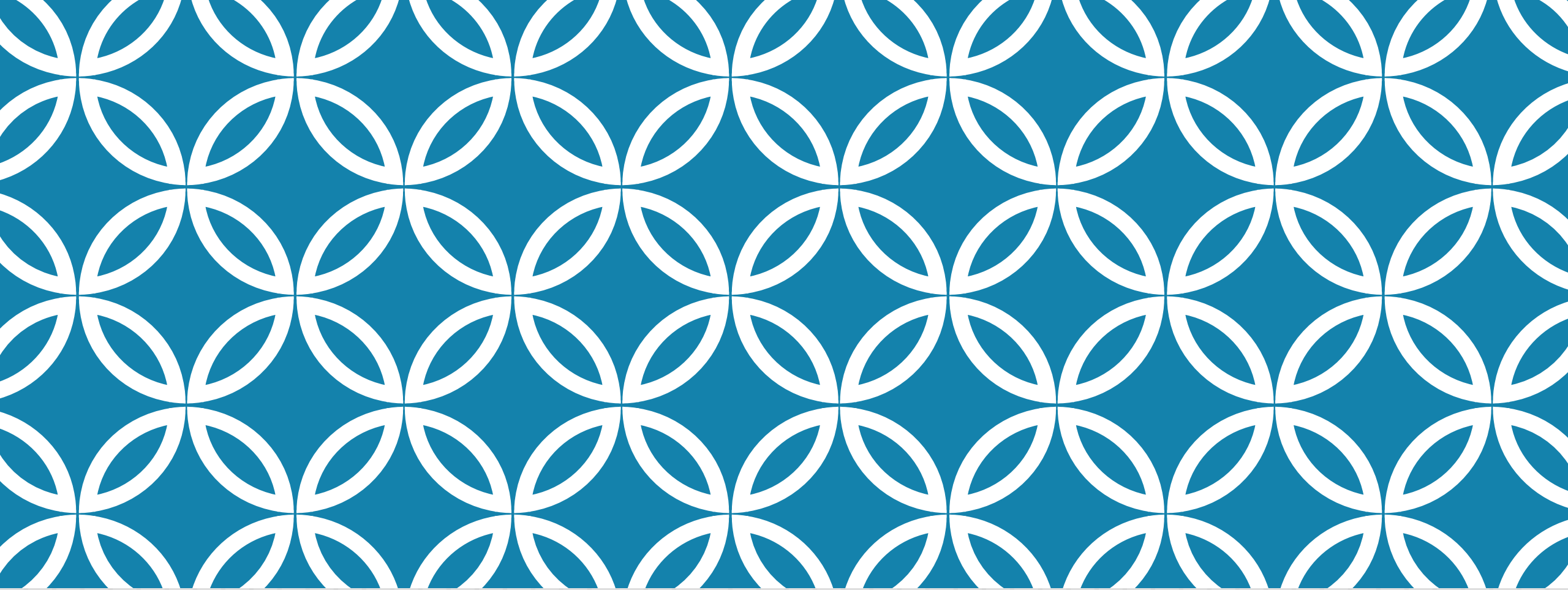


UNIT 4: SPATIAL DATA VISUALIZATION

Dipesh Koirala

OUTLINE

- Scalar Fields
- Isocontours (Topographic Terrain maps), Scalar Volumes
- Direct Volume Rendering (Multidimensional transfer functions)
- Maps (dot, pixel)

- Vector Fields
- Defining Marks and Channels

SPATIAL DATA VISUALIZATION

- Spatial data is any type of data that directly or indirectly *references a specific geographical area or location.*
- Also known as geospatial data, refers to information about the *physical location and shape of objects or features on Earth.*
- Represents a physical object in a geographic coordinate system.

SPATIAL DATA VISUALIZATION

Geometric Data:

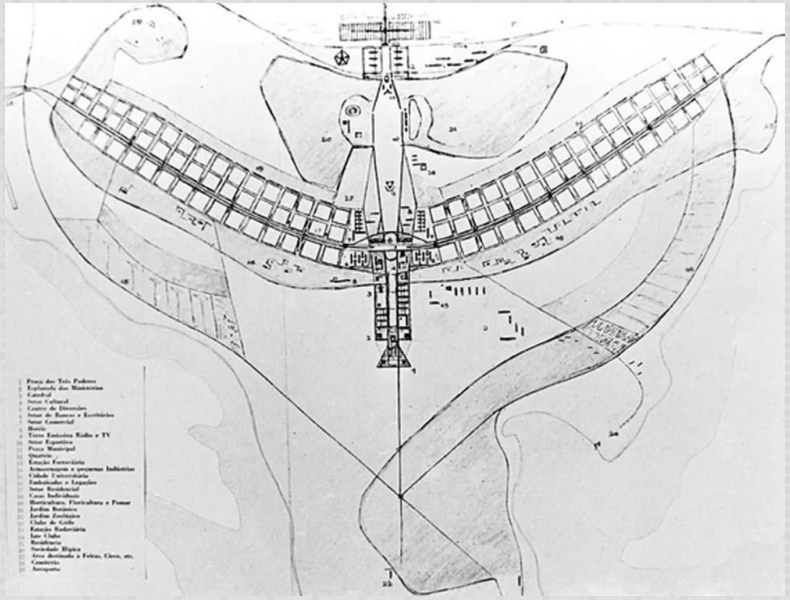
- Geometric data deals with abstract shapes, positions, and relationships in a Euclidean space.
- It operates on a plane (x, y, and an optional z coordinate).
- Examples *include points, lines, and polygons.*
- Geometric data can be in any projection or coordinate system.

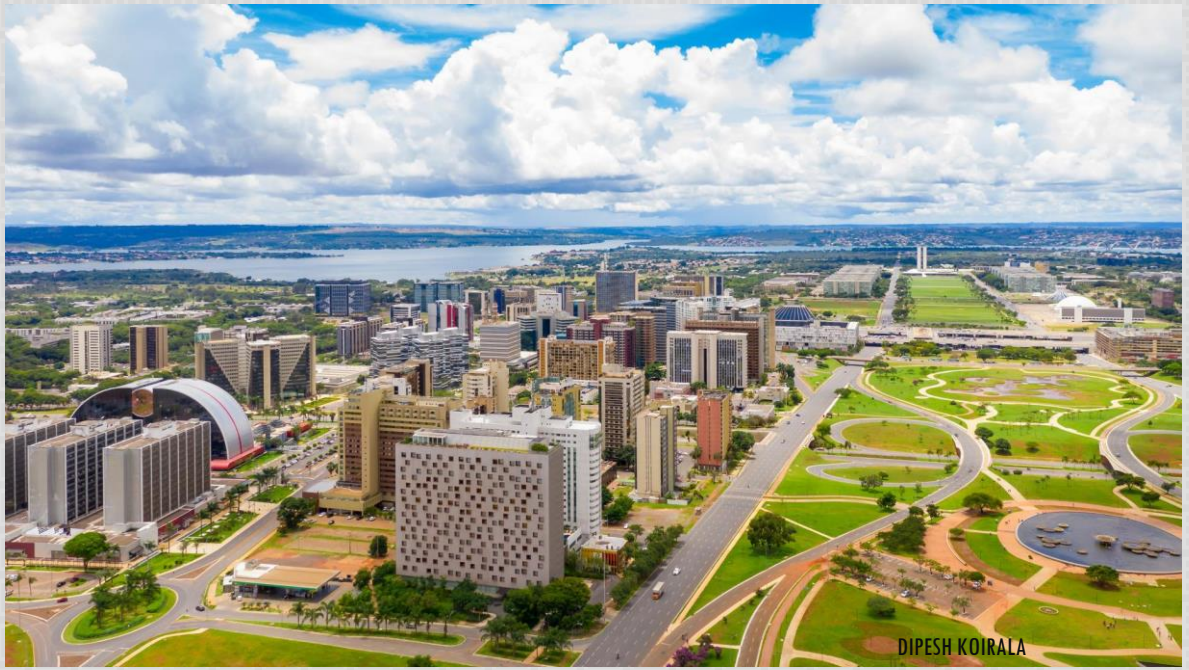
Geographic Data:

- Geographic data describes *objects and their positions relative to Earth's surface.*
- Typically represented using latitude (y) and longitude (x) coordinates (e.g., WGS 84).
- Examples include GPS locations, country borders, and city names.

SPATIAL DATA VISUALIZATION

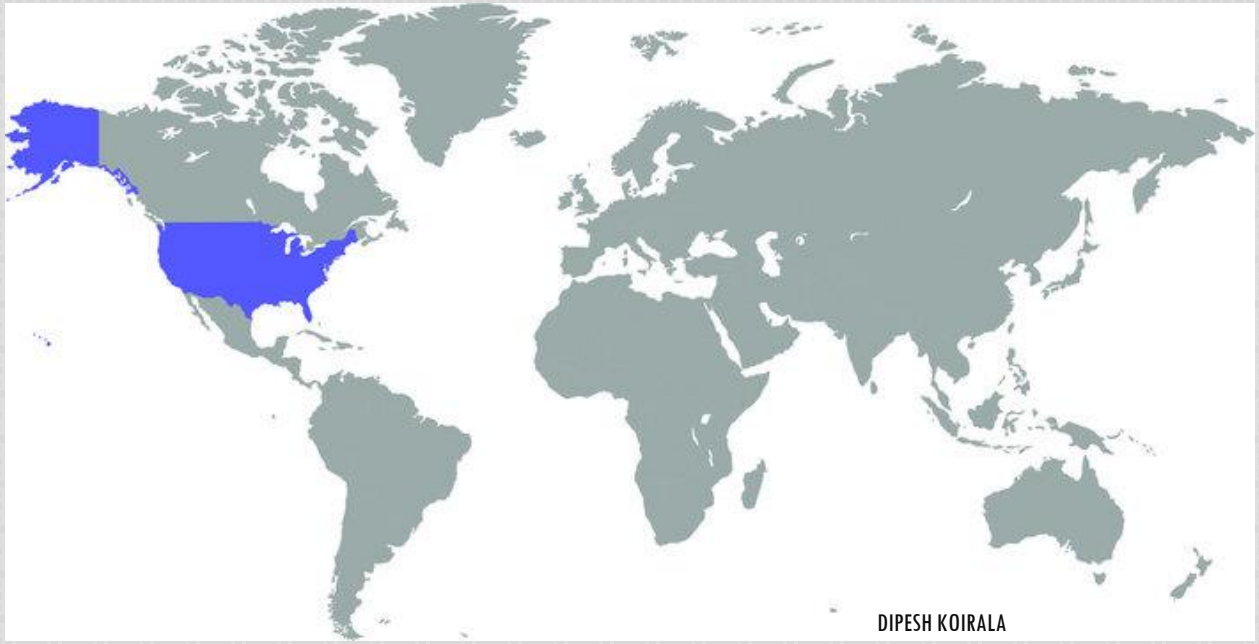
- Spatial data visualization is the *process of using visual elements such as maps, coordinate systems and geometric shapes* to help understand and analyze geographic data.
- These visualizations focus on the relationship between data and its physical location to create insight.
- Is widely used in many fields, including urban planning, public health, environmental science, and business.





SPATIAL DATA VISUALIZATION

- Historically, doctors and scientists have used this kind of presentation to map illness, resources, and even simple navigation.
- The two main spatial data *types are geometry*, where shape information is directly conveyed by spatial elements that do not necessarily have associated attributes, *and spatial fields, where attributes are associated with each cell in the field.*
- *E.g., choropleth map* for geographic data



SPATIAL DATA VISUALIZATION

Choropleth Maps

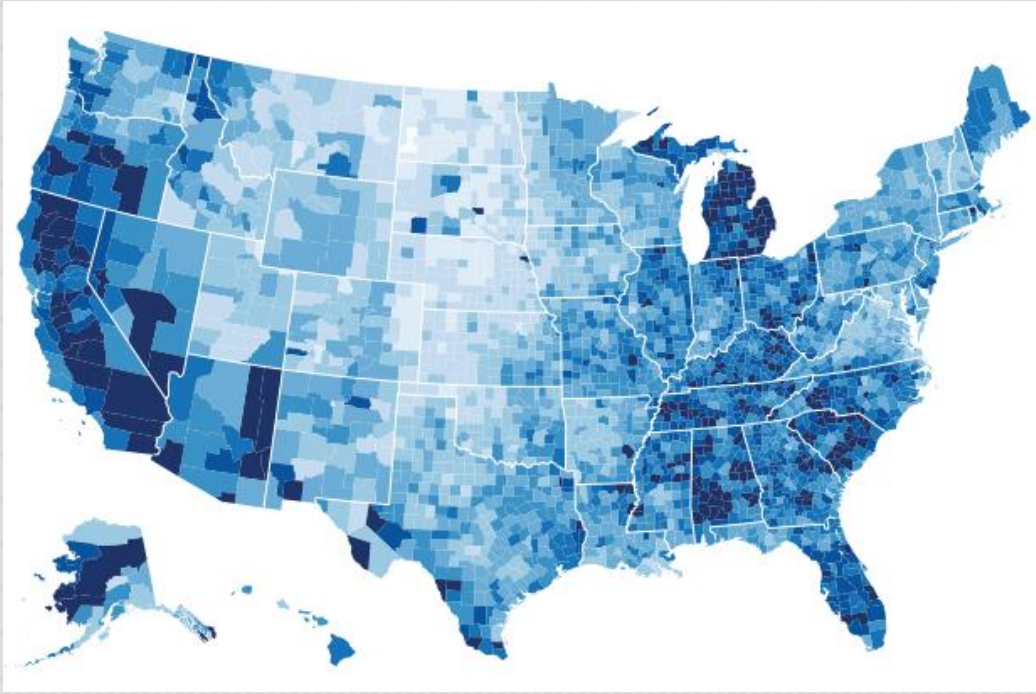
- To show *how some quantity varies across locations.*
- Can do so coloring individual regions in a map according to the map according to the data dimension which to be displayed.

What Data?

- Geographic geometry data. Table with one quantitative attribute per region

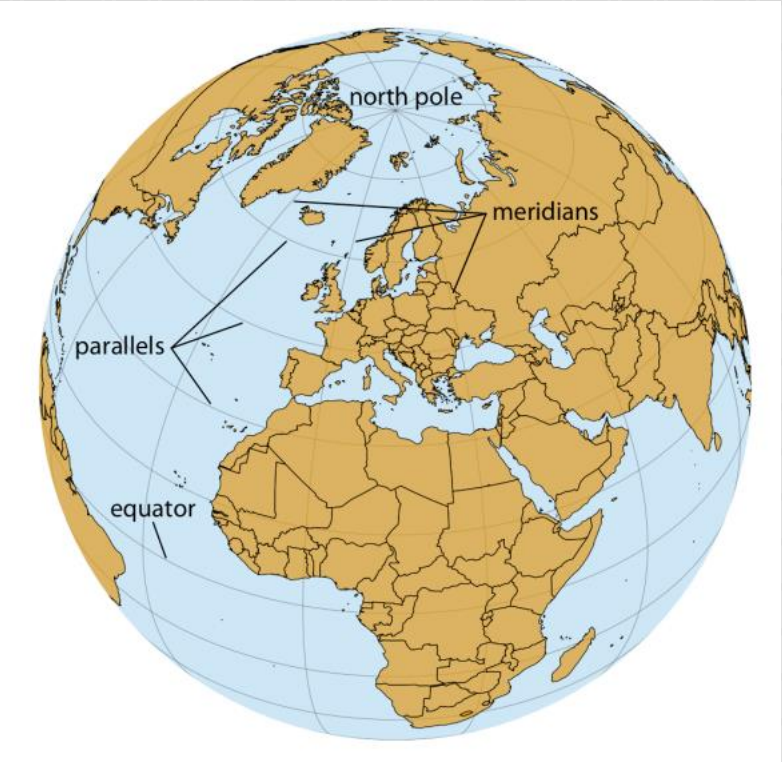
How to Encode?

- Use given geometry for area mark boundaries. Color: sequential segmented colormap.



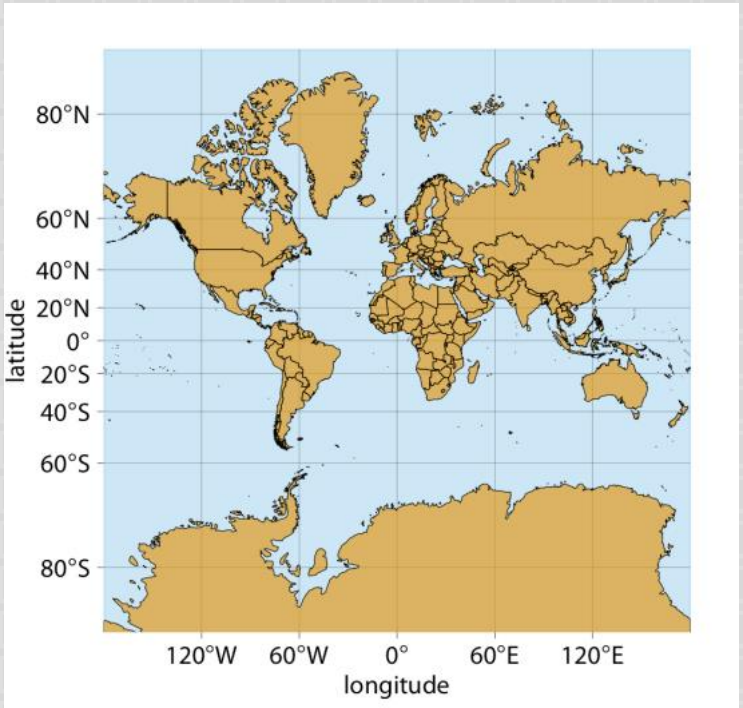
PROJECTIONS

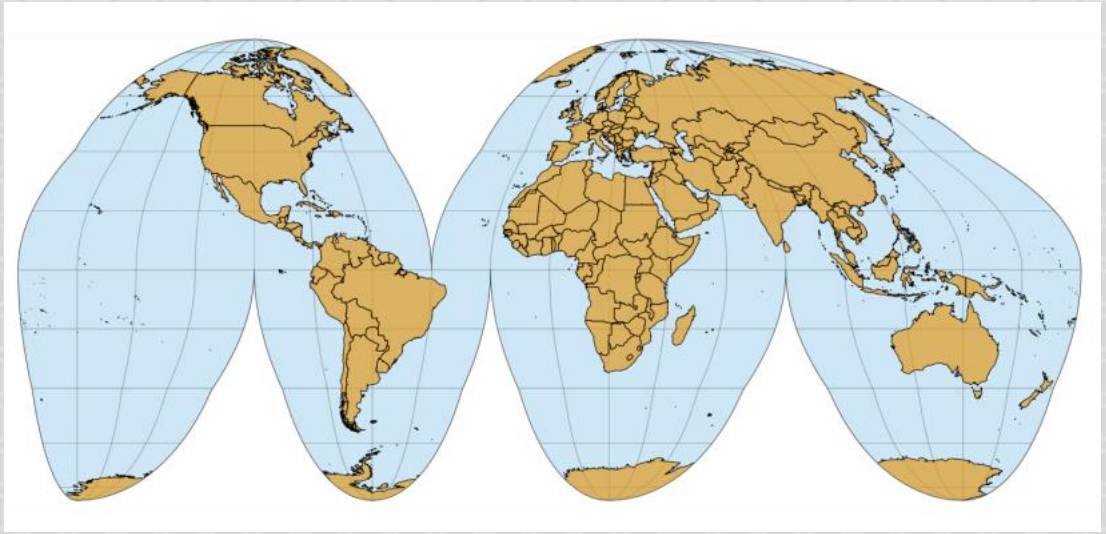
- The earth *is approximately a sphere* , and more precisely an oblate spheroid that is slightly flattened along its axis of rotation.



PROJECTIONS

- The challenge in map making is that we need to take the spherical surface of the earth and flatten it out so we can display it on a map. (*This process is called projection.)*
- Introduces distortions, because a curved surface cannot be projected exactly onto a flat surface.





SPATIAL SCALAR FIELDS

- A scalar field *associates a scalar value to every point in a space.*
- Widely used in physics, engineering and other fields to describe quantities.

Some examples of scalar fields include:

1. Temperature: A scalar field that describes the temperature at each point in space.
2. Pressure: A scalar field that describes the pressure at each point in space.
3. Density: A scalar field that describes the density of a fluid at each point in space.

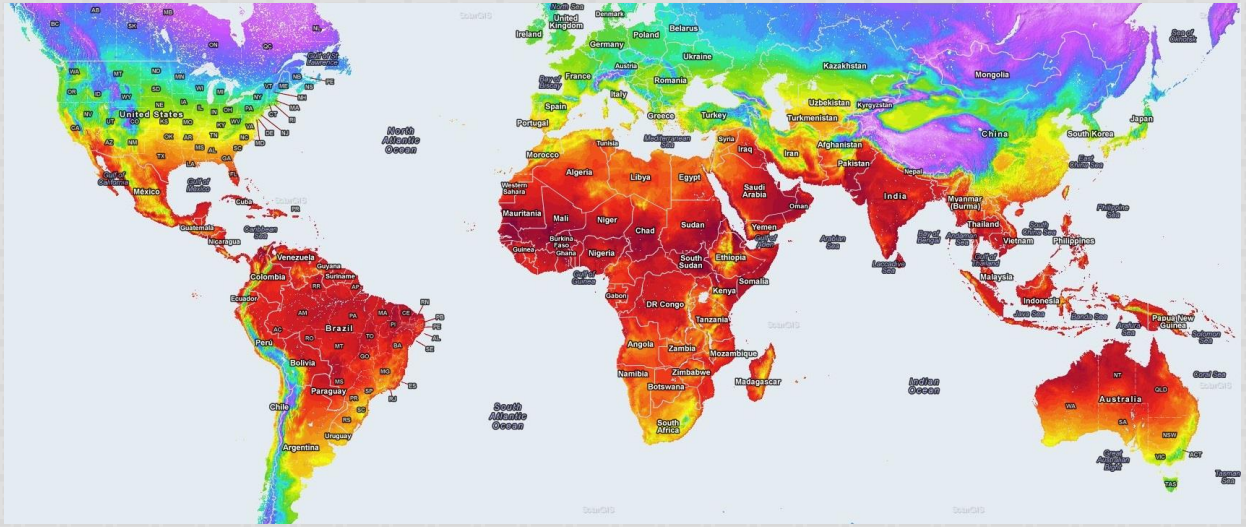
In summer, temperatures at the North Pole can reach over 20°C

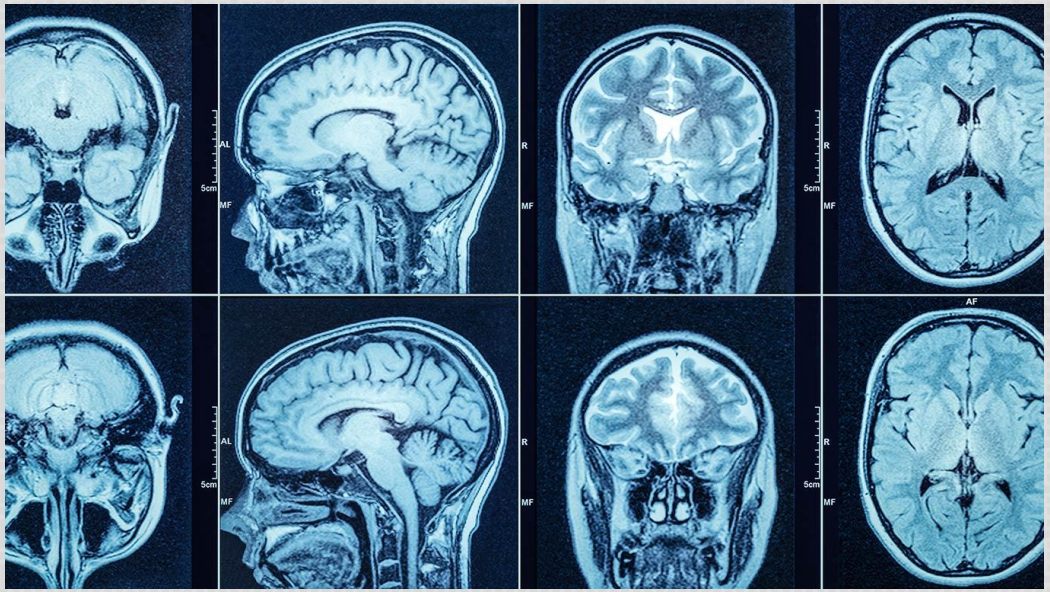
WEATHER IN DEGREES CELSIUS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temp (°C)	-24.2	-20.3	-12.4	-1	8.8	15	15.9	13.4	6.9	-4.1	-15.3	-23.3
Max. Temp (°C)	-19.5	-14.3	-5	4.9	14.7	21	21.5	18.9	12.1	0.2	-11.1	-19.1
Min. Temp (°C)	-28.8	-26.2	-19.8	-6.9	2	9.1	10.4	8	1.8	-8.3	-19.5	-27.4

SPATIAL SCALAR FIELDS

- A scalar spatial field has a single value associated *with each spatially defined cell.*
- Scalar fields are often collected through *medical imaging*, where the measured value is radio-opacity in the case of computed tomography (CT) scans and proton density in the case of magnetic resonance imaging (MRI) scans.





SPATIAL SCALAR FIELD

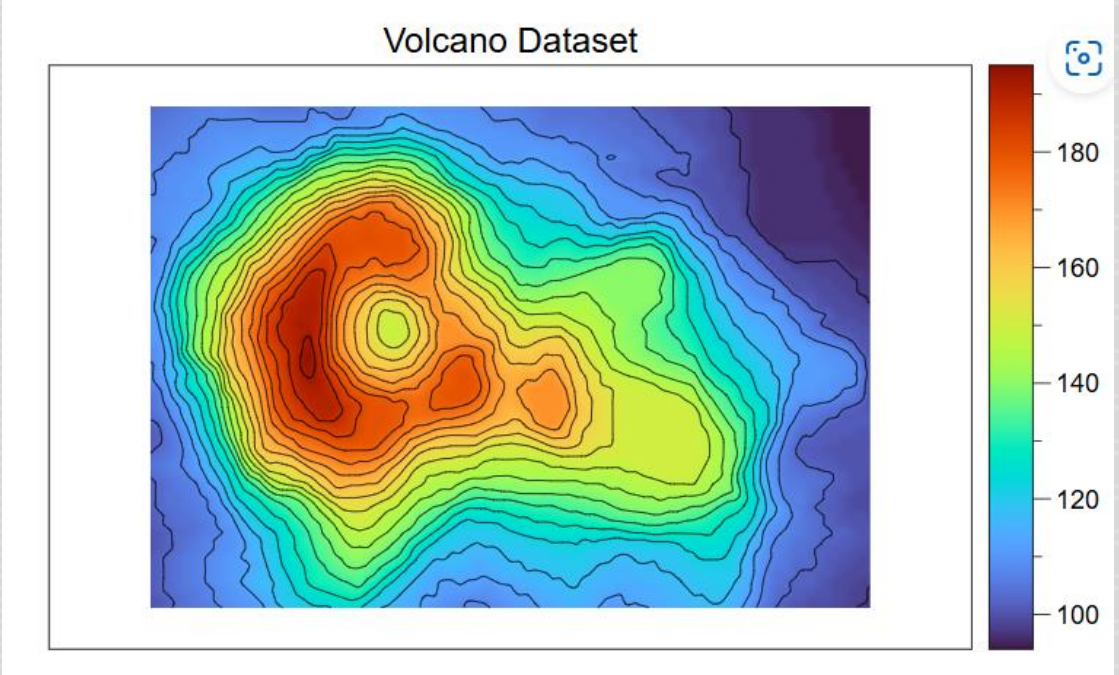
- For scalar fields with one attribute at each field each, the two main visual encoding idiom families are:

i. Isocountours

ii. Direct Volume Rendering

ISOCONTOURS

- A set of isolines, namely, lines that represent the *contours of a particular level of the scalar value*, can be derived from a scalar spatial field.
- Contours are imaginary lines joining places having the *same or equal elevation.*
- These lines provide valuable information about the shape, slope of the terrain or any other variable being represented on the map.



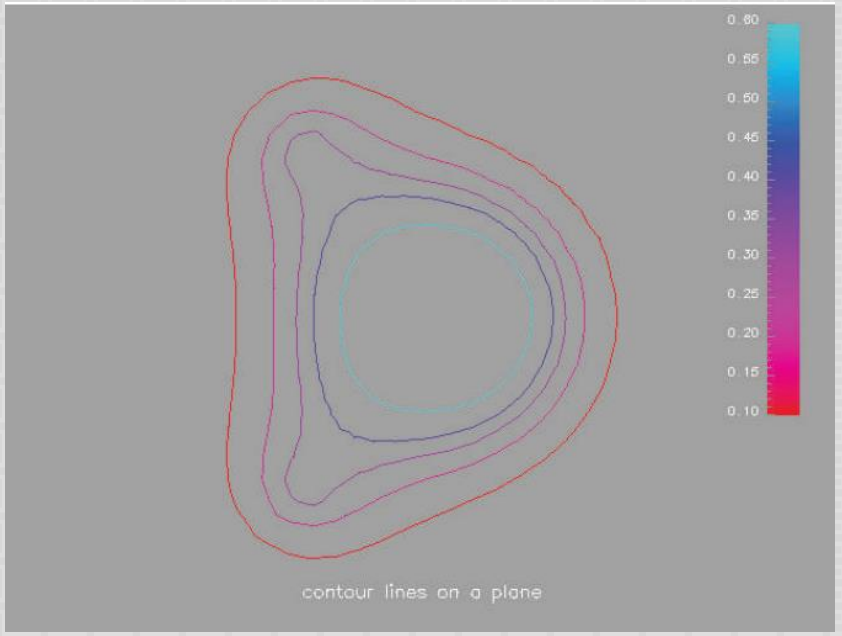
ISOCONTOURS

Isocontours (Characteristics)

- A contour or isovalue map conveys boundary information extracted from an image *depicting a continuous phenomenon*, such as elevation or temperature.

- The term isovalue means “single value,” and thus a contour on such a map indicates the *boundary between points above this value and points below the value*.

- Each isovalue may generate multiple closed contours. Multiple isovalues may be plotted simultaneously, using color, line thickness, line style, or labels to differentiate values.



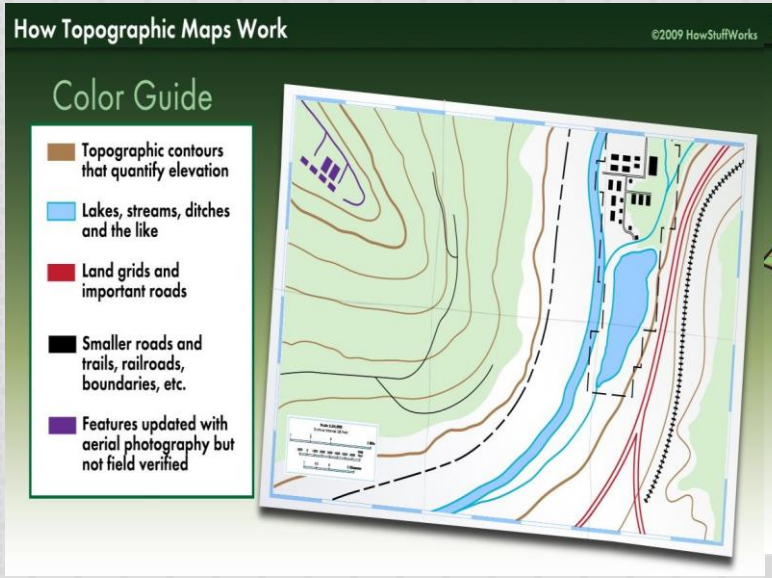
ISOCONTOURS

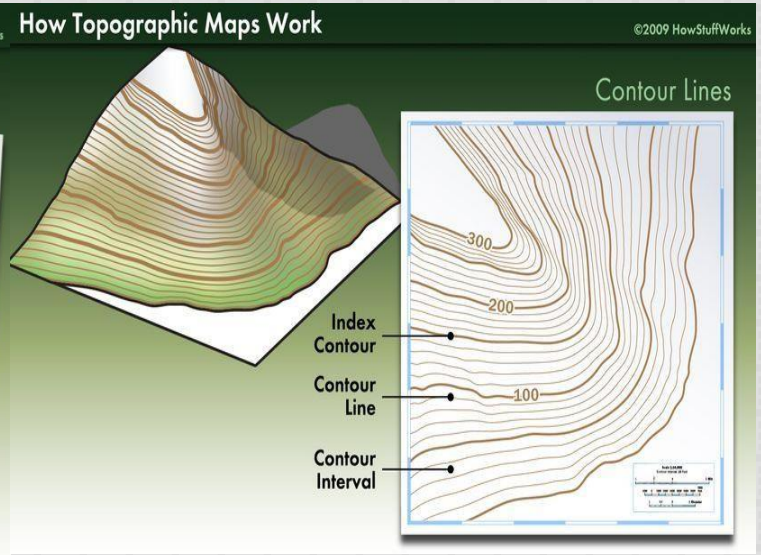
Characteristics

- **Elevation Representation:** Each contour line represents a constant elevation above a reference point, usually mean sea level on a topographic map. For e.g., if the contour interval is set to 10 meters, every contour line will represent a point that is 10 meters higher or lower than the adjacent lines.
- **Gradient and Slope:** Close contour lines indicate a steep slope, while widely spaced lines suggest a gentle slope. The steepest slope on a topographic map is where the contour lines are closest together or when two contour lines merge into one, forming a cliff or a vertical slope.
- Contour lines *never intersect or branch out*. They can form closed loops to indicate hills, depressions, or mountains.
- Close contour lines indicate a steep slope, while widely spaced lines suggest a gentle slope. The steepest slope on a topographic map is where the contour lines are closest together or when two contour lines merge into one, forming a cliff or a vertical slope

SPATIAL DATA VISUALIZATION

- Topographic Terrain Maps



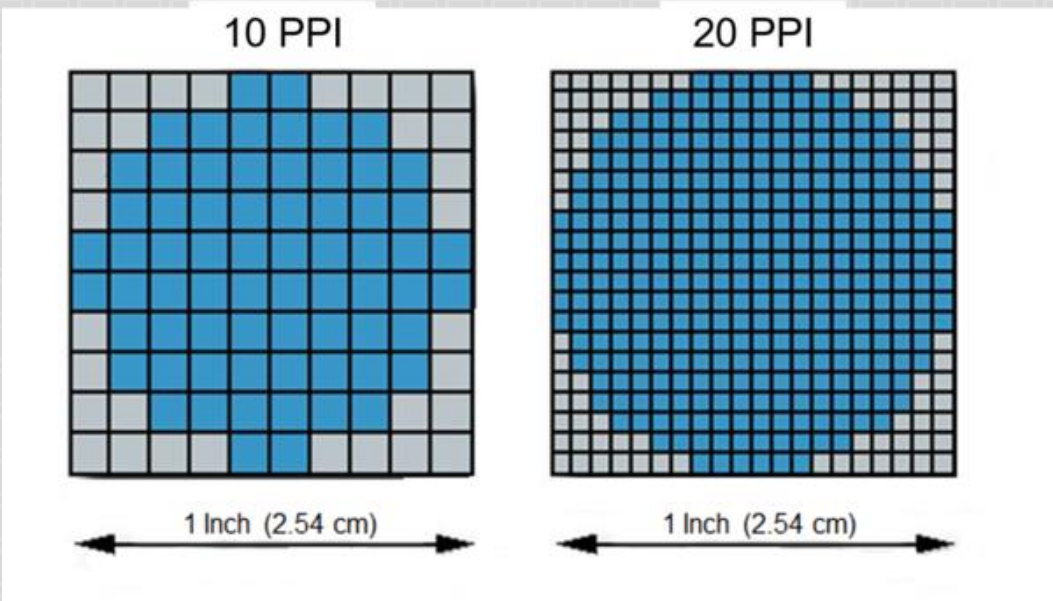


SCALAR VOLUMES

- As pixels are to two-dimensional visualization, *voxels, or volume elements, are to three-dimensional visualization.*

- In a scalar volume, the scalar values are typically represented on a regular grid, forming a three-dimensional array.

- Each grid point, also known as a **voxel**, contains a scalar value.



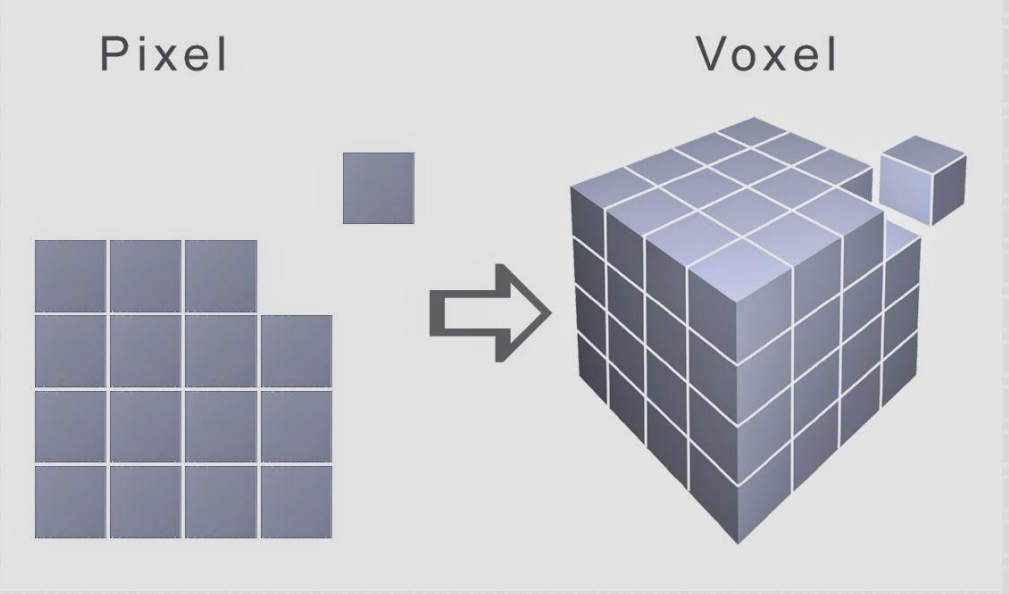
Pixel

SCALAR VOLUMES

- Volume data is generally a sampling of a continuous phenomenon, and can be either acquired via sensors *(e.g., tomographic data sets)* or generated via simulations (e.g., computational fluid dynamics).

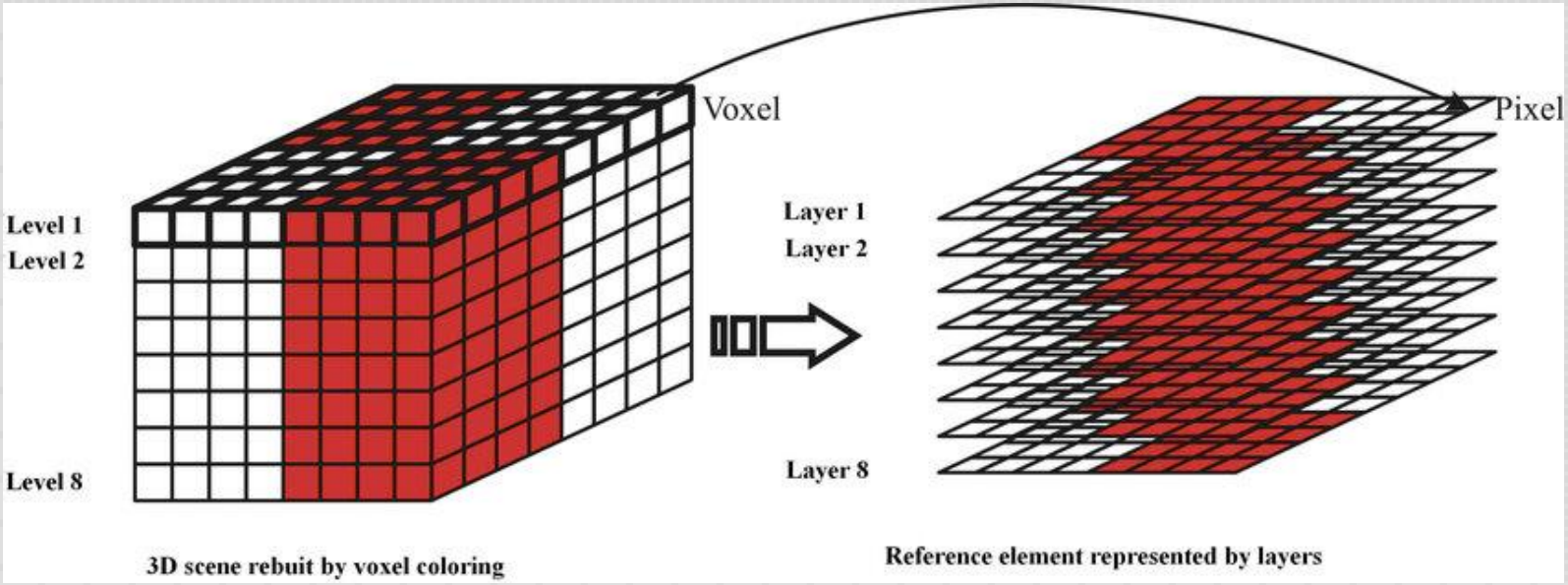
- The goal is to convey to the viewer the structure, patterns, and anomalies within the data.

- Suppose we have a scalar volume representing temperature distribution in a cubic region. *The volume has dimensions of 50 x 50 x 50 voxels.* Each voxel contains a temperature value ranging from 0 to 50 degrees Celsius.



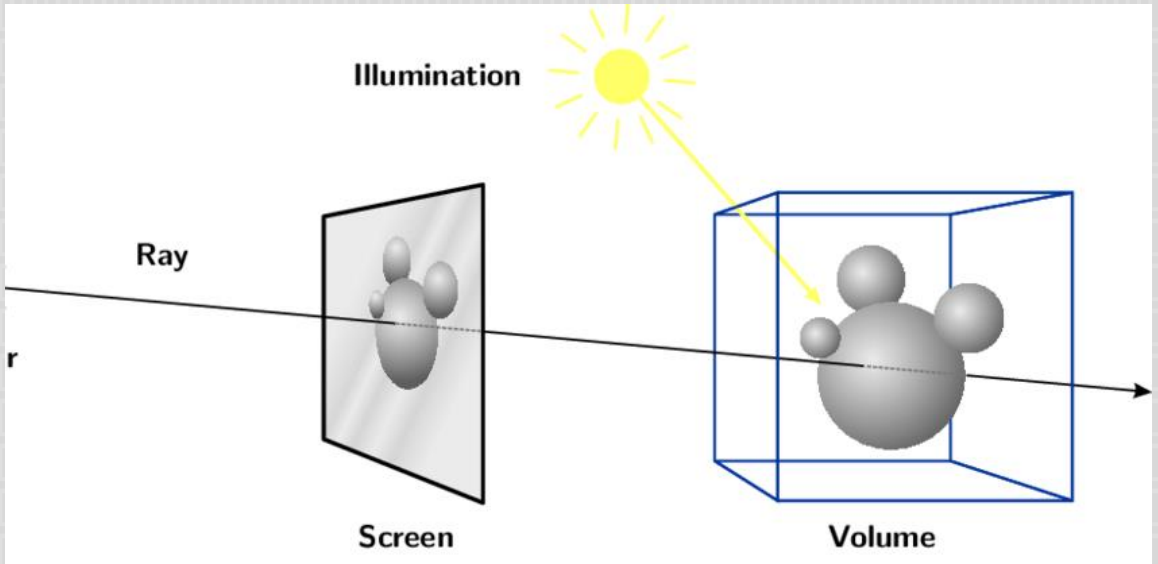
DIRECT VOLUME RENDERING

- Direct volume rendering (DVR) is a visualization technique used *to generate images of volumetric data, such as medical CT or MRI scans, scientific simulations, or 3D models.*
- It allows for the direct exploration and analysis of data without the need for intermediate geometric representations like surfaces or contours.



DIRECT VOLUME RENDERING

- To generate a 2D image from the volumetric data, DVR employs a process *called ray casting.*
- Either cast rays into the volume and compute a pixel value based on the data encountered by the ray, or project each voxel onto the projection plane.
- The basic idea *is to cast rays from the viewpoint of the camera* into the volume and accumulate the properties of the intersected voxels along the ray path.
- A crucial visual encoding design choice with direct volume rendering is *picking the transfer function that maps changes in the scalar value to opacity and color.*



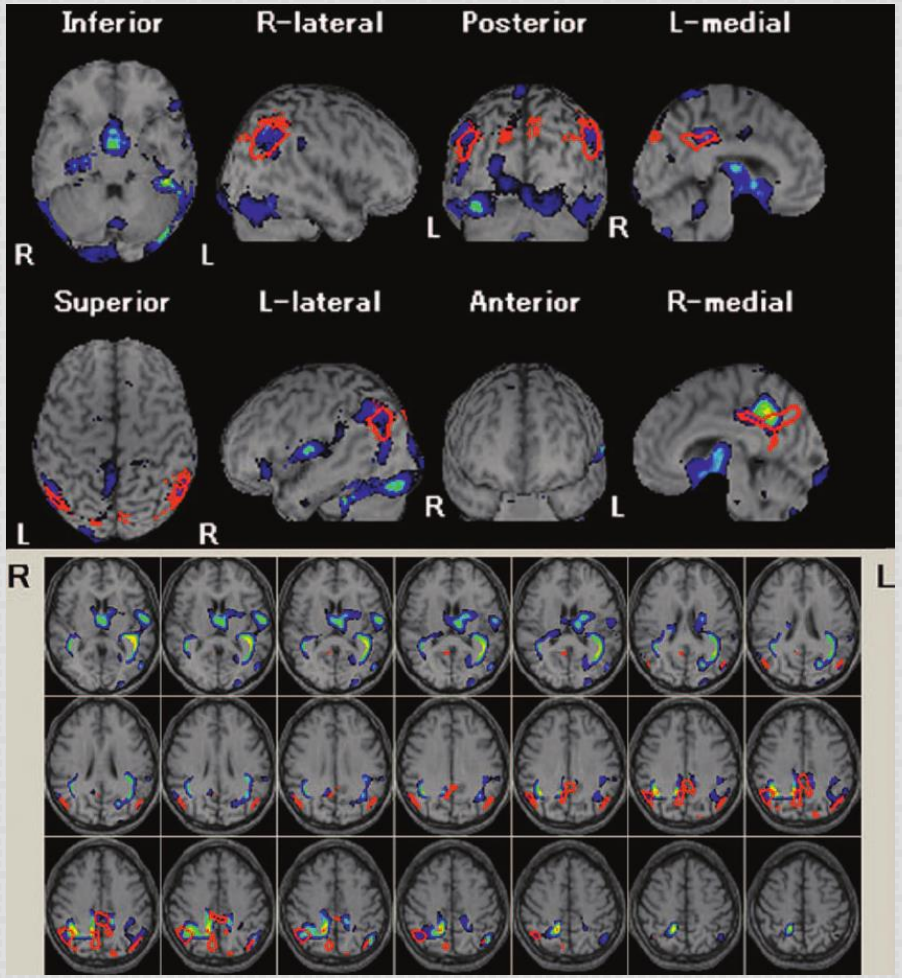
DIRECT VOLUME RENDERING

Here are five key points that explain direct volume rendering:

i. Volumetric Data Representation: Direct volume rendering operates on volumetric datasets

ii. Ray Casting: For each pixel on the image plane, *a ray is cast into the volume*, and its interaction with the data is calculated to determine the final pixel color.

iii. Transfer Function: A transfer function maps the scalar values of the voxels *to optical properties, such as color and opacity.* For example, in medical imaging, a transfer function can be designed to assign different colors to different tissue types or highlight specific structures of interest.



DIRECT VOLUME RENDERING

Here are five key points that explain direct volume rendering:

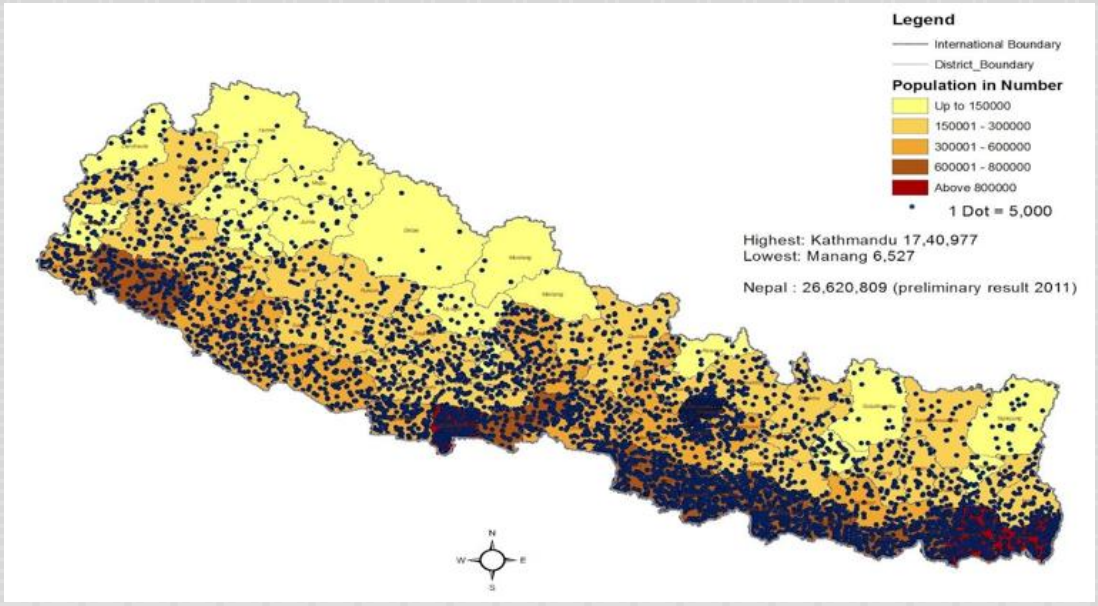
iv. Compositing Techniques: Direct volume rendering employs various compositing techniques to combine the contributions from multiple voxels along a ray. The most commonly used compositing method is the alpha blending technique, where the colors and opacities of voxels are blended based on their positions along the ray.

v. Lighting and Shading: To enhance the visual quality and perception of depth, *direct volume rendering often incorporates lighting and shading techniques.* These techniques simulate the interaction between light sources and the volumetric data, allowing for the depiction of highlights, shadows, and gradients.

MAPS (DOT, PIXEL)

Dot Maps

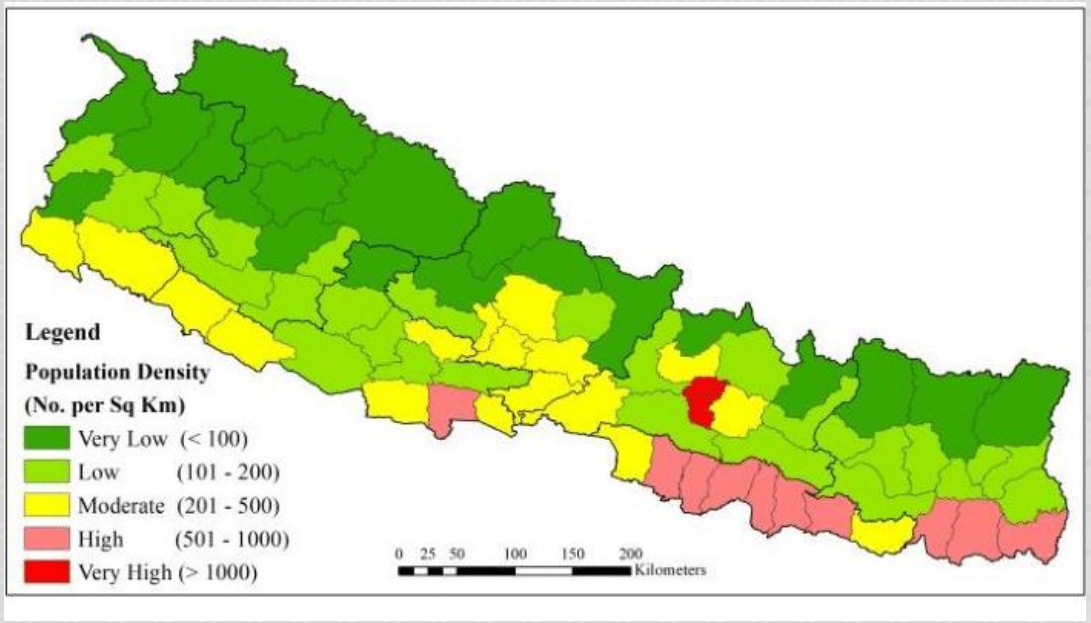
- Uses dots to represent data.
- The density of the dots represents the *density of the data in that area.*
- Dot maps are used to represent the distribution of data points geographically. Each dot on the map signifies a certain quantity of data (e.g., population, events).



MAPS (DOT, PIXEL)

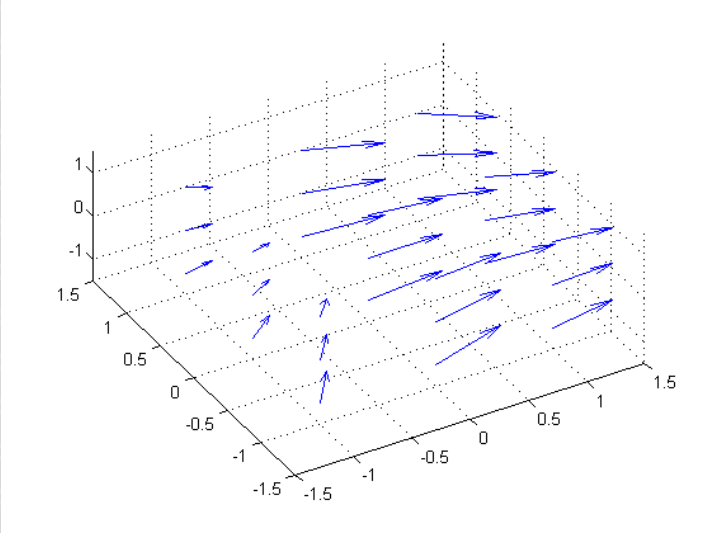
Pixel Maps

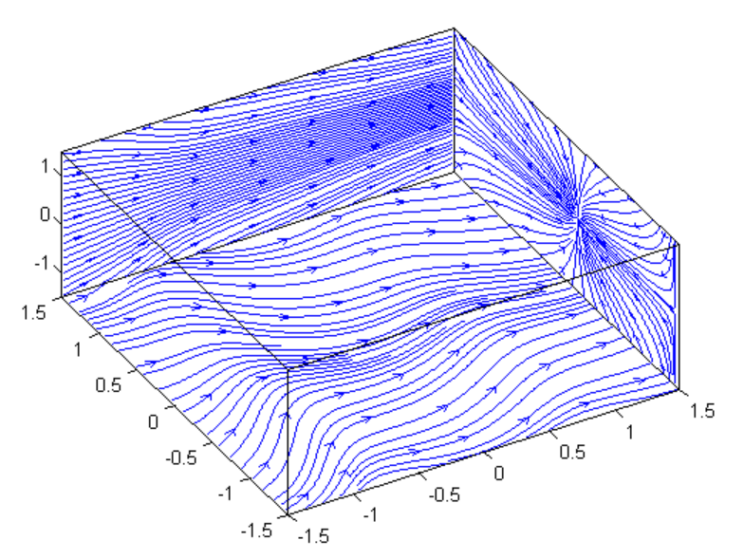
- A pixel map (or bitmap) is typically a rasterized image, where pixels represent color information.
- When used in a mapping context, each pixel could *represent a small unit of space on a map*.



VECTOR FIELDS

- A vector field assigns a *vector (magnitude and direction) to every point in space.*
- Each vector represents a specific attribute, such as velocity or force, at a particular location.
- Vector fields are commonly used in scientific simulations, fluid dynamics, weather forecasting, and many other fields where understanding the behavior of vector quantities is essential.



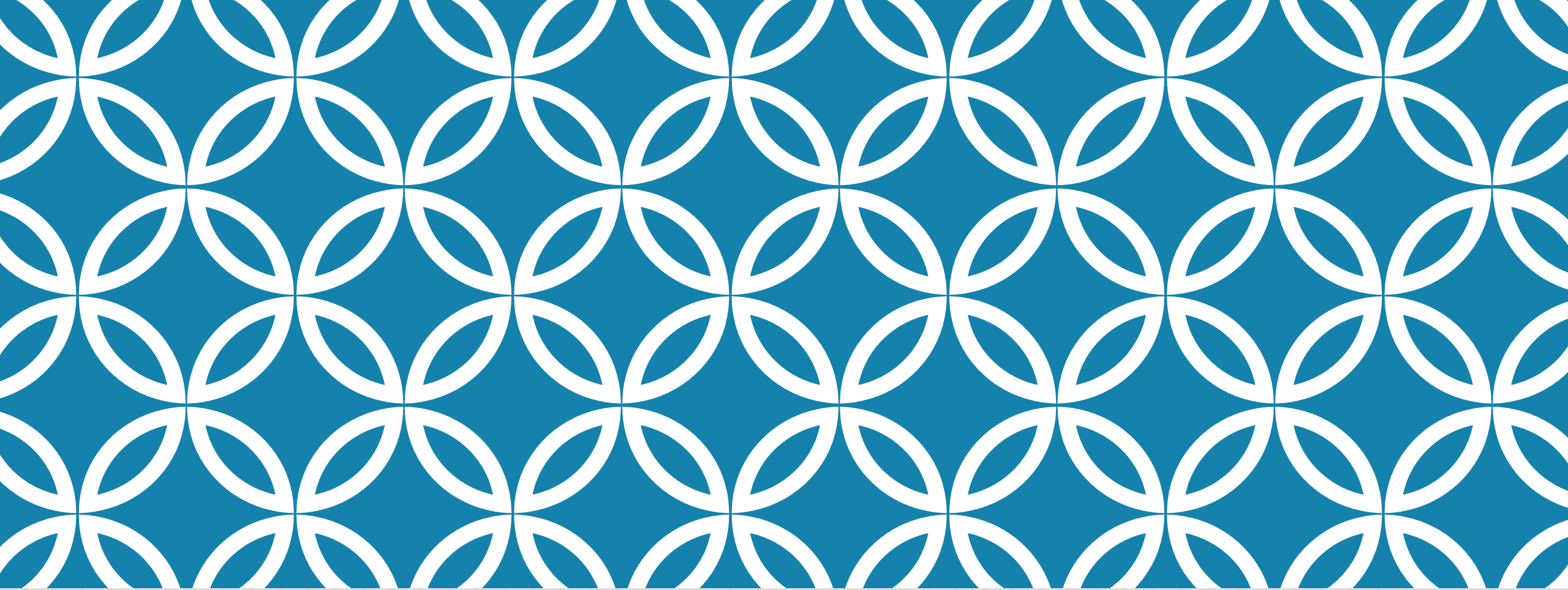


VECTOR FIELDS

Techniques:

- Velocity Plot (Quiver Plot)
- Velocity Plot (Cone Plot)
- Streamlines
- Streamslice
- Stream Tube and Stream Ribbon

Source:
https://web.mit.edu/8.13/matlab/MatlabTraining_IAP_2012/AGV/DemoFiles/ScriptFiles/html/Part8_VectorFields.html



THANK YOU

Dipesh Koirala