



CSE3020 - Data Visualization

Module 3 :Visual Analytics

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Topics to be covered

2

- Visual Variables
- Networks and Trees
- Map Color and Other Channels
- Manipulate View

Visual Variables

3

■ Introduction

- an **aspect of a graphical object** that can visually differentiate it from other objects, and can be controlled during the design process
- Used to communicate visually

Visual Variables

4

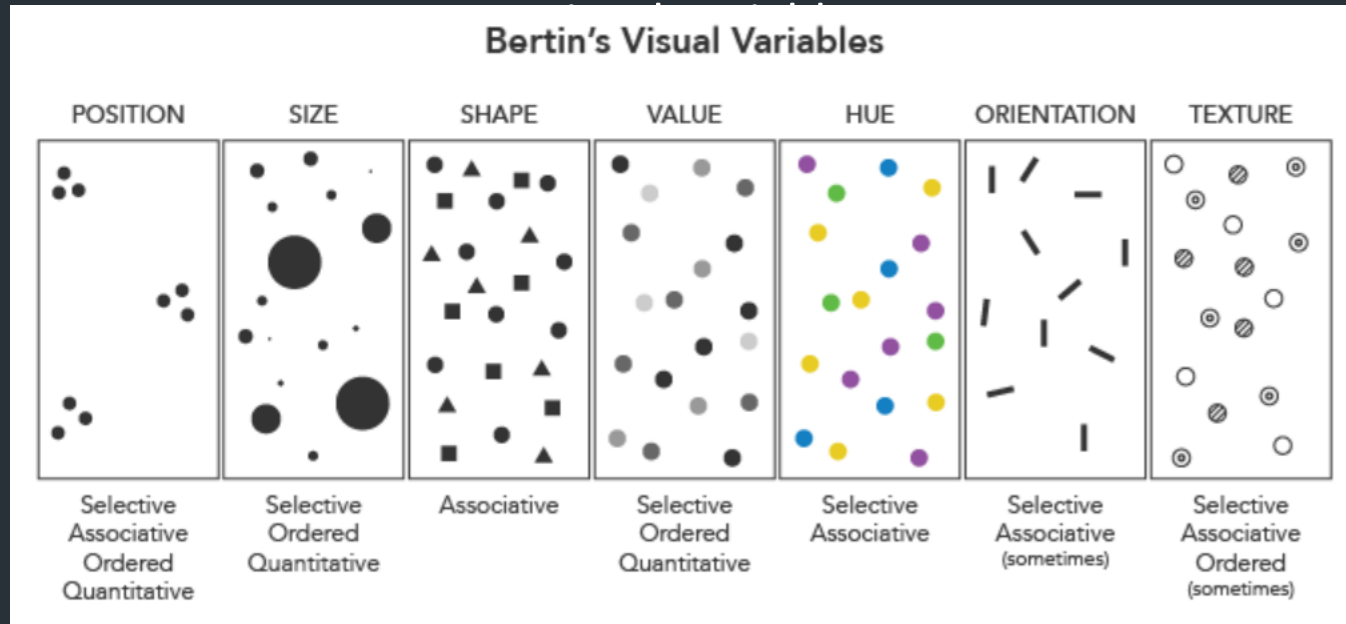
■ Introduction

- Visual Variables
 - Position
 - Size
 - Shape
 - Hue
 - Saturation / Lightness (Value)
 - Orientation
 - Spacing/arrangement
 - Perspective Height
 - Texture

Visual Variables

5







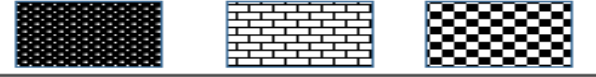
■ Introduction



Visual Variables

6

■ Bertin's Visual Variables

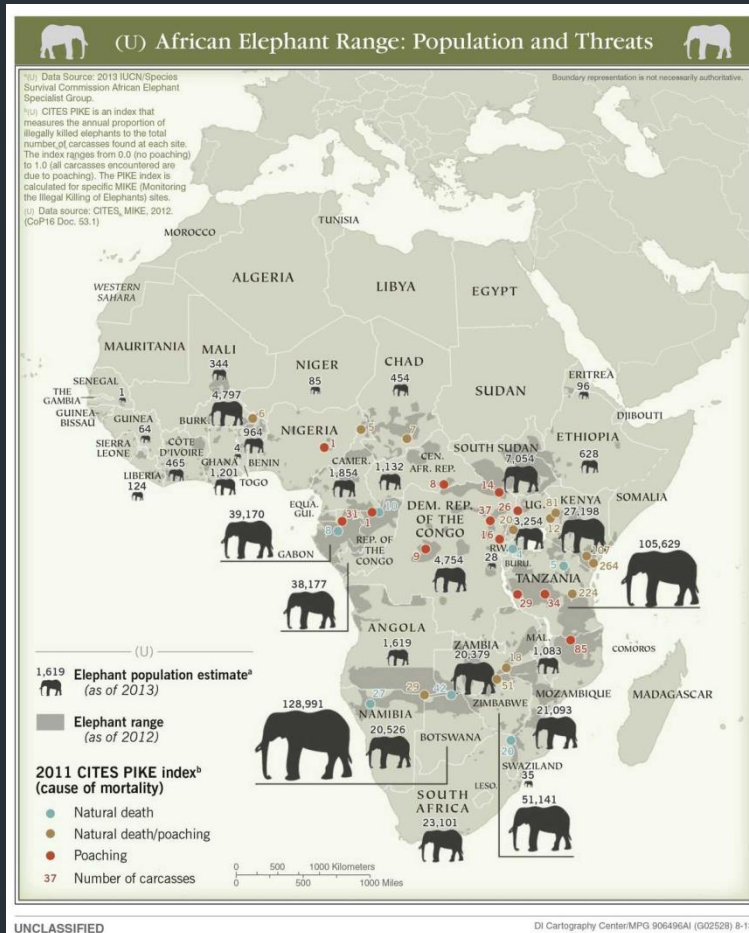
Position: changes in the x,y location	
Size: change in length, area or repetition	
Shape: infinite number of shapes	
Value: changes from light to dark	
Colour : changes in hue at a given value	
Orientation: changes in alignment	
Texture: variation in `grain`	

■ Shape



Visual Variables

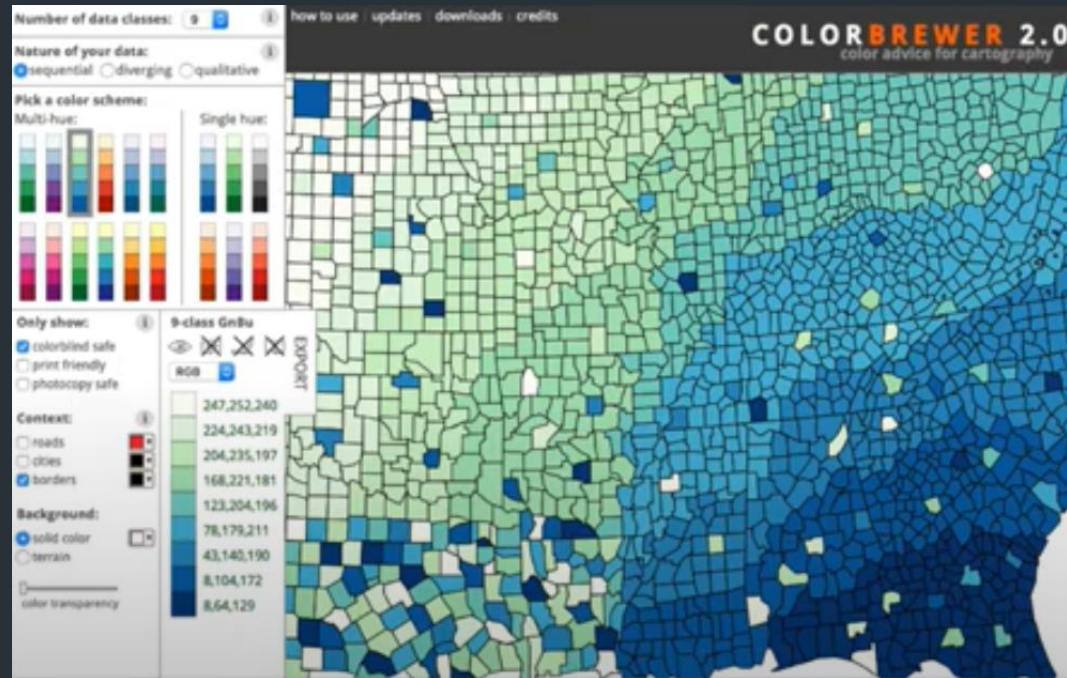
■ Size and Shape



Visual Variables

10

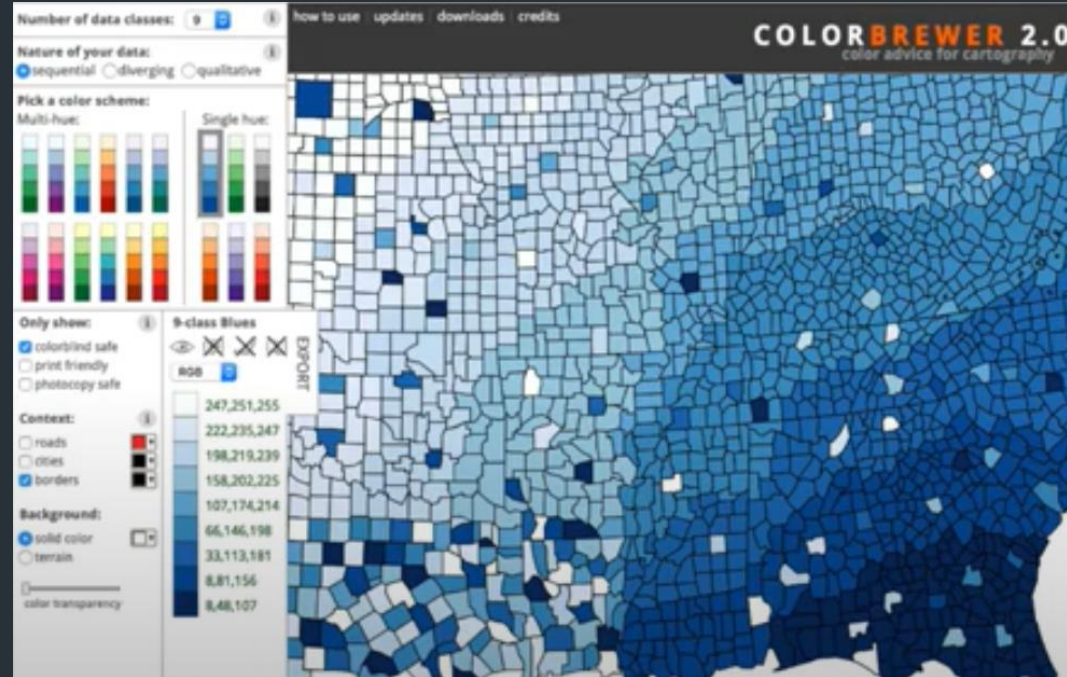
■ Hue



Visual Variables

11

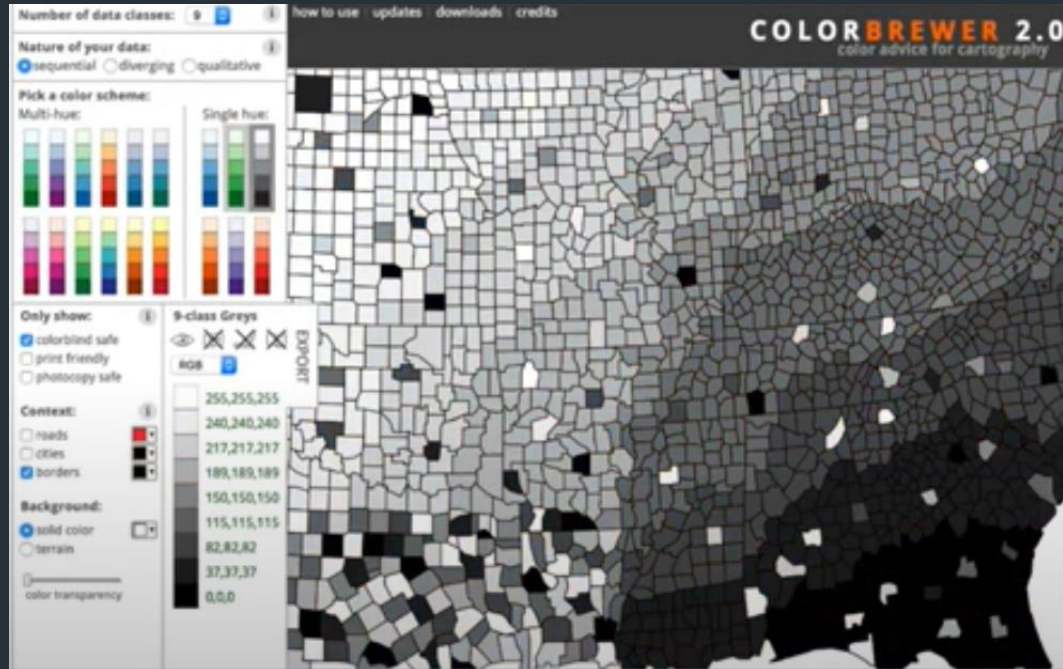
■ Saturation



Visual Variables

12

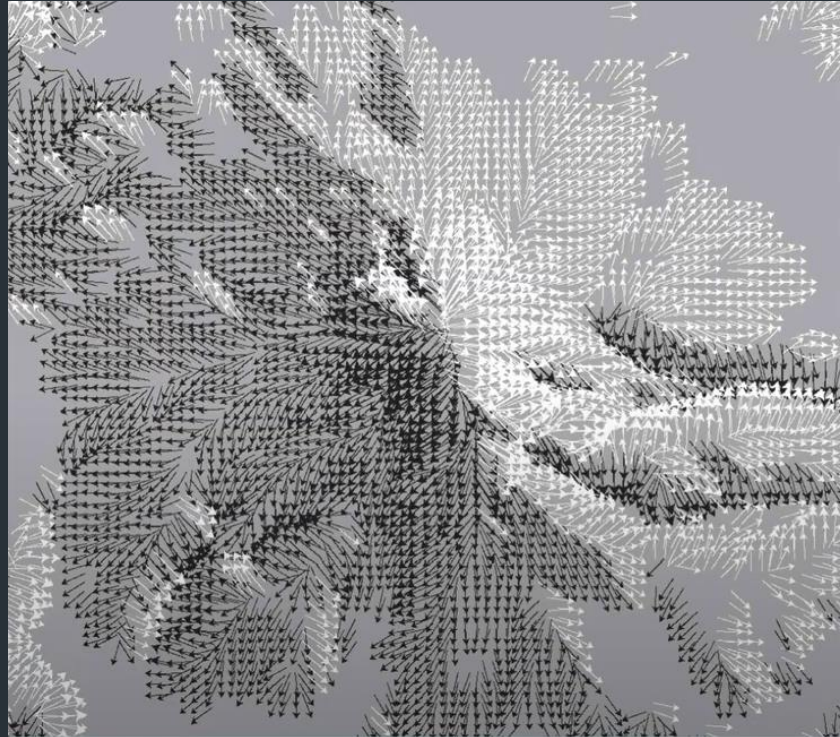
■ Lightness (grayness)



Visual Variables

13

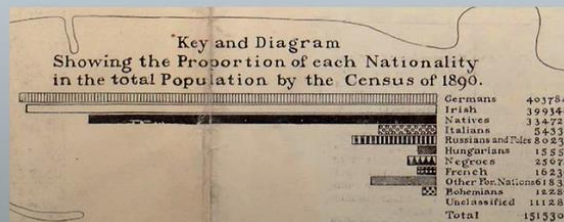
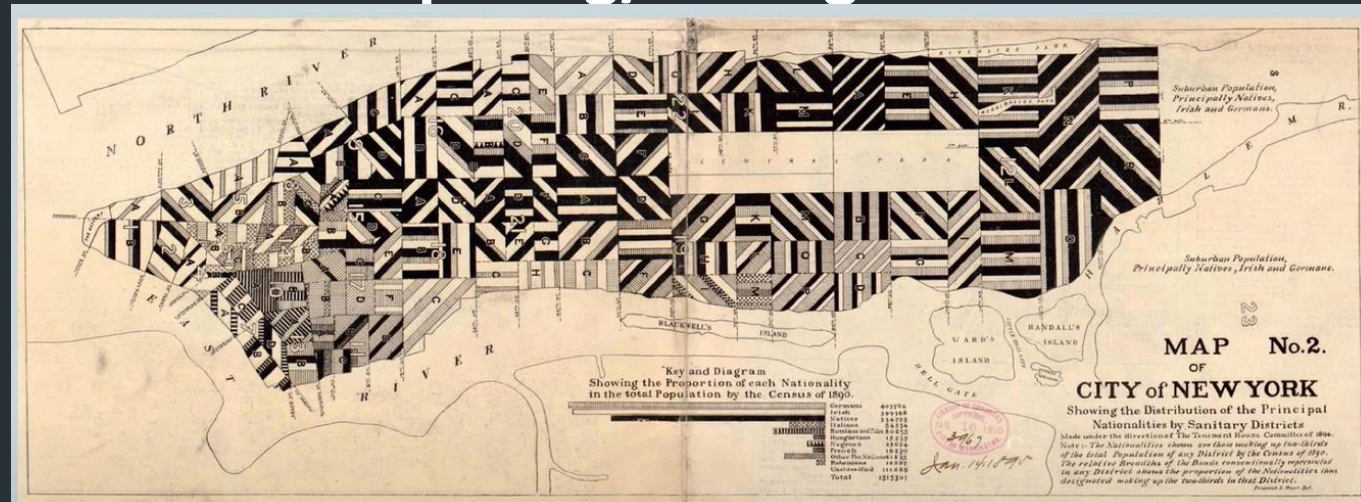
■ Orientation



Visual Variables

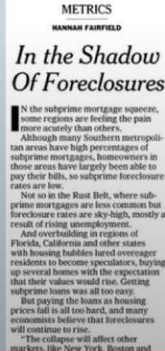
14

■ Spacing/Arrangement



Map of New York City, Showing the Distribution of the Principal Nationalities by Sanitary Districts published in Harper's Weekly (January 5, 1895, pp. 60–61) using 1890 U.S. Census data.

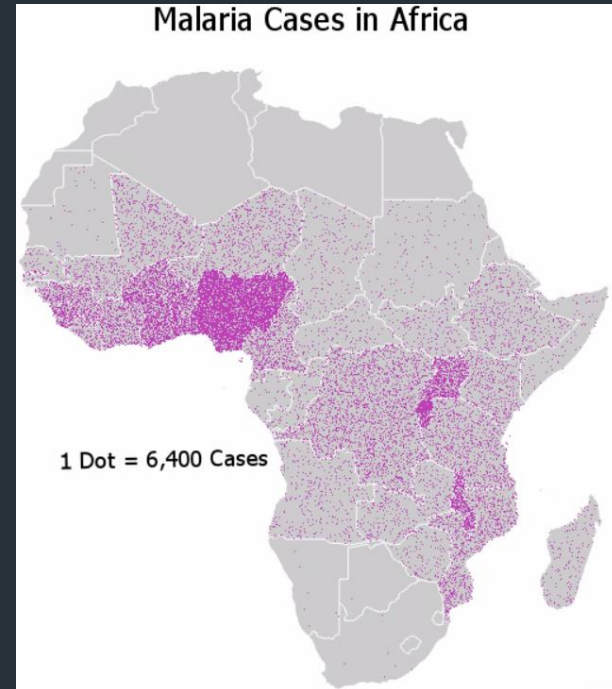
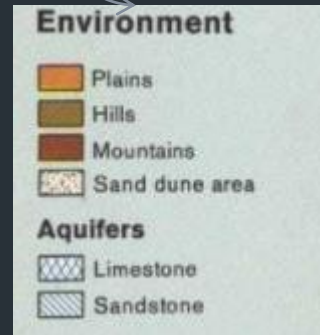
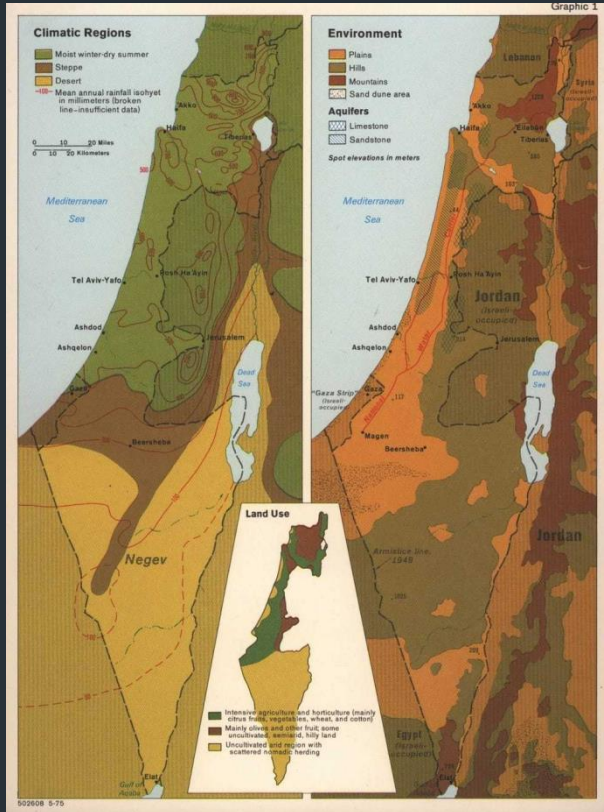
■ Perspective Height



Visual Variables

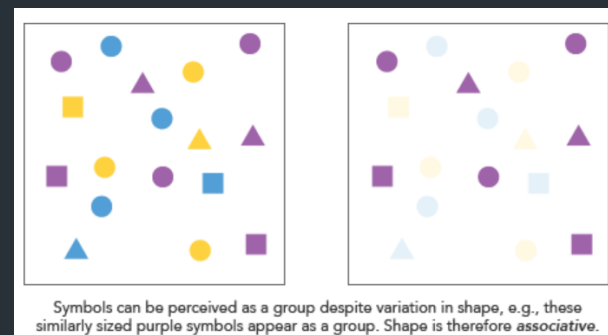
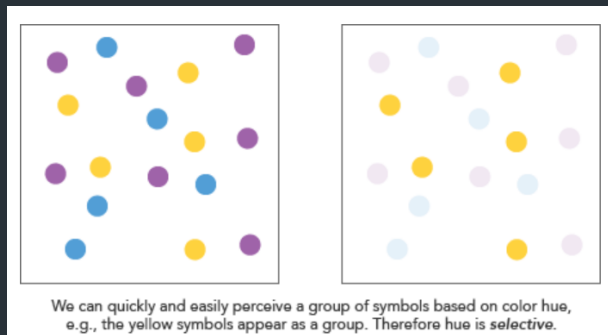
16

■ Texture



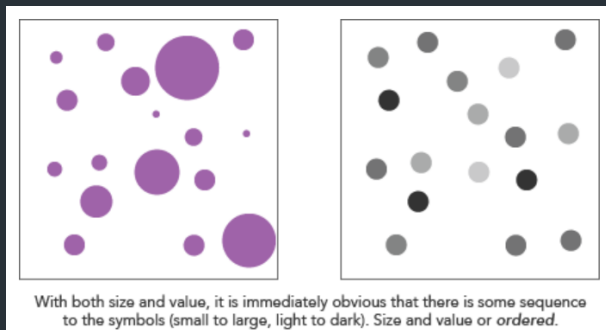
Visual Variables

17



■ Properties of Visual Variable

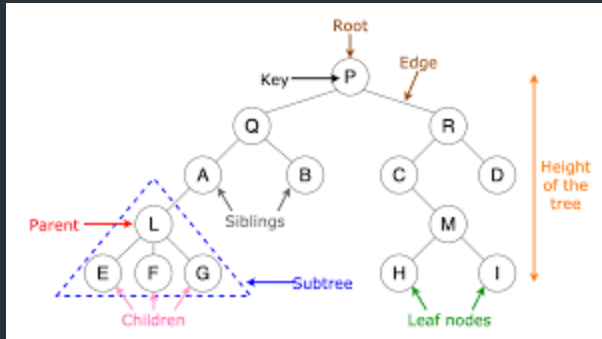
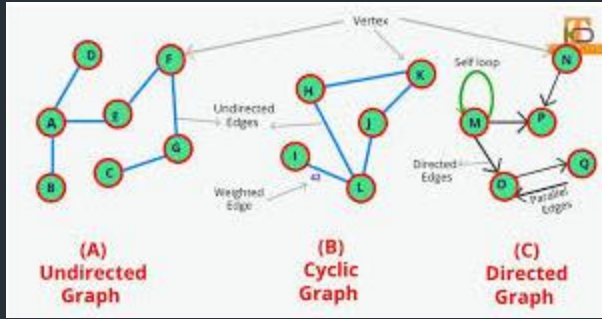
- Selective
 - allows us to immediately isolate a group of signs based on a change in the variable.
 - Ex :Hue
- Associative
 - allows grouping across changes in the variable
 - Ex : Hue and Shape
- Ordered
- Quantitative



■ Properties of Visual Variable

- Ordered
 - immediately recognizable sequence
 - Ex: Size, Value, Position, Symbol
- Quantitative
 - allow an estimation of the actual numerical difference between symbols
 - Ex: Size

Networks and Trees¹⁹



■ Graphs and Trees

■ Graph

- Vertex/node with one or more edges connecting it to another node.
- Cyclic or acyclic
- Edge can be weighted (value) or categorized

■ Tree

- Undirected graph where two nodes are connected by only one edge
- used for hierarchy
- Edge can be weighted (value) or categorized

Networks and Trees²⁰

- **Design Choices**

- Connectivity

- Node-link graphs
- Good for finding pairwise/multiway relations
- Good for following paths through structure
- Force-directed placement

- Containment

- Effective at showing hierarchical structure
- Good for finding attributes of leaf nodes
- Treemaps, nested views

- Matrices

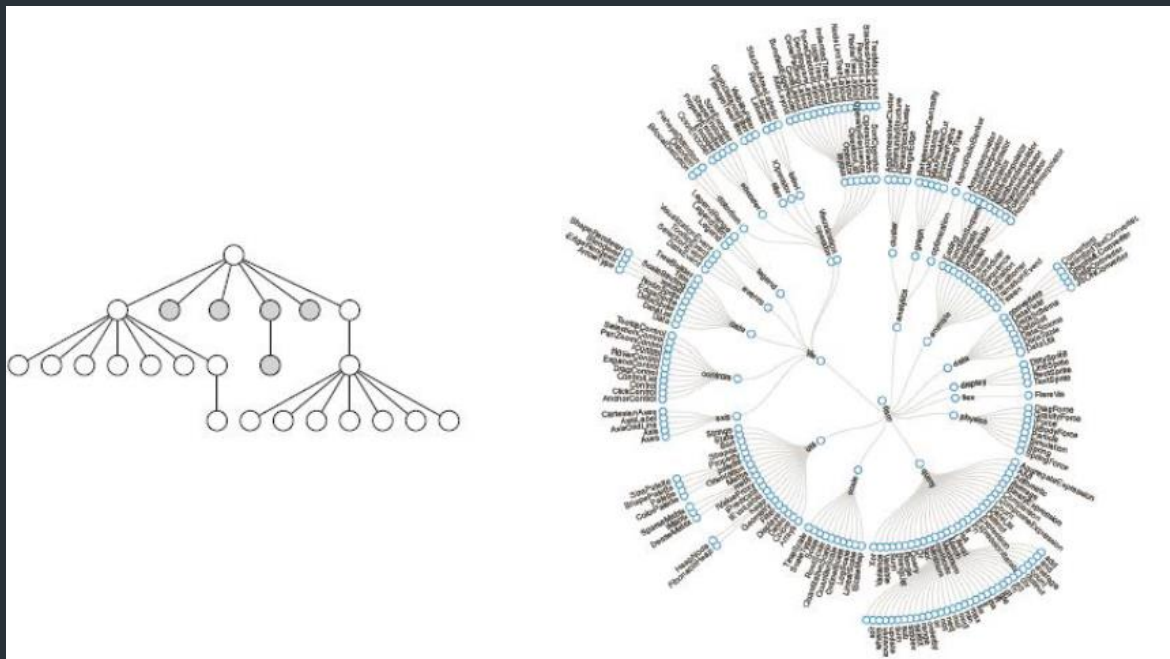
Networks and Trees²¹

- **Node Link Diagrams**

- Visual encoding idiom for tree and network data is with node–link diagrams, where **nodes are drawn as point marks** and the **links** connecting them are drawn as **line marks**

Networks and Trees²²

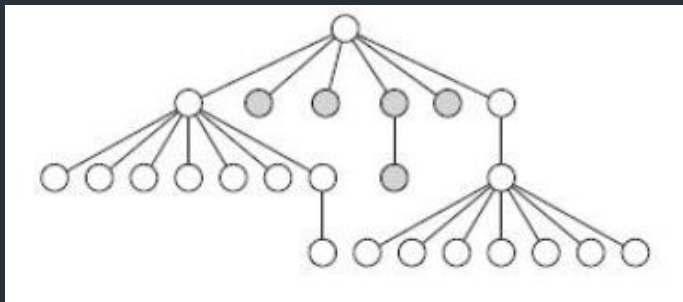
■ Node Link Diagrams



(a) Triangular vertical for tiny tree

(b) Spline radial layout for small tree

Networks and Trees²³

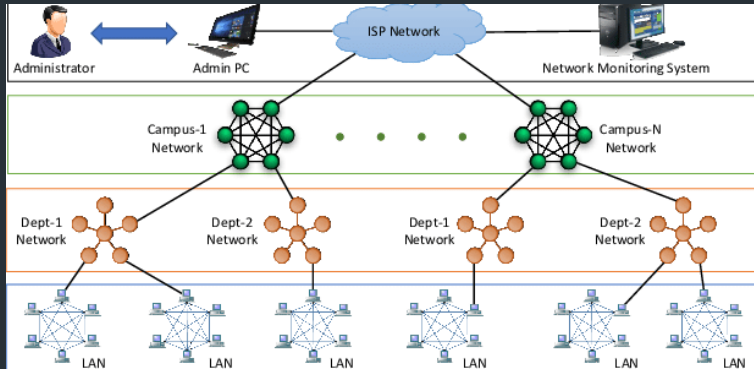


■ Node Link Diagrams

- directly connected by a single link are perceived as having the **tightest grouping**
- nodes with a long path of multiple hops between them are **less closely grouped**.
- The number of hops within a path - the number of individual links that must be traversed to get from one node to another - is a network-oriented way to measure distances.

Networks and Trees²⁴

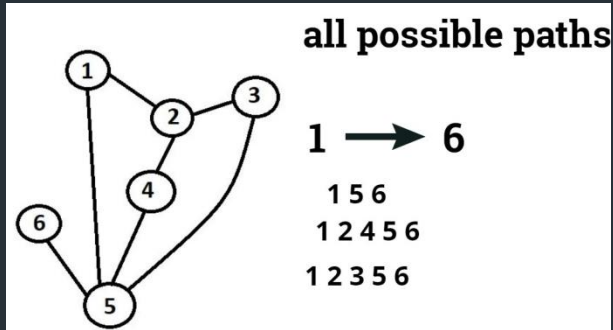
■ Node Link Diagrams



- It is well suited for tasks that involve understanding the network topology
 - direct and indirect connections between nodes in terms of the number of hops between them through the set of links.
- Examples of topology tasks include
 - finding all possible paths from one node to another,
 - finding the shortest path between two nodes,
 - finding all the adjacent nodes one hop away from a target node,
 - finding nodes that act as a bridge between two components of the network that would otherwise be disconnected.

Networks and Trees²⁵

■ Node Link Diagrams



- Examples of topology tasks include
 - finding all possible paths from one node to another,
 - finding the shortest path between two nodes,
 - finding all the adjacent nodes one hop away from a target node,
 - finding nodes that act as a bridge between two components of the network that would otherwise be disconnected.

Networks and Trees²⁶

- Example: Force-Directed Placement
 - One of the **most widely used idioms** for node-link layout using connection marks is force directed placement
 - Application areas:
 - network visualization, large graph visualization, knowledge representation, system management, or mesh visualization
 - **Minimize** the number of distracting artifacts such as **edge crossings and node overlaps**

Networks and Trees²⁷

- Example: Force-Directed Placement
 - Force-directed graph drawing algorithms assign forces among the set of edges and the set of nodes of a graph drawing.
 - Spring-like attractive forces based on Hooke's law are used to attract pairs of endpoints of the graph's edges towards each other.
 - simultaneously repulsive forces based on Coulomb's law are used to separate all pairs of nodes

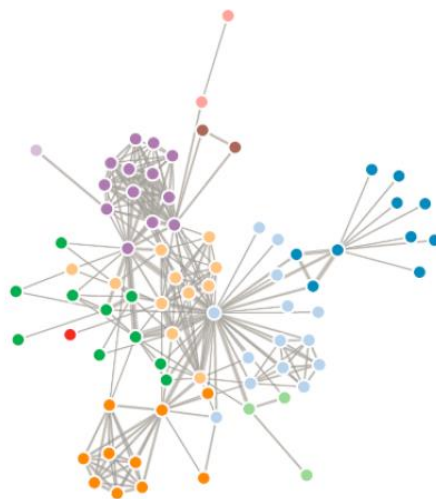
Networks and Trees²⁸

■ Example: Force-Directed Placement

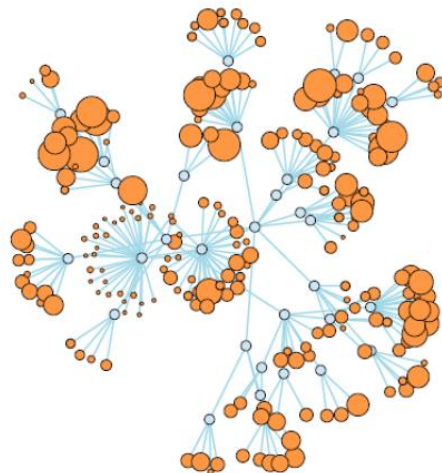
Idiom	Force-Directed Placement
What: Data	Network.
How: Encode	Point marks for nodes, connection marks for links.
Why: Tasks	Explore topology, locate paths.
Scale	Nodes: dozens/hundreds. Links: hundreds. Node/link density: $L < 4N$

Networks and Trees²⁹

■ Example: Force-Directed Placement



(a)



(b)

(a) with size coding for link attributes. (b) with size coding for node attributes.

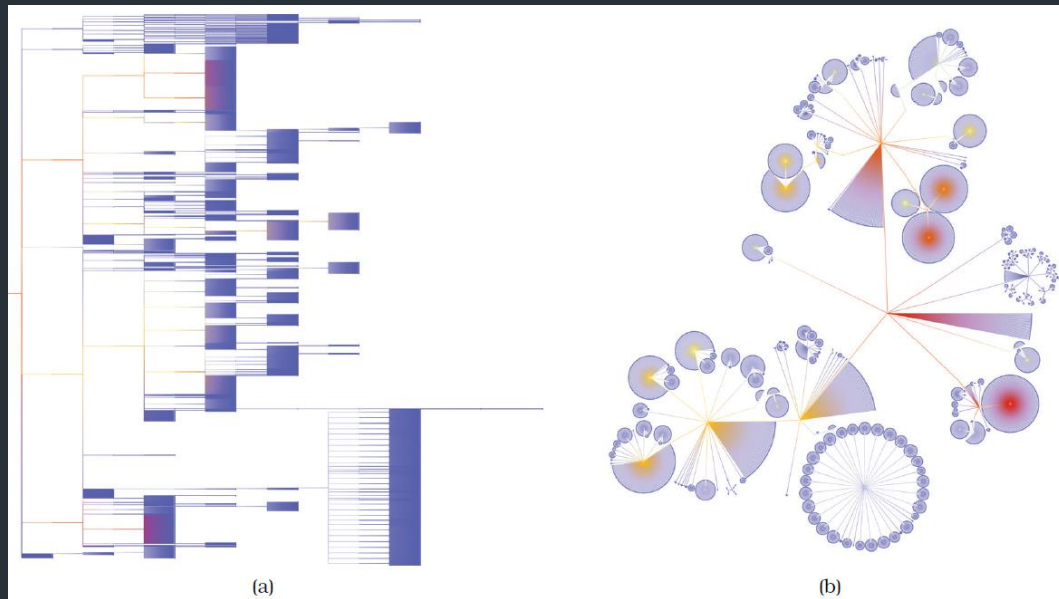
Networks and Trees³⁰

■ Example: Force-Directed Placement

Two layouts of a 5161-node tree.

(a) Rectangular horizontal node-link layout.

(b) BubbleTree node-link layout.

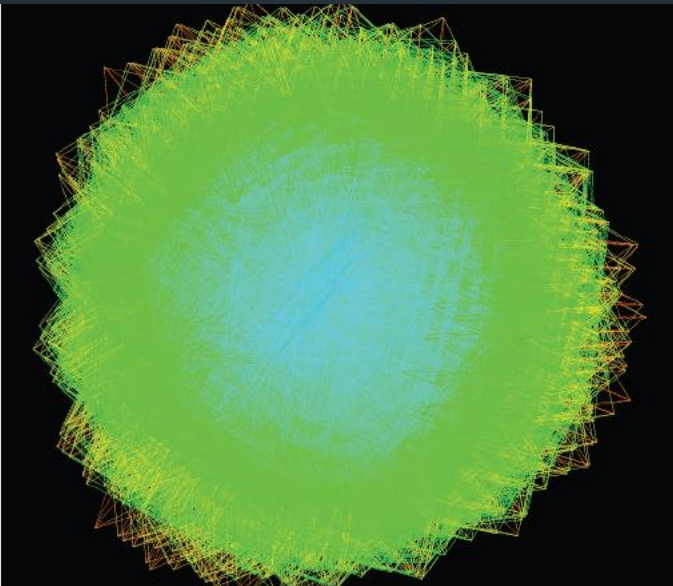
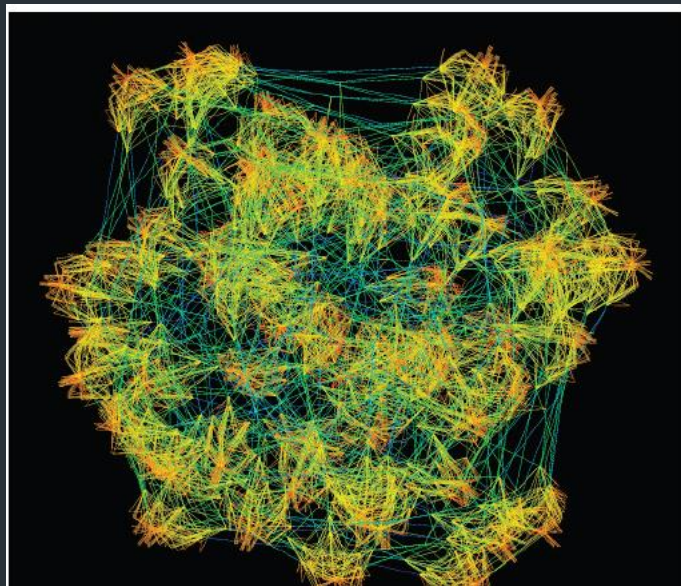


Networks and Trees³¹

- Example: Force-Directed Placement
- Strength
 - Very easy to implement. Relatively easy to understand and explain at a conceptual level
- Weakness
 - Nondeterministic layout
 - different each time the algorithm is run
 - Scalability
 - visual and time complexity
 - Very brittle
 - based on optimization algorithms - get stuck in local minimum

Networks and Trees³²

- Scalable Force-Directed Placement
 - edges are colored by length



Networks and Trees³³

■ Multilevel Force-Directed Placement

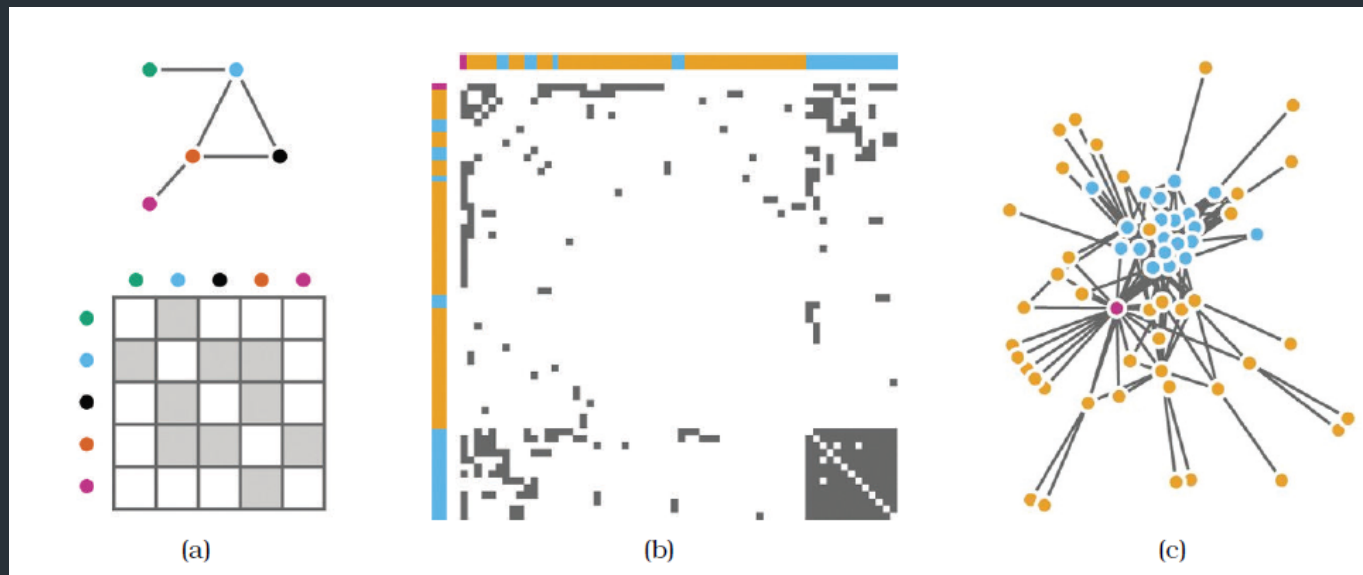
Idiom	Multilevel Force-Directed Placement (sfdp)
What: Data	Network.
What: Derived	Cluster hierarchy atop original network.
What: Encode	Point marks for nodes, connection marks for links.
Why: Tasks	Explore topology, locate paths and clusters.
Scale	Nodes: 1000–10,000. Links: 1000–10,000. Node/link density: $L < 4N$.

Networks and Trees³⁴

- Adjacency Matrix View
 - network can be visually encoded as an **adjacency matrix** view
 - network is transformed into the derived dataset of a table with two key attributes that are separate
 - full lists of every node in the network, and one value attribute for each cell records whether a link exists between the nodes that index the cell

Networks and Trees³⁵

■ Adjacency Matrix View



(a) Node-link and matrix views of small network.

(b) Matrix view of larger network. (c) Node-link view of larger network

Networks and Trees³⁶

■ Adjacency Matrix View

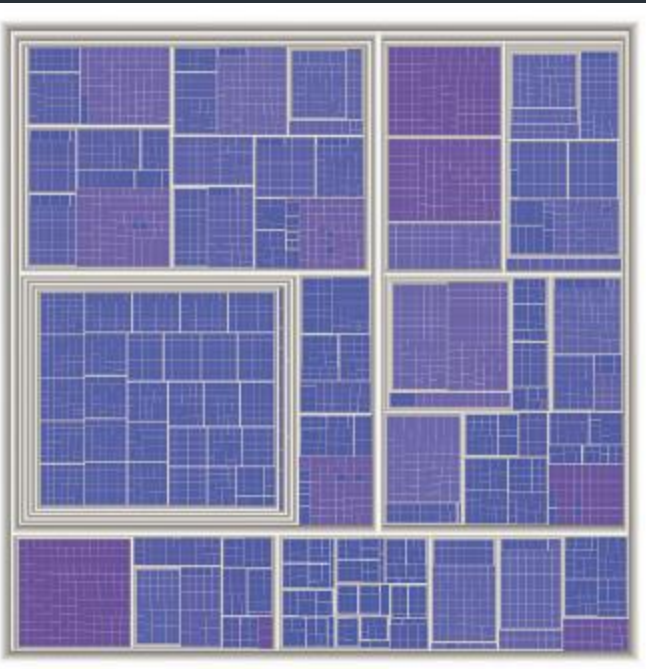
Idiom	Adjacency Matrix View
What: Data	Network.
What: Derived	Table: network nodes as keys, link status between two nodes as values.
How: Encode	Area marks in 2D matrix alignment.
Scale	Nodes: 1000. Links: one million.

Networks and Trees³⁷

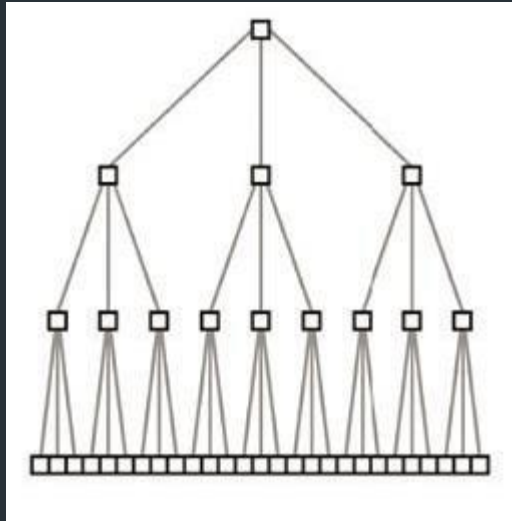


■ Containment

- Containment marks are very effective at showing complete information about hierarchical structure, in contrast to connection marks that only show pairwise relationships between two items at once.
- **Tree Maps:** The idiom of tree maps is an alternative to node-link tree drawings, where the hierarchical relationships are shown with containment rather than connection.



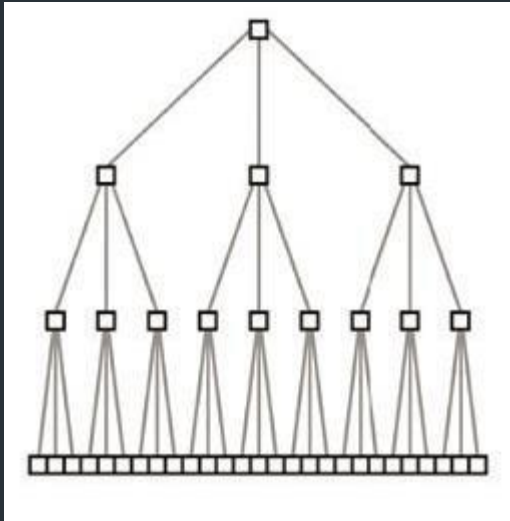
Seven different visual encoding idioms for tree data



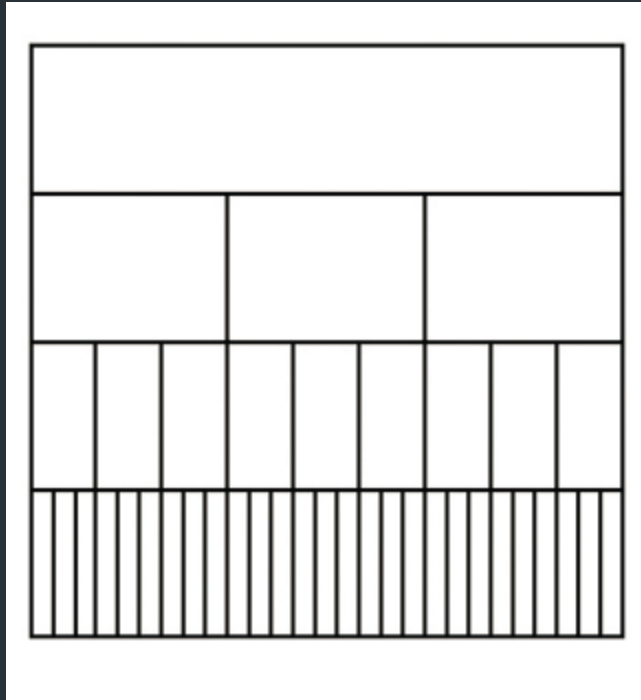
- **Using different combinations of visual channels.**
- (a) Rectilinear vertical node–link
- Connection to show link relationships
- Vertical spatial position
 - tree depth
- Horizontal spatial position
 - sibling order.

Seven different visual encoding idioms for tree data

■ (b) Icicle



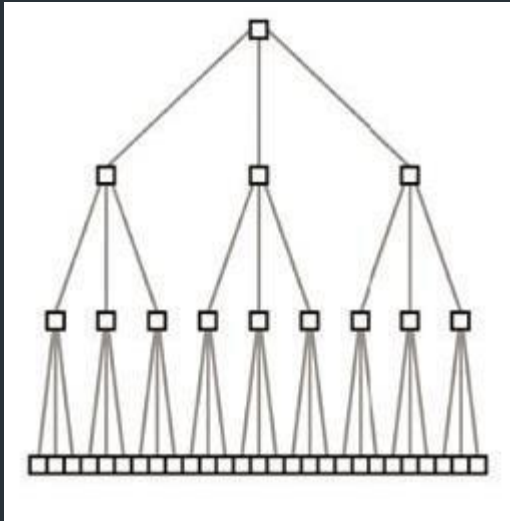
Seven different visual encoding idioms for tree data



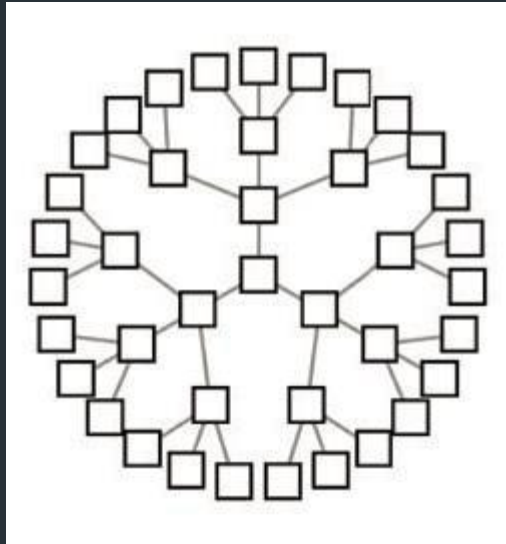
- **Using different combinations of visual channels.**
- (b) Icicle
- Vertical spatial position and size
 - tree depth
- Horizontal spatial position
 - link relationships and sibling order

Seven different visual encoding idioms for tree data

■ © Radial Node link



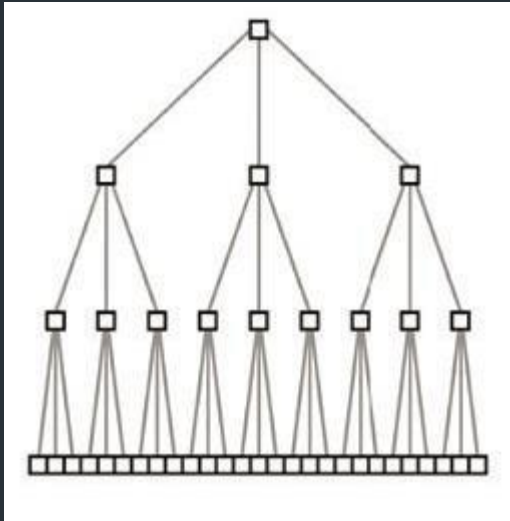
Seven different visual encoding idioms for tree data



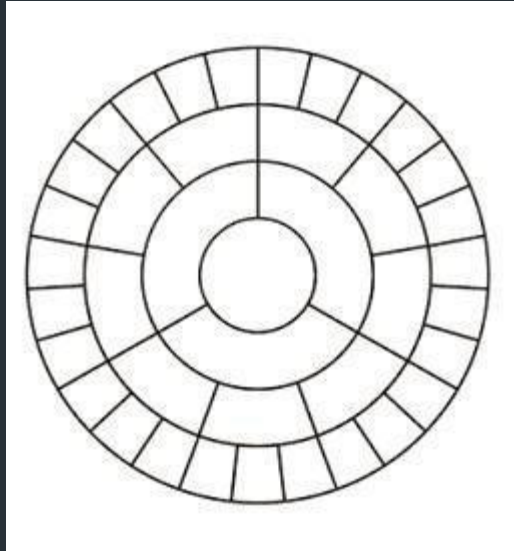
- **Using different combinations of visual channels.**
- (c) Radial node-link
- connection to show link relationships
- Radial depth spatial position
 - tree depth
- radial angular position
 - sibling order

Seven different visual encoding idioms for tree data

■ (d) Concentric circles



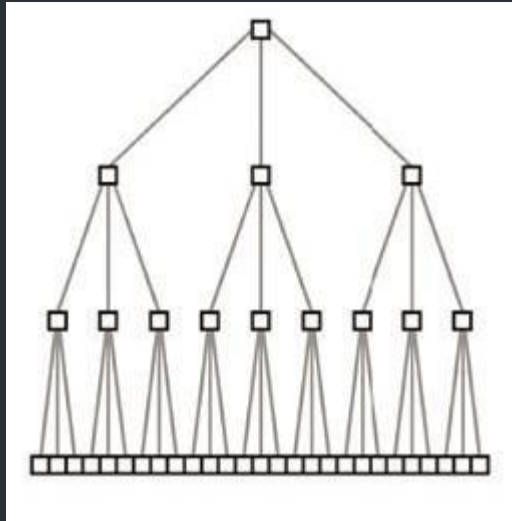
Seven different visual encoding idioms for tree data



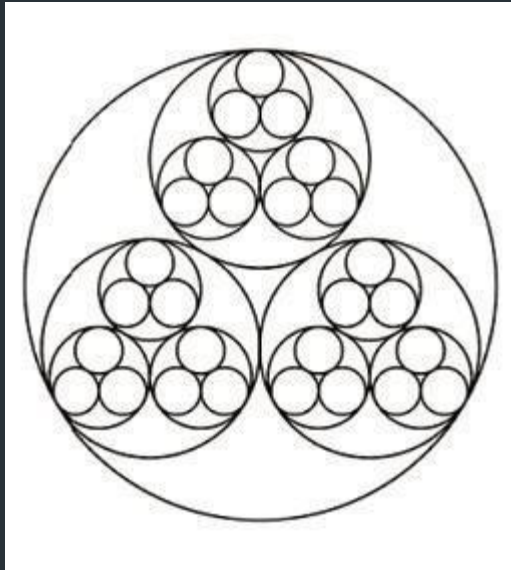
- **Using different combinations of visual channels.**
- (d) Concentric circles, with radial depth spatial position and size showing tree depth and radial angular spatial position showing link relationships and sibling order.

Seven different visual encoding idioms for tree data

- (e) Nested circles



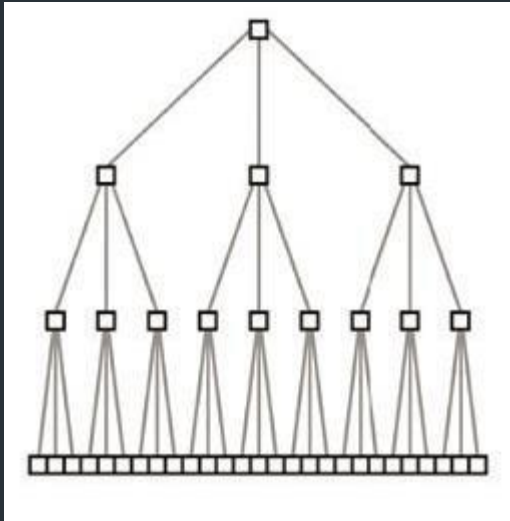
Seven different visual encoding idioms for tree data



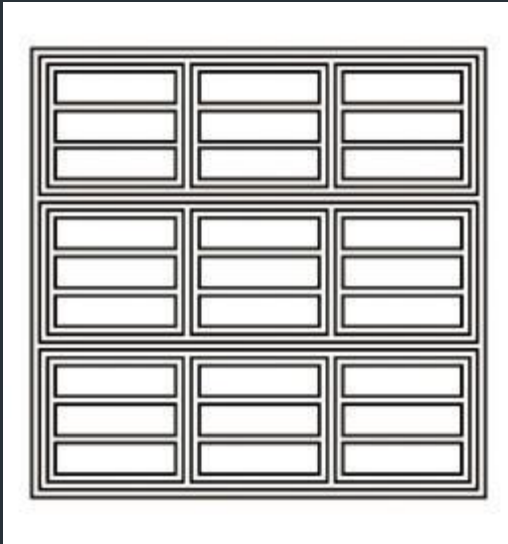
- **Using different combinations of visual channels.**
- (e) Nested circles, using radial containment, with nesting level and size showing tree depth

Seven different visual encoding idioms for tree data

■ (f) Treemap



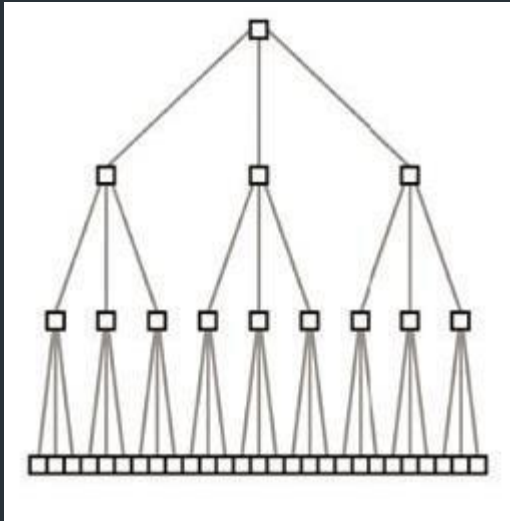
Seven different visual encoding idioms for tree data



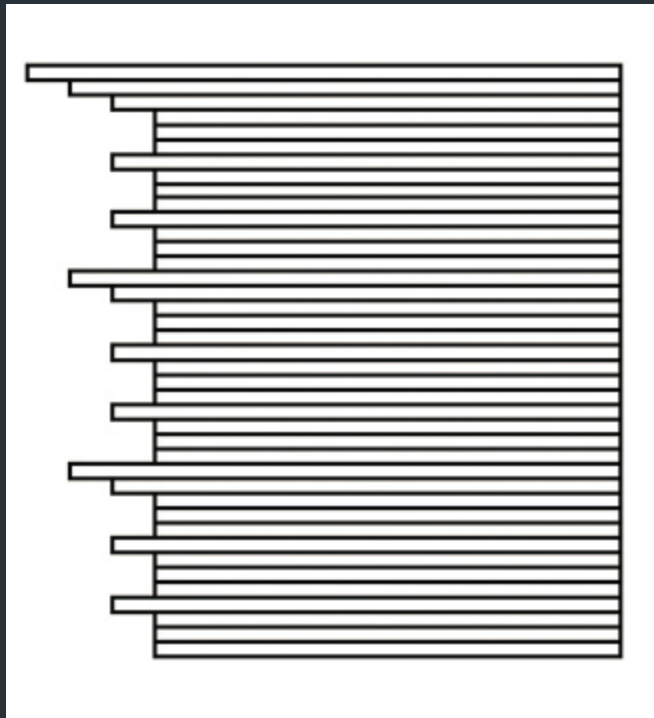
- **Using different combinations of visual channels.**
- (f) Treemap, using rectilinear containment, with nesting level and size showing tree depth

Seven different visual encoding idioms for tree data

■ (g) Indented outline



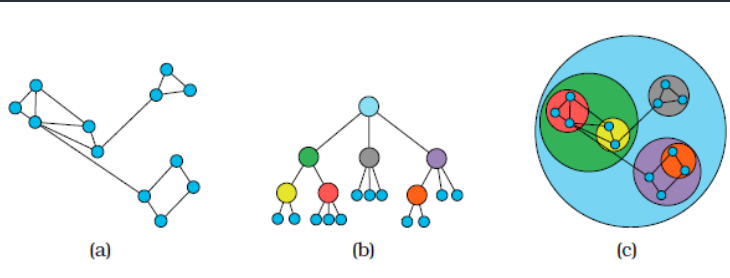
Seven different visual encoding idioms for tree data



- **Using different combinations of visual channels.**
- (g) Indented outline, with horizontal spatial position showing tree depth and link relationships and vertical spatial position showing sibling order

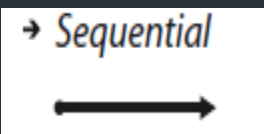
Compound Network

- A compound network is a combination of a **network** and a **tree** on top of it, where the nodes in the network are the leaves of the tree.
- Thus, the interior nodes of the tree encompass multiple network nodes.
- (a) shows a network (b) shows a cluster hierarchy built on top of it. (c) shows a combined view using of containment marks for the associated hierarchy and connection marks for the original network links



Map Color and Other Channels

Introduction - Color



- The *color* is best understood in terms of three separate channels: luminance, hue, and saturation.
- Sequential ordered colormaps
 - show a progression of an attribute from a minimum to a maximum value
- Diverging ordered colormaps
 - have a visual indication of a zero point in the center where the attribute values diverge to negative on one side and positive on the other.
- Bivariate colormaps are designed to show two attributes simultaneously using carefully designed combinations of luminance, hue, and saturation

Color Space

- The **color space** of what colors the human visual system can detect is three dimensional; that is, it can be adequately described using three separate axes.
- There are many ways to mathematically describe color as a space and to transform colors from one such space into another.
- Some of these are extremely convenient for computer manipulation, while others are a better match with the characteristics of human vision.

Color Space

■ RGB System

- The most common color space in computer graphics is the system where colors are specified as triples of red, green, and blue values
- not useful as separable channels

Color Space

■ HSL System

- The **hue–saturation–lightness** or **HSL** system is more intuitive and is heavily used by artists and designers.
- The **hue** axis captures what we normally think of as pure colors that are not mixed with white or black: red, blue, green, yellow, purple, and so on.
- The **saturation** axis is the amount of white mixed with that pure color. For instance, pink is a partially desaturated red.
- The **lightness** axis is the amount of black mixed with a color.

Luminance, Saturation and Hue⁵⁷

- Color can be confusing in visual analysis because it is sometimes used as a magnitude channel and sometimes as an identity channel.
- *Luminance* and *saturation* are **magnitude** channels, while *hue* is a **identity** channel.

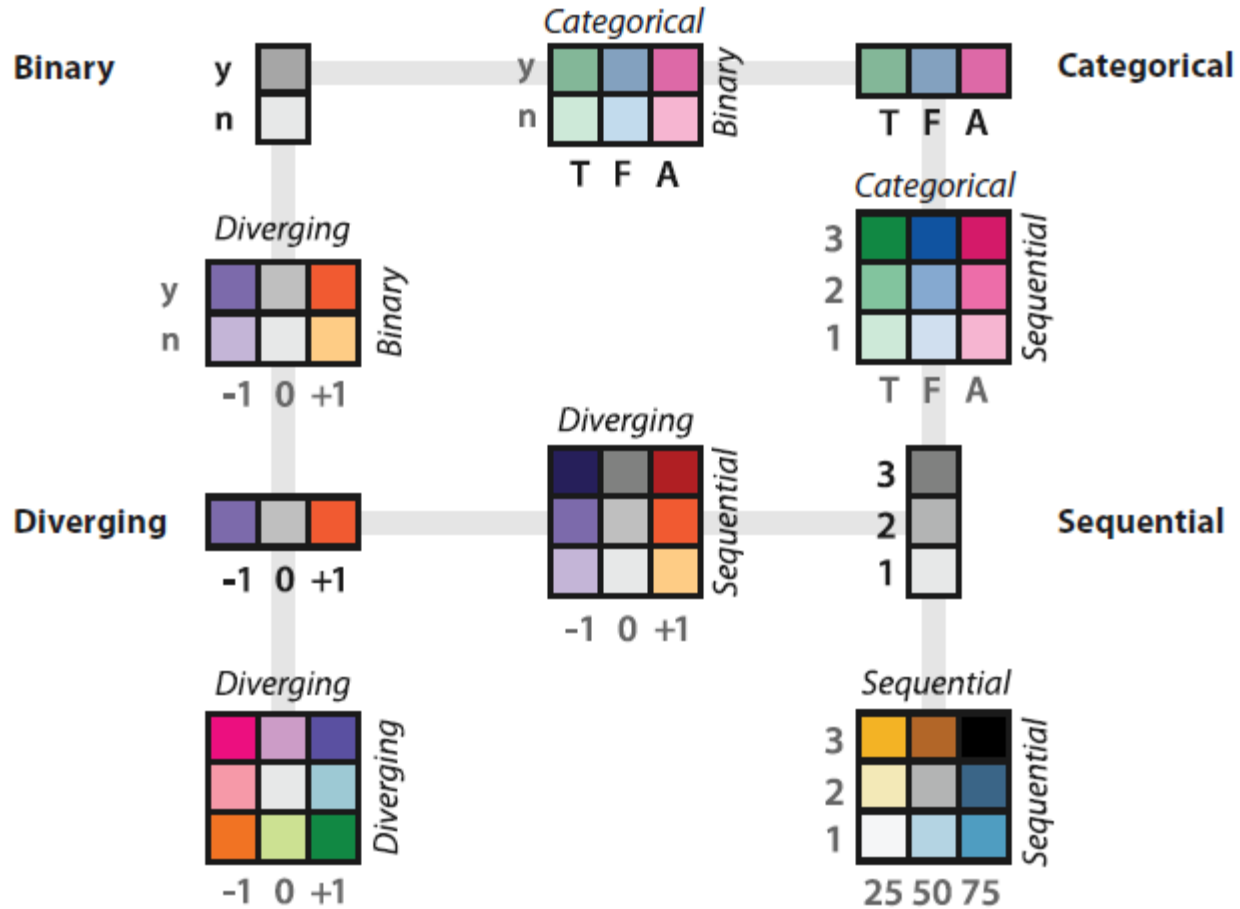


Transparency

- A fourth channel strongly related to the other three color channels is **transparency**
- Transparency is used most often with superimposed layers, to create a foreground layer that is distinguishable from the background layer

Colormaps

- A **colormap** specifies a mapping between colors and data values; that is, a visual encoding with color
- Colormaps can be **categorical** or **ordered**, and ordered colormaps can be either **sequential** or **diverging**.



Ordered Colormaps

- An **ordered** colormap is appropriate for encoding ordinal or quantitative attributes.
- A **sequential** colormap ranges from a minimum value to a maximum value.
- A **diverging** colormap has two hues at the endpoints and a neutral color as a midpoint, such as white, gray, or black, or a high-luminance color such as yellow

Other Channels

■ Size Channels

- Size is a magnitude channel **suitable for ordered data**.
- Length is one-dimensional (1D) size; more specifically, height is vertical size and width is horizontal size. Area is two-dimensional (2D) size, and volume is three-dimensional (3D) size.

Other Channels

■ Angle Channels

- The *angle* channel encodes magnitude information based on the **orientation** of a mark: the direction that it points.
- With **angle**, the orientation of one line is judged with respect to another line.
- With **tilt**, an orientation is judged against the global frame of the display.



Other Channels

■ Shape Channels

- Shape as a identity channel that can be **used with point and line marks**.
- Applying the shape channel to line marks results in stipple patterns such as dotted and dashed lines.

■ Motion Channels

- Several kinds of **motion** are also visual channels, including **direction** of motion, **velocity** of motion, and flicker **frequency**.
- Motion is less studied than other channels