TOPIC 1: Visualization of volumetric data

Volume visualization is the creation of graphical representations of data sets that are defined on three-dimensional grids
[1]
. It is a powerful tool for understanding and analyzing complex data sets
[2]
. There are various software packages available to help visualize volumetric data, such as tomviz
[3]
. Multimodality volumetric visualization provides correlation information and helps the user to visualize the presence of spatial localization in the data
[4]
. Image-based visualization can also be used to visualize large volumetric data using Fourier transforms
[5]
.

Volume Data:

Volume data consists of voxels. A voxel is the basic volume element and it can be represented as a point in a 3D space with a certain position and a color.
This gives an opportunity to keep up to six scalar parameters. Usually, the points belong to the fixed grid, so the volume data can be stored as a table.
In this case, the runtime representation can be kept as a multidimensional array, and volume data can be represented as a *.csv file in a device's local storage. However, more commonly the dataset is broken into several slices, and every slice is stored as a bitmap image.
The approach allows for significantly reducing the model size due to the sophisticated compressing algorithm which could be applied to the images.

Volumetric Visualization

In this section, we'll take a look at the four main ways how to visualize volumetric datasets and we'll discuss the advantages and disadvantages of different technologies in volumetric visualizaation.

Site-Based Approach

This is the most straightforward solution, which implies the separate visualization of every slice of the volume dataset with an opportunity to scroll them interactively.

Further, the simplicity of the implementation and low computational complexity are the key advantages of the technique.

However, its main problem is that the viewer should use the imagination to reconstruct an entire object structure.

As a result, the slice-based approach is not the most suitable for visual analyses of very complex and unknown structures.

But, it suits the detection of features inside well-known objects, such as parts of the human body. That's why the methodology is widely used in medicine.

For example, it is the most popular way of representation for MRI and CT. It is worth mentioning, that general CT and MRI studies have a much lower resolution in one of the dimensions, which causes some difficulties in utilizing the datasets with more advanced technologies.

Advantages:

As there are many tools for visualizing polygonal mesh models, the idea behind Indirect Volume Rendering is obvious. The approach consists of two steps.

- It contains all the typical features of 3D object visualization such as rotation, usage of different amounts of light sources, interaction with other 3D objects, and so on.
- As a result, it makes complex 3D structure analysis much simpler.

- It is especially useful for the visual detection of meaningful details inside unknown datasets.
- Due to the performance optimization of common 3D rendering engines, the visualization can be handled by any modern office workstation.
- Moreover, the technique allows developers to use much more sophisticated noise reduction algorithms.

Disadvantages:

The disadvantages of the approach are caused by the first step of the visualization process.

- Firstly, conversion of the volume dataset to the polygonal mesh surface leads to the loss of the data from inside the surface area.
- Secondly, the isosurface extraction algorithm can require complex calculations, so preprocessing can take a noticeable amount of time, that's why usually it is impossible to interactively change the threshold of the surface extraction.

TOPIC 2: vector fields

Volumetric vector fields can be visualized using various techniques such as contour slices, slice planes, and isosurfaces
[1]

. Scalar fields are 2D or 3D volumes of scalars while vector fields are 3D volumes of vectors
[2]

. There is a new approach to the visualization of volumetric vector fields with an adaptive distribution of animated particles that has been introduced
[3]

. Additionally, there are methods for more effective volume visualization of three-dimensional vector fields using LIC
[4]

.

In vector calculus and physics, a vector field is an assignment of a vector to each point in a subset of space
[1]

. Vector volume data contains more information than scalar data because each coordinate point in the data set has three values associated with it
[2]

. Techniques for visualizing vector volume data include scalar techniques, determining starting points for stream plots, and plotting subregions of volumes
[3]

.

TOPIC 3: processes and simulations,Visualization

The process of visualizing volumetric data involves several steps. First, the data needs to be loaded into a software tool that can handle volumetric data. Then, the data can be preprocessed to remove noise or artifacts and to enhance features of interest. Next, the data can be visualized using various techniques such as isosurfaces, volume rendering, or slice planes
[1]

[2]

[3]

.Isosurfaces are surfaces that represent a constant value of a scalar field. They can be used to show the shape and location of structures in the volumetric data. Volume rendering is a technique that creates images by integrating the color and opacity of voxels along rays through the volume. It can be used to show both internal and external structures in the volumetric data. Slice planes are 2D planes that cut through the volume at a specified position and orientation. They can be used to show cross-sectional views of the volumetric data
[1]

[3]

.In addition to visualization techniques for scalar fields, there are also techniques for visualizing vector fields in volumetric data. These include streamlines, stream ribbons, and glyphs

[4]

.Stimulation refers to applying an external force or signal to a system in order to observe its response

Steps to Create a Volume Visualization

Creating an effective visualization requires a number of steps to compose the final scene. These steps fall into four basic categories:

1. Determine the characteristics of your data. Graphing volume data usually requires knowledge of the range of both the coordinates and the data values.
2. Select an appropriate plotting routine. The information in this section helps you select the right methods.
3. Define the view. The information conveyed by a complex three-dimensional graph can be greatly enhanced through careful composition of the scene. Viewing techniques include adjusting camera position, specifying aspect ratio and project type, zooming in or out, and so on.
4. Add lighting and specify coloring. Lighting is an effective means to enhance the visibility of surface shape and to provide a three-dimensional perspective to volume graphs. Color can convey data values, both constant and varying.

TOPIC 4 :Visualization of maps

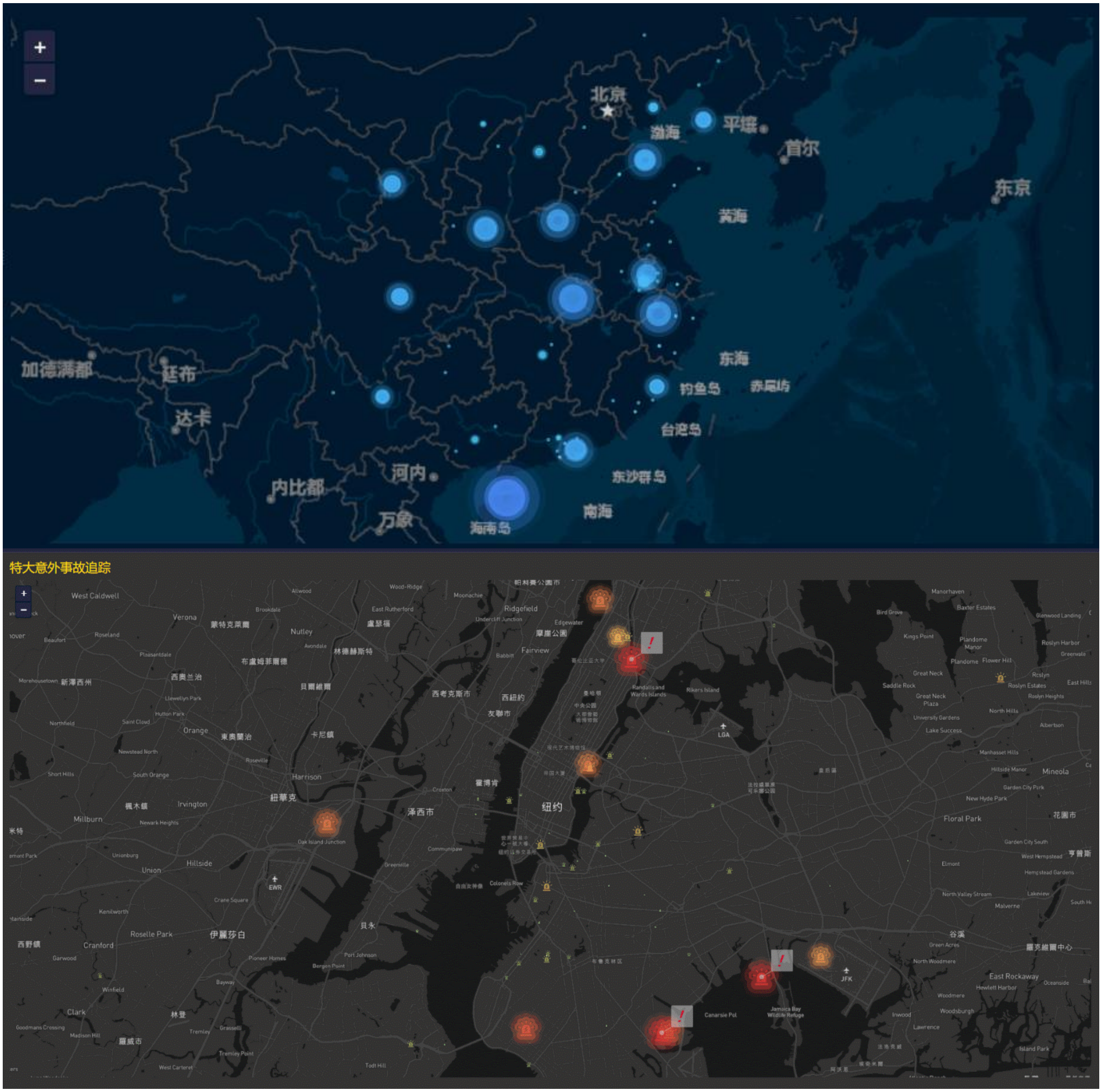
Maps are a common way to visualize geospatial data. There are several techniques for visualizing maps in data visualization, including point maps, choropleth maps, heatmaps, and cartograms
[1]
[2]
.Point maps are one of the simplest ways to visualize geospatial data. They place a point at any location on the map that corresponds to a specific data point. Choropleth maps use color shading or patterns to represent different values of a variable across regions such as countries or states. Heatmaps use color intensity to represent the density of points in an area. Cartograms distort the size or shape of regions based on a variable of interest
[1]
[2]
.Interactive map data visualizations can be created using various tools such as Tableau, Google My Maps, and ArcGIS Online
[3]
[4]
[5]
. These tools allow users to create custom maps with compelling data visualizations that guide the interpretation of the data.In conclusion, there are many methods for visualizing geospatial data on a map. The choice of technique depends on the type and amount of data being visualized and the insights that need to be communicated.

Map visualization is used to analyze and display the geographically related data and present it in the form of maps. This kind of data expression is clearer and more intuitive. We can visually see the distribution or proportion of data in each region. It is convenient for everyone to mine deeper information and make better decisions.

There are many types in map visualization, such as administrative maps, heatmaps, statistical maps, trajectory maps, bubble maps, etc. And maps can be divided into 2D maps, 3D maps or static maps, dynamic maps, interactive maps… They are often used in combination with points, lines, bubbles, and more. In this article, you will find examples of the top 10 map types in data visualization!

1. Point Map

Point maps are straightforward, especially for displaying data with a wide distribution of geographic information. For example, some companies have a wide range of business. If the company wants to view the data of each site (specific location) in a certain area, it will be more complicated to implement with general maps, and the accuracy is not high. Then you can use the point map for precise and fast positioning.



Use scenarios: distribution of point events. Point maps can also realize special recognition of big events. Like the accident tracking map above, it can identify relatively serious events with picture, text or dynamic effects.

2. Line Map

You may not use line maps often, because they are relatively difficult to draw. However, the line map sometimes contains not only space but also time. For the analysis of special scenes, its application value is particularly high.

Use scenarios: route distribution for riding or driving, bus or subway line distribution, such as the taxi route of New York City on the map above.

.

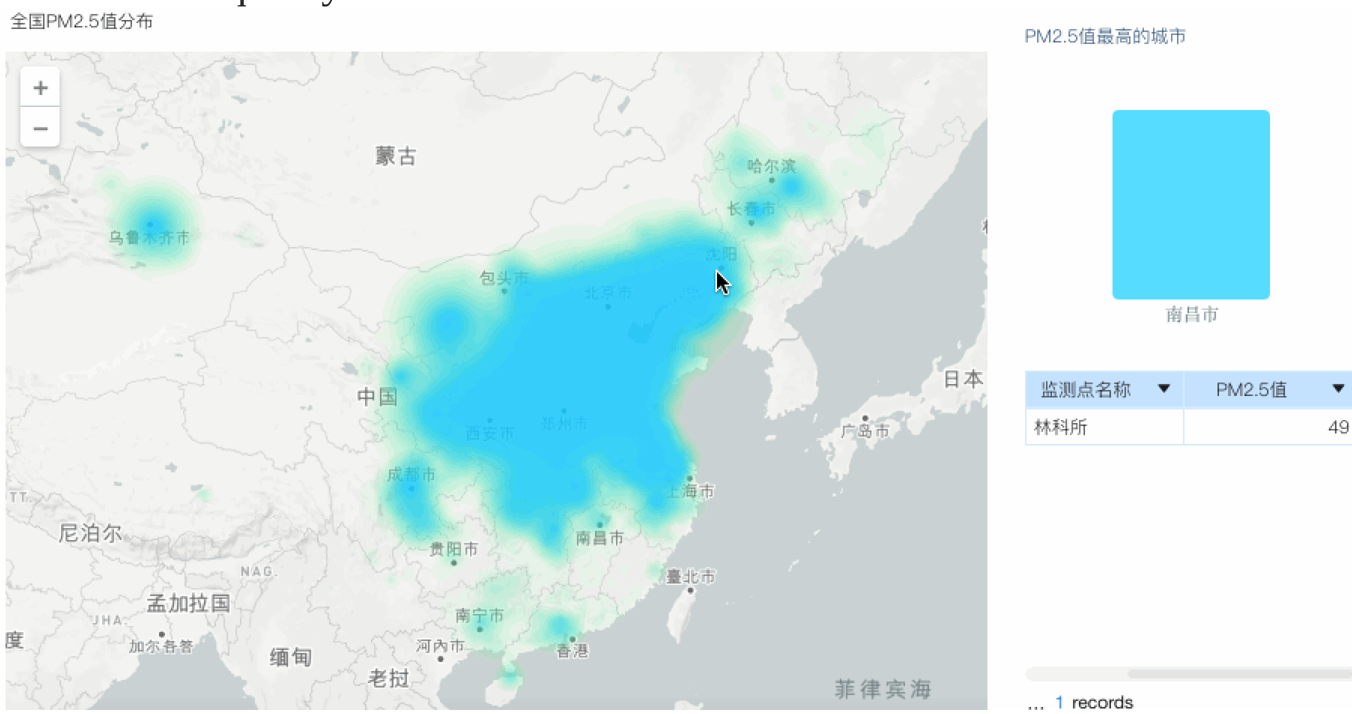
3. Flow Map

Flow maps are often used to visualize origin-destination flow data. The origin and destination can be points or surfaces. The interaction data between the origin and the destination is usually expressed by a line that connects the geometric center of gravity of the space unit. The width or color of the line indicates the flow direction value between the origin and the destination. Each spatial location can be either a origin or a destination.

Use scenarios: inter-regional trade, traffic flow, population migration, shopping consumption behavior, communication information flow, aviation routes, etc.

4. Heatmap

The heatmap is used to indicate the weight of each point in the geographical range. It is usually displayed in a special highlight. As shown in the figure below, it is a haze map. The darker the color of the area, the worse the air quality of the area.



Use scenarios: PM 2.5 distribution, registration date and age distribution, product preference distribution, etc.

Topic 5: geographic information

Geographic information can be visualized using various techniques such as maps, heatmaps, choropleth maps, and cartograms

[1]

[2]

[3]

. Maps are one of the most common ways to visualize geographic information. They can be used to show the location of points of interest, the distribution of data across regions, or the relationship between different variables and geographical locations

[2]

.Heatmaps use color intensity to represent the density of points in an area. Choropleth maps use color shading or patterns to represent different values of a variable across regions such as countries or states. Cartograms distort the size or shape of regions based on a variable of interest

[1]

[2]

.There are several tools available for geospatial visualization such as ArcGIS, QGIS, Tableau, and Google Earth

[4]

. These tools allow users to create custom maps and visualizations that help them explore and analyze geographic data.In conclusion, geospatial visualization is an important step in any GIS project. The choice of technique depends on the type and amount of data being visualized and the insights that need to be communicated.

GeoMapping used to develop complex visualizations of large geographically related data. Maps are only the ways of visualizing data.

By visualizing geospatial data, show and correlate different variables to geographical locations by layer all these variables over maps. GeoMap can be the map of any country, world, region map which has colors and values assigned to regions. Geospatial Visualization can be 2D contains latitude and longitude, and can be three dimensional also

We create maps using abstract shapes and colors to reveal geographic patterns and tell stories about human existence. Visualize the maps by giving colors, shapes to understand geographic patterns and in the form of stories. Follow the below process to create interactive Geospatial visualizations -

- Data collection
- Data processing
- Exploration with web-based tools as map box, carto, etc.
- To build prototypes, port visualizations into java script with tools leaflet.js, react.

What are the Different map layers or map types use to visualize geospatial data?

The various types of map layers or map types use to visualize geospatial data are listed below:

- Point Map
- Choropleth Map
- Cluster Map
- Heat Map
- Proportional symbol map
- Cartogram map
- Hexagonal binning map
- Topographic map

- Spider map
- Flow map
- Time-space distribution map

We discuss a few of them below.

Point Map

Point map can be used to plot places and locations using latitude and longitude data. It uses points or dots to locate the data.

Choropleth Map

Choropleth Map shows data in the form of the aggregate sum of geographic regions. Uses categorical or numerical data and use color scales to assign colors to data.

Cluster Map

Cluster maps represent a large number of data points using a single map. Each cluster labeled with many points grouped in this cluster.

Heat Map

Heat maps used to visualize a large amount of continuous data on a map using various color spectrums.

Flow map

Flow maps (Path Maps)- Instead of concentrating on the earth's physical features, they illustrate the movement of things over time across the earth, like migrating humans or animals, resources, vehicles, traffic, and weather patterns

Spider map

Spider map a variation of the flow map. Instead of focusing on discrete pairs of source and destination data points, the spider map focuses on the associations between origin points and multiple destination points – some of which may be common.

Time-space distribution map

A time-space distribution map is an advanced form of geospatial data mapping that combines a point map's precision with a flow map's dynamism. The most common use case of the map is monitoring the locations of vehicles or mobile devices through GPS

TOPIC 6: GIS systems

Geographic Information Systems (GIS) are an important tool for data visualization. GIS software allows users to create maps and visualizations that help them explore and analyze geographic data
[1]

[2]

.GIS systems can be used to visualize various types of geospatial data such as satellite imagery, terrain data, and demographic data. Visualization elements include coloring, map extent, labels, boundaries, interactivity, 3D models, and more
[1]

.There are several GIS software tools available for creating maps and visualizations such as ArcGIS, QGIS, and Google Earth
[3]

. These tools allow users to create custom maps with compelling data visualizations that guide the interpretation of the data.In addition to GIS software tools, there are also specialized tools for geospatial data visualization such as Tableau. Tableau allows users to create interactive dashboards that combine geographic information with other types of data [4]

.In conclusion, GIS systems are an essential tool for geospatial data visualization. They allow users to create custom maps and visualizations that help them explore and analyze geographic data.

Below are some common map elements and design attributes to consider when visualizing your data:

Map Elements:

- Title
- Map Symbols
- Legend
- Map Scale
- North Arrow
- Map Area
- Labels
- Borders and Neatlines
- Graticule or Coordinate Grid

Map Design

- Colors and Shading
- Typography/Font
- Focus of attention
- Map element hierarchy/Figure-ground considerations

TOPIC 7 : collaborative visualizations

Collaborative visualizations are an important tool for data visualization. Collaborative visualization is the shared use of computer-supported, interactive visual representations of data by more than one person with the common goal of contribution to joint information processing activities
[1]

[2]

.Real-time, collaborative cloud visualization tools allow users to accurately visualize their cloud environment in real time
[3]

. These tools can be used to create interactive dashboards that combine geographic information with other types of data.There are several data visualization tools available with collaborative features such as Tableau, Miro, and YouTeam
[4]

[5]

. These tools allow teams to present data in the most effective way possible and collaborate on projects remotely.In conclusion, collaborative visualizations are an important tool for data visualization. They allow teams to present data in the most effective way possible and collaborate on projects remotely.

Patterns of collaboration are always changing, which makes it challenging to visualize and understand. We already know that teams in Miro expand as their companies grow, and as more people at the company adopt the product. So, we asked ourselves: what if we can view these interactions as a social network? All users are connected to each other through the boards where they collaborate, so maybe we could simply take various events — such as when a board loads, or a widget is created — and construct a graph. We can monitor how the graph changes over time, as more teams use Miro to collaborate with each other, to see how the patterns of collaboration also evolve.

TOPIC 8 : Evaluating visualizations

Criteria for evaluating data visualization tools

Top considerations for choosing visualization tools include:

- ease of use and ability to map data to the visualization;
- type and quality of visualization output;
- availability of tool to run on laptop, tablet or server;
- cost considerations of the visualization tool and training if available;
- data import options;
- how the tool is installed and the system requirements for installation;
- interactivity of visualizations; and
- security of the tool relative to how the data is accessed.

  - Data visualization is one of the most important branches in data science. It is one of the main tools use to analyze and study relationships between different variables. Data visualization can be used for descriptive analytics. Data visualization is also used in machine learning during data preprocessing and analysis; feature selection; model building; model testing; and model evaluation.

- In machine learning (predictive analytics), there are several metrics that can be used for model evaluation. For example, supervised learning (continuous target) model can be evaluated using metrics such as the R2 score, mean square error (MSE), or mean absolute error (MAE). Furthermore, a supervised learning (discrete target) model, also referred to as a classification model can be evaluated using metrics such as accuracy, precision, recall, f1 score, the area under ROC curve (AUC), etc.

- Unlike machine learning models that can be evaluated by using a single performance metric, a data visualization cannot be evaluated by looking at just a single metric. Instead, a good data visualization can be evaluated based on the characteristics or components of the data visualization.

- In this article, we discuss the essential components of good data visualization. In Section II, we present the various components of a good data visualization. In Section III, we examine some examples of good data visualizations. A brief summary concludes the article.

- **II. Components of a Good Data Visualization**

- A good data visualization is made up of several components that have to be pieced up together to produce an end product:

- a) **Data Component**: An important first step in deciding how to visualize data is to know what type of data it is, e.g. categorical data, discrete data, continuous data, time series data, etc.

- b) **Geometric Component:** Here is where you decide what kind of visualization is suitable for your data, e.g. scatter plot, line graphs, barplots, histograms, qqplots, smooth densities, boxplots, pairplots, heatmaps, etc.

- c) **Mapping Component:** Here you need to decide what variable to use as your *x-variable (independent or predictor variable)* and what to use as your *y-variable (dependent or target variable)*. This is important especially when your dataset is multi-dimensional with several features.

- d) **Scale Component:** Here you decide what kind of scales to use, e.g. linear scale, log scale, etc.

- e) **Labels Component:** This includes things like axes labels, titles, legends, font size to use, etc.

- f) **Ethical Component**: Here, you want to make sure your visualization tells the true story. You need to be aware of your actions when cleaning, summarizing, manipulating, and producing a data visualization and ensure you aren't using your visualization to mislead or manipulate your audience.