

# Introduction to Data Visualization

**Vetria L. Byrd, PhD**

Assistant Professor

Computer Graphics Technology

Purdue University

International HPC Training Consortium

Visualization Seminar Series

March 01, 2017

**PURDUE**  
POLYTECHNIC



# ABOUT THIS WEBINAR

## ASSUMPTIONS

**Target Audience:** Beginners

**Pre-requisites:** No prior knowledge of visualization required

**Software Requirements:** None

# ABOUT THIS WEBINAR

## GOALS

1. Provide viewers with an introduction to data visualization
2. Provide a summary of visualization capabilities
3. Identify first steps towards visualizing different types of data

# ABOUT THIS WEBINAR

## OBJECTIVES

1. Explore the underlying principles of data visualization,
2. Explore the visualization process
3. Explore some visualization applications
4. Explore different types of visualization tools for different types of data

# ABOUT THIS WEBINAR

## EXPECTED OUTCOMES

By the end of this webinar, viewers will

1. Understand the purpose of visualization
2. Be able to identify their data visualization needs
3. Identify the visualization tools available to assist with visualizing their data

# AGENDA

## INTRODUCTION TO DATA VISUALIZATION

- Brief Introduction
- Purpose Of Visualization
- High Level Overview
- Visualization Applications
- You've Got Data, Now What?
- Q&A

# Introductions

**PURDUE**  
POLYTECHNIC



## Academic Preparation

- Computer Science (PhD, MS)
- Biomedical Engineering (MSMBE)



## What I Am Doing Now

### Academic Appointment

- Assistant Professor
- Purdue University
- Computer Graphics Technology
- Curriculum Development for New Major in Data Visualization
- Research Focus: Data Visualization

## What I've Done



### Visualization Initiatives

- BPViz: Broaden Participation in Visualization (2014/2016/2017)
- Research Experience for Undergraduates in Collaborative Data Visualization Applications (2014/2015)



*Agent for "Insight"*

**PURDUE**  
POLYTECHNIC



**What do you think of when  
you hear**

**Data Visualization?**



# DATA VISUALIZATIONS

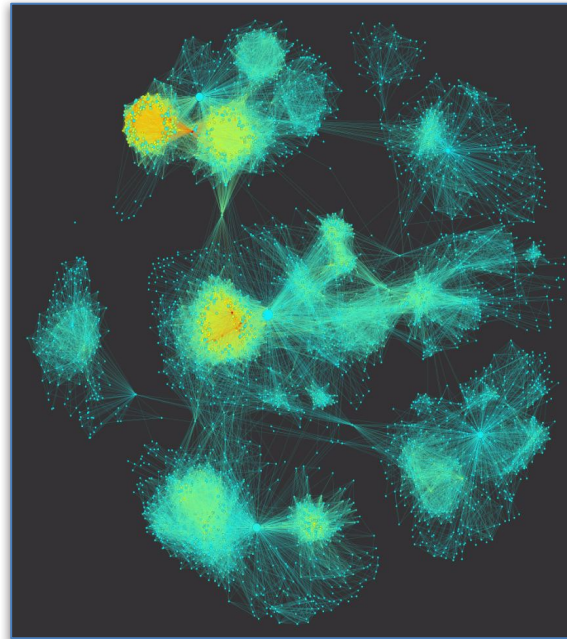
WE'VE ALL SEEN THEM



Internet Users in the World (Based on Region)

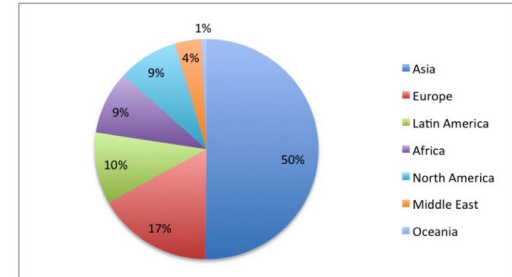


Source: <http://mindymcadams.com/tojou/2011/10-useful-resources-about-data-visualization/>



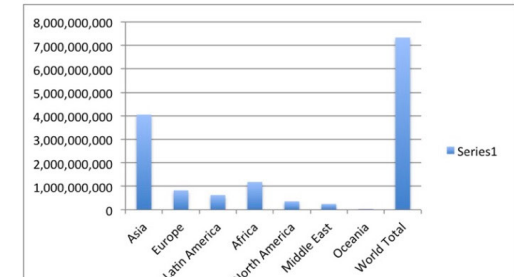
Facebook Network Visualization  
Anonymous friend networks  
Created by Christine Mintert & Fisher Adelakin  
CGT 270 Class Assignment  
Data Source:  
<http://snap.stanford.edu/data/index.html#socnets>

Percentage of Internet Users in Regions Around the World in 2016



Why those percentages?

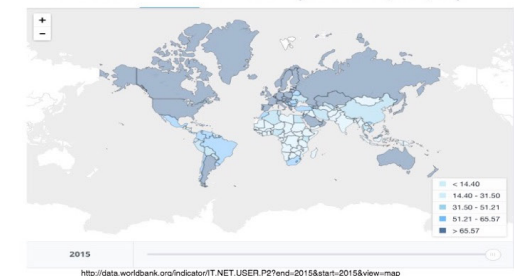
It's based on the relative population of the region to the rest of the world!



[Wind Map](#)

[Prime Number Patterns](#)

Internet Users in the World (per 100 people)



Created by Mridhula Venkataramani, CGT 270 class assignment

# What is Data Visualization?



# What is Data Visualization?

<http://mindymcadams.com/tojou/2011/10-useful-resources-about-data-visualization/>

Last accessed 02/27/17

- Representing large amounts of disparate information in a visual form often allows you to see patterns that would otherwise be buried in vast, unconnected data sets. ...
- Visualizations allow you to understand and process enormous amounts of information quickly because it is all represented in a single image or animation.

# What is the purpose of Visualization?

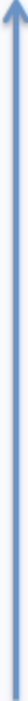


“The purpose of  
visualization  
is “*insight*”,  
not pictures.”

~Ben Shneiderman

# Advancing Beyond Data to True Insight

Relationship



Data

Source: Ackoff, Russell L., "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

Relevance



# Advancing Beyond Data to True Insight

Relationship



Information

Data becomes information when it has *meaning* and we understand context and relationship – the who, what, where, and when



Relations

Data

Source: Ackoff, Russell L., "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

Relevance





# Advancing Beyond Data to True Insight

Relationship



Knowledge

Knowledge is information aggregated to a point where it has meaning and *purpose* – the how

Patterns



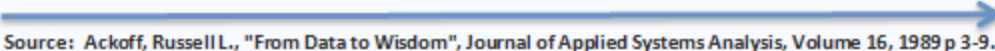
Information

Data becomes information when it has *meaning* and we understand context and relationship – the who, what, where, and when

Relations



Data



Relevance

Source: Ackoff, Russell L., "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

# Advancing Beyond Data to True Insight

Relationship



Understanding

Understanding is cognitive *and* analytical. It is the process by which one can *synthesize new knowledge* from what was already known.

Causality



Knowledge

Knowledge is information aggregated to a point where it has meaning and *purpose* – the how

Patterns



Information

Data becomes information when it has *meaning* and we understand context and relationship – the who, what, where, and when

Relations



Data



Relevance

Source: Ackoff, Russell L., "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

# Advancing Beyond Data to True Insight

Relationship



Wisdom

Wisdom builds on our past to give us new understanding and, by incorporating values, judgment and experience, the ability to predict.

Principles



Understanding

Understanding is cognitive *and* analytical. It is the process by which one can *synthesize new knowledge* from what was already known.

Causality



Knowledge

Knowledge is information aggregated to a point where it has meaning and *purpose* – the how

Patterns



Information

Data becomes information when it has *meaning* and we understand context and relationship – the who, what, where, and when

Relations



Data



Relevance

Source: Ackoff, Russell L., "From Data to Wisdom", Journal of Applied Systems Analysis, Volume 16, 1989 p 3-9.

# Questions?

## Next: What does Insight Lead to



# What does Insight lead to?



# INSIGHT LEADS TO

## Discovery

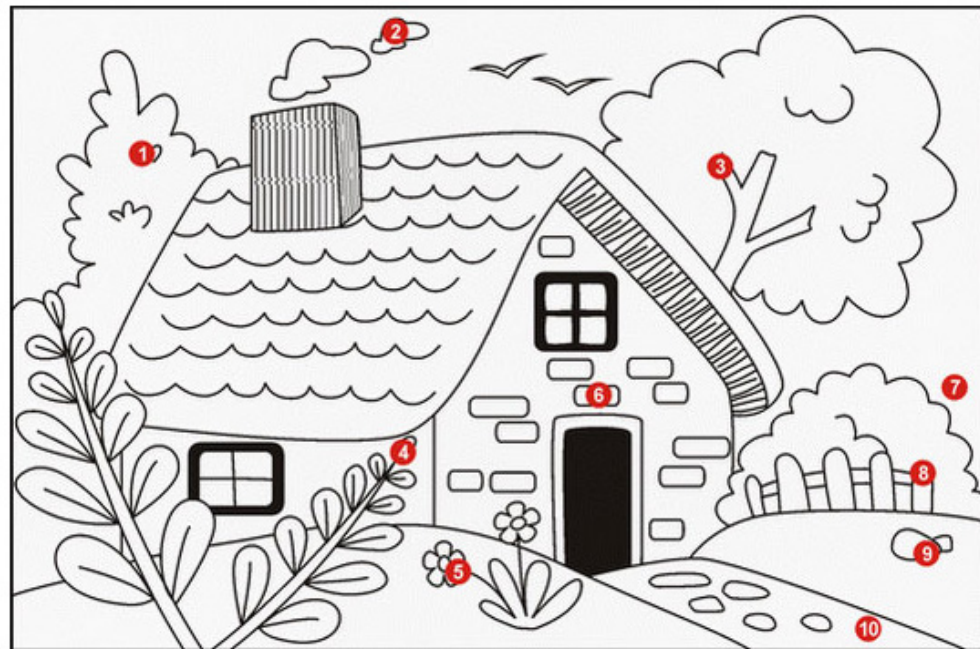
- Visualizing Patterns over time
- Spotting Differences

Decision Making

Analysis of Data

Explanation

Storytelling



# INSIGHT LEADS TO

Discovery

- Visualizing Patterns over time
- Spotting Differences

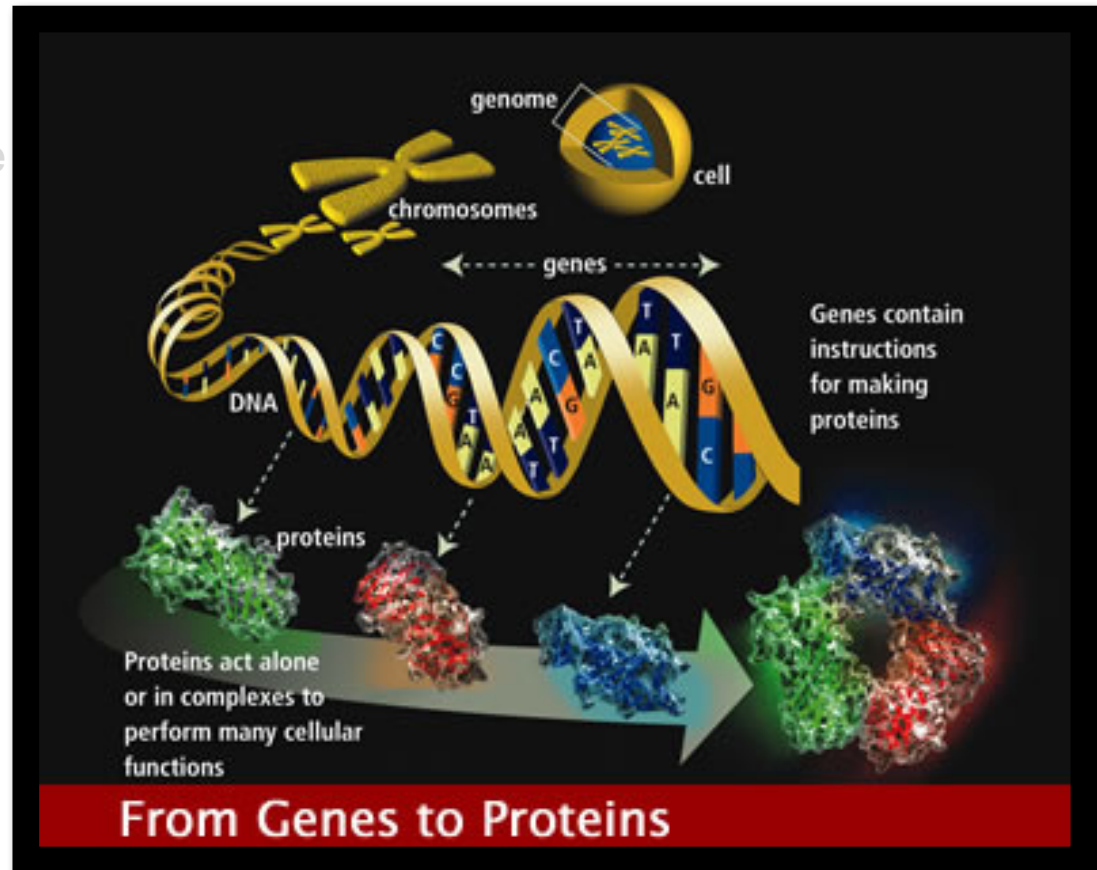
Decision Making

Analysis of Data

Explanation

Storytelling

**Allows users to answer questions they didn't know they had**



Human Genome Project

<https://pradipjntu.files.wordpress.com/2011/05/molecularmachine.jpg>

# INSIGHT LEADS TO

Discovery

Decision Making

Analysis of Data

Explanation

Storytelling



*Katherine Johnson (played by Taraji P. Henson) calculates orbital insertion trajectories for the Mercury program using Euler's method in this scene from the movie Hidden Figures. Credit: <sup>TM</sup> and © 2017 Twentieth Century Fox Film Corporation. All rights reserved.*



# INSIGHT LEADS TO

## Discovery

- Visualizing Patterns over time
- Spotting Differences

## Decision Making

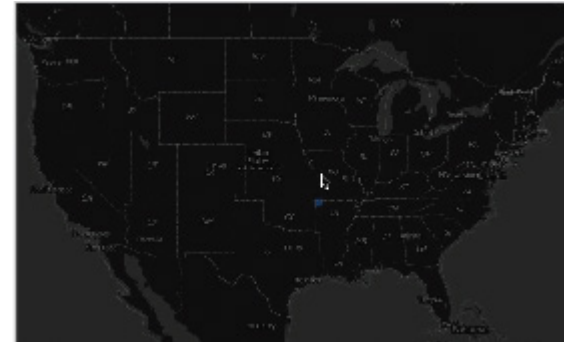
## Analysis of Data

## Explanation

## Visualizing Spatial Relationships

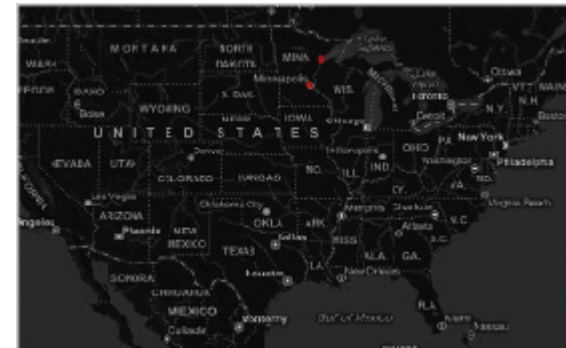
## Storytelling

Muehlenhaus, I. (2012). **Chapter 8, Visualizing Spatial Relationships**, Visualize This: The Flowing Data Guide to Design, Visualization, and Statistics, pp 271-326.



Watch the Growth of Walmart and Sam's Club

<http://datafl.ws/197>



Watch the Growth of Target Stores

<http://datafl.ws/198>

# INSIGHT LEADS TO

Discovery

- Visualizing Patterns over time
- Spotting Differences

Decision Making

Analysis of Data

Explanation

Storytelling

COVER FEATURE



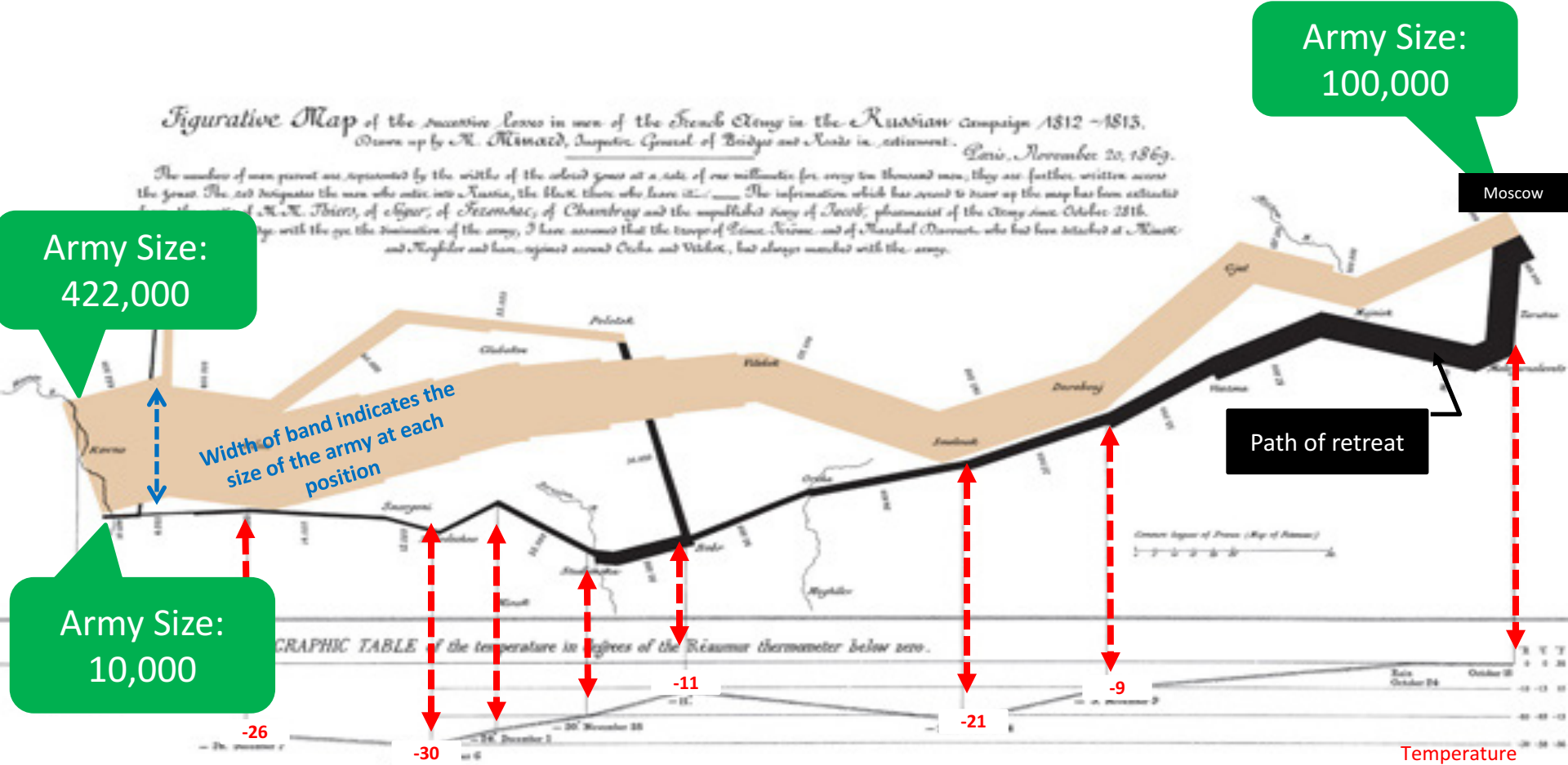
**Storytelling:  
The Next  
Step for  
Visualization**

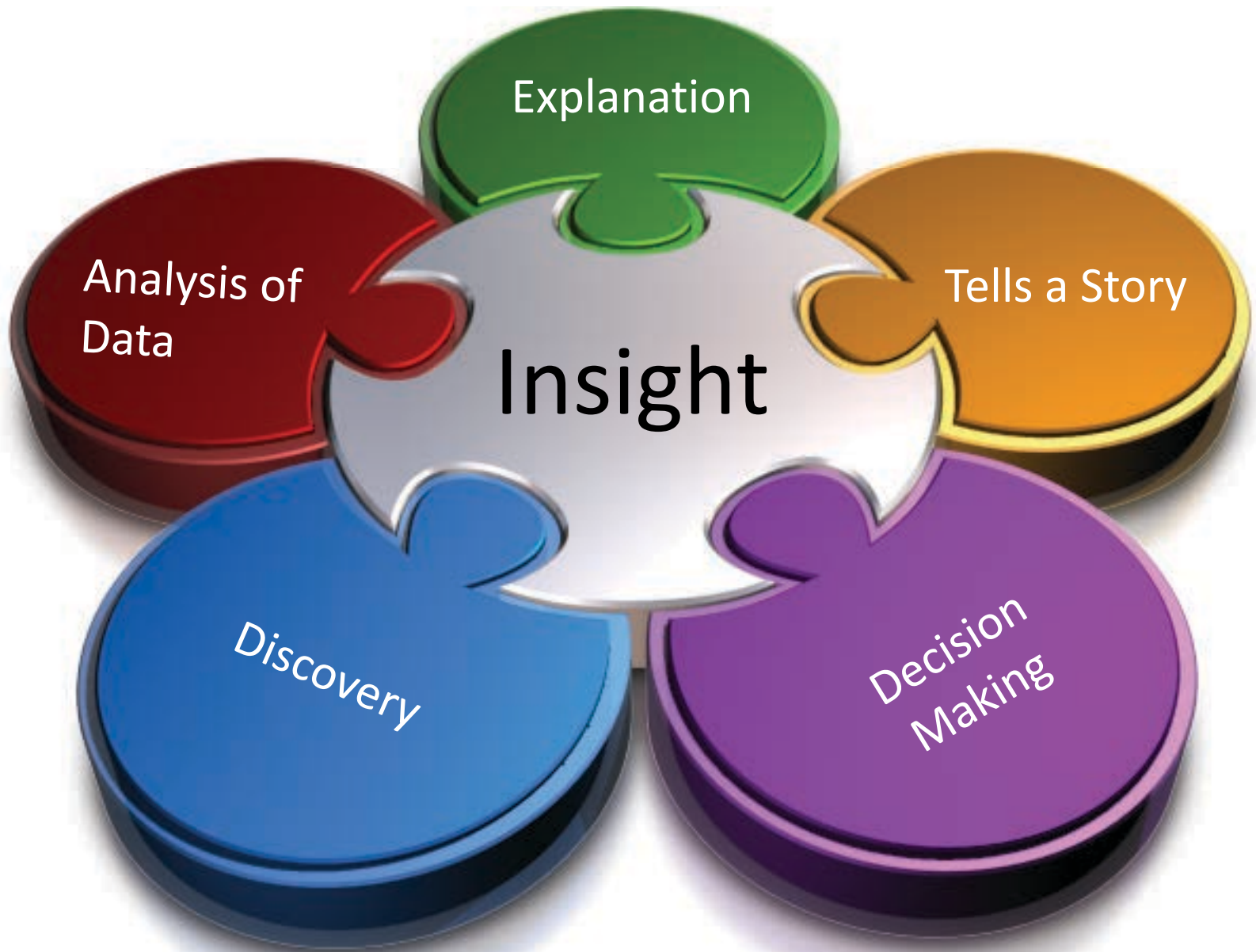
Robert Kosara and Jock Mackinlay, *Tableau Software, Seattle*

R. Kosara and J. Mackinlay, "Storytelling: The Next Step for Visualization," in *Computer*, vol. 46, no. 5, pp. 44-50, May 2013.

# Story Telling with Visualization

## Napoleon's Invasion of Russia in 1812 By Jacque Minard





# Questions?

## Next: Visualization Applications



# Visualization Applications

## Why is visualization important?



# Visualization Applications

## Biovisualization (BioVis)

The visualization of  
biological data;  
Often grouped with  
computer animation



March 2010 | volume 7 | number 3

# Visualization Applications

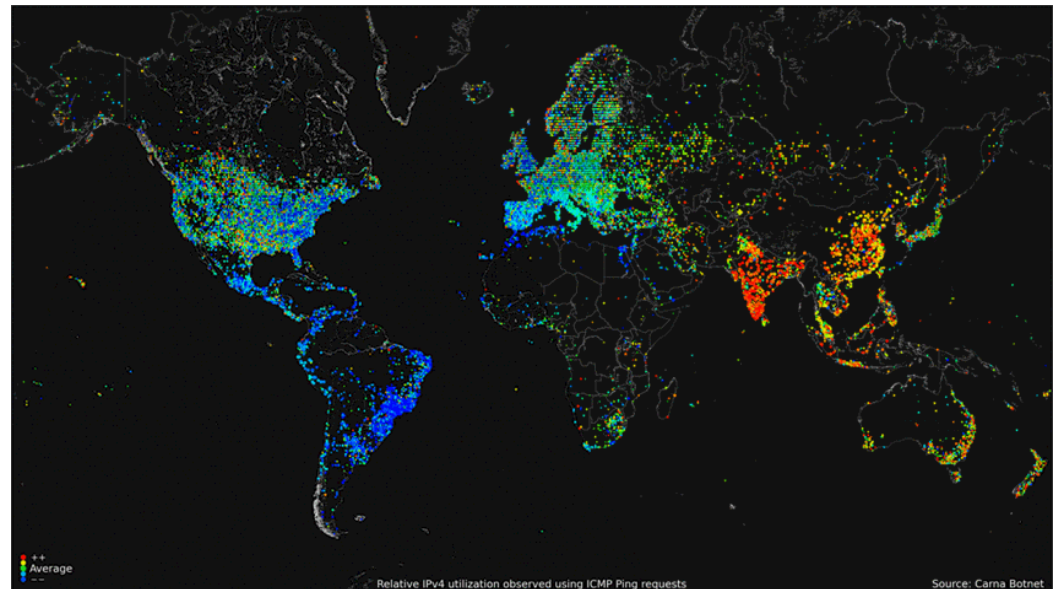
## Information Visualization (InfoVis)

Interdisciplinary

Study of the “visual  
representation of  
large-scale collections  
of non-numerical  
information



Social Media Data  
Survey Data  
Observed Data



Internet Usage

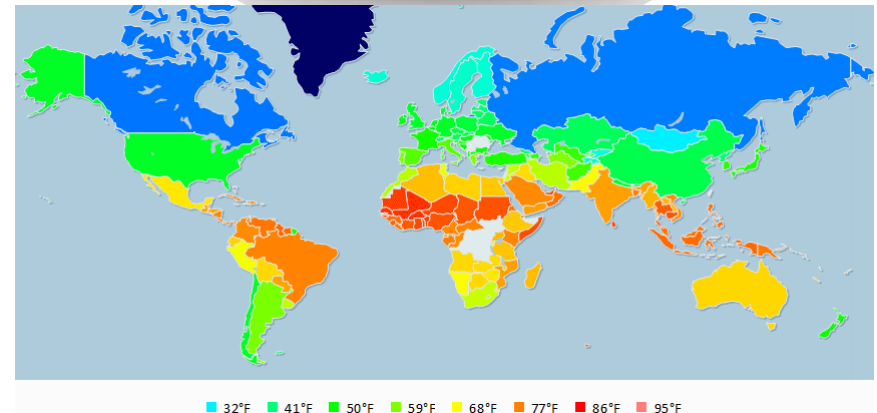
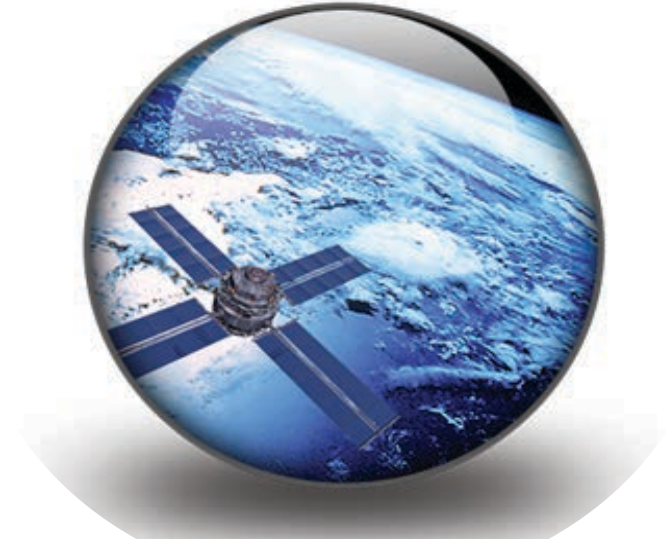
Source: <http://www.cernea.net/wp-content/uploads/2013/03/internet.gif>



# Visualization Applications

## Geographic Visualization

Communicates geospatial information in ways that, when combined with human understanding, allow for data exploration and decision-making processes.



MacEachren, A.M. and Kraak, M.J. 1997 Exploratory cartographic visualization: advancing the agenda. *Computers & Geosciences*, 23(4), pp. 335-343. Jiang, B., and Li, Z. 2005. Editorial: Geovisualization: Design, Enhanced Visual Tools and Applications. *The Cartographic Journal*, 42(1), pp. 3-4 [MacEachren, A.M.](#) 2004. Geovisualization for knowledge construction and decision support. *IEEE computer graphics and applications*, 24(1), pp.13-17

# Visualization Applications

## Scientific Visualization (SciVis)

Primarily concerned with the visualization of three-dimensional phenomena

Emphases on realistic renderings of volumes, surfaces, illumination sources, etc.

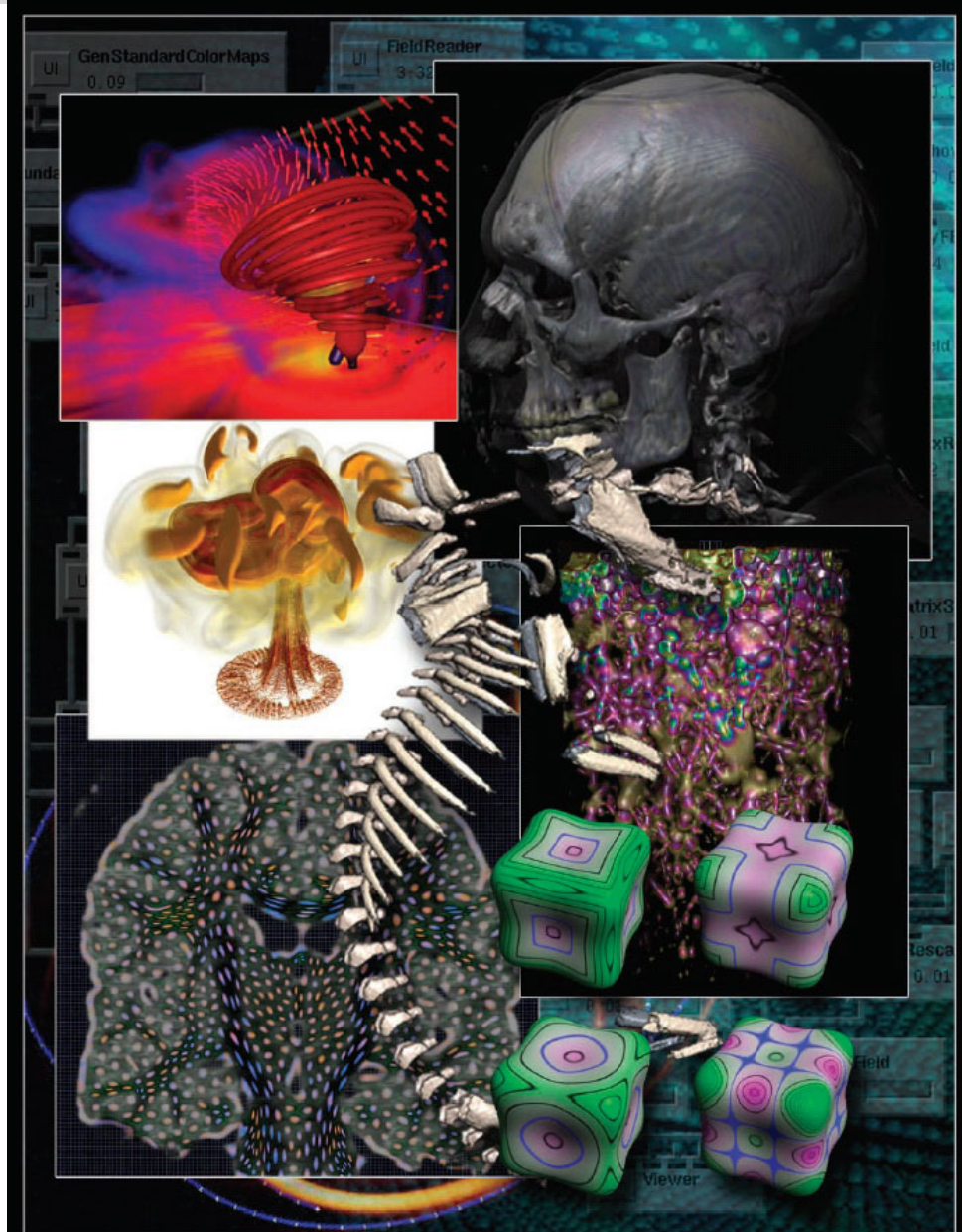


Image Source:

<http://www.sci.utah.edu/the-institute/highlights/24-research-highlights/cibc-highlights/253-top-scientific-visualization-research-problems.html>

# Questions?

## Next: High Level Overview



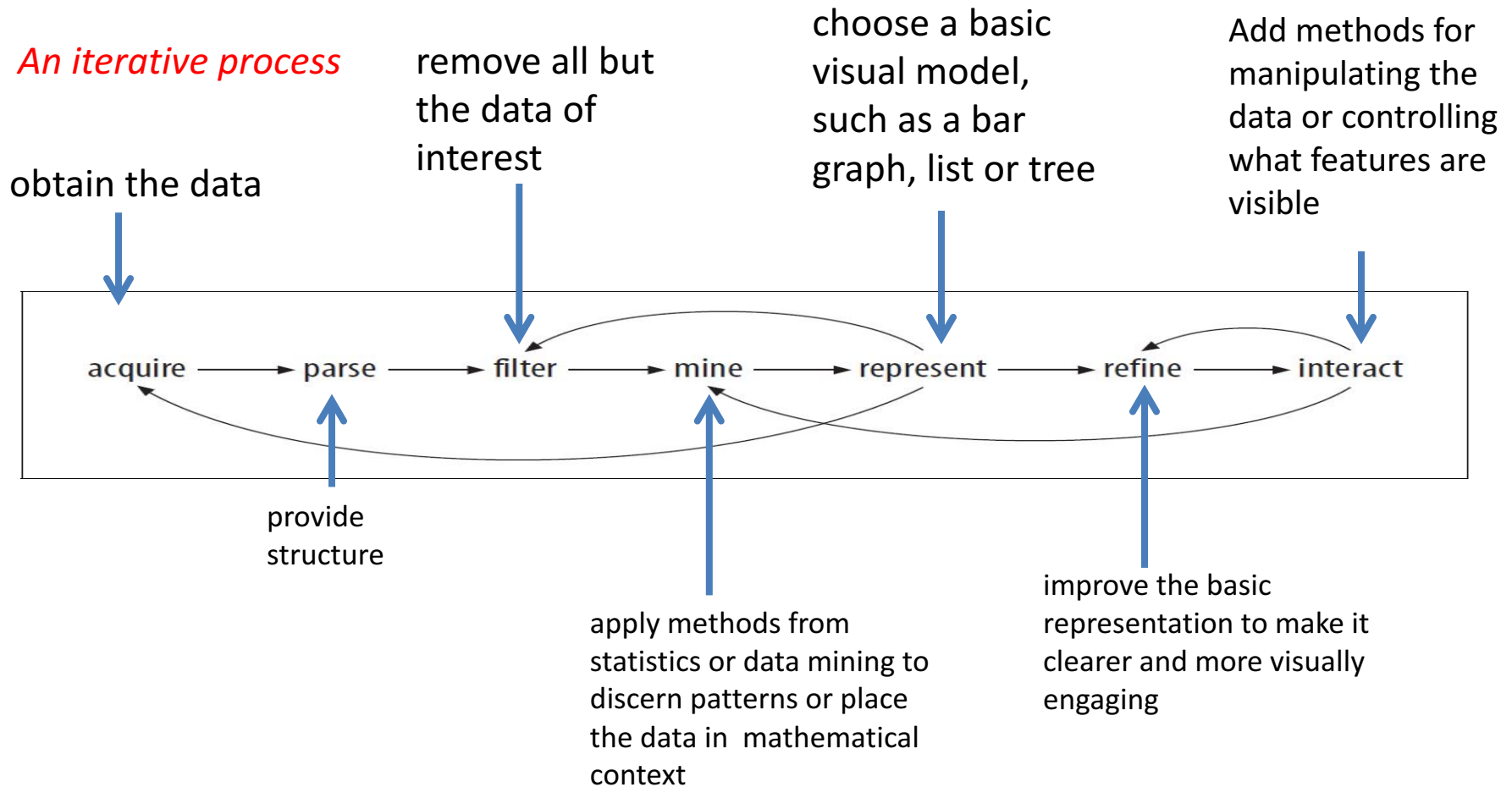
# Data Visualization Process

## High Level Overview



# Data Visualization Process

*An iterative process*



# Visualization Process

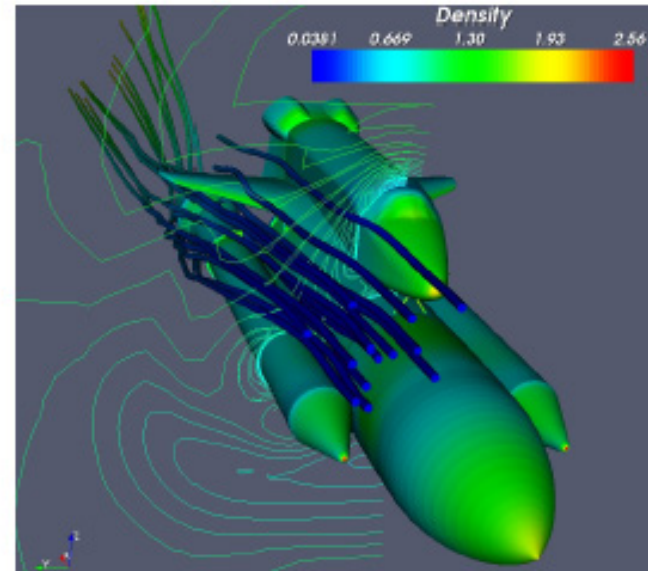
Taking raw data and converting it to a form that is viewable and understandable to humans.

```
0265640 132304 133732 032051 037334 024721 055013 052226 001662
0265660 025537 064663 054606 043294 074076 124153 133218 126614
0265700 144210 056426 044700 042650 165230 137037 003655 006254
0265720 134453 124327 176005 027034 107634 170774 073702 067274
0265740 072451 007735 147620 051064 157435 113057 155356 114603
0265760 107204 102316 171451 046040 120223 001774 030477 046673
0266000 171217 116055 155117 134444 167210 041405 147127 050505
0266020 004137 046472 124015 134360 173550 053517 044635 021135
0266040 070176 047705 113754 175477 105532 076515 177366 056333
0266060 041023 074017 127113 003234 037025 037640 066171 123424
0266100 067701 037406 140000 165341 072410 100032 125455 056646
0266120 066716 071402 055672 132571 105645 170073 050376 072117
0266140 024451 007424 114200 077733 024434 012546 172404 102345
0266160 040223 050170 055164 164634 047154 126525 112514 032315
0266200 016041 176055 042766 025015 176334 017234 110060 014515
0266220 117156 030746 154234 125001 151144 163706 136237 164376
0266240 137055 062276 161755 115466 005322 132567 073216 002655
0266260 171466 126161 117155 065763 016177 014460 112765 055527
0266300 003767 175367 104754 036436 172172 150750 043643 145410
0266320 072074 000007 040627 070552 175011 002151 125132 140214
0266340 060115 014356 015164 067027 120206 070242 030065 131334
0266360 170601 170106 040437 127277 124446 136631 041462 116321
0266400 020243 005602 004146 121574 124651 005634 071331 102070
0266420 157504 160307 166330 079251 024520 114433 167273 030635
0266440 133614 106171 144160 010552 007365 026416 160716 100413
0266460 026630 007210 000630 121224 076033 140764 000737 003276
0266500 114060 042647 104475 110537 066716 104754 075447 112254
0266520 030374 144251 077734 015157 002513 173526 035531 150003
0266540 146207 015135 024446 130101 072457 040764 165513 156412
0266560 166410 067251 156160 106406 136770 030516 064740 022032
0266600 142166 123707 175121 071170 076357 037233 031136 015232
0266620 075074 016744 044055 102230 110063 033350 052765 172463
```

# Visualization Process

There are several steps between raw data and a finished visualization

```
0265640 132304 133732 032051 037334 024721 015013 052226 001662
0265660 025537 064663 054606 043294 074076 124153 135218 126614
0265700 144210 056426 044700 042550 165230 137037 003655 006254
0265720 134453 124327 176005 027034 107614 170774 073702 067274
0265740 072451 007735 147620 051064 157435 113057 155356 114603
0265760 107204 102316 171451 046040 120223 001774 030477 046673
0266000 171317 116055 155117 134444 167210 041405 147327 050505
0266020 004137 046472 124015 134360 173550 053517 044635 021135
0266040 070176 047705 113754 175477 105532 076515 177366 056333
0266060 041023 074017 127113 003214 037025 037640 066171 123424
0266100 067701 037406 140000 165341 072410 100032 125455 056646
0266120 006716 071402 055672 132571 105645 170073 050376 072117
0266140 024451 007424 114200 077733 024434 012546 172404 102345
0266160 040223 050170 055164 164634 047154 126525 112514 032315
0266200 016041 176055 042766 025015 176314 017234 110060 014515
0266220 117156 030746 154234 125001 151144 163706 136237 164376
0266240 137055 062276 161755 115466 005322 132567 073216 002655
0266260 171466 126161 117155 055763 016177 014460 112765 055527
0266300 003767 175367 104754 036436 172172 150750 043643 145410
0266320 072074 000007 040627 070552 175011 002151 125132 140214
0266340 060115 014356 015164 067027 120206 070242 030055 131334
0266360 170601 170106 040437 127277 124446 136631 041462 116321
0266400 020243 005602 004146 121574 124651 005634 071331 102070
0266420 157504 160307 166330 074251 024520 114433 167273 030635
0266440 133614 106171 144160 010552 007365 026416 160716 100413
0266460 026630 007210 000630 121224 075033 140754 000737 003276
0266500 114060 042647 104475 110537 066716 104754 075447 112254
0266520 030374 144251 077734 015157 002513 173526 035531 150003
0266540 146207 015135 024446 130101 072457 040764 165513 156412
0266560 166410 067251 156160 106406 136770 030516 064740 022032
0266600 142166 123707 175121 072170 076357 037233 031136 015232
0266620 075074 016744 044055 102230 110063 033350 052765 172463
```



**Why do we care?**  
**I just want a pretty picture!**





# Visualization

Visualization is the tool that will take us forward from the traditional output of high performance computing (HPC) that we are used to into a visual medium that allows researchers to *collaborate* and *elaborate* on the finding's they've got.

***Tim Carroll***

*Director and Global Lead,*

*Dell Research Computing Solutions*

*HPC Source (Spring 2011)*

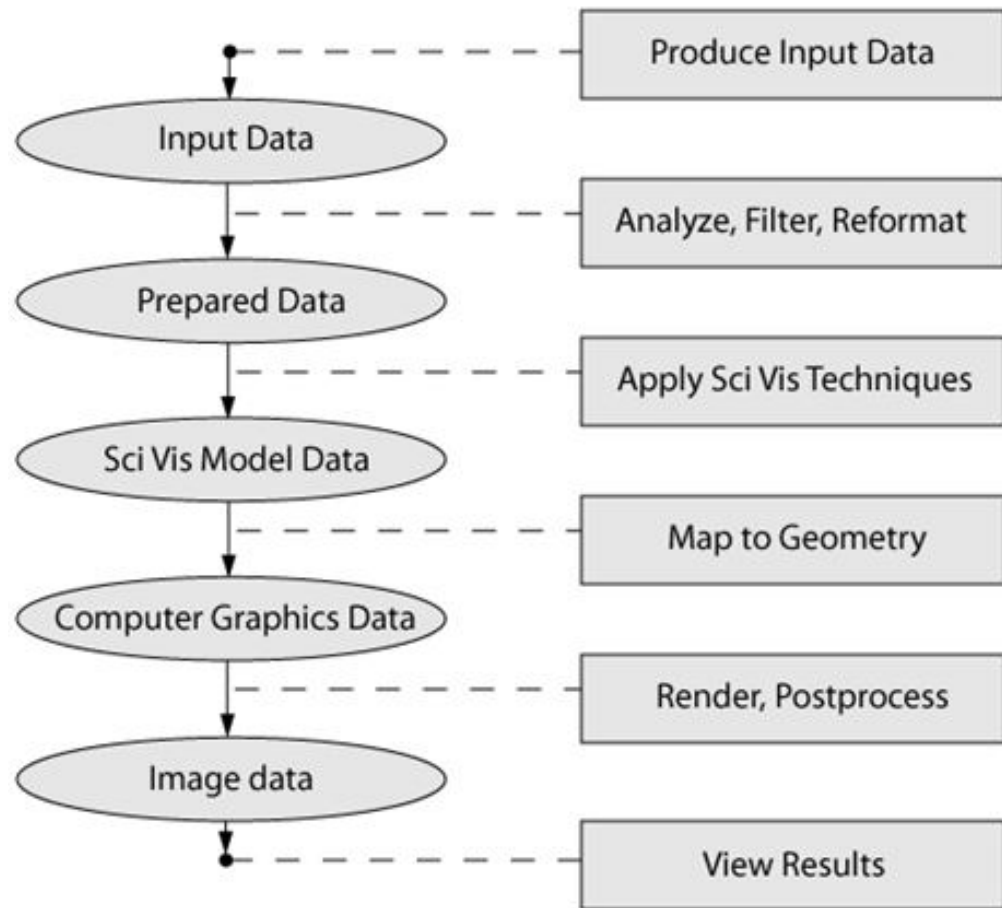
# Scientific Visualization

- Primarily concerned with the visualization of three-dimensional phenomena (architectural, meteorological, medical, biological, etc.),
- Where the emphasis is on realistic renderings of volumes, surfaces, illumination sources, and so forth, perhaps with a dynamic (time) component.

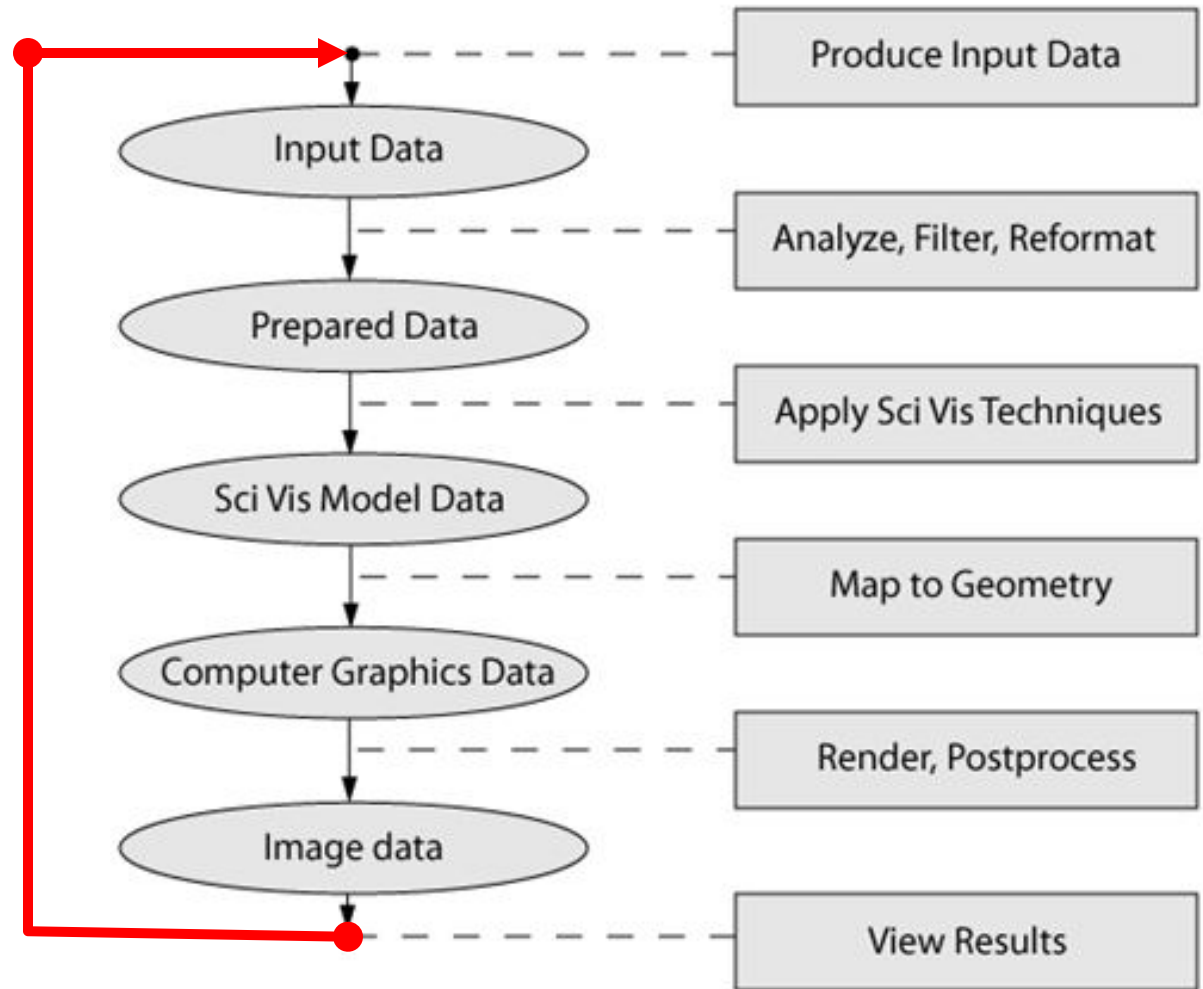
# Scientific Visualization Pipeline



What's Missing?



# Scientific Visualization Pipeline



# Scientific Visualization Pipeline: Step 1 . . .

## Produce Data

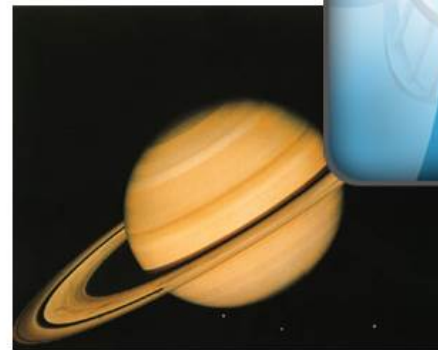
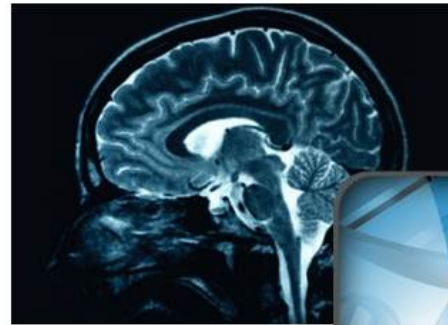
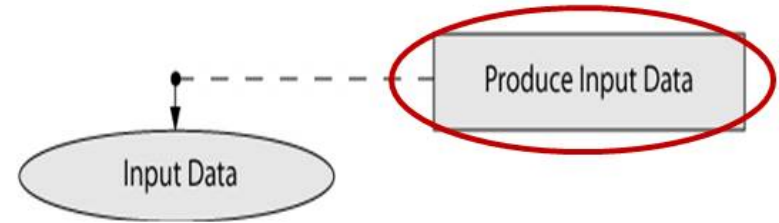
Simulated Data

Images

Numerical

Some measured value

Observed Phenomena



# Scientific Visualization Pipeline:

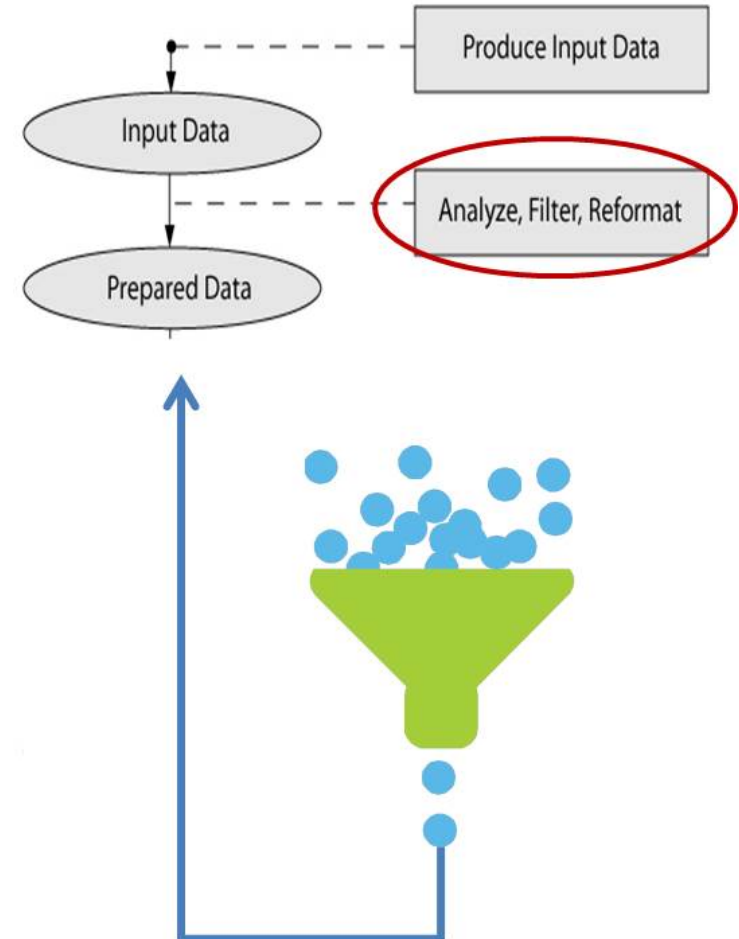
## Step 2 . . .

# Analyze, Filter, Reformat

### Cleaning up the data

- Removing noise
- Replacing missing values
- Clamping values to be within a specific range of interest

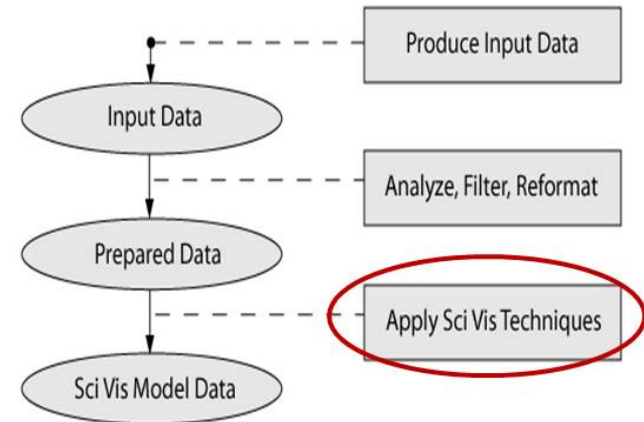
Performing operations to yield more useful data



# Scientific Visualization Pipeline: Step 3

## Apply SciVis Techniques

- Converts raw information into something more understandable
- Visually extracting meaning from a scientific data set using various techniques



Contour



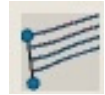
Clip



Threshold



Glyphs

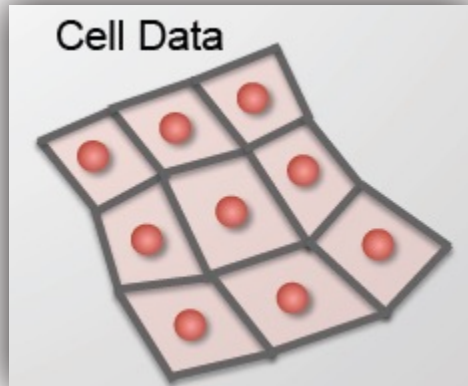


Streamlines

# Scientific Visualization Pipeline

## Step 4 . . .

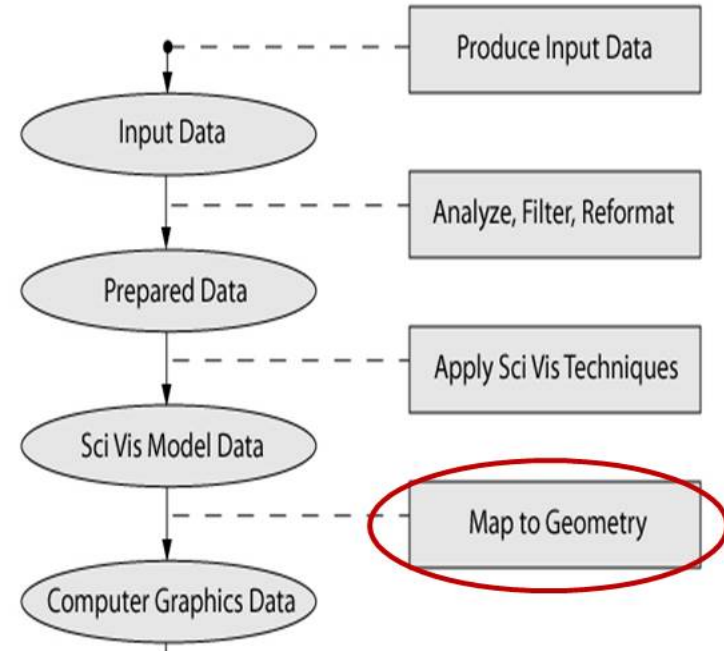
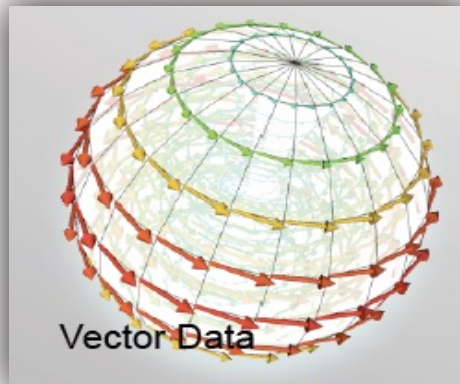
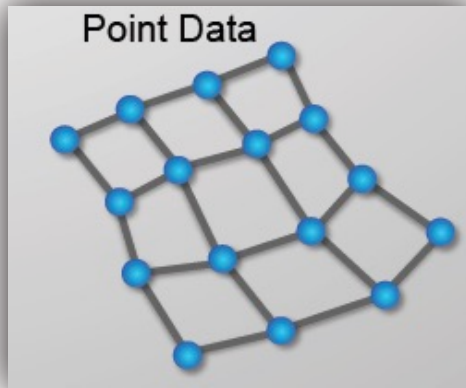
# Map to Geometry



Scalars, vectors,  
tensors

1D, 2D, 3D

Mesh



Adopted from

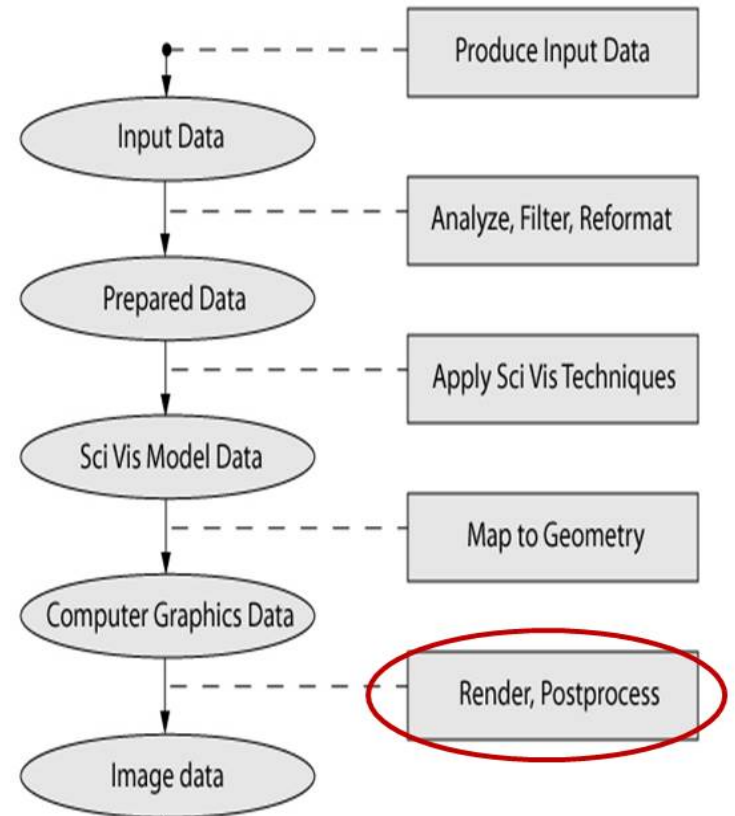
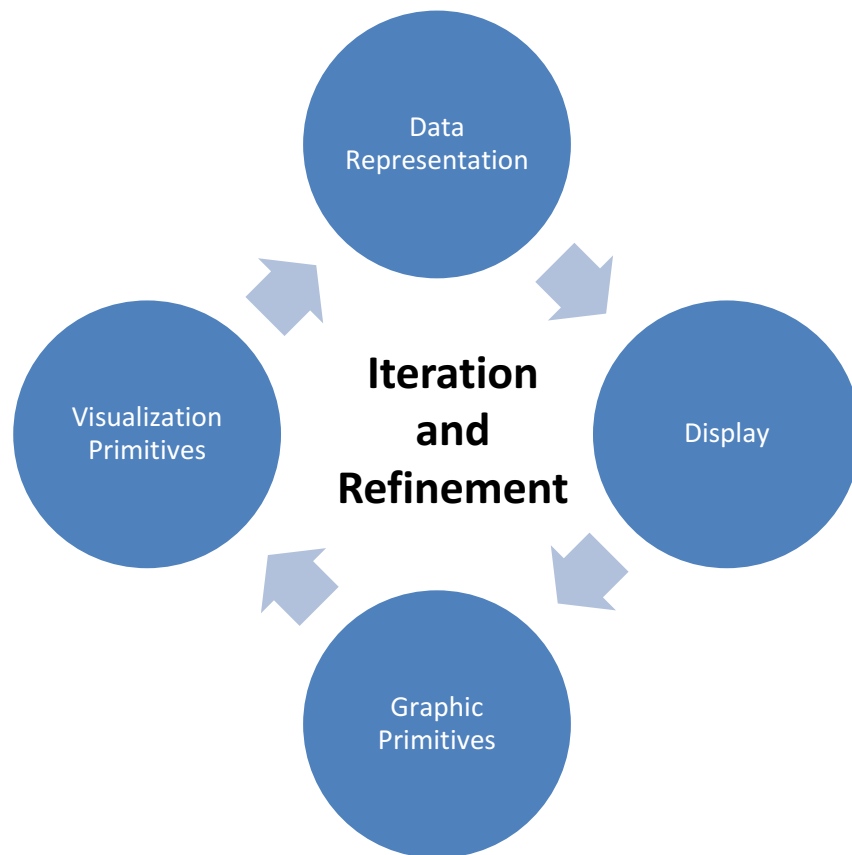
<http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/>



# Scientific Visualization Pipeline:

Step 5 . . .

## Render, Post Process

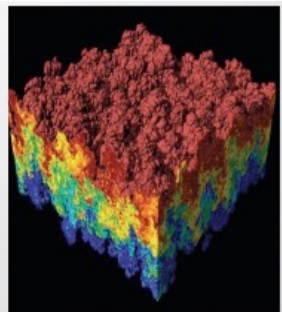


Adopted from

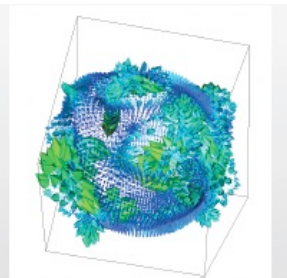
<http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/>

# Scientific Visualization Pipeline: Step 6 . . .

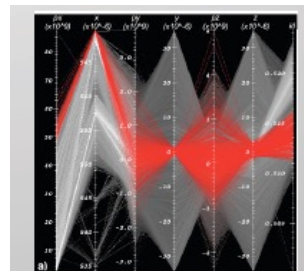
## View Results



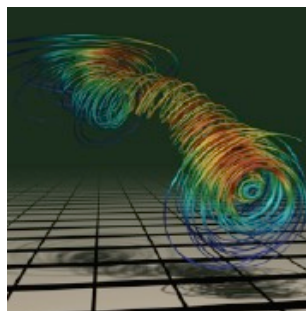
Pseudocolor Rendering



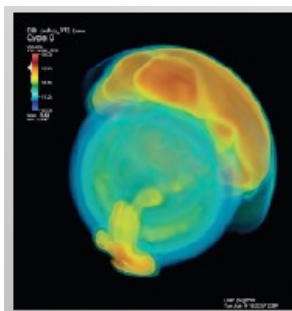
Vector / Tensor Glyphs



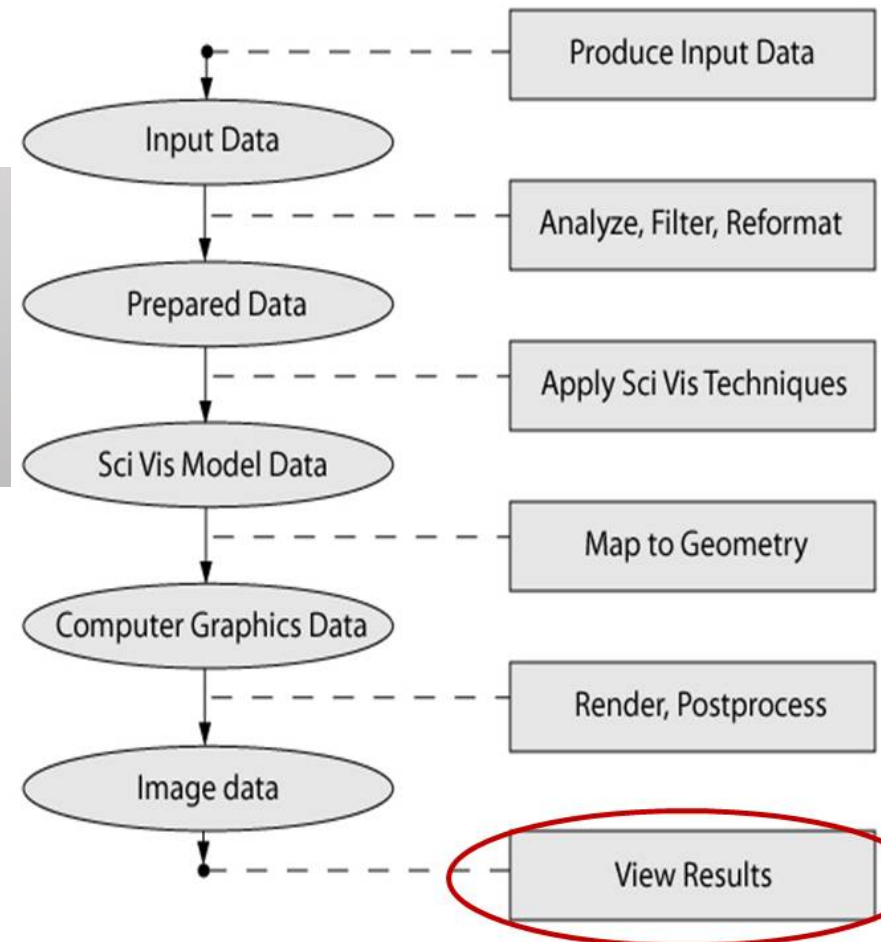
Parallel Coordinates



Streamlines



Volume Rendering



Adopted from

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

# Questions?

## Next: The Importance of Data Visualization



# Why is Data Visualization Important?



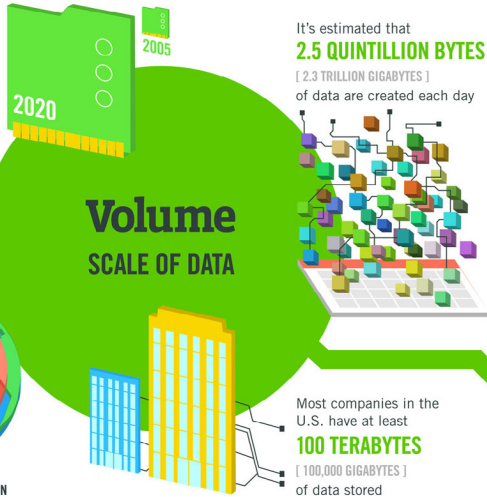
# IBM Big Data Platform

**40 ZETTABYTES**  
[ 43 TRILLION GIGABYTES ]  
of data will be created by 2020, an increase of 300 times from 2005

**6 BILLION PEOPLE** have cell phones

**WORLD POPULATION: 7 BILLION**

## Volume SCALE OF DATA



## The FOUR V's of Big Data

From traffic patterns and music downloads to web history and medical records, data is recorded, stored, and analyzed to enable the technology and services that the world relies on every day. But what exactly is big data, and how can these massive amounts of data be used?

As a leader in the sector, IBM data scientists break big data into four dimensions: **Volume, Velocity, Variety and Veracity**

Depending on the industry and organization, big data encompasses information from multiple internal and external sources such as transactions, social media, enterprise content, sensors and mobile devices. Companies can leverage data to adapt their products and services to better meet customer needs, optimize operations and infrastructure, and find new sources of revenue.

By 2015 **4.4 MILLION IT JOBS** will be created globally to support big data, with 1.9 million in the United States



As of 2011, the global size of data in healthcare was estimated to be **150 EXABYTES** [ 161 BILLION GIGABYTES ]

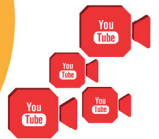


**30 BILLION PIECES OF CONTENT** are shared on Facebook every month



By 2014, it's anticipated there will be **420 MILLION WEARABLE, WIRELESS HEALTH MONITORS**

**4 BILLION+ HOURS OF VIDEO** are watched on YouTube each month



**400 MILLION TWEETS** are sent per day by about 200 million monthly active users

## Variety DIFFERENT FORMS OF DATA



The New York Stock Exchange captures **1 TB OF TRADE INFORMATION** during each trading session



Modern cars have close to **100 SENSORS** that monitor items such as fuel level and tire pressure

## Velocity ANALYSIS OF STREAMING DATA

By 2016, it is projected there will be **18.9 BILLION NETWORK CONNECTIONS** — almost 2.5 connections per person on earth



**1 IN 3 BUSINESS LEADERS** don't trust the information they use to make decisions



**27% OF RESPONDENTS** in one survey were unsure of how much of their data was inaccurate

**27% OF RESPONDENTS**

## Veracity UNCERTAINTY OF DATA

Poor data quality costs the US economy around **\$3.1 TRILLION A YEAR**



# Why should you care about Visualization?



# Why Should You Care About Visualization

- There is a demand for people who understand the visualization process and is able to transform raw complex data into a visual representation that does not overwhelm.
- Regardless of major, research interest, or academic background, at some point you will visualize some type of data. ~ Vetricia Byrd, 2017

# WHY SHOULD YOU CARE?

HPCwire

Since 1987 - Covering the Fastest Computers in the World and the People Who Run Them

- There is a demand for people who understand the visualization process and is able to transform raw complex data into a visual representation that does not overwhelm.



<https://www.hpcwire.com/2014/07/31/byrd-emphasizes-value-visualization-xsede14/>

July 31, 2014

Regardless of major, research interest, or academic background, etc., at some point you will visualize some type of data. ~ Vetricia Byrd, 2014

Engineering

Computer Science

Research

Physics

Industry

Biomedical Engineering

Non-STEM

The Arts

Athletics

Academia

Statistics

STEM

Chemistry

Biology

Socially

**PURDUE**  
POLYTECHNIC



# You've Got Data

## Now What?



# YOU'VE GOT DATA

## NOW WHAT?

### Questions

1. What does the data look like?
2. What needs to be communicated?
3. What are you interested in utilizing the resulting visualization(s) for
  - ✓ Analysis of data
  - ✓ Explanation
  - ✓ Communication (Storytelling)
  - ✓ Discovery
  - ✓ Decision Making
4. What has been done before?
5. [Where do I start?](#)



Image Source: Types of data. Translation of document hosted by João Batista Netoat  
[https://commons.wikimedia.org/wiki/File:Data\\_types\\_-\\_pt\\_br.svg](https://commons.wikimedia.org/wiki/File:Data_types_-_pt_br.svg)

More types of data: Biological, Social Media, Network Data, Survey Data, Cybersecurity, Temporal, Image data, Topical, . . . this is NOT an exhaustive list

# Visualization is a Process



# RESOURCES

## A STARTING POINT: OPEN SOURCE VISUALIZATION TOOLS

- Information Visualization
  - Gephi
  - Tableau (not open source but free)
- Scientific Visualization
  - ParaView
  - VisIt
- Geo Visualization
  - ARC GIS
  - D3.js
- Cyber Security Visualization
  - Survey of Security Visualization
  - Survey of Cybersecurity Visualization

# WANT MORE?

[https://keshif.me/demo/VisTools?utm\\_content=26335725&utm\\_medium=social&utm\\_source=twitter](https://keshif.me/demo/VisTools?utm_content=26335725&utm_medium=social&utm_source=twitter)

Created with **Keshif**
**Data-Visualization Tools & Books**

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### 430 Data-Visualization Tools

#### Highlights

★★★	8
★★	37
★	90

#### Features

Charting	256
Web-based	242
Design focused	61
Spreadsheet	55
Infographics	33
Statistical	32
Color	31
Scientific	24

#### Data Types

Multivariate	150
Time	136
Geographical	118
Network	52
Text	21


#### Data Processing

Aggregate	14
Filter	12
Advanced	12
Formula	8
Convert	8
Programming	7
Clean	6
Yes	5
Extract	5
Scrape	4
Transform	3

#### Cost


Free	241
Paid	71
Free & Paid	33

★s




**Keshif**

Charting + Web-based + JavaScript + Graphical Interface




**D3.JS**

Charting + Web-based + JavaScript




**Tableau Public**

Charting + Statistical + Infographics + Web-based + Scripting + Graphical Interface



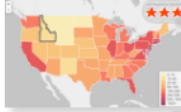
**ColorBrewer 2.0**

Color + Web-based + Graphical Interface




**NodeXL**

Charting + Graphical Interface



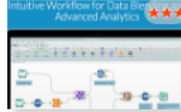
**Leaflet.js**

Charting + Web-based + JavaScript




**RStudio**

Charting + Statistical + Web-based + Graphical Interface + R



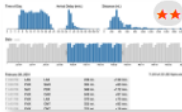
**alteryx**

Charting + Statistical + Graphical Interface + R



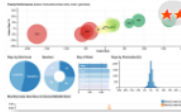
**Trifacta**

Charting + Web-based + Graphical Interface + Scripting




**Crossfilter**

Web-based + JavaScript



**dc.js**

Charting + Web-based + JavaScript



**Trifacta Data Wrangler**

Charting + Web-based + Graphical Interface + Scripting + Y

#### Main

Categorized	342
Active	291
Open-Source	184

#### Tags

Search	5
Platform	23
d3	23
Excel	10
Business Intelligence	10
Storytelling	8
PDF	5
VIS2015	4
Vega	4
Technology	4
jQuery	4
SVG	3
Mockups	3
Journalism	3
iOS	3
Faceted Browsing	3

#### Programming

Graphical Interface	123
JavaScript	89
R	20
Python	20
Scripting	12
HTML	10
Java	8
RESTful API	6
Ruby	5
SQL	4
JSON	4
PHP	3
Scala	2
Processing	2
Other	2

#### Author

📄 Data is public at [Google Sheets](#). Contribute to this open resource! For info, contact [@adilyalcin](#)  
📄 All rights for the images belong to their respective owners. Acknowledgements

# Questions?

**PURDUE**  
POLYTECHNIC



## Vetria L. Byrd

Assistant Professor

Computer Graphics Technology

[vlbyrd@purdue.edu](mailto:vlbyrd@purdue.edu)

<https://polytechnic.purdue.edu/profile/vbyrd>

<http://web.ics.purdue.edu/~vbyrd/>



@VByrdPhD, @BPViz

Purdue Polytechnic Institute



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Thank You Image Source:

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