
CSCI 39594

Introduction to Visualization

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Course Instructor



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About Me

- ▶ PhD Research, UCL and BT Plc, Adastral Park Lab
 - ▶ Exploration of a huge dataset of images
- ▶ Researcher, Medical Image Management, Middlesex University
 - ▶ Visualization of PET images in Matlab
- ▶ Research Associate, University College London
 - ▶ Attention Modelling
 - ▶ Visualization and Telepresence
- ▶ Visualization and VR Specialist, Virginia Tech
- ▶ Director of Visualization, Clemson University

Course Details

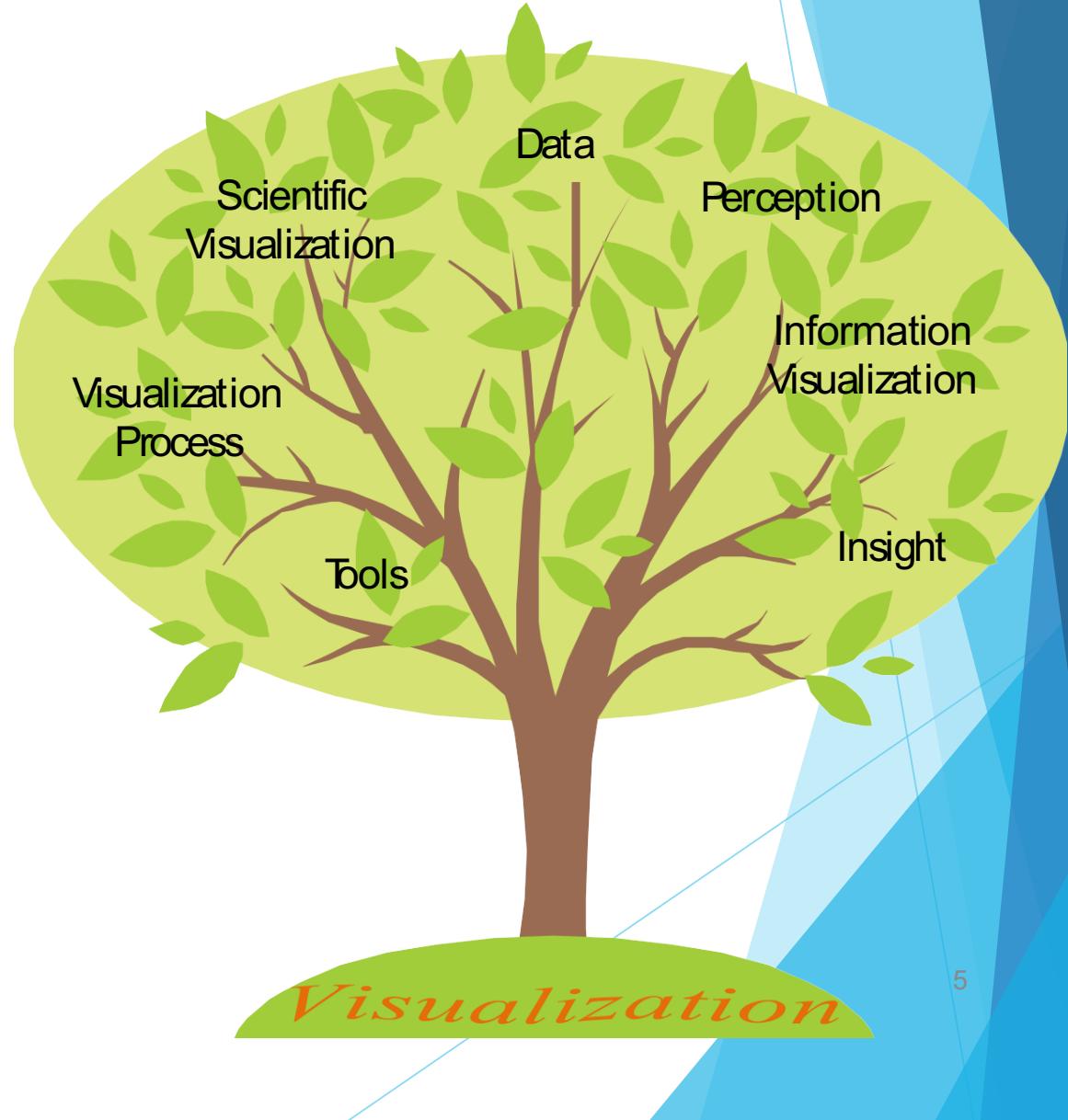
[https://github.com/oyekoya/CSCI-39594-
AdvancedVisualTools](https://github.com/oyekoya/CSCI-39594-AdvancedVisualTools)

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The City University of New York

Visualization

- Provides an overview of visualization
- Explores the underlying principles of visualization



GOAL

- ▶ Equip participants with a summary of visualization capabilities which will ultimately help them to identify their visualization needs and tools available to visualize their data.



I've Got Data to Visualize, Where
Do I begin?



What does visualization mean?

Visualization

vis·u·al·ize

[vizh-oo-uh-lahyz]

verb, vis·u·al·ized, vis·u·al·iz·ing.

verb (used without object)

1. to recall or form mental images or pictures.

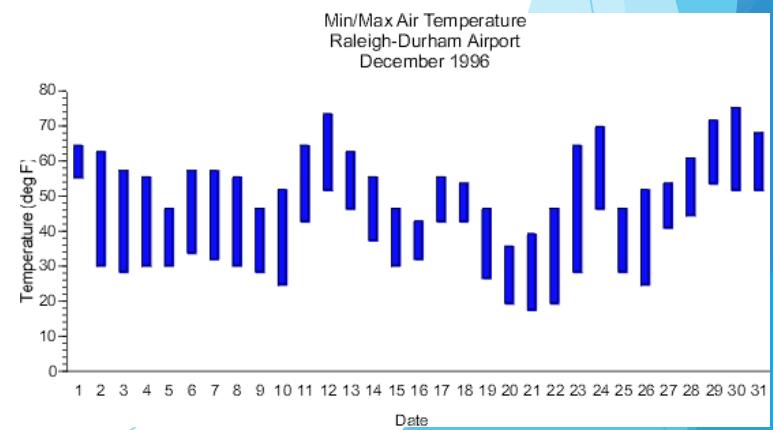
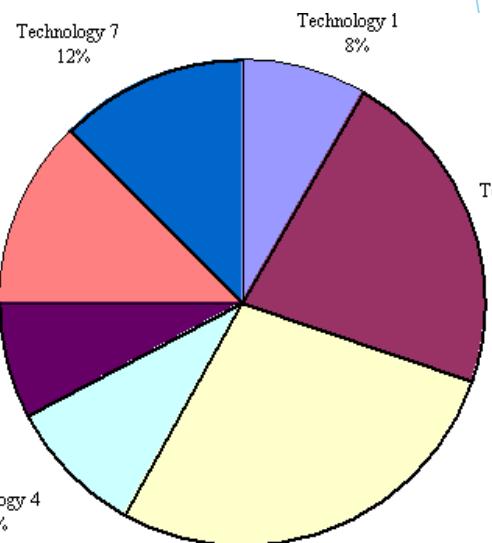
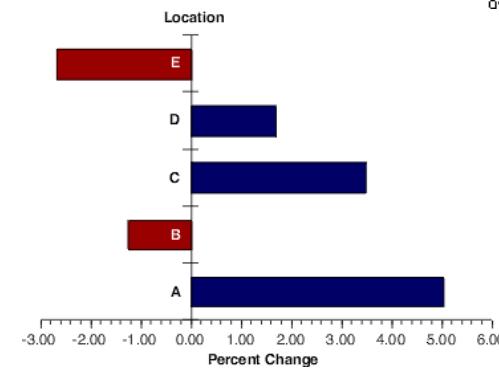
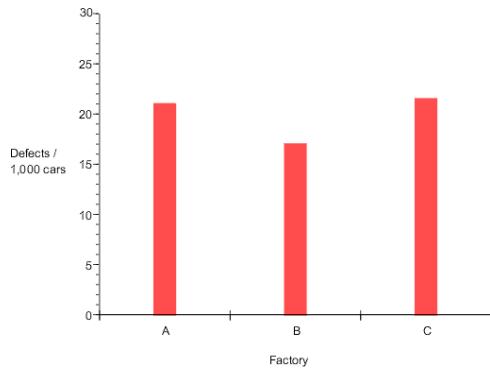
verb (used with object)

2. to make visual or visible

3. to form a mental image of.

4. to make perceptible to the mind or imagination.

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What does visualization mean?

When should you start thinking
about visualization?



What does visualization mean?

When should you start thinking
about visualization?

What is the purpose of
Visualization?

“The purpose of
visualization
is “*insight*”, not
pictures.”

~Ben Shneiderman

Dictionary.com

in·sight

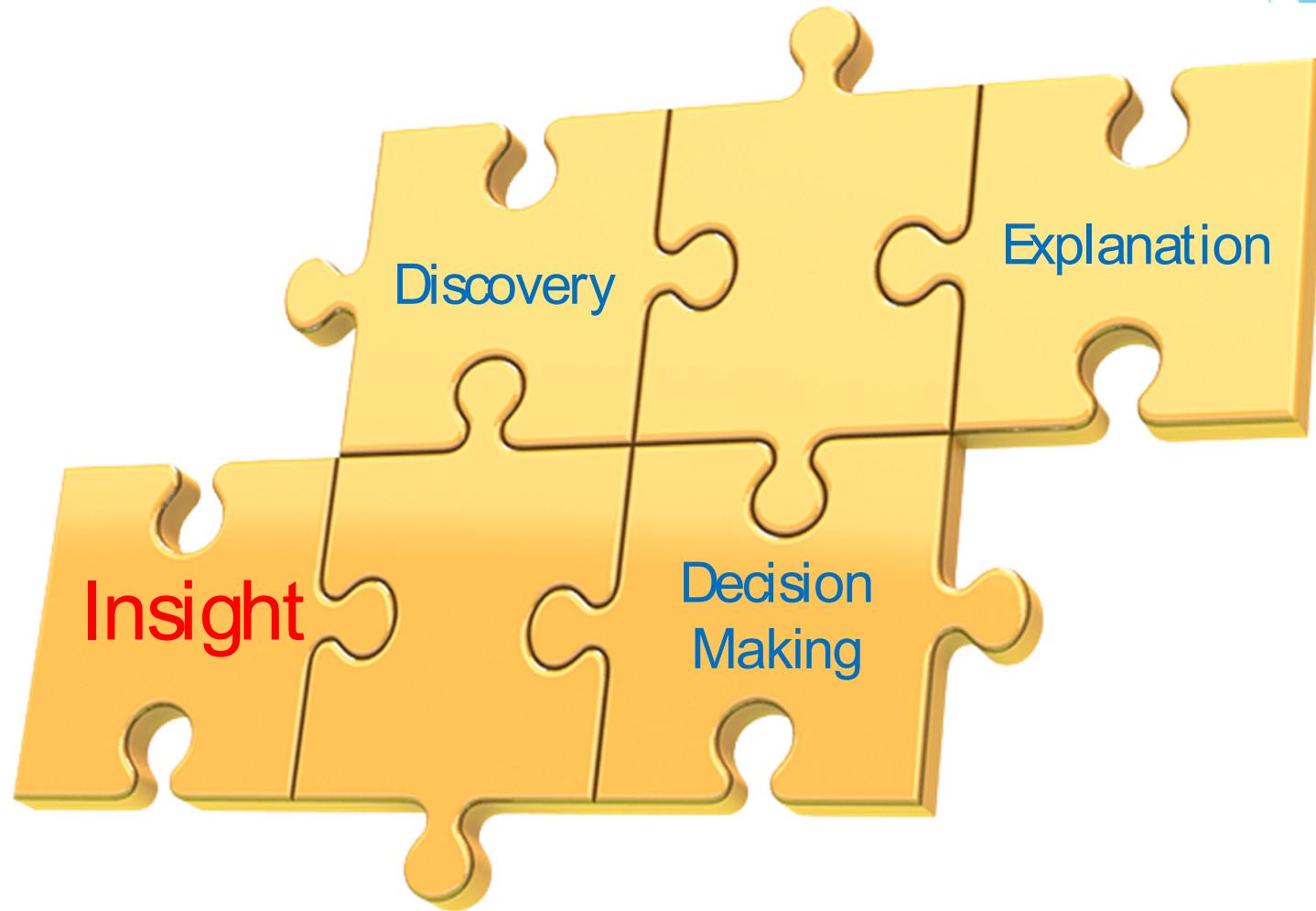
noun

1. an instance of apprehending the true nature of a thing, especially through intuitive understanding: *an insight into 18th-century life.*
2. penetrating mental vision or discernment; faculty of seeing into inner character or underlying truth.
3. *Psychology*.
 - a. an understanding of relationships that sheds light on or helps solve a problem.
 - b. (in psychotherapy) the recognition of sources of emotional difficulty.
 - c. an understanding of the motivational forces behind one's actions, thoughts, or behavior; self-knowledge.



Why is “insight”
important?

Main Goals of This “Insight”



“Insight” Leads to Discovery

- Visualizing Patterns over Time



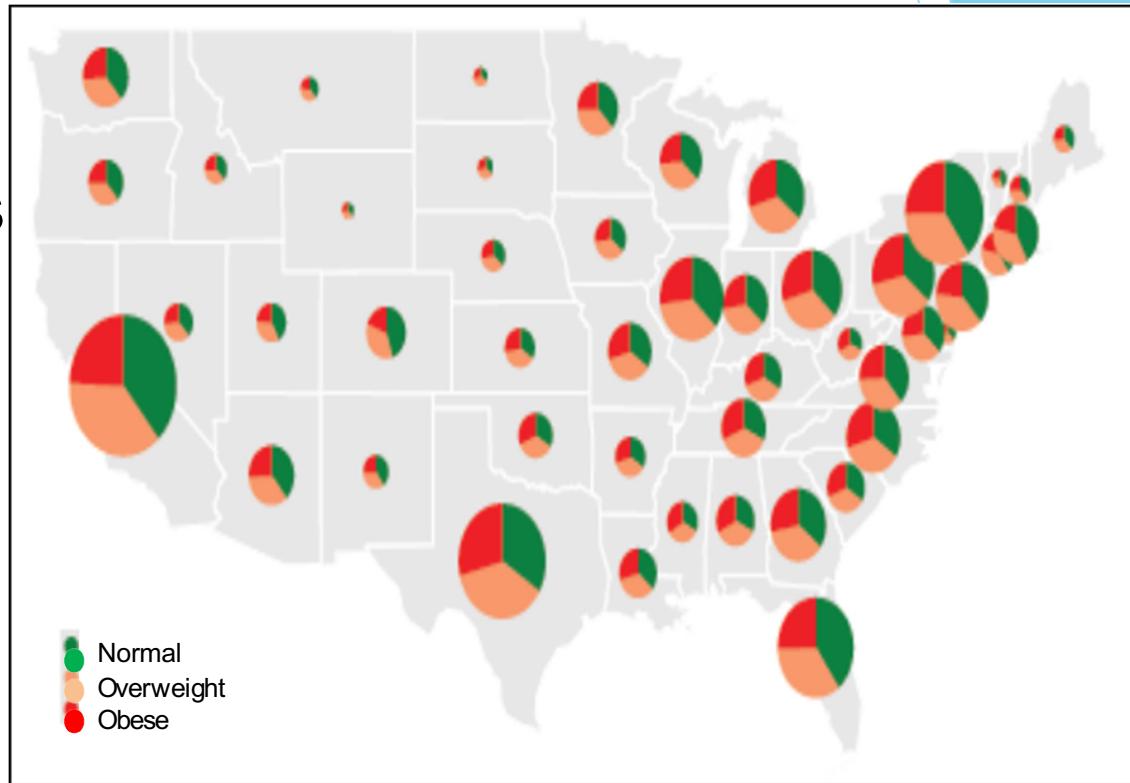
Source: greenbookblog.org



- Spotting Differences

“Insight” Leads to Explanation

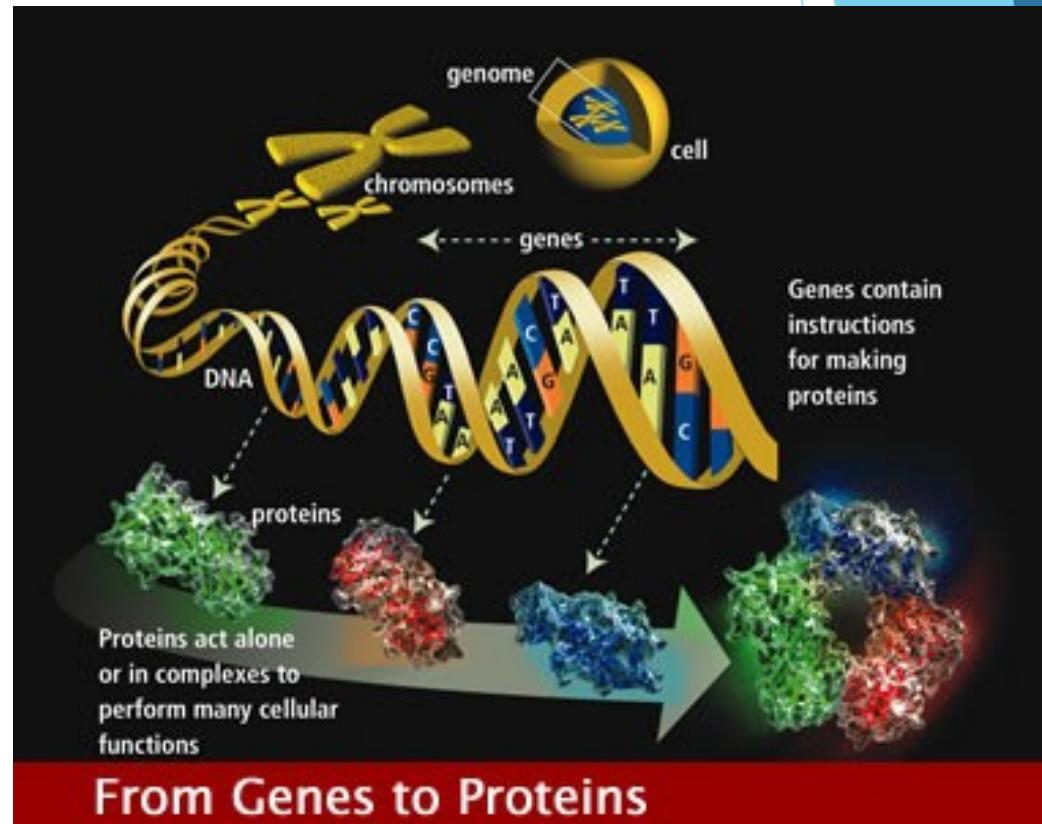
- Visualizing Spatial Relationships



Source: A Tour through the Visualization Zoo by Heer, Bostock & Ogievetsky (ACM Queue, 2010)

“Insight” Leads to Decision Making

- Provide compact graphical presentations & user interfaces for data possibly extracted from larger data sets
- Allows users to answer questions they didn't know they had





Can anyone think of any other
uses of visualization?

Visualization: Telling Stories with Data

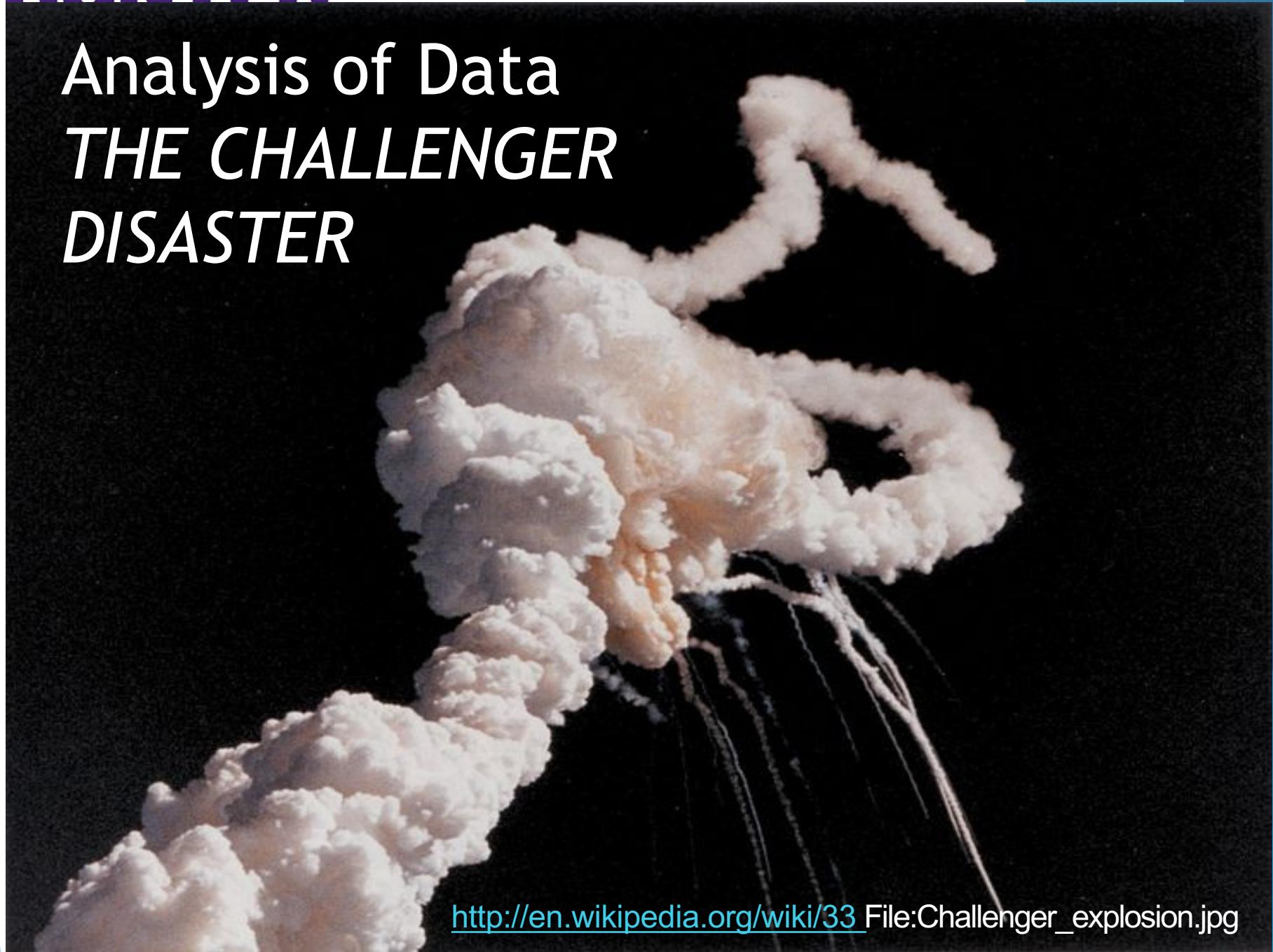


Image Source: <http://flowingdata.com/2011/11/04/telling-stories-with-data-visweek-2011/>

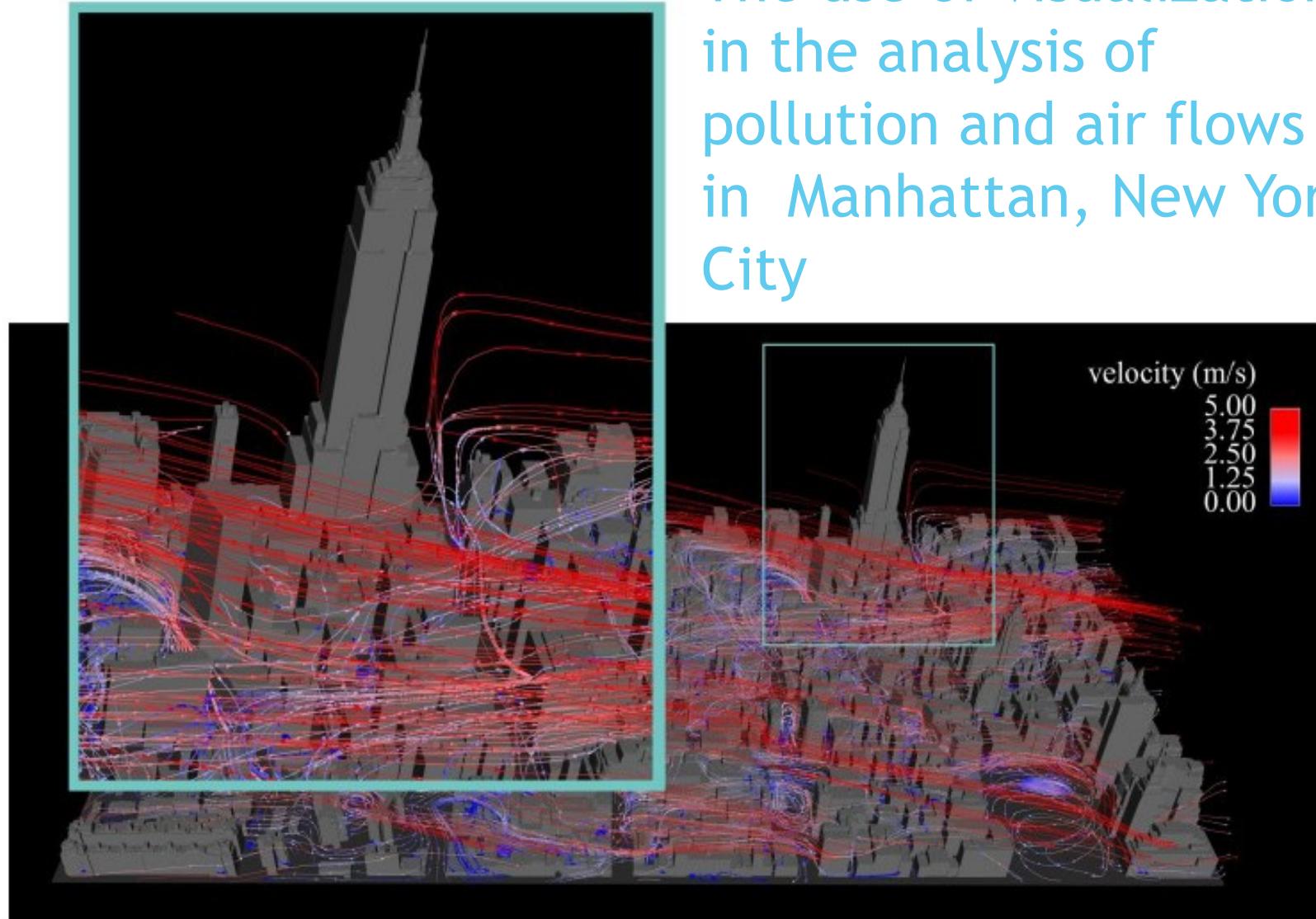
Narrative Visualization:
Telling Stories with Data
Edward Segel, Jeffrey
Heer, *IEEE Trans.
Visualization & Comp.
Graphics (Proc. InfoVis)*,
2010

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Analysis of Data *THE CHALLENGER DISASTER*



http://en.wikipedia.org/wiki/33_File:Challenger_explosion.jpg



Courtesy of RENCI, University of North Carolina at Chapel Hill.



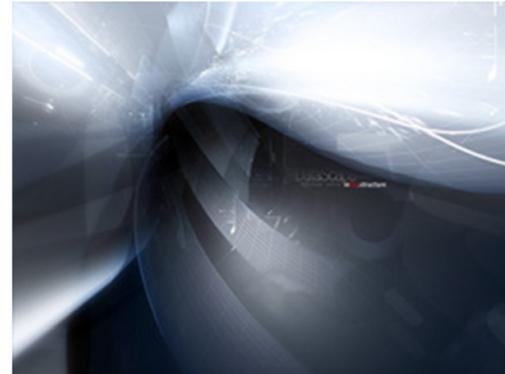
Visualization is Powerful

- About 75% of the visual cortex is devoted to our visual system; or 75% of the brain is devoted to our visual cortex
- We are really good at
 - pattern matching
 - understanding things by sight

History of Communication

- 01 Rocks and Caves
- 02 Ideograms
- 03 The Alphabet
- 04 The Art of the Book
- 05 The Printing Press
- 06 The Masters of Type
- 07 Breaking the Grid
- 08 The Avantgarde
- 09 The Modernists
- 10 The Computer

10



Desktop
wallpapers

http://citrinitas.com/history_of_viscom

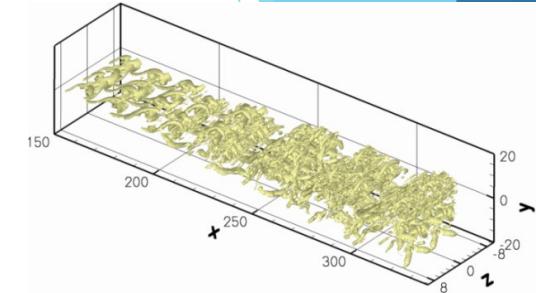
Visualization

- The craft of visualization has been practiced for many years.
 - There has always been a need for people to visualize information
- The medium of choice for representing information has continued to evolve



Evolution of Presenting Information

3D Renderings of a Simulation Over Time



Animated 2D Images



3D Static Images



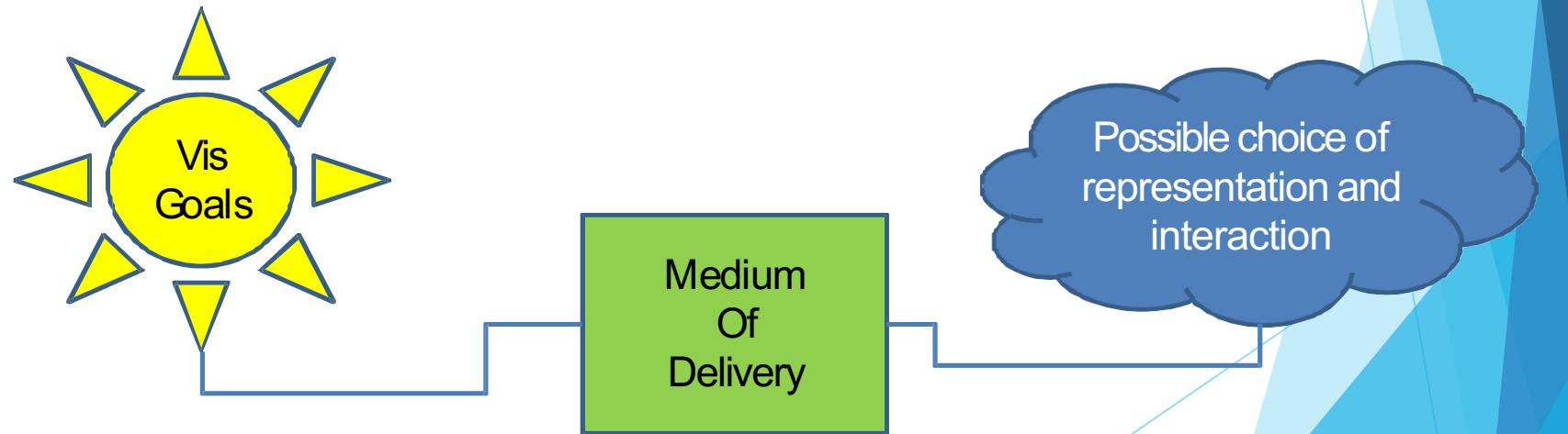
Vector Display and Plotter Graphics



Characters on Paper

Visualization Process

- What type of information being investigated?
- Is the primary goal to convey quantitative or qualitative information?
- How detailed should the representations be?



Adopted from citutor.org

Visualization Involves

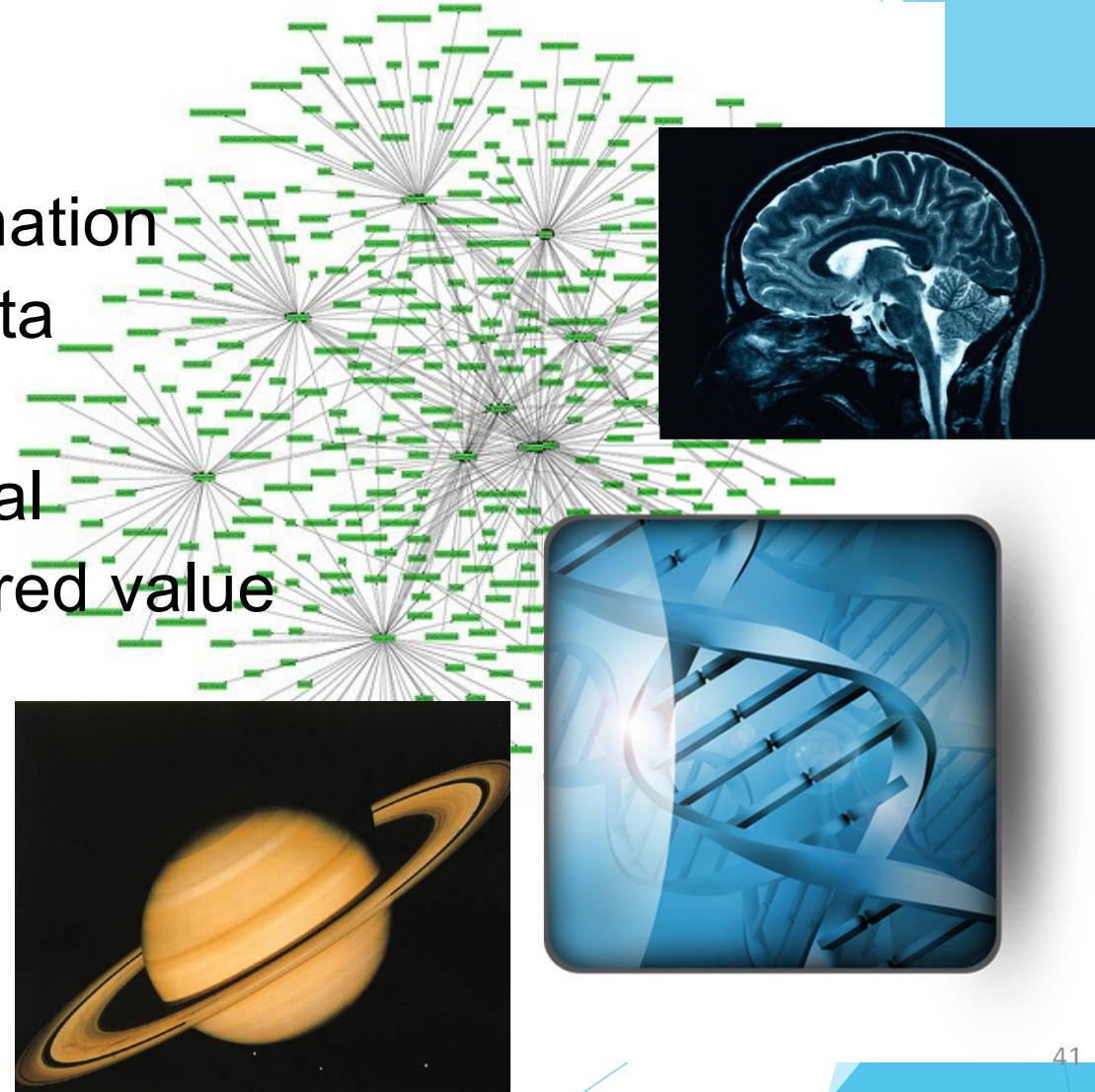
Handling Data

- Typically, work needs to be done on the data before it can be appropriately visualized
- Cleaning up the data
 - Removing noise
 - Replacing missing values
 - Clamping values to be within a specific range of interest,
 - Etc.,
- Performing operations to yield more useful data



The Data

- Images
- Survey information
- Simulated Data
- Numerical
- Non-Numerical
- Some measured value
- Network
- Database
- Etc. . . .



Data Dictates Which Tools To

Use

- Non-numeric Data
- Social Media Data
 - ▶ – Facebook & Twitter
- Survey Data
- Test Scores
- Shopping Habits
- Athletic records
- Etc.,



- Simulated Data
- Images
- Medical Data
- Biological Data
- High Precision Data
- Some Observed Phenomenon
- Etc.,

The Remainder of the Presentation

- ▶ Visualization Applications
- ▶ Underlying Principles
- ▶ The Practice of Scientific Visualization
- ▶ The Practice of Information Visualization
- ▶ Now What . . . What's Next?

Visualization Software



Scientific Visualization:
Paraview, VMD, VisIt, CUDA

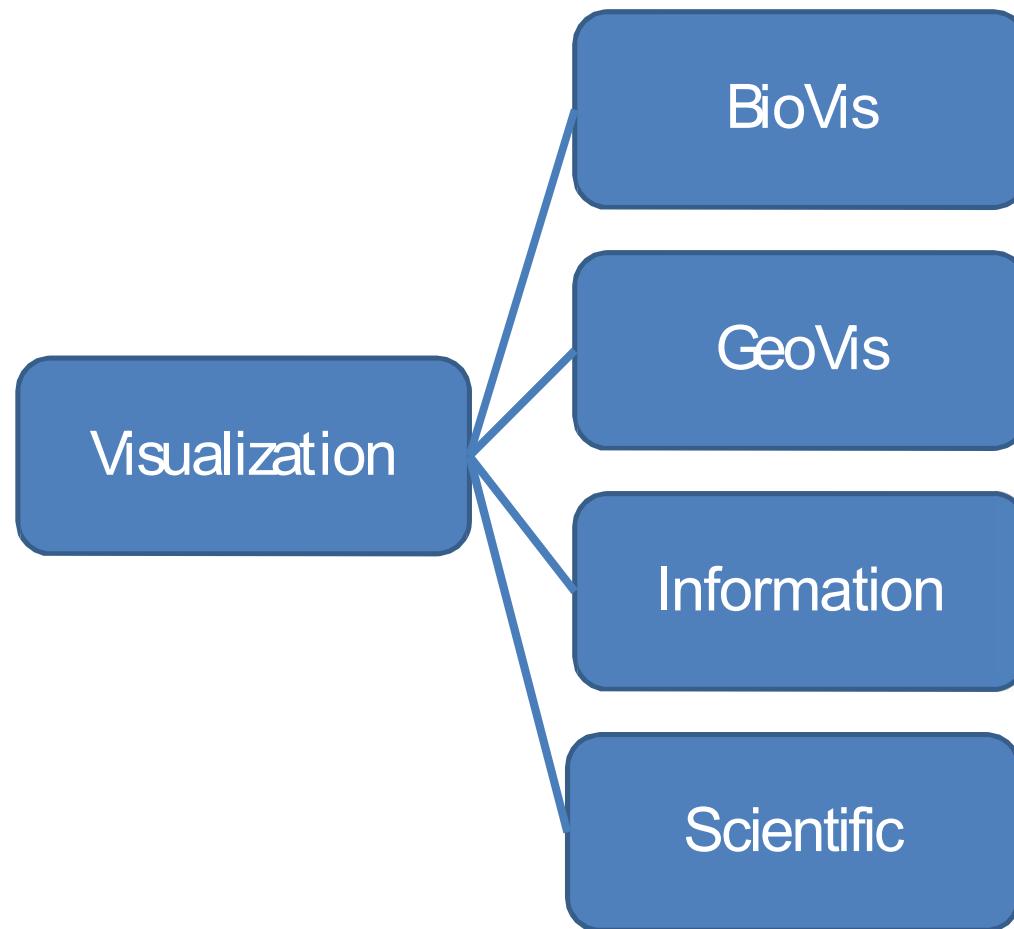


Information Visualization:
Tableau, Gephi, Graphviz,
D3.js, Three.js



Virtual Reality: Unity3D,
Adobe Creative Cloud (Fuse,
Photoshop, Premiere Pro)

Range of Visualization Applications



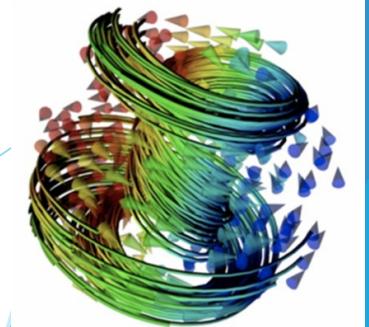
Biological Data



Geospatial Data



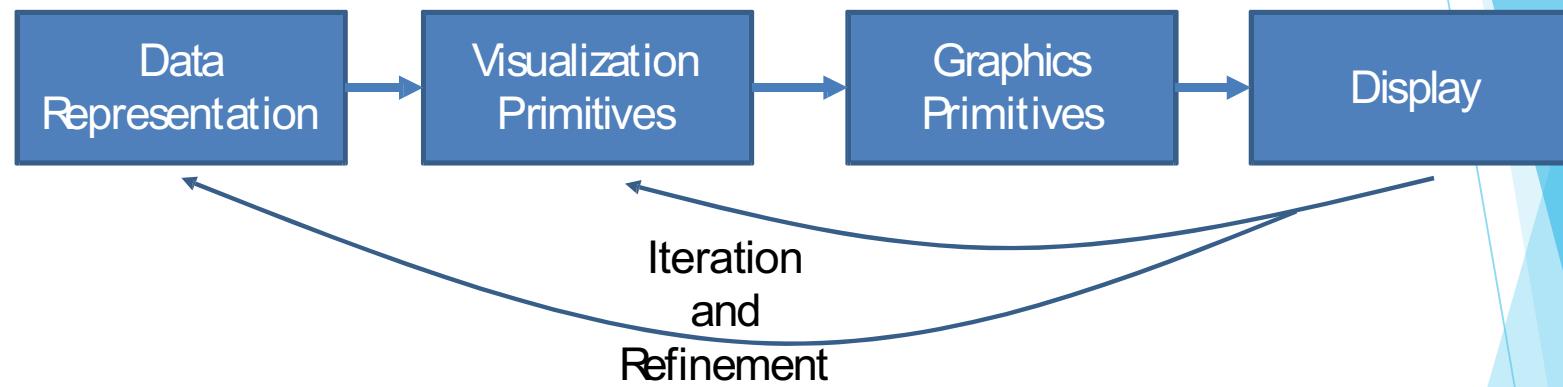
Non-numerical information



Simulated, 3D Phenomena

UNDERLYING PRINCIPLES

From Data to Insight



Insight NOT Pictures

- Mass Audience
 - Demonstrate a concept
- Individual Scientist
 - Uncover patterns in the data
 - Compare patterns
 - Discover new patterns that give clues to a better expression of the process

Motivation for VISUALIZATION

To develop visual representations based on underlying data that are

- Concise (Yes)
- Unambiguous (Preferably)
- Intuitive (Trainable)
- Interactive (Desirable)
- Scalable (We wish)

Tradeoffs

- Interactive Visualization
 - Ability to control specific portions of the dataset (*pro*)
 - Examine and control the type and parameters of the visual output (*pro*)
 - Might limit (*cons*)
 - the percentage of the data that can be examined at a given moment
 - types of representation available
- Qualitative Overview
 - View the entire dataset
- Quantitative Study
 - Represent a subset of the data

Visualization Process

Underlying Principles

At one level (*analytical*):

- Simply a transfer function between numbers and images
- This transfer may be irreversible and cause distortion of meaning

At another level (*barrage of procedures*):

- Each procedure influences the final outcome and its ability to convey meaningful information
- The process includes consideration for data filtering, representation, potential inaccuracy, and human perception

Data Dictates Which Tools To Use Remember this List?

Scientific Visualization

- Simulated Data
- Medical Data
- Biological Data
- High Precision Data
- Some Observed Phenomenon
- Etc.,

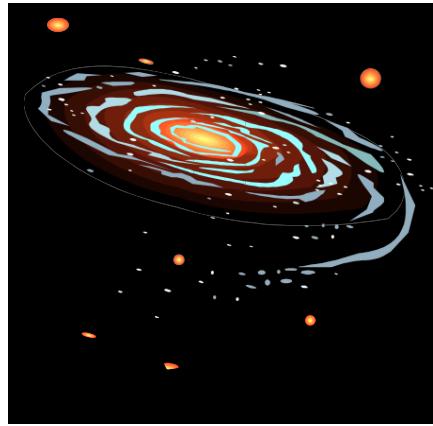
Information Visualization

- Non-numeric Data
- Social Media Data
- Survey Data
- Test Scores
- Shopping Habits
- Athletic records
- Etc.,

THE PRACTICE OF SCIENTIFIC VISUALIZATION

Scientific Visualization

➤ The Practice of
Scientific
Visualization



- The use of data-driven computer graphics to aid in the understanding of scientific information
- Is scientific visualization just computer graphics?
- Computer graphics is the medium in which modern visualization is practiced
- However, visualization is more than simply computer graphics

Visualization components

Viz Elements

- Glyphs
(e.g. Alphabets, Arrows)
- Lines
- Triangles
- Voxels*

*Cannot be directly represented on displays

Viz Attributes

- Transforms
(Position, Rotation, Scale)
- Color
- Opacity
- Shade/Texture

View Attributes

- Orthographic Projection
- Perspective Projection
- Canvas Size
- Light

Will be covered in Scientific Visualization Lecture

VIZ REINFORCEMENT

- Shade - Texture - Light
- Add Context (e.g. Connectivity, Map Overlay)
- Distortion (e.g. displacement)
- Motion (e.g. Camera)
- Filter (e.g. threshold, resample, subset, slice, clip)

Scientific Visualization Process

Basic Steps of The Scientific
Visualization Process

- Data Filtering
- ▶ Typically, work needs to be done on the data before it can be appropriately visualized
 - ▶ Cleaning up the data
 - Removing noise
 - Replacing missing values
 - Clamping values to be within a specific range of interest,
 - Etc.,
 - Performing operations to yield more useful data

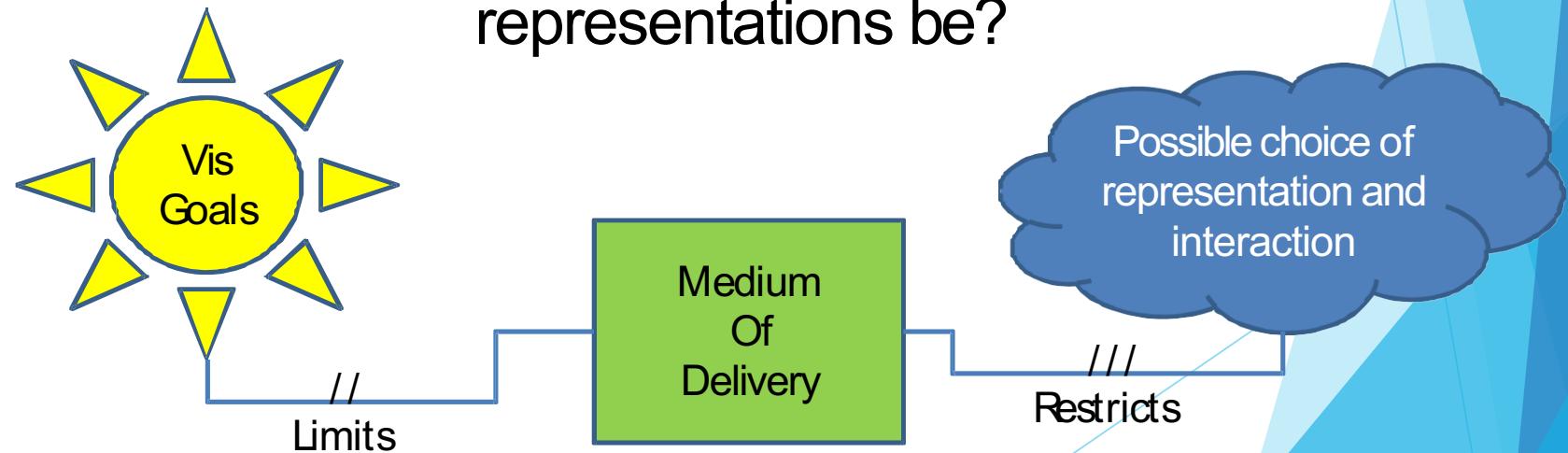
Applicable to
any field where
visualization is
used

Scientific Visualization Process

Basic Steps of The Scientific Visualization Process

- Data Filtering
- Representation Issues

- What type of information being investigated?
- Is the primary goal to convey quantitative or qualitative information?
- How detailed should the representations be?



Scientific Visualization Process

Basic Steps of The Scientific Visualization Process

- Data Filtering
- Representation Issues
- Accuracy

- Whenever data changes representation, the possibility for the introduction of error exists
 - Representing three-dimensional imagery on a two-dimensional display
 - Which representation to focus on
 - Which to leave in the background
 - Selection of viewpoint
 - Color & lighting

Scientific Visualization Process

Basic Steps of The Scientific Visualization Process

- Data Filtering
- Representation Issues
- Accuracy
- Human Perception



- Mapping of information from imperceptible forms to something we can interpret and analyze
- Each of our brains interpret incoming signals differently
- Human perceptual biases
 - Not necessarily universal
- A scale or legend should always be used to illustrate how information is being mapped.

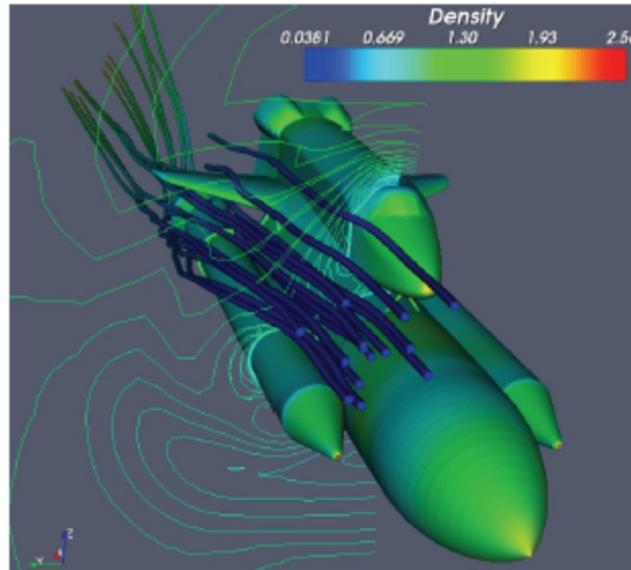
What is Scientific Visualization?

The Practice
of Scientific
Visualization

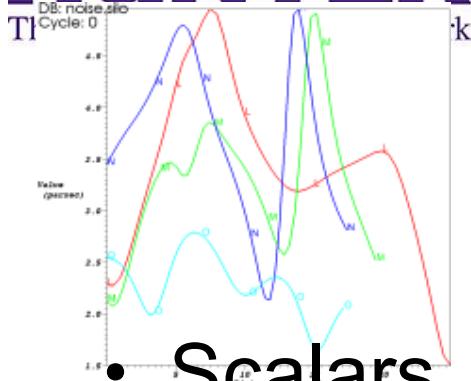
- Visually extracting meaning from a scientific data set
- Data set
 - Cloud (simulation)
 - Physical experiment
 - Scientific instrumentation
- Techniques
 - ❖ Art, Statistics, Image processing, “info” vis, Gaming techniques

What is Scientific Visualization?

Process of converting raw information into something understandable

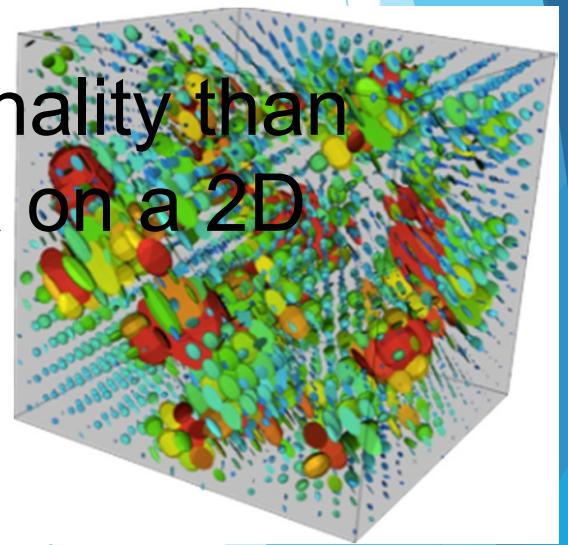
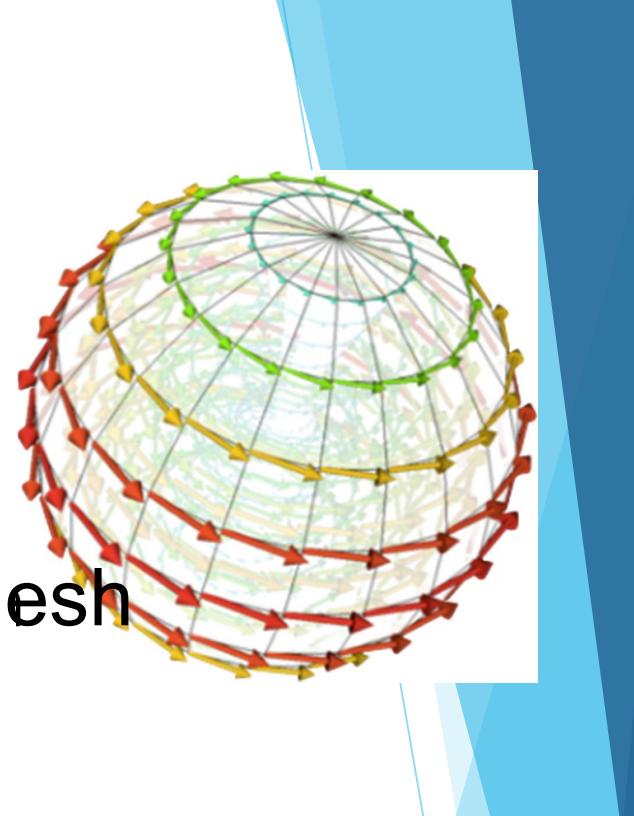
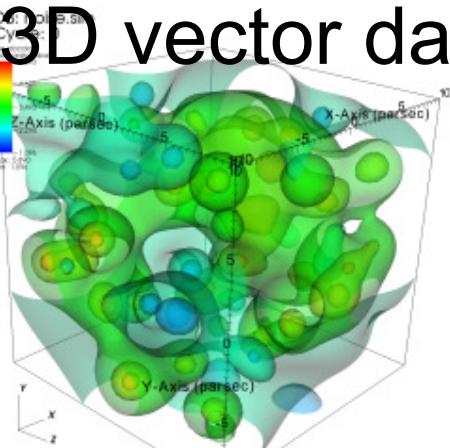
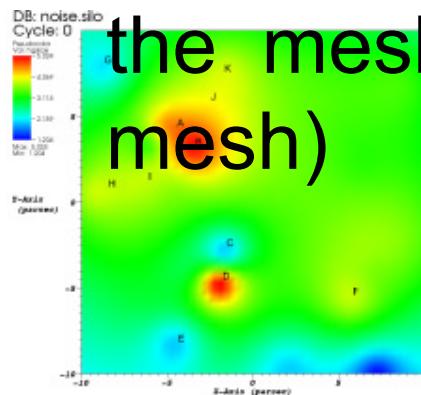


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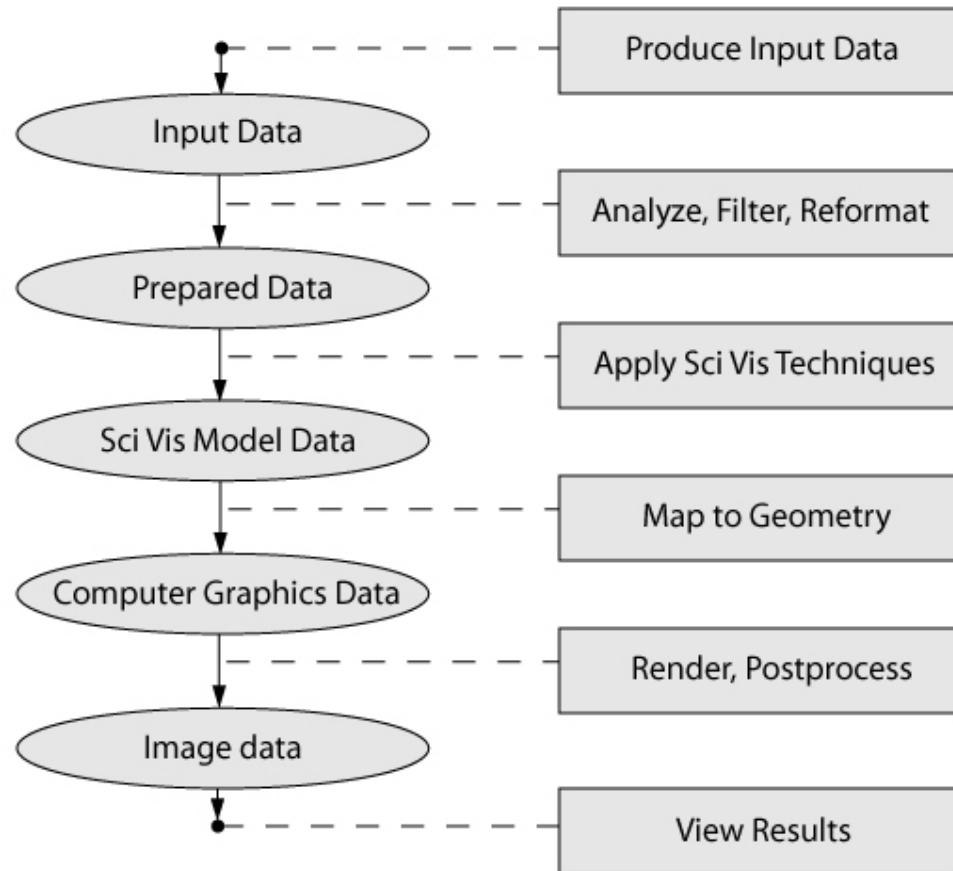


Variables

- Scalars, Vectors, Tensors
- Sits on points or cells of a mesh
 - Points: linear interpolation
 - Cells: piecewise constant
- Could have different dimensionality than the mesh (e.g. 3D vector data on a 2D mesh)

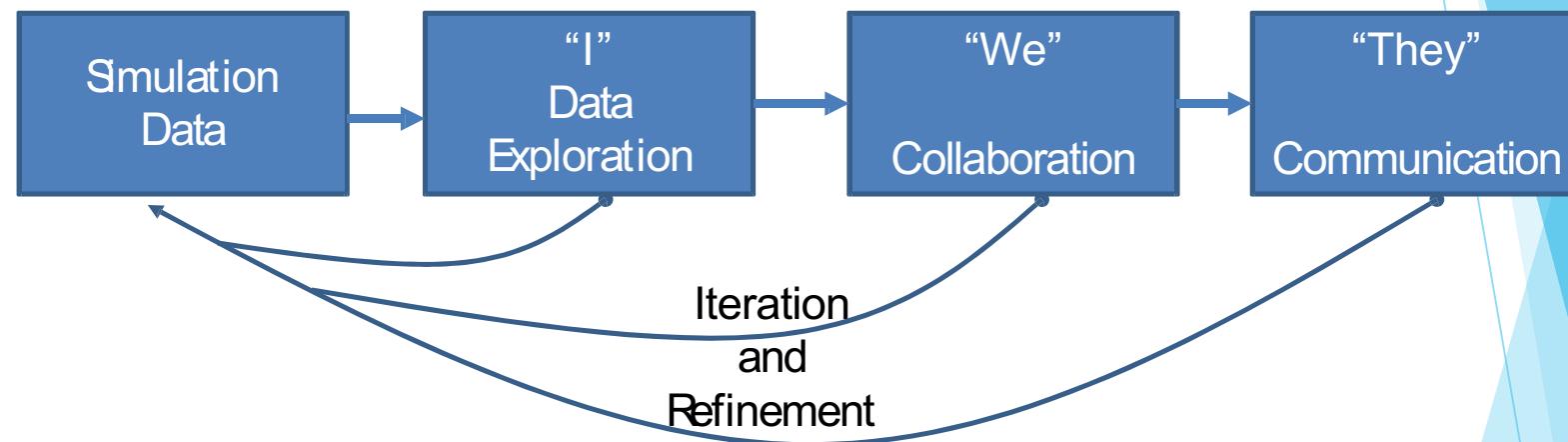


Scientific Visualization Pipeline



<http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/>

“I, We, They” Development Path



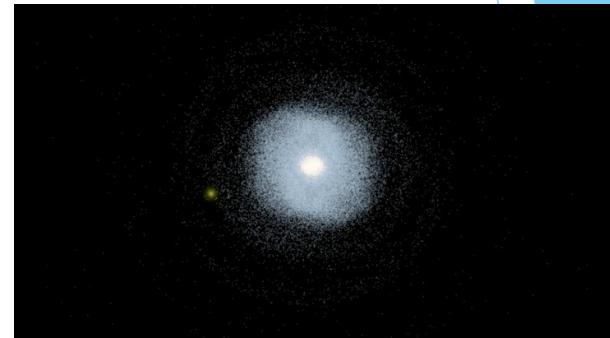
Colliding Galaxies

- This simulation consists of approximately 1.5 million particles representing stars in two galaxies in a collision
- Algorithms were implemented in C++ to read and filter "snapshots" of the collision of the Milky Way Galaxy with the Sagittarius Dwarf Galaxy (SDG) simulation

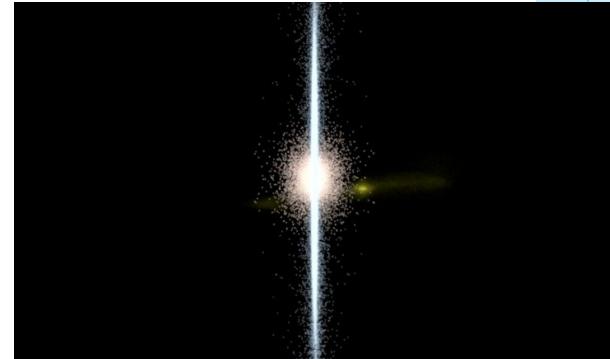
Visualizing Colliding Galaxy Data

- The Data Set:
 - for the full collision consists of 475 snapshots
 - covering a period of 4 billion years.
 - Snapshot data is filtered to allow for the analysis of particle data one particle at a time.

- View over the disk



- View across the disk, showing extended small



THE PRACTICE OF INFORMATION VISUALIZATION

Information Visualization

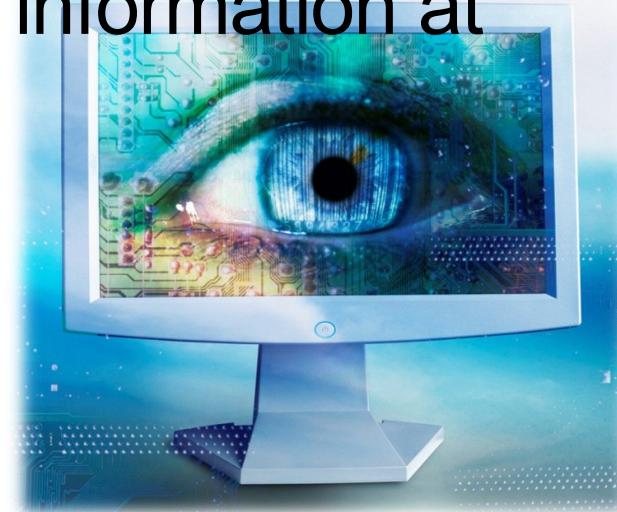
- The field of information visualization has emerged "from research in human-computer interaction, computer science, graphics, visual design, psychology, and business methods.

Information Visualization

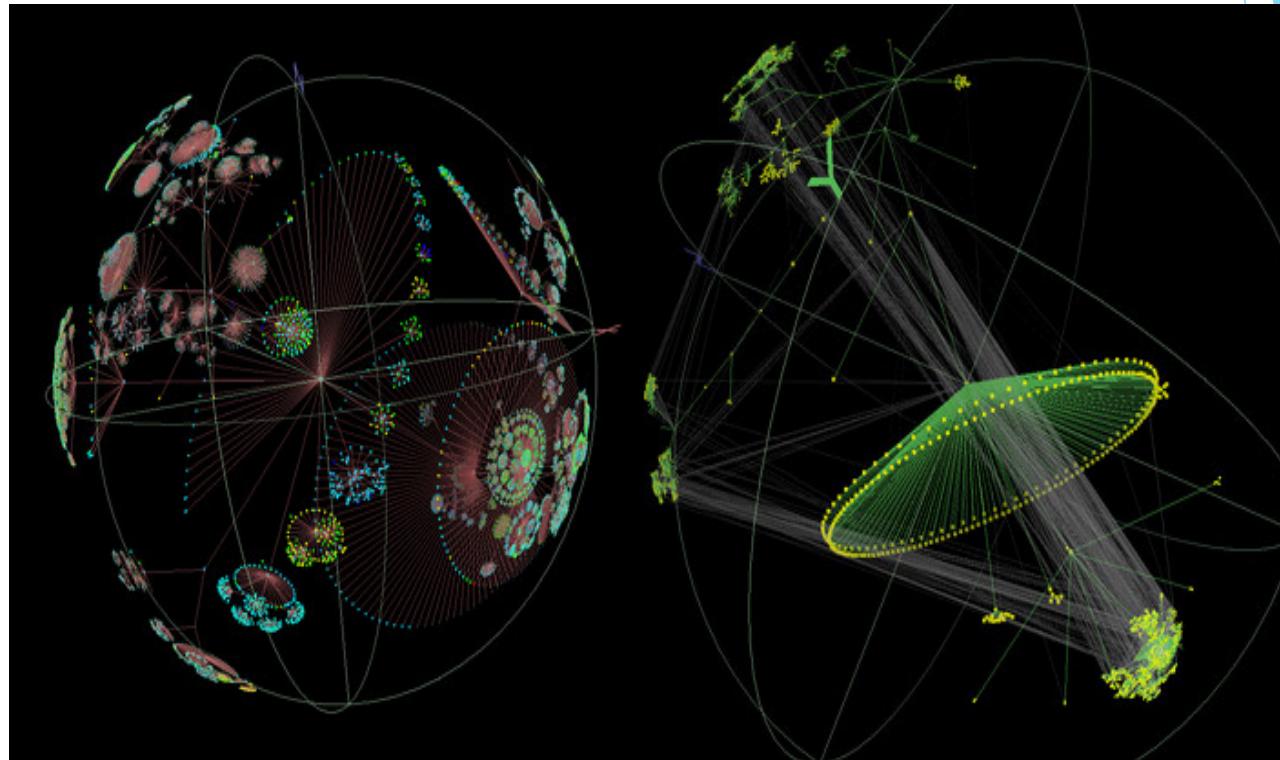
- The interdisciplinary study of "the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems, library and bibliographic databases, networks of relations on the internet, and so forth".

Information Visualization

- Presumes that "visual representations and interaction techniques take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once.



Information Visualization



Walrus: information visualisation is used here to create abstractions.
<http://www.caida.org/tools/visualization/walrus/gallery1/>

http://citrinitas.com/history_of_viscom

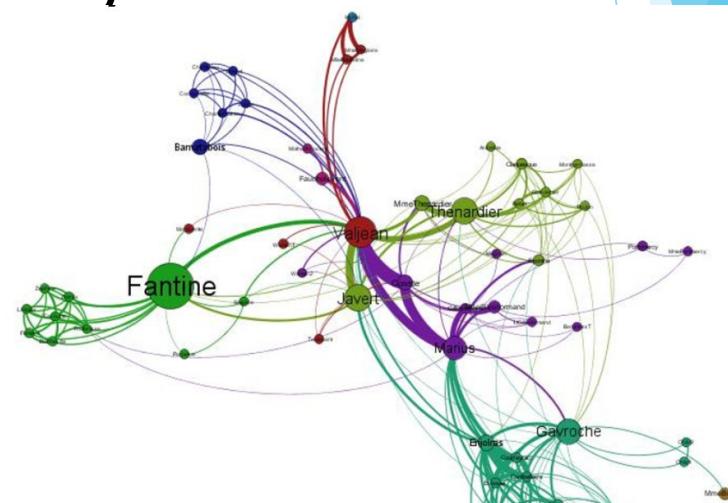
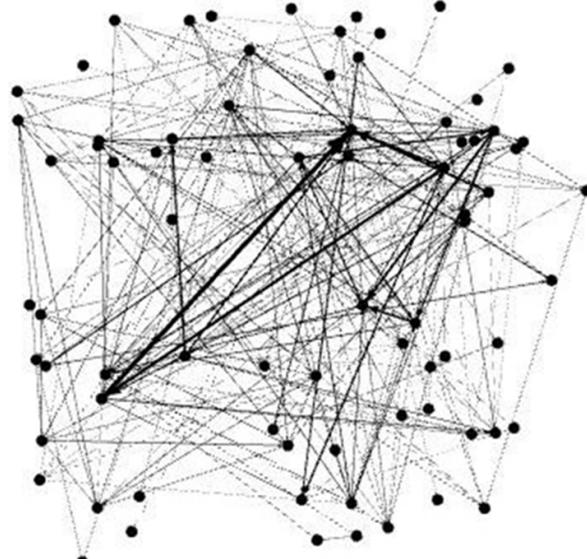
Information Visualization

- Often applied to data that is not generated by scientific inquiry.
 - Graphical representations of data for business, government, news and social media.



Information Visualization

- Information visualization focused on the creation of approaches for conveying abstract information in intuitive ways.



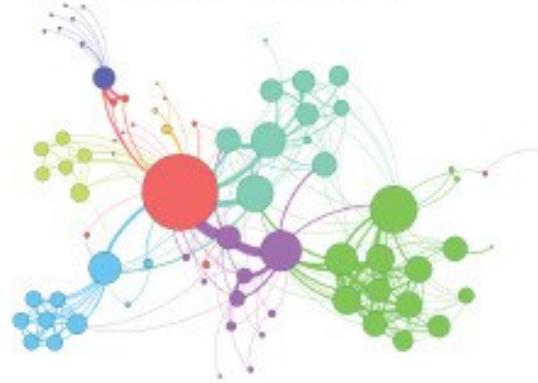
Same dataset visualized differently (Using Gephi)

Various Layouts Exist

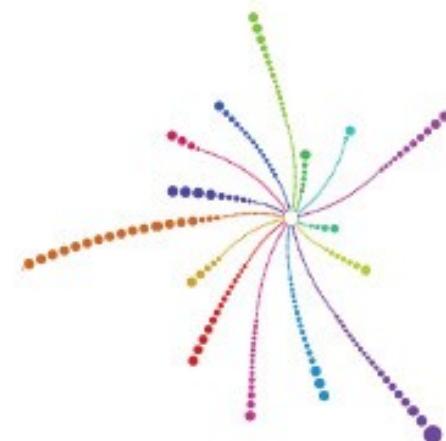
OpenOrd



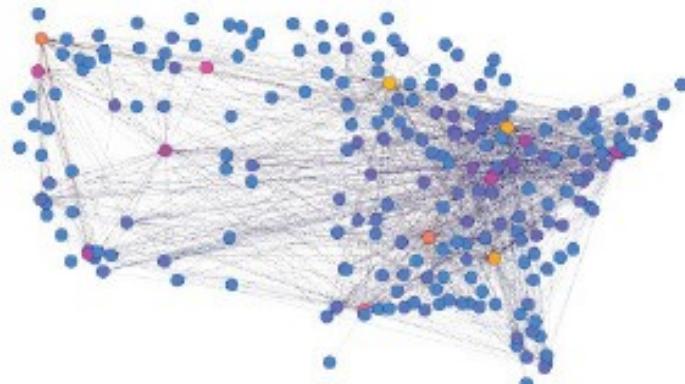
ForceAtlas 2



Radial Axis



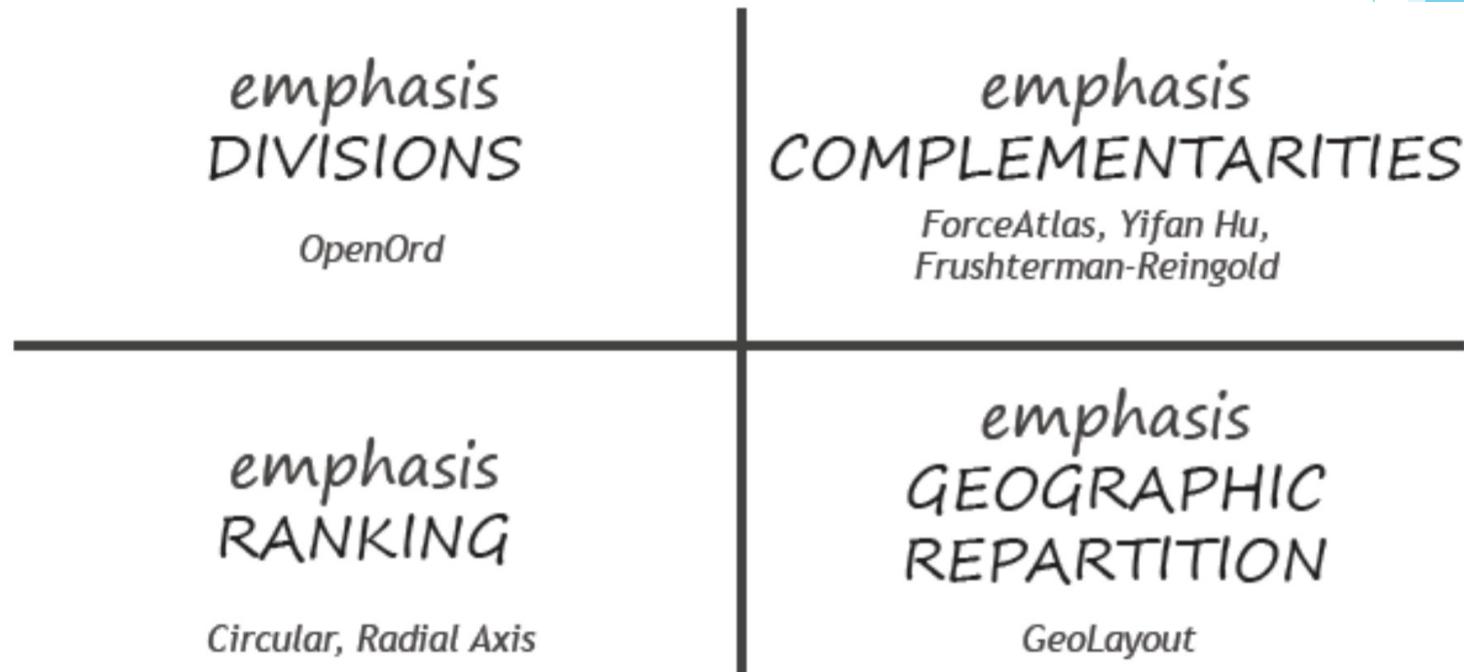
GeoLayout



Airlines sample dataset: <http://gephi.org/datasets/airlines-sample.gexf>

How to Choose a Layout?

Select a layout according to the feature of the topology you want to highlight



What Do Researchers Use Today?

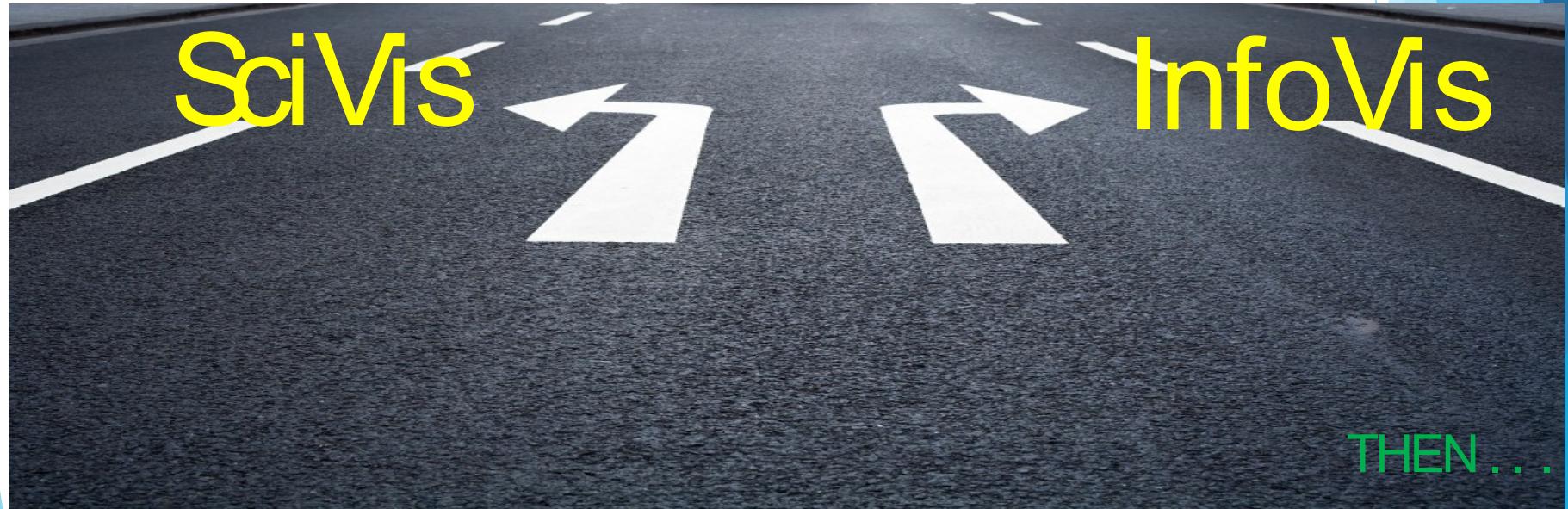
- Everything!

There is no single optimal visualization technique for all situations, especially for high dimensional data *(Hoffman & Grinstein, 2002)*

What's Next



Determine what type of data you have . . .



NodeBox

Text

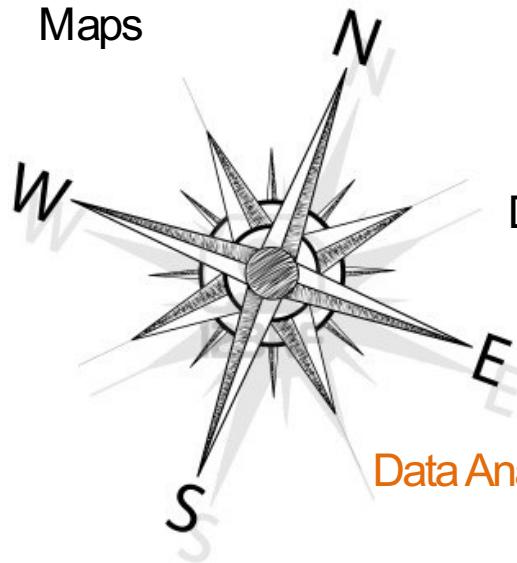
Entry-level Tools

Scalar Fields

Processing

Parallel Coordinates

Maps



Data Analysis

Online Visualizations

Graphs and Trees

Navigating Through the Visualization Zoo

Mapping

Data Exploration

Data Analysis Tools

Interactive GUI Controls

Gephi

Vector Fields

Tabular Data

Volume Rendering

Streamlines