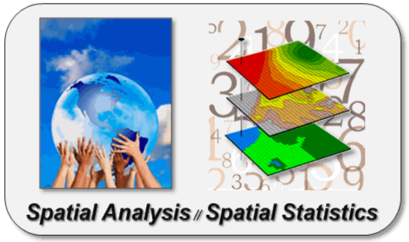
*Spatial*STEM:

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/Courses/SpatialSTEM/Workshop/

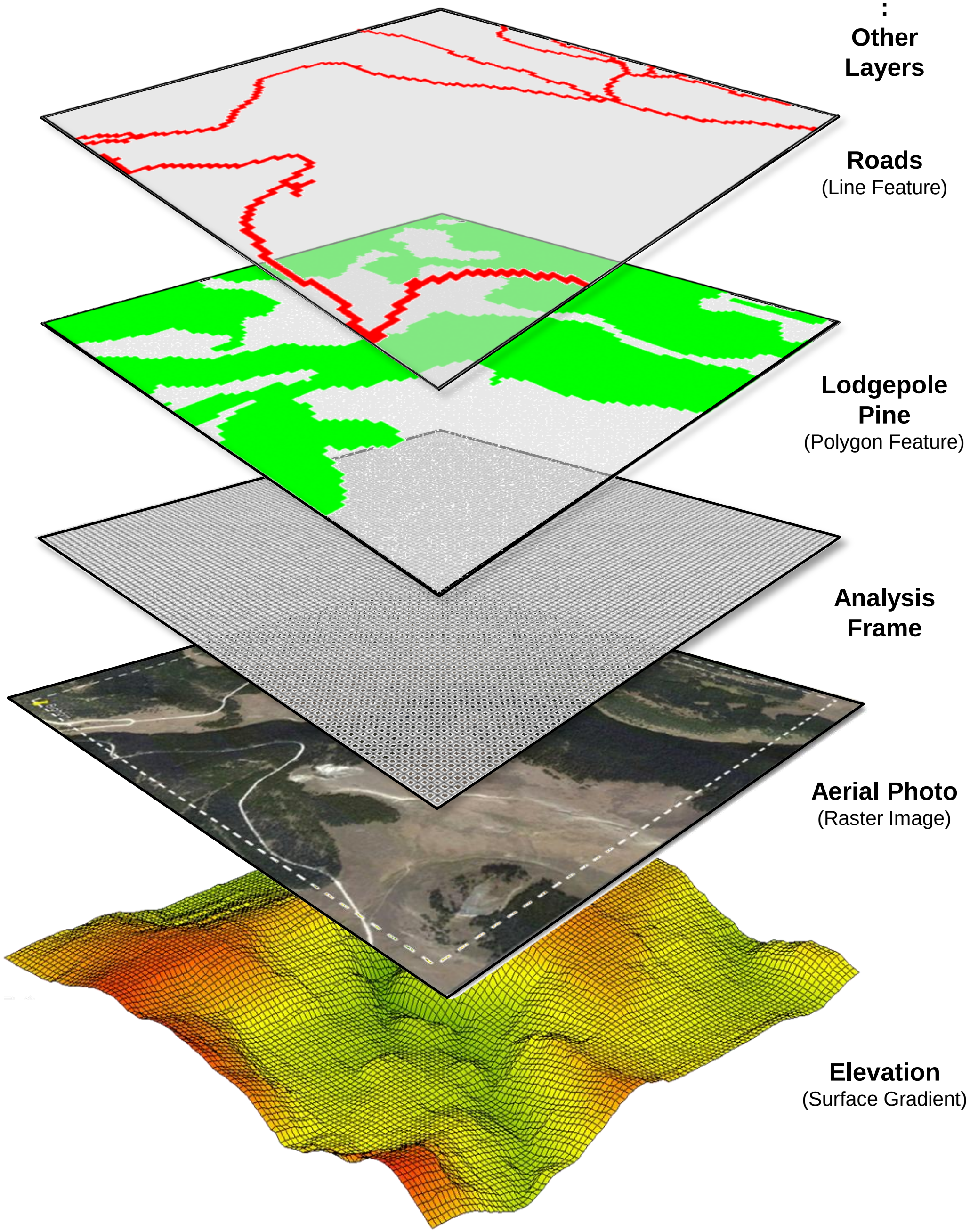
Presented by

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

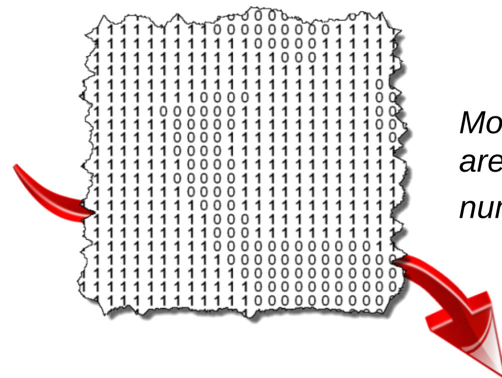
Email: jberry@innovativegis.com — Website: www.innovativegis.com/basis

Grid-based Data Organization *(Numerical Context)*



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* **Map Stack**.



Modern digital maps are organized sets of numbers first **(data)***…*

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

…pictures later **(graphics)**.

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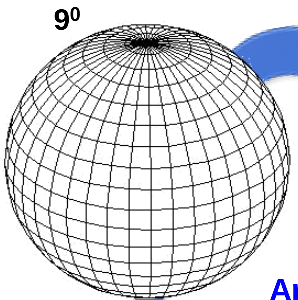
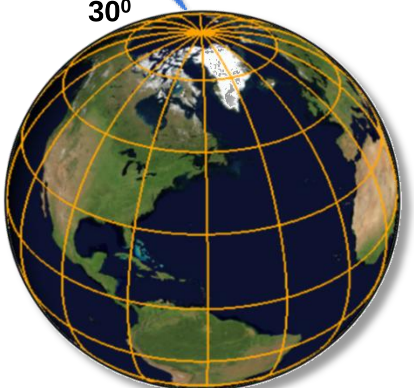
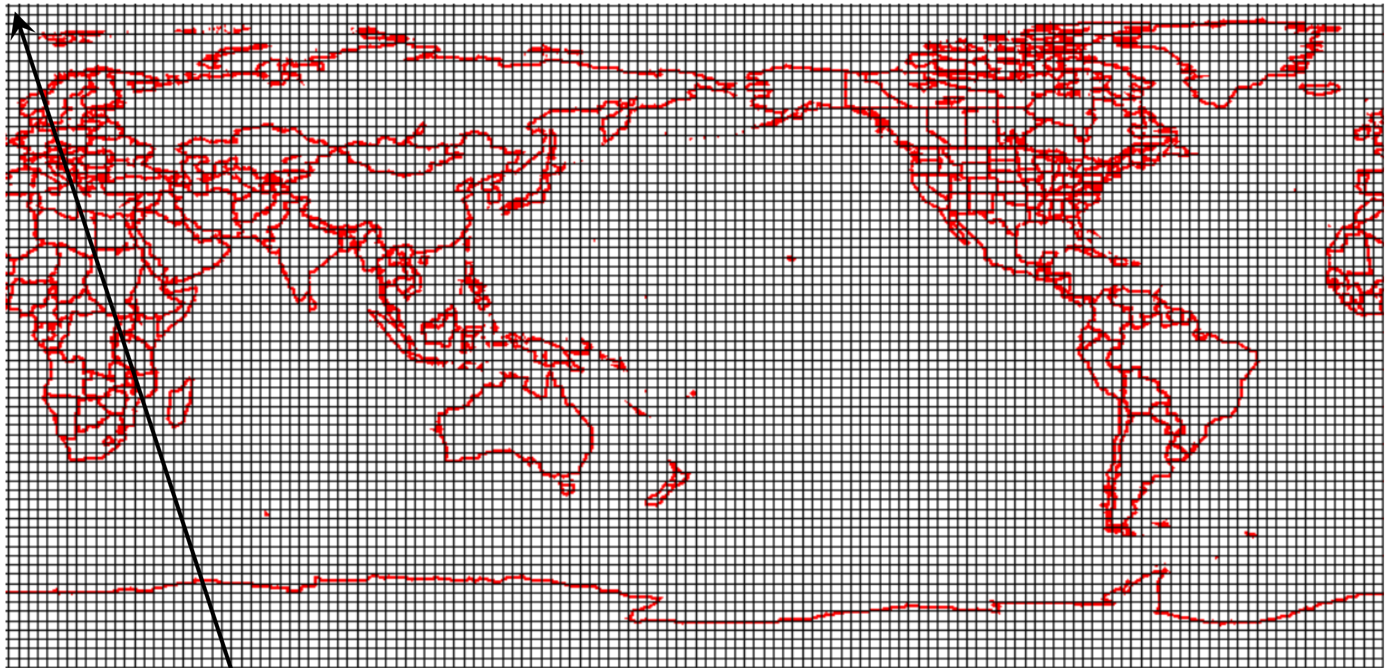
Grid-based Map Data *(geo-registered matrix of map values)*



Analysis Frame
(grid "cells")



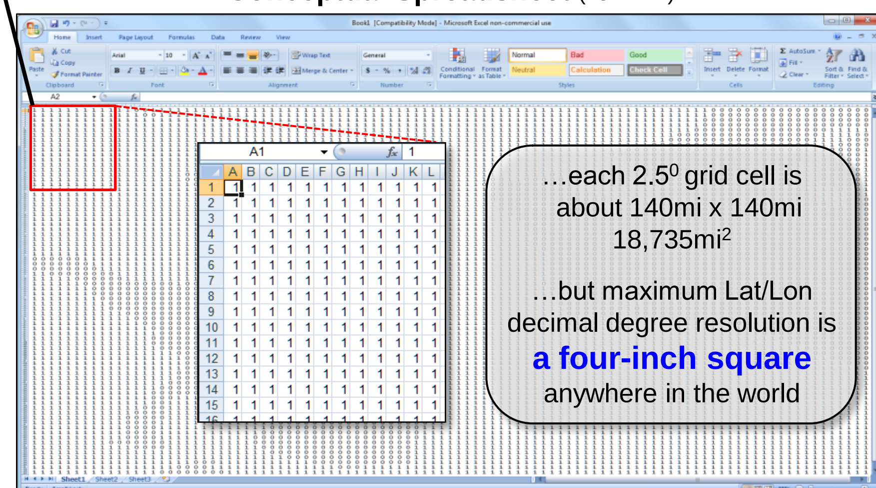
2.5^0 Latitude/Longitude Grid (140mi grid cell size)



Coordinate of first grid cell is 90^0 N 0^0 E

#Rows= 73 #Columns= 144

Conceptual Spreadsheet (73 x 144)



Lat/Lon

…from Lat/Lon
"crosshairs to grid cells"
that contain map **values** indicating <u>characteristics or conditions at each location</u>

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

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

*All **spatial topology** is <u>inherent in the grid</u>.*

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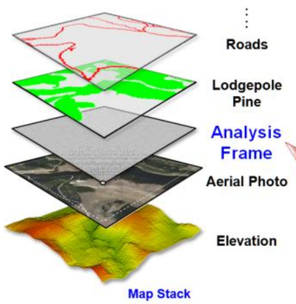
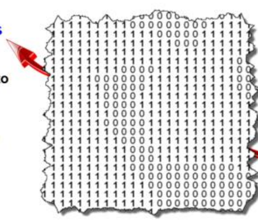
Grid-based Map Data *(Lat/Lon as the Universal Spatial dB Key)*

Spatially Keyed data in the cloud

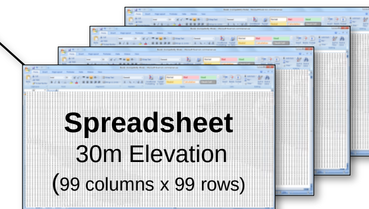
…**Spatially Keyed** data in the cloud are <u>downloaded and configured</u> to the **Analysis Frame** defining the **Map Stack**

"moving Lat/Lon <u>from crosshairs to grid cells</u>"





Conceptual Organization



Wyoming's Bighorn Mts.

RDBMS Organization

"Where"

2D Matrix→ 1D Field

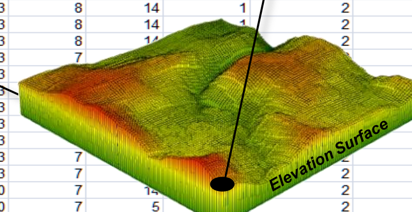
Keystone Concept

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

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 <u>spatial relationships are implicit in the relative Lat/Lon positioning</u>.

Lat/Lon as a Universal Spatial Key

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	[illegible]	[illegible]	2	0	500	50.1
0.000134989	0.001214903	1	5	2487	6.94267	13	7	[illegible]	[illegible]	[illegible]	0	500	49.1
0.000134989	0.001484881	1	6	2484	8.24707	13	[illegible]	[illegible]	[illegible]	[illegible]	0	500	48.1
0.000134989	0.001754860	1	7	2481	8.83946	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	500	47.1
0.000134989	0.002024838	1	8	2479	7.89355	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	500	46.1
0.000134989	[illegible]	1	9	2472	10.7096	13	[illegible]	[illegible]	[illegible]	[illegible]	0	500	45.1
[illegible]	[illegible]	1	10	2467	9.73483	13	[illegible]	[illegible]	[illegible]	[illegible]	0	500	44.1
0.000134989	[illegible]	1	11	2459	11.6533	13	7	[illegible]	[illegible]	[illegible]	0	500	43.1
[illegible]	[illegible]	1	12	2453	11.451	13	7	[illegible]	[illegible]	2	0	500	42.1
0.000134989	[illegible]	1	13	2442	13.4447	0	7	[illegible]	[illegible]	2	0	500	41.1
[illegible]	[illegible]	1	14	2437	9.6861	0	7	5	[illegible]	2	0	49.2843	40.1
[illegible]	[illegible]	1	15	2428	11.1091	3	7	5	1	2	0	500	39.1
[illegible]	[illegible]	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	[illegible]	[illegible]	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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.1
0.000134989	0.005534557	1	21	2400	2.42448	16	7	14	1	1	0	37.799	33.1
0.000134989	0.005804536	1	22	2404	4.58453	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	32.1
0.000134989	0.006074514	1	23	2409	3.80529	16	7	14	1	1	0	35.799	31.1
0.000134989	0.006344492	1	24	2415	6.10775	16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30.6
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	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	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



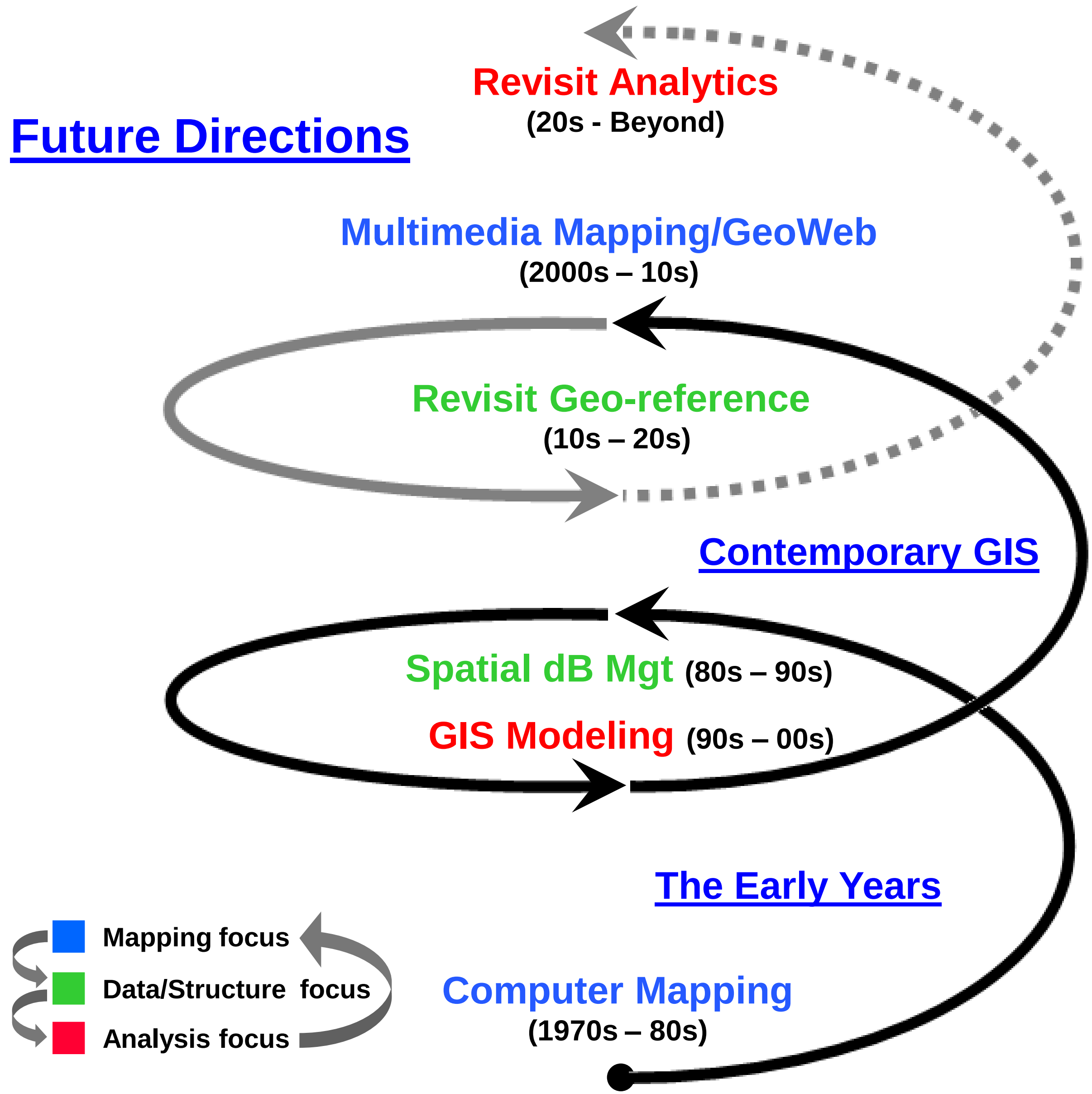
Data Space

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

"What"

(Berry)

A Peek at the Bleeding Edge *(2010s and beyond)*



(See Beyond Mapping III, “Topic 27”, GIS Evolution and Future Trends, www.innovativegis.com/basis)

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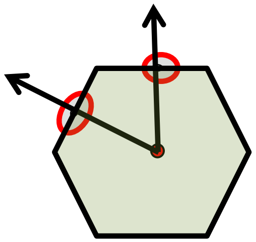
Alternative Geographic Referencing

Tightly Clustered Groupings

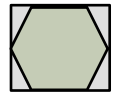
Continuous Nested Grid Elements

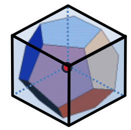
Hexagonal Grid

(6 facets)



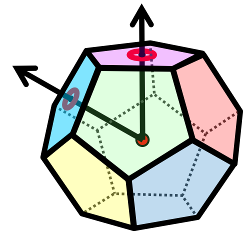
Hexagon



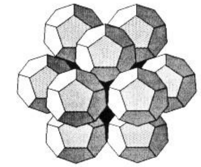


Consistent

distances and adjacency
to surrounding grid elements



Dodecahedral

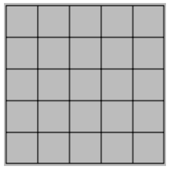


Dodecahedral Grid

(12 facets)

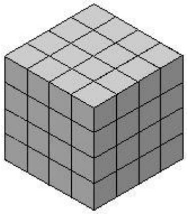
Square Grid

(8 facets)



Inconsistent

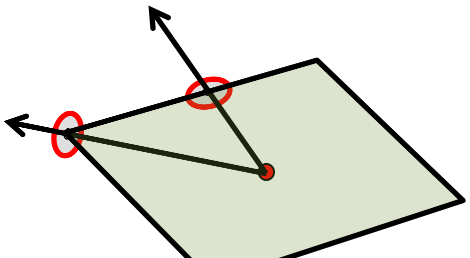
distances and adjacency
to surrounding grid elements
(Orthogonal and Diagonal)



Cubic Grid

(26 facets)

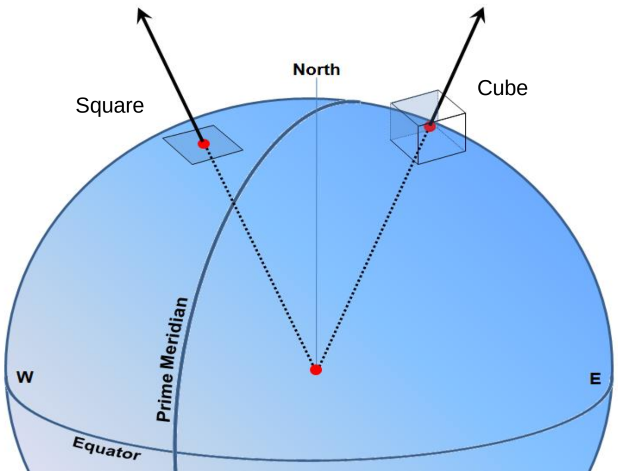
Cartesian Coordinate System

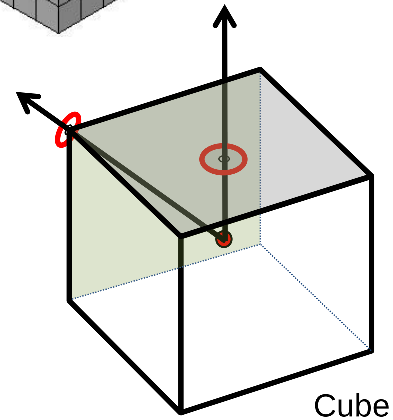


Square

2D Grid Element

(Planimetric)





Cube

3D Grid Element

(Volumetric)

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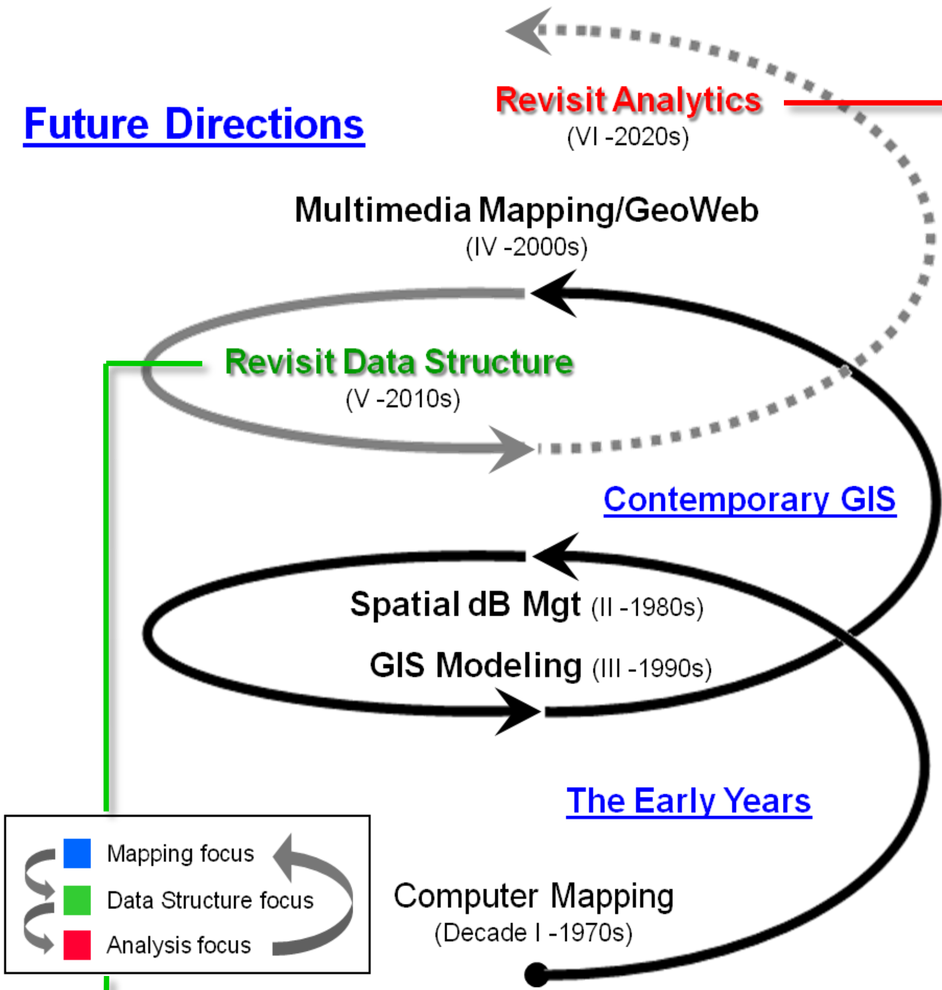
Overview of Map Analysis Approaches



Data Structure

Advances in **Data Storage** and **Geo-referencing** will lead to revision of 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.

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

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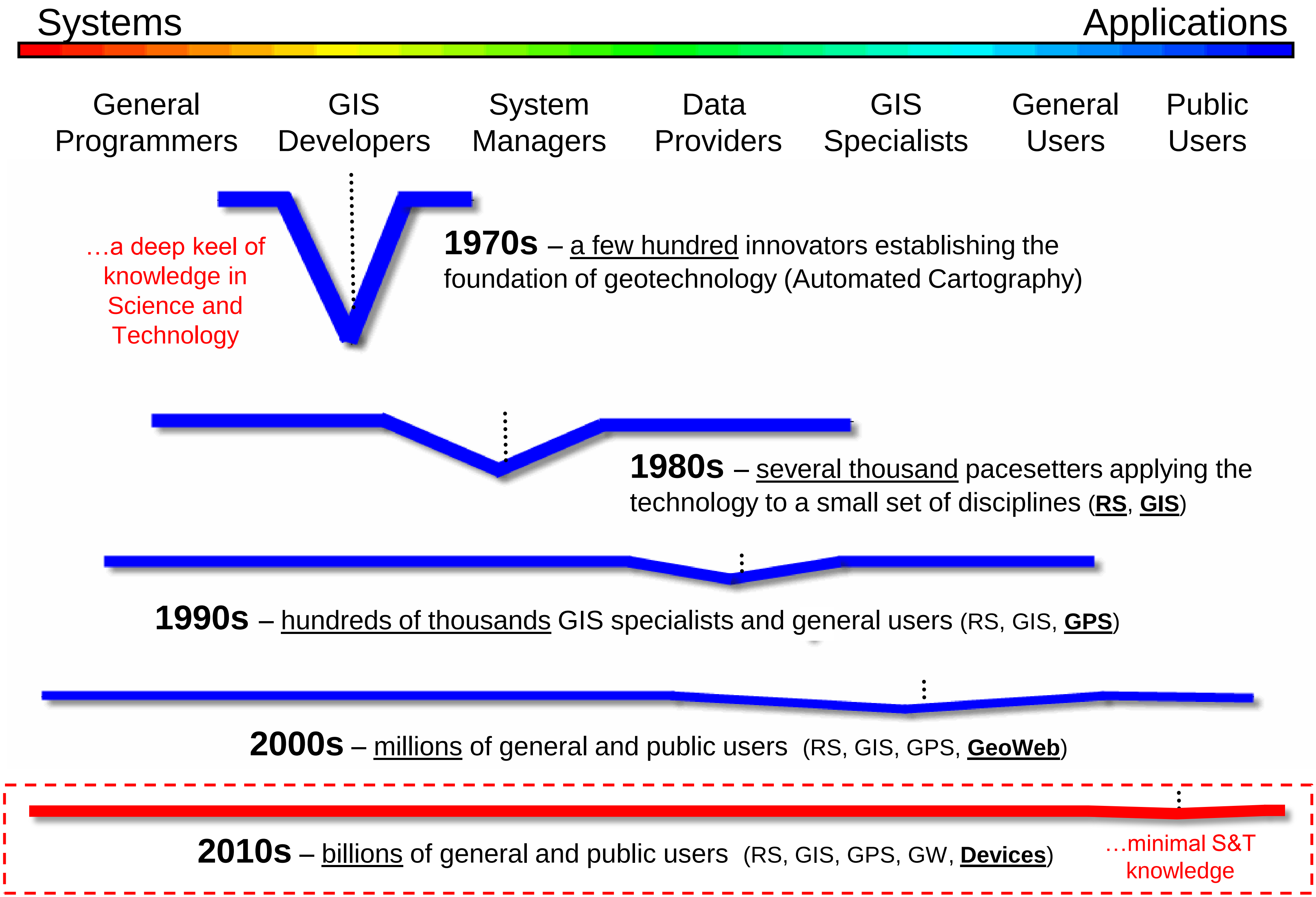
Simultaneously Trivializing and Complicating GIS



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Where are we headed?

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

…but will GIS education and professionals **lead or follow**?

1) *Solutions to complex spatial problems need to* **engage "domain expertise"** *through GIS– 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* ***GIS 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– 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)