2415	6.10775	16	7	14	1	1	0	31.799	30.1
0.000134989	0.006614471	1	25	2422	10.3792	16	7	14	1	1	0	33.799	30.2
0.000134989	0.006884449	1	26	2430	9.36706	16	7	14	1	1	0	32.799	29.8
0.000134989	0.007154428	1	27	2432	4.84897	16	7	14	1	1	0	31.799	29.4
0.000134989	0.007424406	1	28	2432	4.064	16	7	14	1	1	0	30.799	29.0
0.000134989	0.007694384	1	29	2432	4.064	16	7	14	1	1	0	29.799	28.6
0.000134989	0.007964363	1	30	2432	4.43188	16	7	14	1	1	0	28.799	28.2

Lat/Lon as a **Universal Spatial Key**



Data Space

Each column (**field**) represents a single map layer with the values in the rows indicating the characteristic or condition at each grid cell location (**record**)

"What"

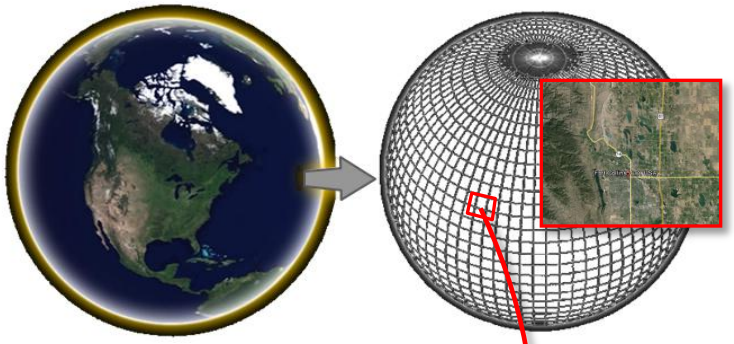
Each of the conceptual grid map spreadsheets (matrices) can be converted to **interlaced RDBMS format** with a long string of numbers forming the **data field** (map layer) and the **records** (values) identifying the information at each of the individual grid cell locations.

Once a set of mapped data is stamped with its Lat/Lon "**Spatial Key**," it can be **linked to any other database table with spatially tagged records** without the explicit storage of a fully expanded grid layer— all of the spatial relationships are implicit in the relative Lat/Lon positioning.

(Berry)

5-step Process for **Unlocking the Universal Spatial Db Key**

Spatially Aware Database
(XY, Value)

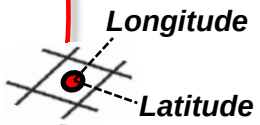


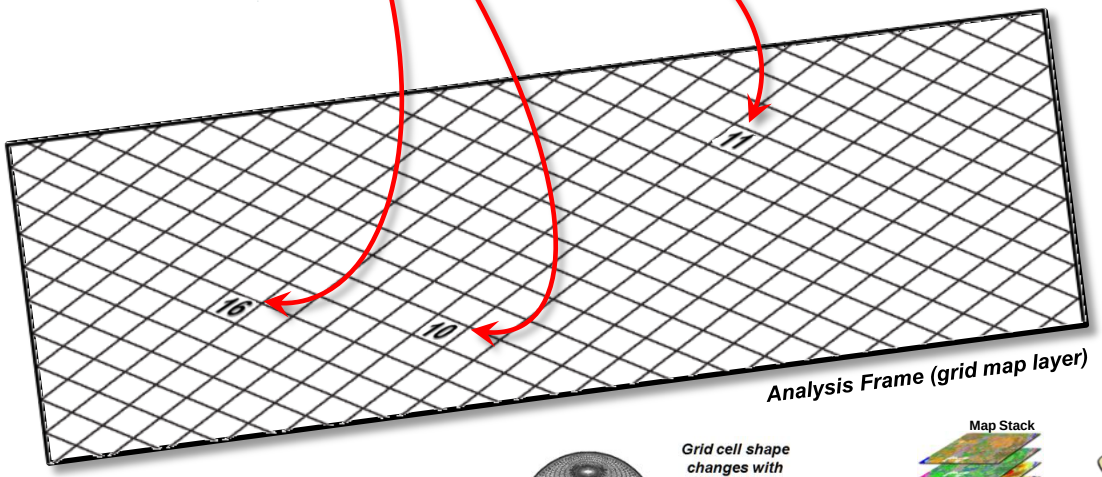
What (Value)

…value indicates characteristic or condition at a location

Where (XY)

…Lat/Lon coordinates identify earth position of a dB record

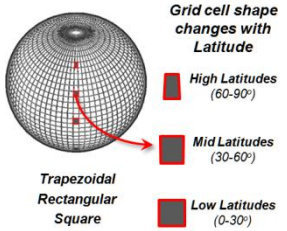


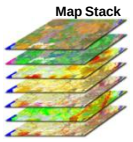


*…**but** Lat/Lon grid cells are only square at the equator—*

so is the entire idea a bust?

Hint: spatial resolution of the analysis frame is key





Shish Kebab of numbers

Step 1. ***User identifies the geographic extent of the analysis window.***

Step 2. ***User specifies the cell size of the analysis window.*** *…e.g., 100m*

Step 3. ***Computer determines the Lat/Lon ranges defining each grid cell (cutoffs) and the centroid location.*** *…defines the Analysis Frame*

Step 4. ***Computer determines the appropriate grid cell for each database record that falls within the analysis frame's geographic extent based on its Lat/Lon coordinates… then repeats for all selected dB records.***

Step 5. ***Computer summarizes the values if more than one value "falls" into an individual grid cell-- result is a "Grid Map Layer" for inclusion in a map stack for subsequent map analysis.***

(Berry)

GIS Development Cycle *(…where we're heading)*

GIS Evolution

Revisit Analytics
(2020s)

Future Directions

GeoWeb
(2000s)

Revisit Geo-reference
(2010s)

Contemporary GIS

Spatial dB Mgt (1980s)

Map Analysis (1990s)

The Early Years

Computer Mapping
(1970s)

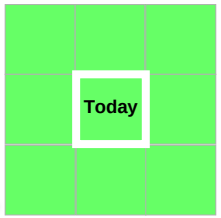
…about every decade

- Mapping focus
- Data/Structure focus
- Analysis focus

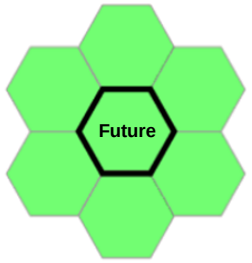
Future Directions

2D Planar
(X,Y Data)

Cartesian Coordinates

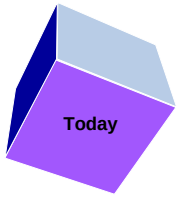


Square
(4 sides)

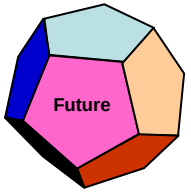


Hexagon
(6 sides)

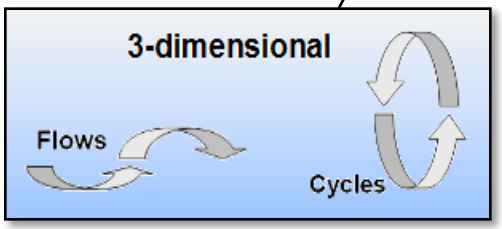
3D Solid
(X,Y,Z Data)



Cube
(6 squares)

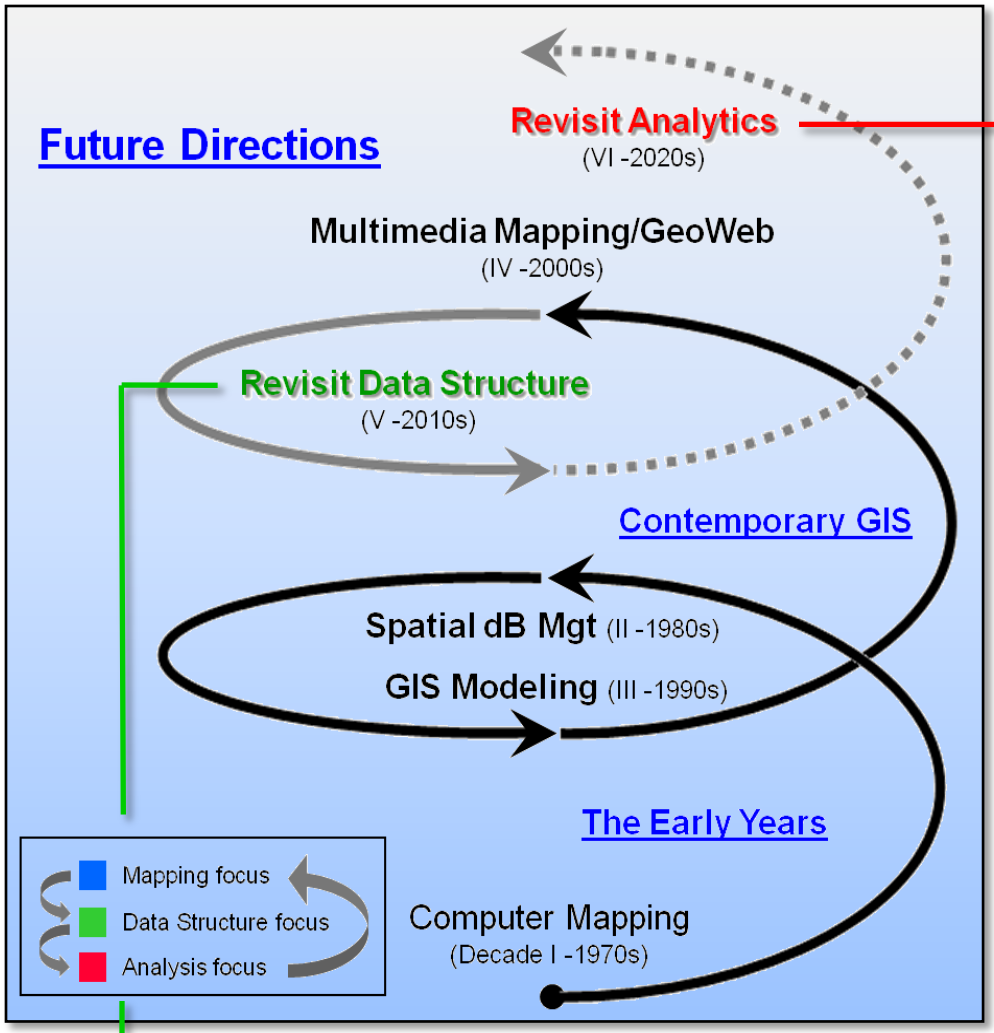


Pentagonal Dodecahedral
(12 pentagons)



(Berry)

Overview of Map Analysis Approaches



Map Analysis and Modeling

Spatial Analysis —

1) **recoding** of all operations to take advantage of increased precision/accuracy in the new geo-referencing and data structures;

2) incorporate **dynamic influences** on effective movement/connectivity (e.g., direction, accumulation, momentum); and

3) **uncertainty and error propagation** handing for all analytical processing.

…emphasis on **Data Accuracy** (correct WHAT characterization)
vs.
Precision (proper WHERE placement)

Spatial Statistics —

1) **uncertainty and error propagation** handing for all analytical processing;

2) **localized expression** of most statistical metrics will be employed; and

3) **CART, Induction and Neural Networks** techniques requiring large N will replace traditional multivariate data analysis

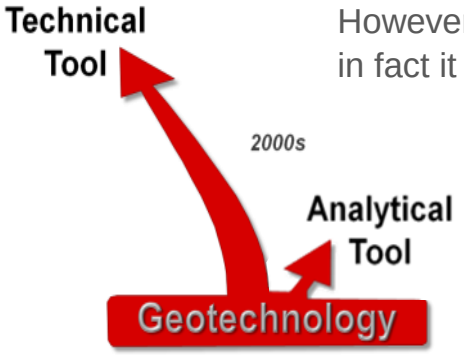
Data Structure

Advances in **Data Storage** (*Universal Database Key*) and **Geo-referencing** (*solid Dodecahedral cells*) will revise existing analytical operations and spawn new ones that will radically change our paradigm of what maps are and how they are utilized– *moving well beyond traditional mapping and geo-query*.

(Berry)

Evolving Geospatial Understanding *(extending mindsets from Technological to Analytical)*

The lion's share of the growth has been GIS's ever expanding capabilities as a ***"technical tool"*** **for corralling vast amounts of spatial data** and providing near instantaneous access to remote sensing images, GPS navigation, interactive maps, asset management records, geo-queries and awesome displays.



However, GIS as an ***"analytical tool"*** **hasn't experienced the same meteoric rise**— in fact it can be argued that the analytic side of GIS has somewhat stalled… partly **because** of…

…but recognition that modern digital
"***maps are numbers first, pictures later***"
and we do mathematical and statistical things to map variables that moves Geospatial Technology from–

"**Where** *is* **What**"
graphical inventories, to a

"**Why, So What** *and* **What If**"
problem solving environment—

"**thinking analytically with maps**"

within a
SpatialSTEM Framework

…increasingly thought of as a ***"market-driven"*** ***Technological Tool***

The Enlarging GIS Community *(evolution)*

Systems — *Applications*

General Programmers | GIS Developers | System Managers | Data Providers | GIS Specialists | General Users | Public Users

…a deep keel of knowledge in Science, Technology, Engineering and Math/Stat

1970s – a few hundred innovators establishing the foundation of geospatial technology

Automated Cartography
Machine Processing of Remotely Sensed Data

1980s – several thousand pacesetters applying the technology to a small set of disciplines (RS, GIS)

1990s – hundreds of thousands GIS specialists and general users (RS, GIS, GPS)

2000s – millions of general and public users (RS, GIS, GPS, GeoWeb)

2010s – billions of general and public users (RS, GIS, GPS, GW, Devices) …minimal STEM knowledge

(Berry)

Where are we headed?

The STEM community will revolutionize how we ***conceptualize, utilize and visualize*** *spatial relationships…*

…but will Geospatial Technology ***lead or follow****?*

1) *Solutions to complex spatial problems need to* **engage "domain expertise"** *through map analysis/modeling – outreach to other disciplines to establish* **spatial reasoning skills** *needed for effective solutions that integrate a* **multitude of disciplinary and general public perspectives**..

2) *Grid-based map analysis and modeling involving* **Spatial Analysis** *and* **Spatial Statistics** *are in large part simply* **spatial extensions of traditional mathematical and statistical** *concepts and procedures.*

3) *The recognition by the* ***Geospatial community*** *that* **quantitative analysis of maps is a reality** *and the recognition by the* ***STEM community*** *that* **spatial relationships exist and are quantifiable** *should be the glue that binds the two perspectives – through a common coherent and comprehensive SpatialSTEM approach.*

The Bottom Line

"…**map analysis → quantitative analysis of mapped data**"

— not your grandfather's map …nor his math/stat

THANK YOU ***for your kind attention – any final thoughts or questions?***

(Berry)