Introduction to Data Visualization

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Assistant Professor
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Purdue University

Summer Undergraduate Research Fellowship Program (SURF Program)

Purdue University

June13, 2017

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ABOUT THIS TALK

ASSUMPTIONS

Target Audience: Beginners

Pre-requisites: No prior knowledge of visualization

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ABOUT THIS TALK

GOALS

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

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ABOUT THIS TALK

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

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ABOUT THIS TALK

EXPECTED OUTCOMES

By the end of this presentation, you will

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

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AGENDA

INTRODUCTION TO DATA VISUALIZATION

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

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INTRODUCTIONS

What majors are represented today?

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About Me

Vetria L. Byrd, PhD

Academic Preparation

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

UAB THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
Knowledge that will change your world

What I've Done

CLEMSON UNIVERSITY

Visualization Initiatives

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

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

Agent for "Insight"

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About Me

Vetria L. Byrd, PhD

Research Interests

- Data Visualization
- Big Data
- Visualization of Heterogeneous Data
- Uncertainty Visualization
- High Performance Computing (HPC) for Data Visualization
- Broadening Participation in Visualization

Faculty Liaison for Purdue University's Women in HPC Group

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FOUR TYPES OF VISUALIZATIONS

GEORGES GRINSTEIN (KEYNOTE PRESENTATION, VINCI 2016)

- **Exploratory**
  - Have no hypotheses about the data
  - Explore data interactively as undirected searches
- **Confirmatory**
  - Have specific hypotheses about the data
  - Goal-oriented examination of the hypotheses
- **Presentation**
  - Facts to be presented are fixed a priori
  - Select appropriate presentation techniques
- **Interactive**
  - Interactions with a pre-defined animation

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DATA VISUALIZATIONS

WE'VE ALL SEEN THEM

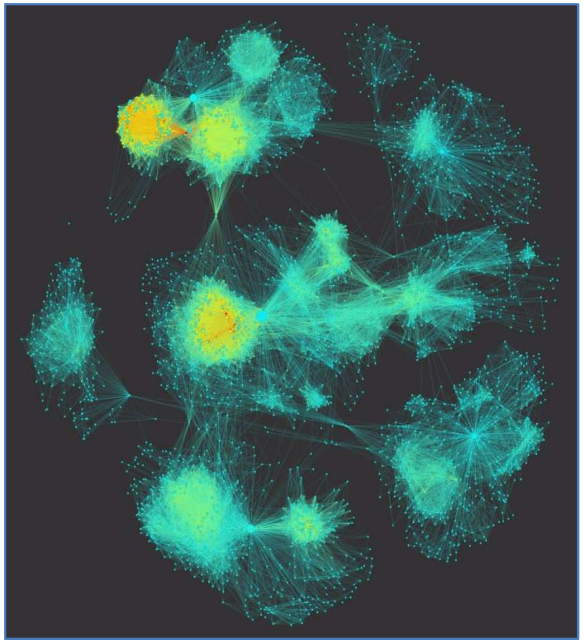
Source: http://mindymcadams.com/tojou/2011/10-useful-resources-about-data-visualization/

[Wind Map](http://hint.fm/wind/)

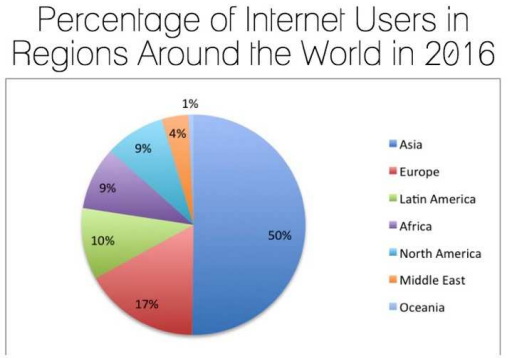
http://hint.fm/wind/

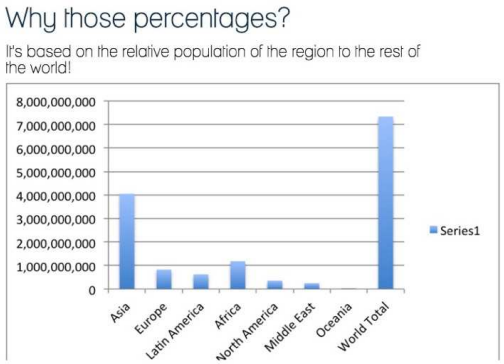
Engineering Intelligence Through Data Visualization at Uber

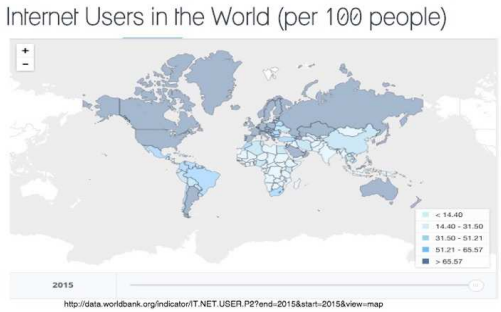
https://eng.uber.com/data-viz-intel/



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







Created by Mridhula Venkataramani, CGT 270 class assignment

What is Data Visualization?

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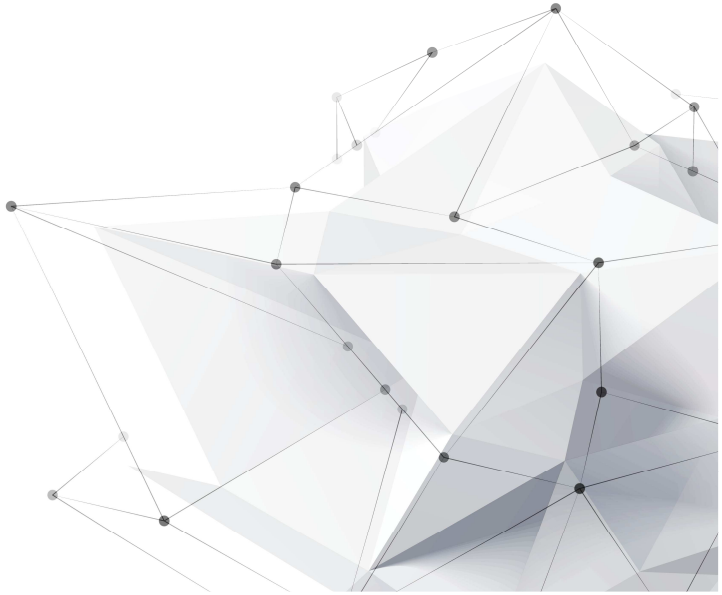

What is Data Visualization?

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.

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What is the purpose of Visualization?

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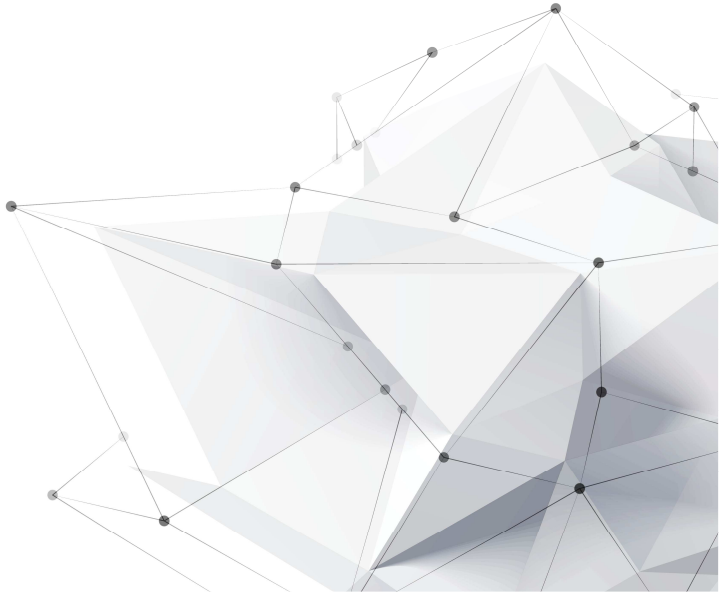
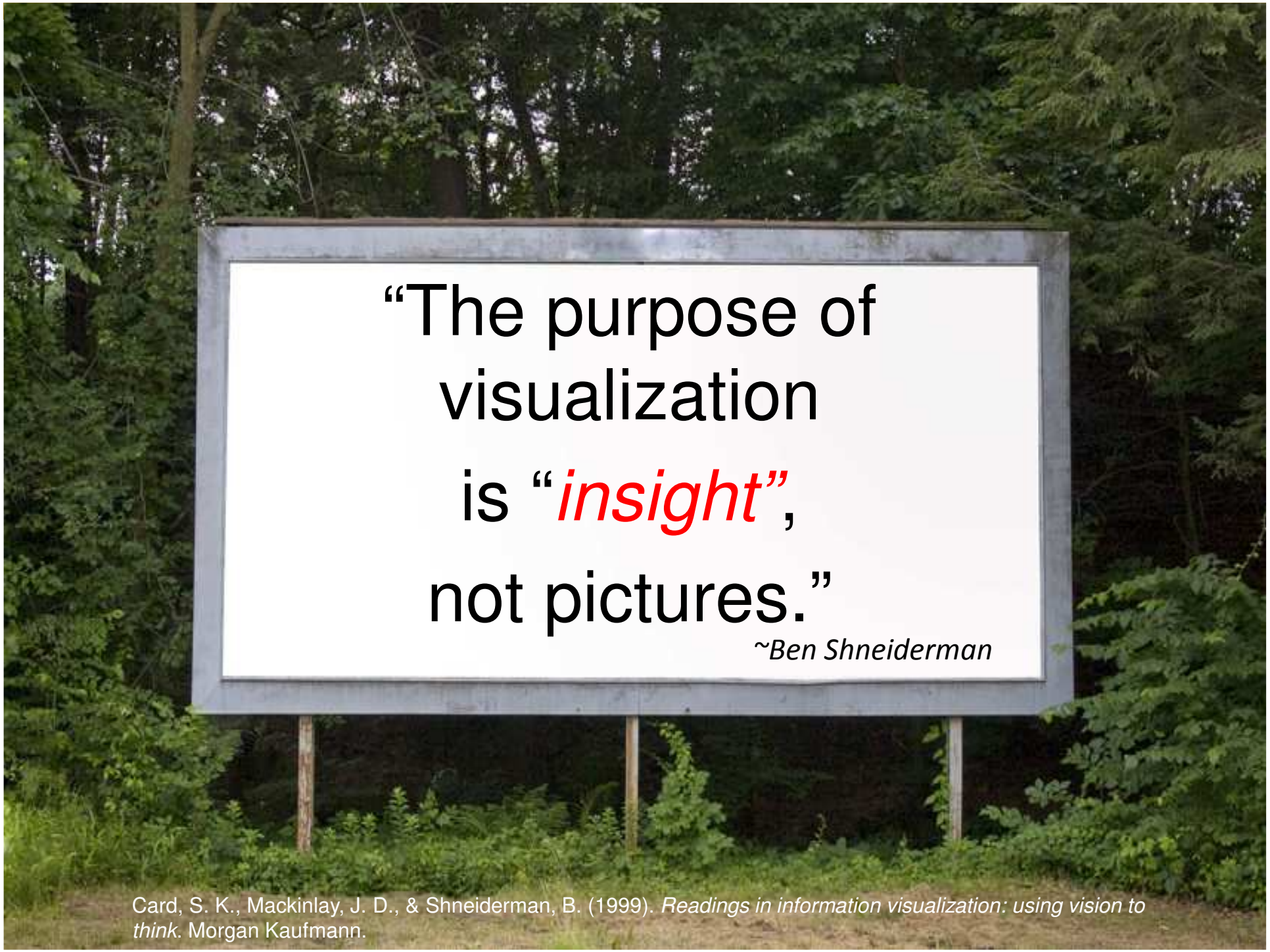
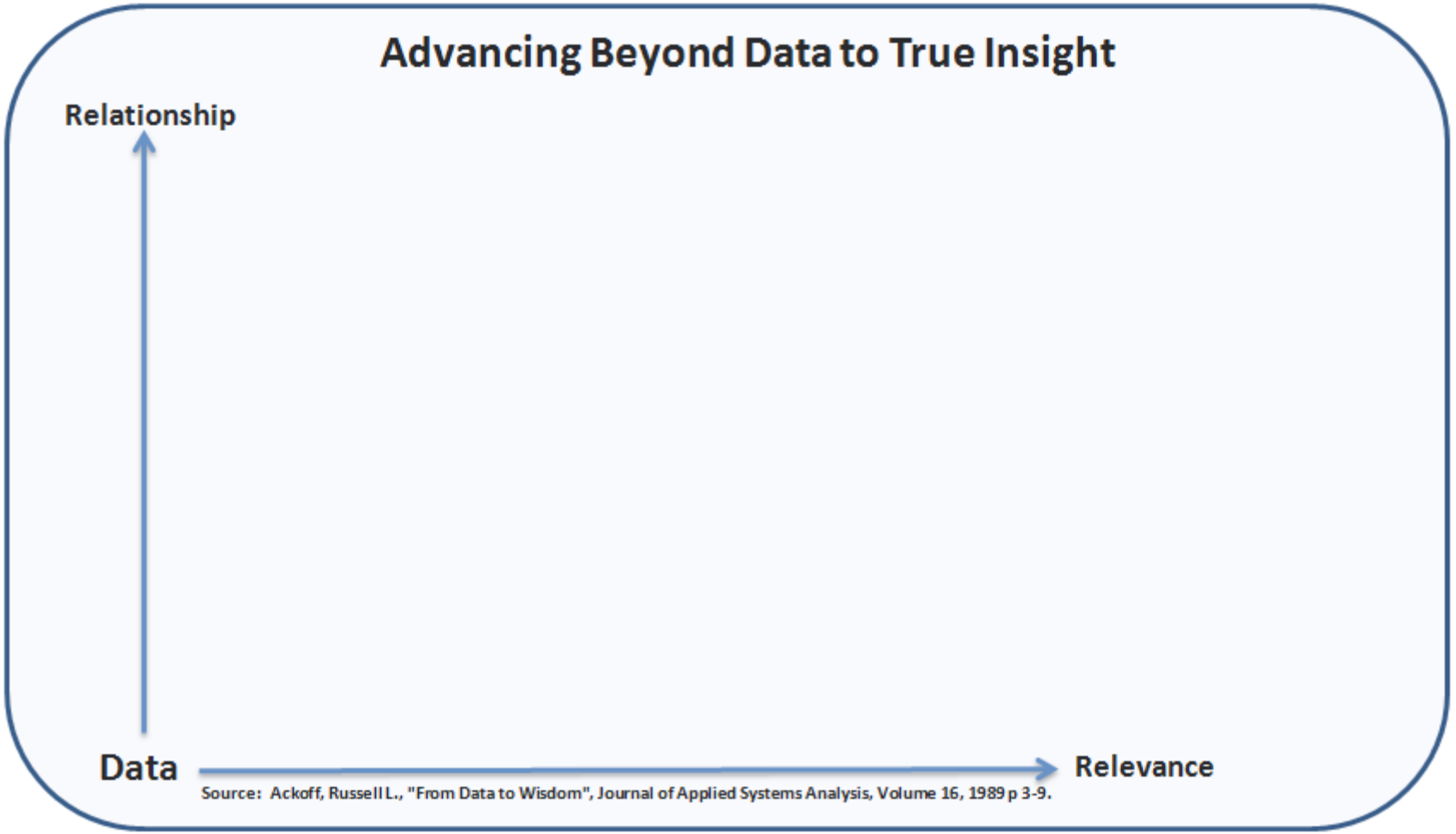




Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999). *Readings in information visualization: using vision to think*. Morgan Kaufmann.

FROM DATA TO INSIGHT



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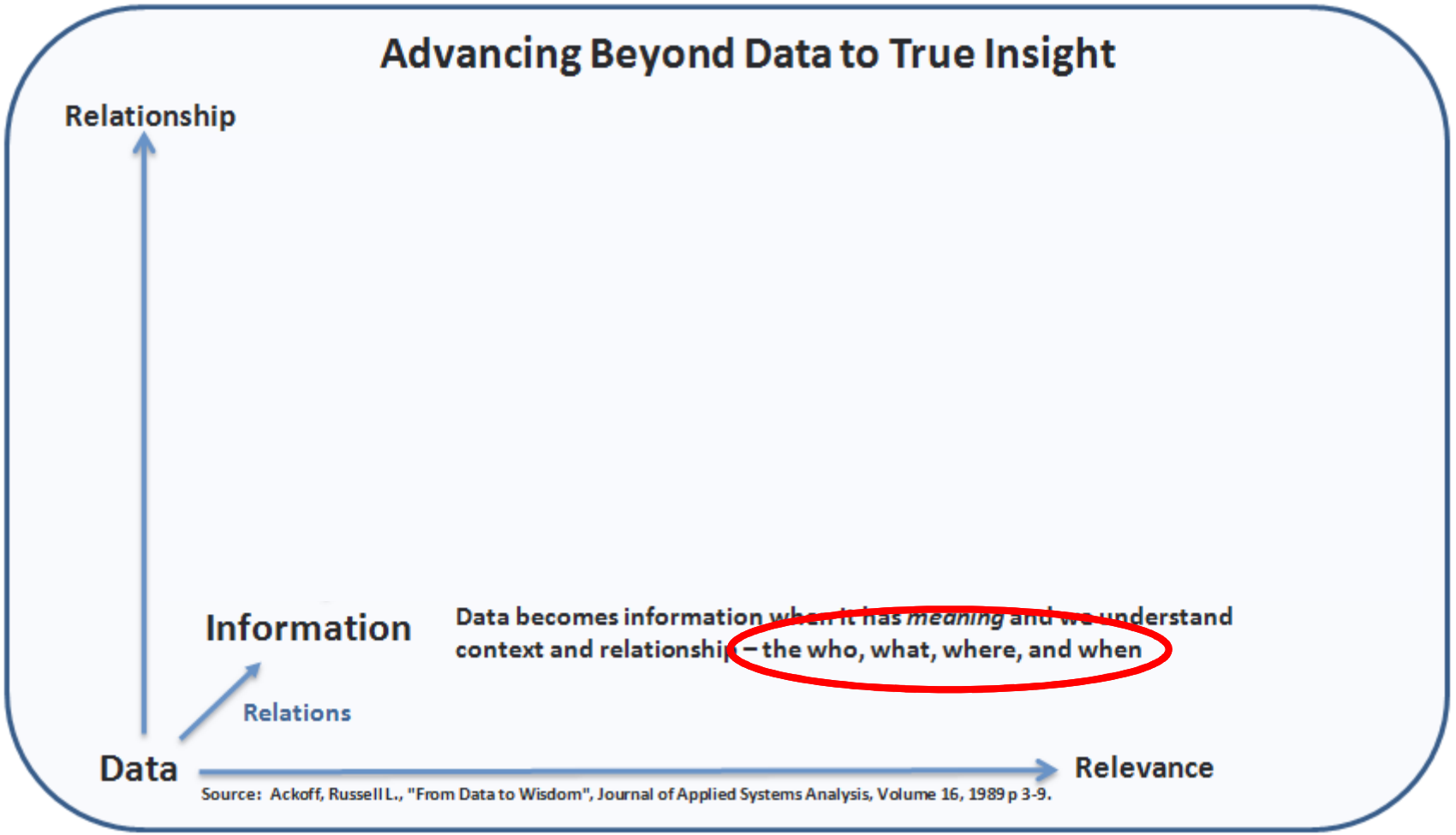
FROM DATA TO INSIGHT



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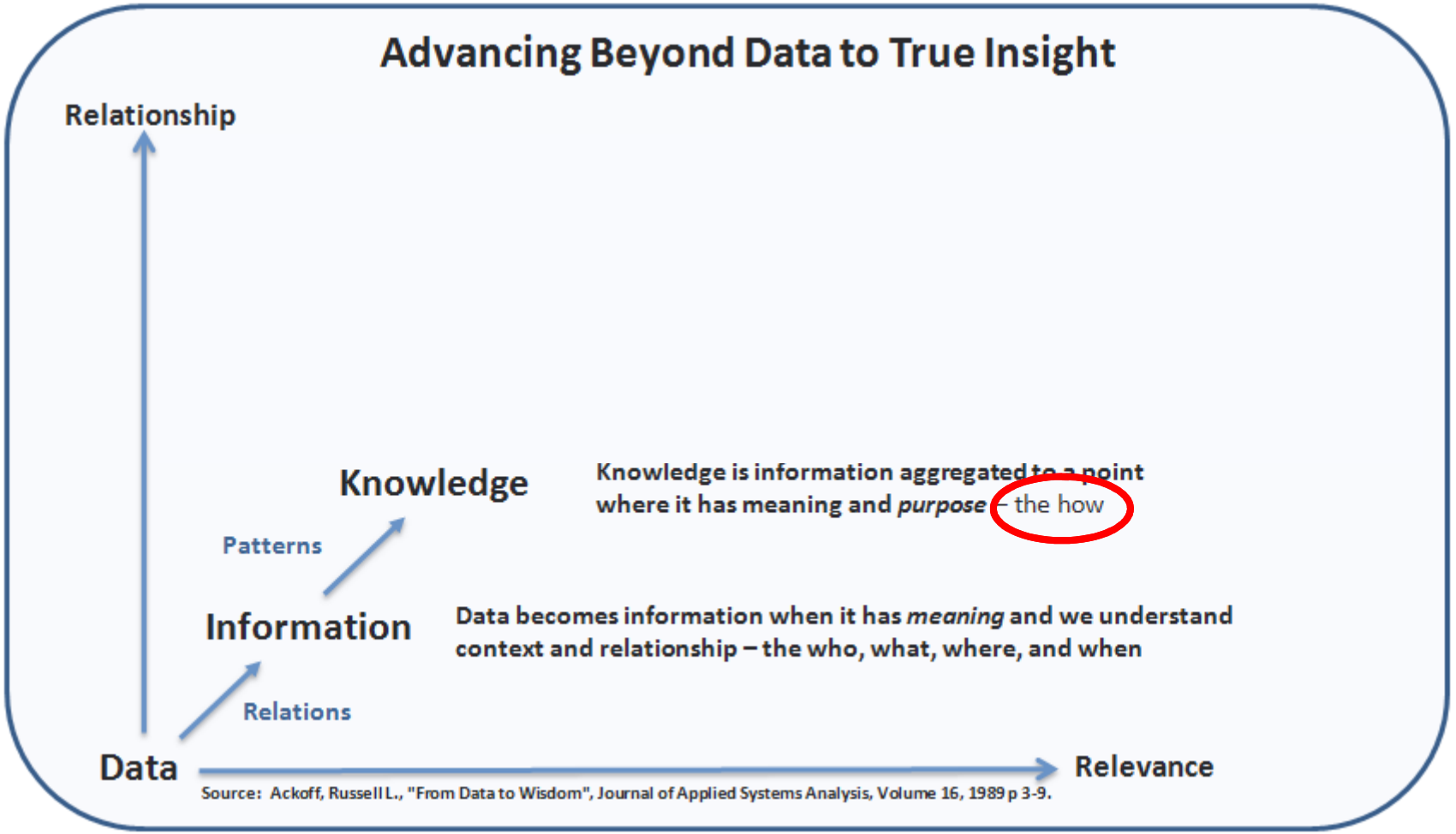
FROM DATA TO INSIGHT



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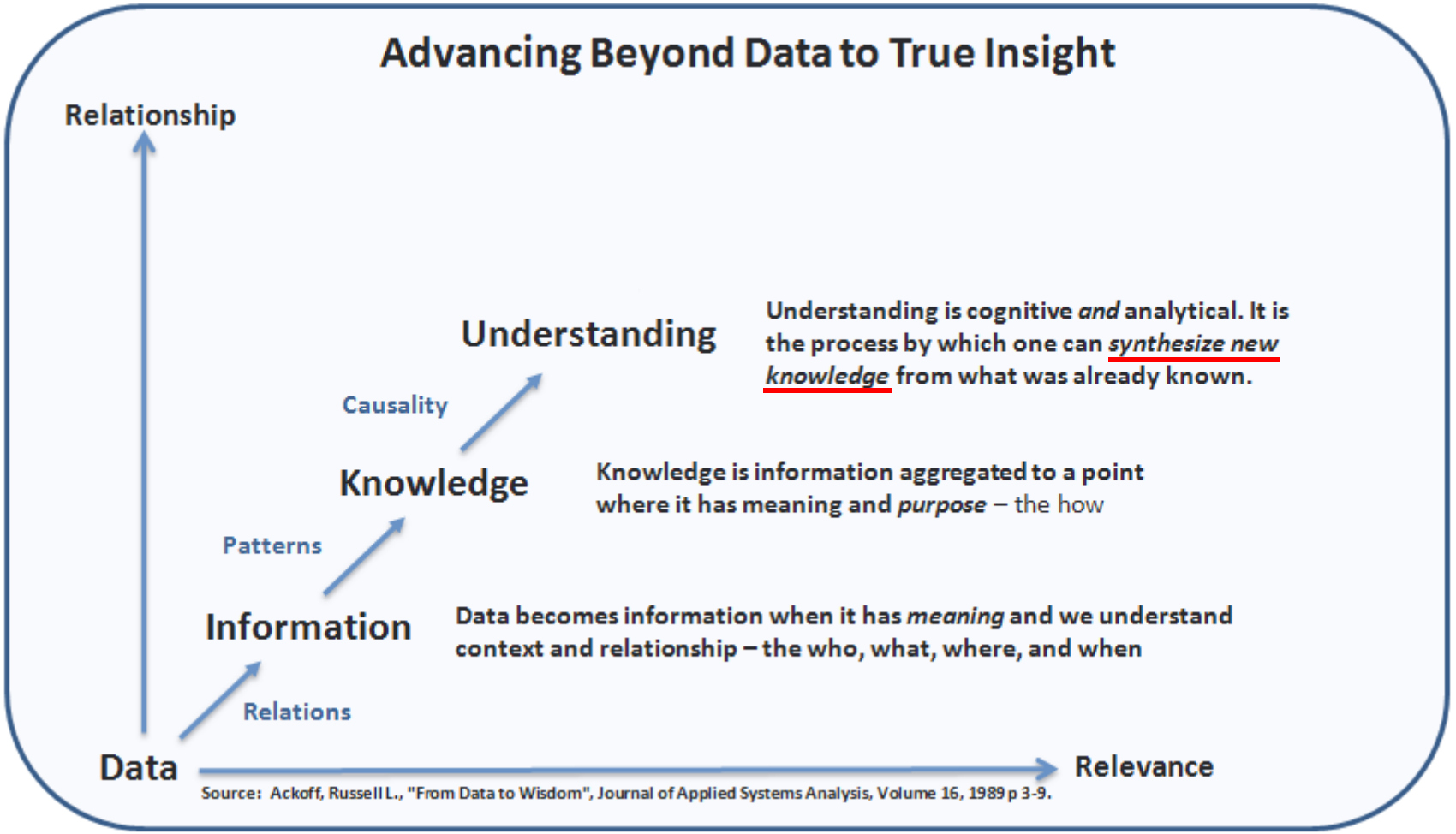
FROM DATA TO INSIGHT



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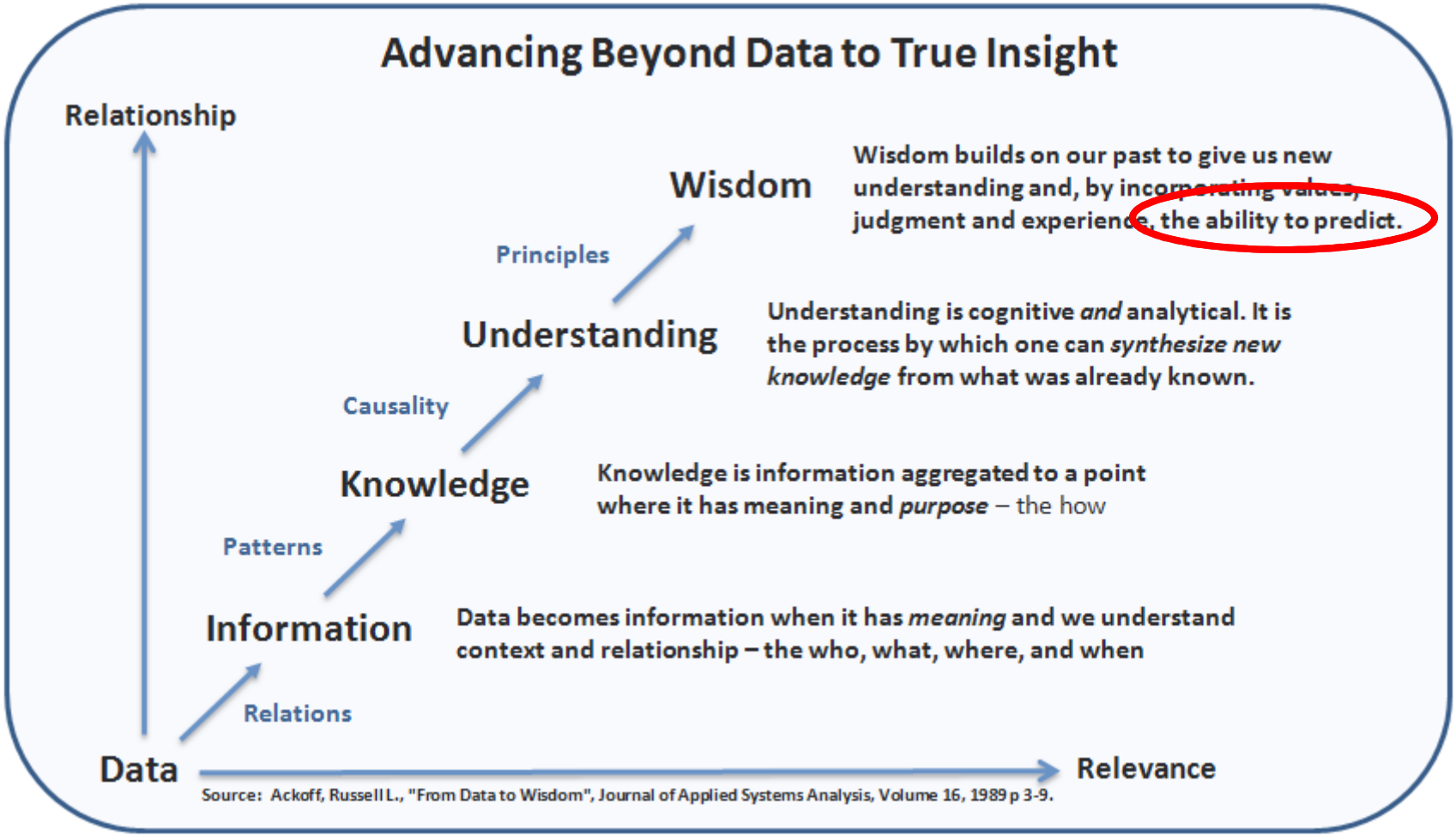
FROM DATA TO INSIGHT



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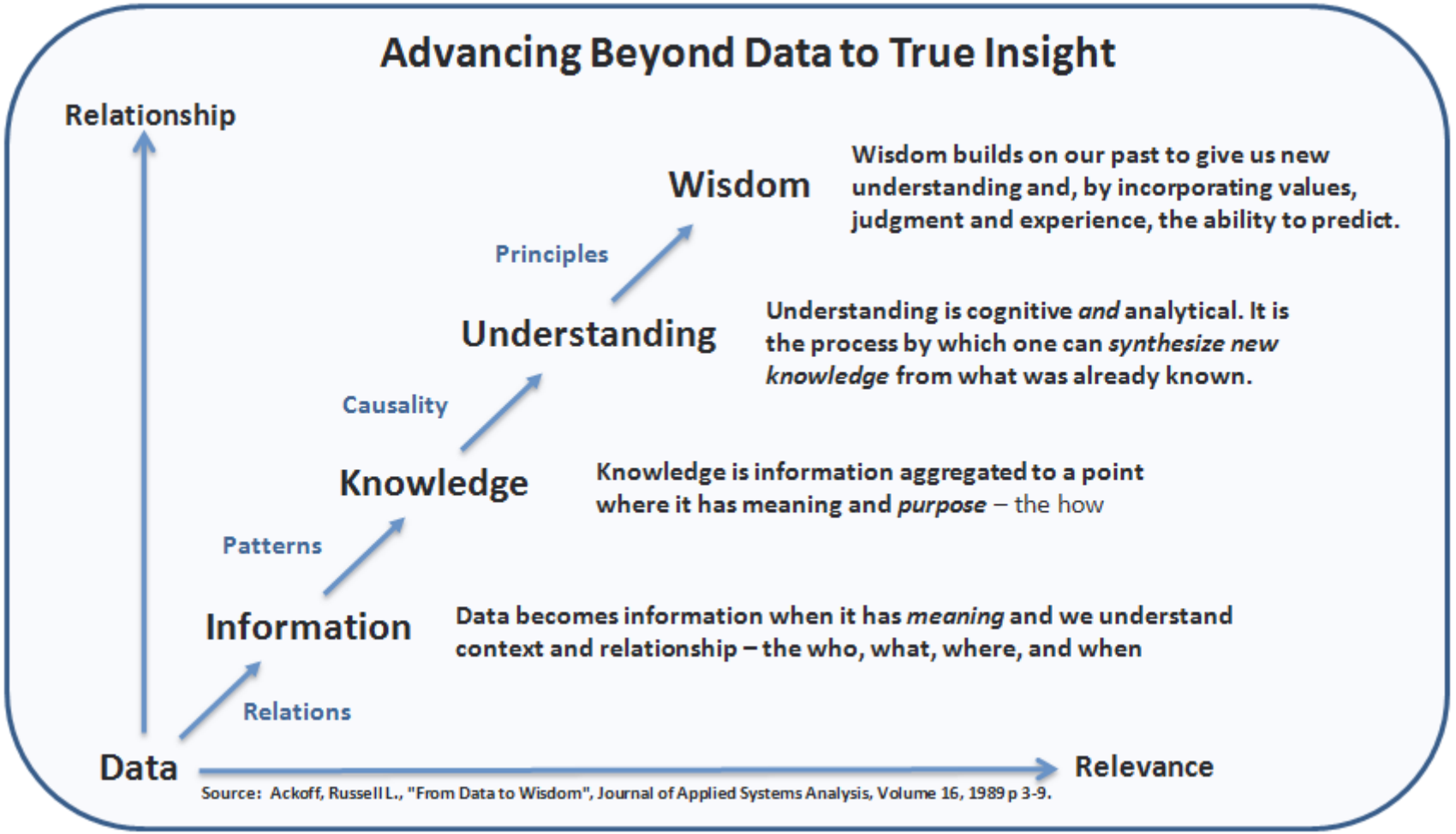
FROM DATA TO INSIGHT



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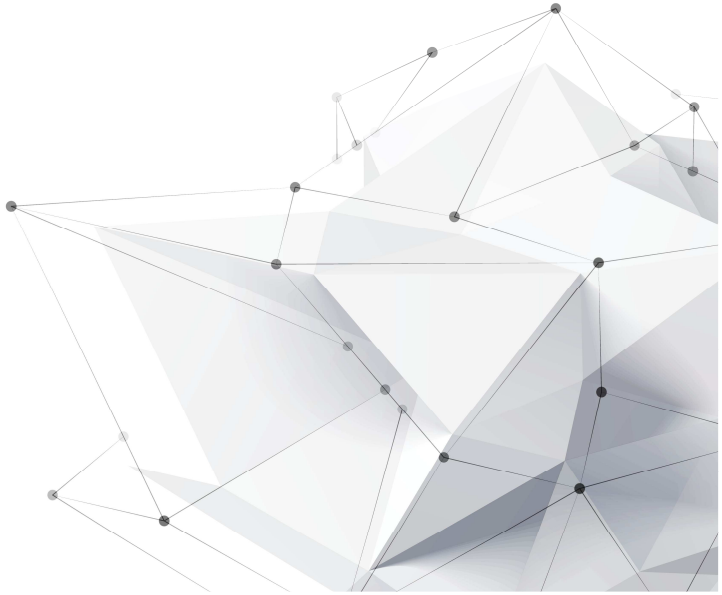
What does insight lead to?



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INSIGHT LEADS TO

Discovery

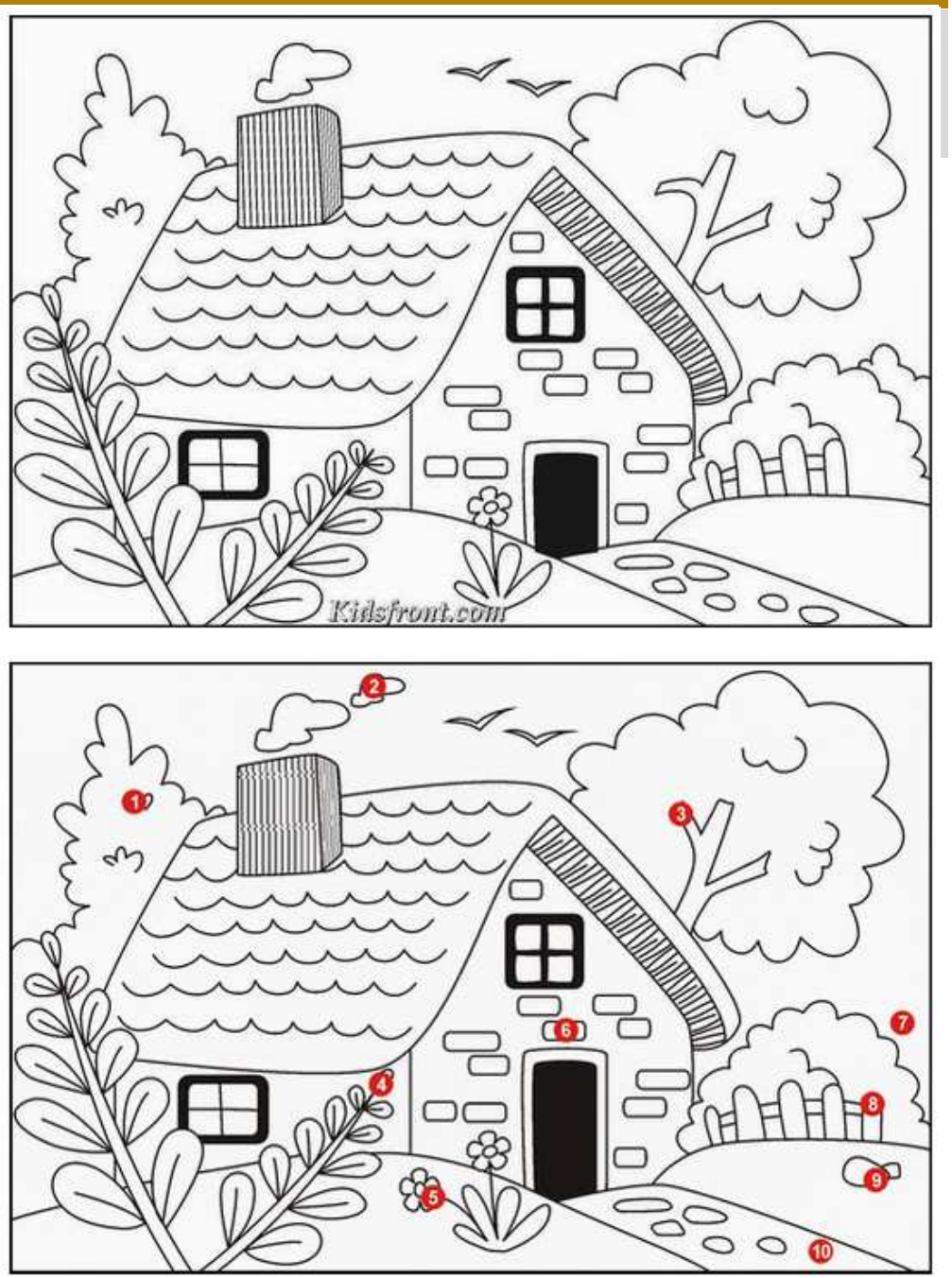
- Visualizing Patterns over time
- Spotting Differences

Decision Making

Analysis of Data

Explanation

Storytelling



http://www.kidsfront.com/spot-differences/9.html

INSIGHT LEADS TO

Discovery

10101010101010101010101001010101
01010701010101010100107001011001 10
01100110011001100111001100110010101
01010107010101010111000101110001 01
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10101010101010101110001100101010 10
10101010001010101001010001010101
01010107010101010101010101070101
01010101010101010101010101010101
01010101011100110011001100101010 01

Spotting Differences

- Visualizing Patterns
- Spotting Differences

How many 7's do you see?

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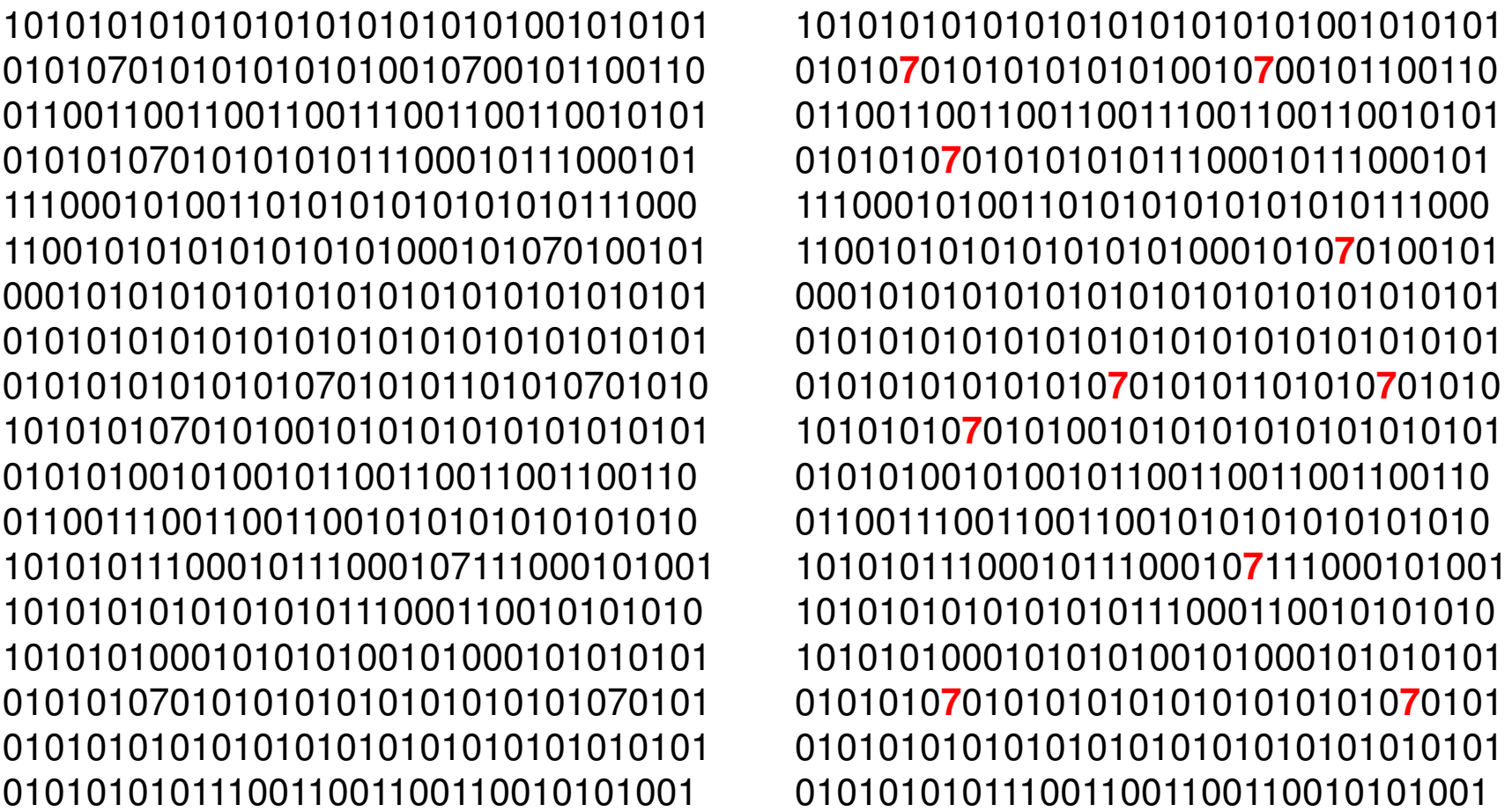
INSIGHT LEADS TO

Discovery

Spotting Differences



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INSIGHT LEADS TO

Discovery

- Visualizing Patterns over time
- Spotting Differences

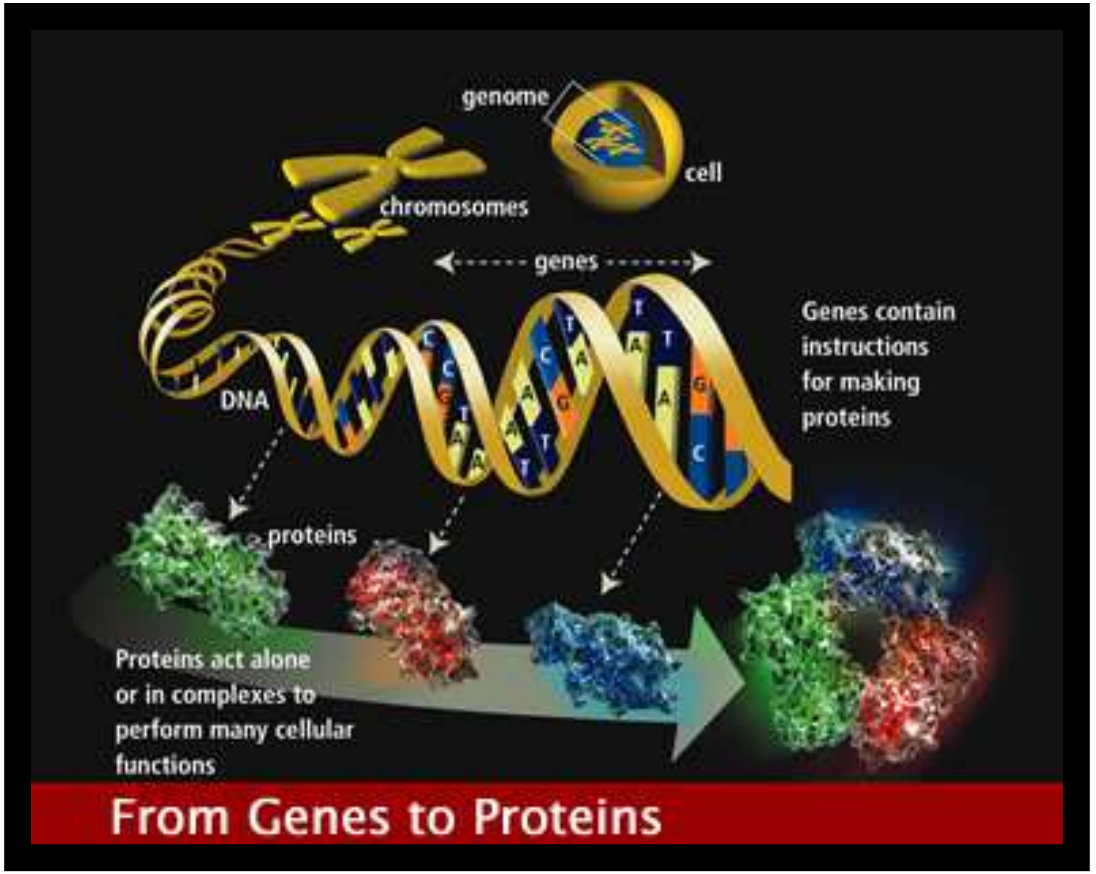
Decision Making

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

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INSIGHT LEADS TO

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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: ™ and © 2017 Twentieth Century Fox Film Corporation. All rights reserved.

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INSIGHT LEADS TO

Discovery

- Visualizing Patterns over time
- Spotting Differences

Decision Making

Analysis of Data

Explanation

Visualizing Spatial Relationships

Storytelling

Watch the Growth of Walmart and Sam's Club

http://datafl.ws/197

Watch the Growth of Target Stores

http://datafl.ws/198

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

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INSIGHT LEADS TO

Discovery
- Visualizing Patterns over time
- Spotting Differences

Decision Making

Analysis of Data

Explanation

Storytelling

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

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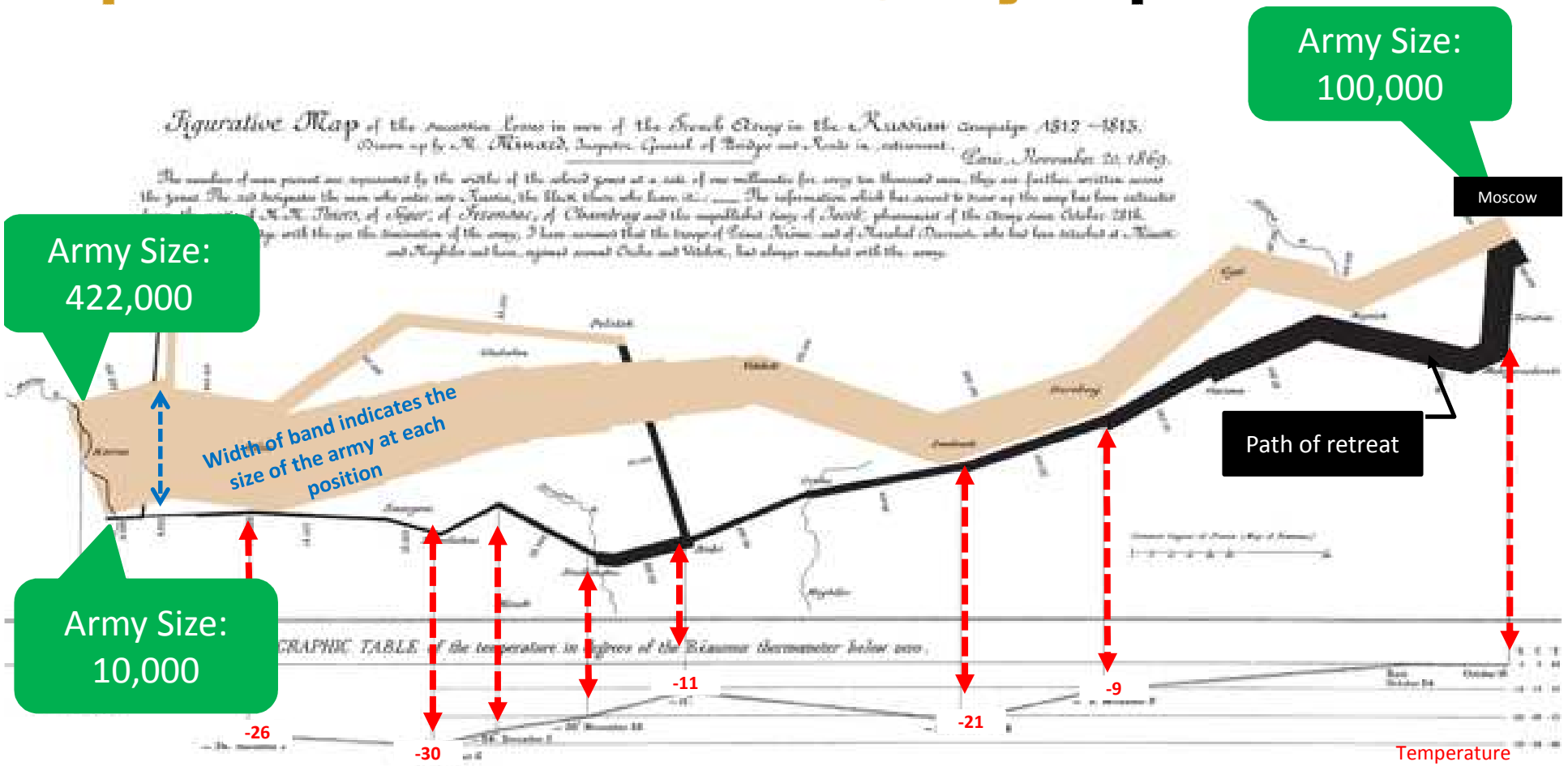
Story Telling with Visualization

Napoleon's Invasion of Russia in 1812 By Jacque Minard



Hans Rosling's 200 Countries, 200 Years, 4 minutes

[The Joy of Stats - BBC Four]

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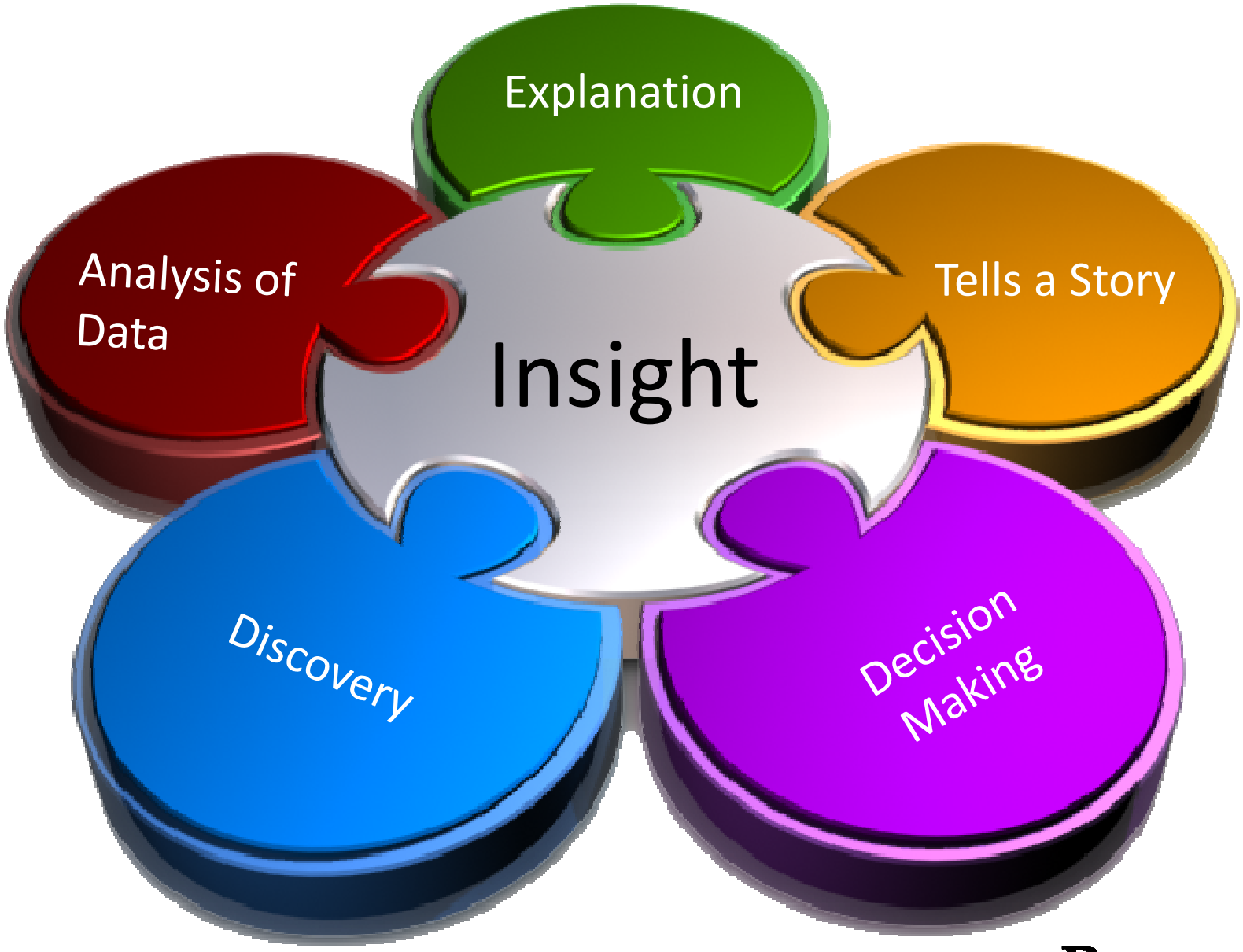

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Visualization Applications

Why is visualization important?

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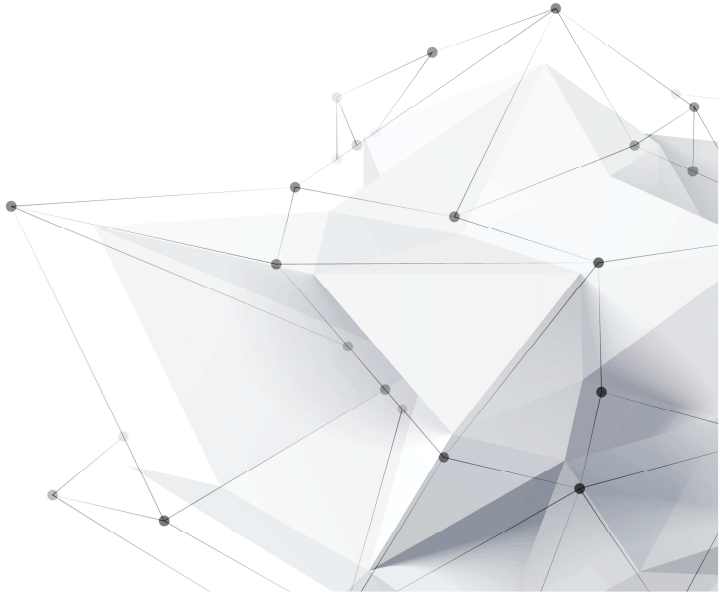
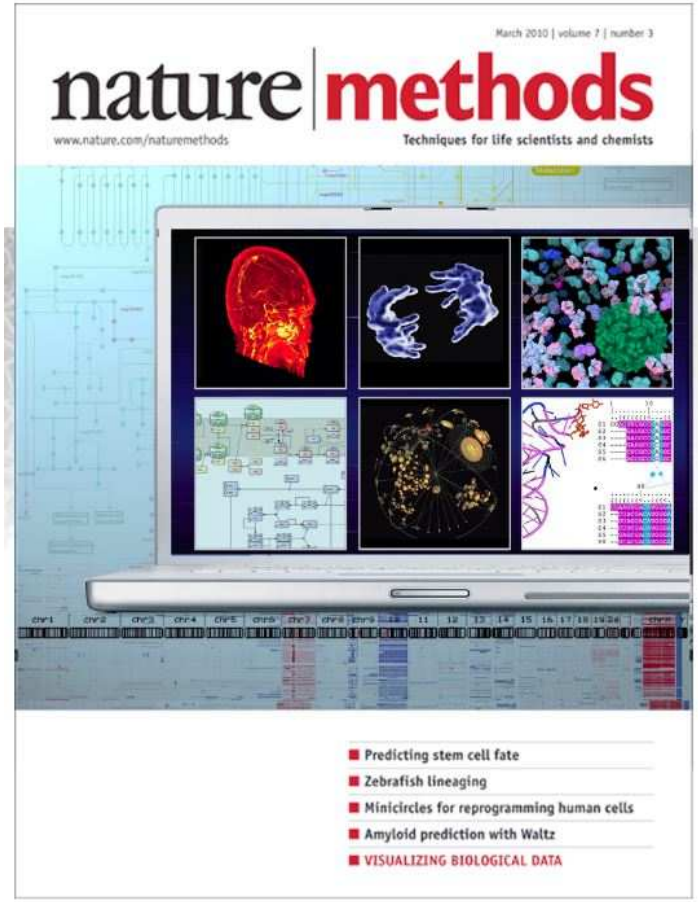


Visualization Applications

Biovisualization (BioVis)

The visualization of biological data;

Often grouped with computer animation



March 2010 |volume 7 | number 3

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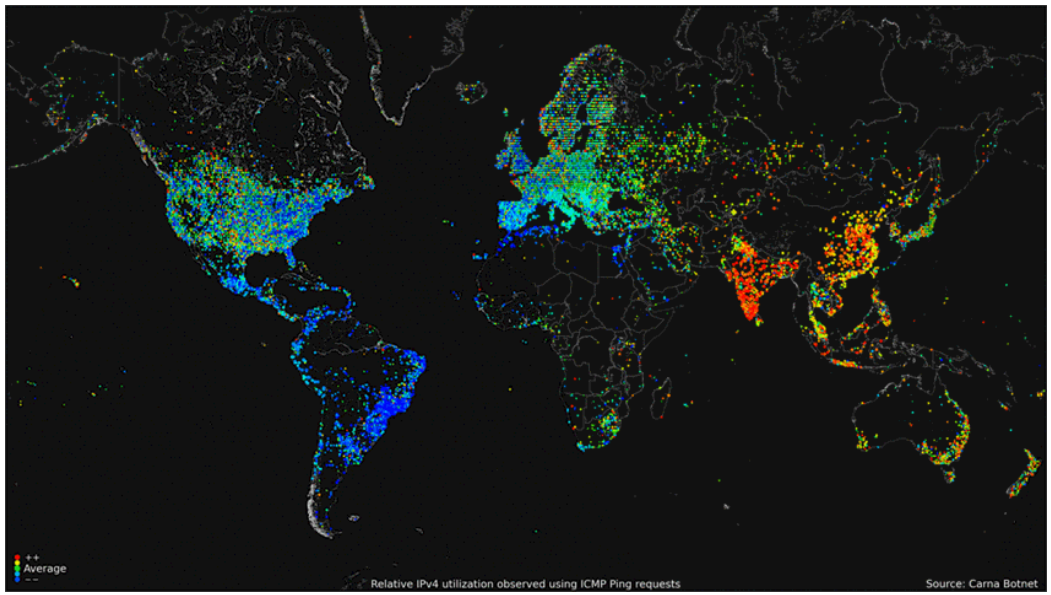
Visualization Applications

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

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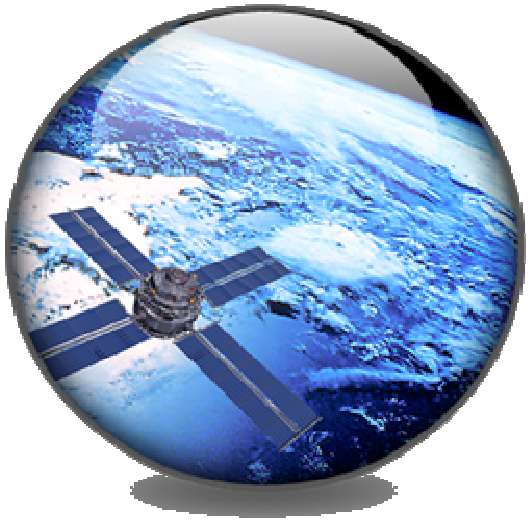
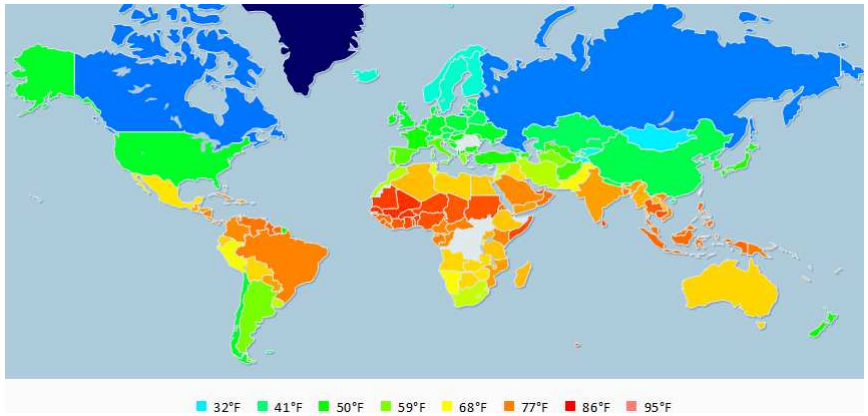
Visualization Applications

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

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Visualization Applications

Scientific Visualization (SciVis)

Primarily concerned with the visualization of three-dimensional phenomena

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

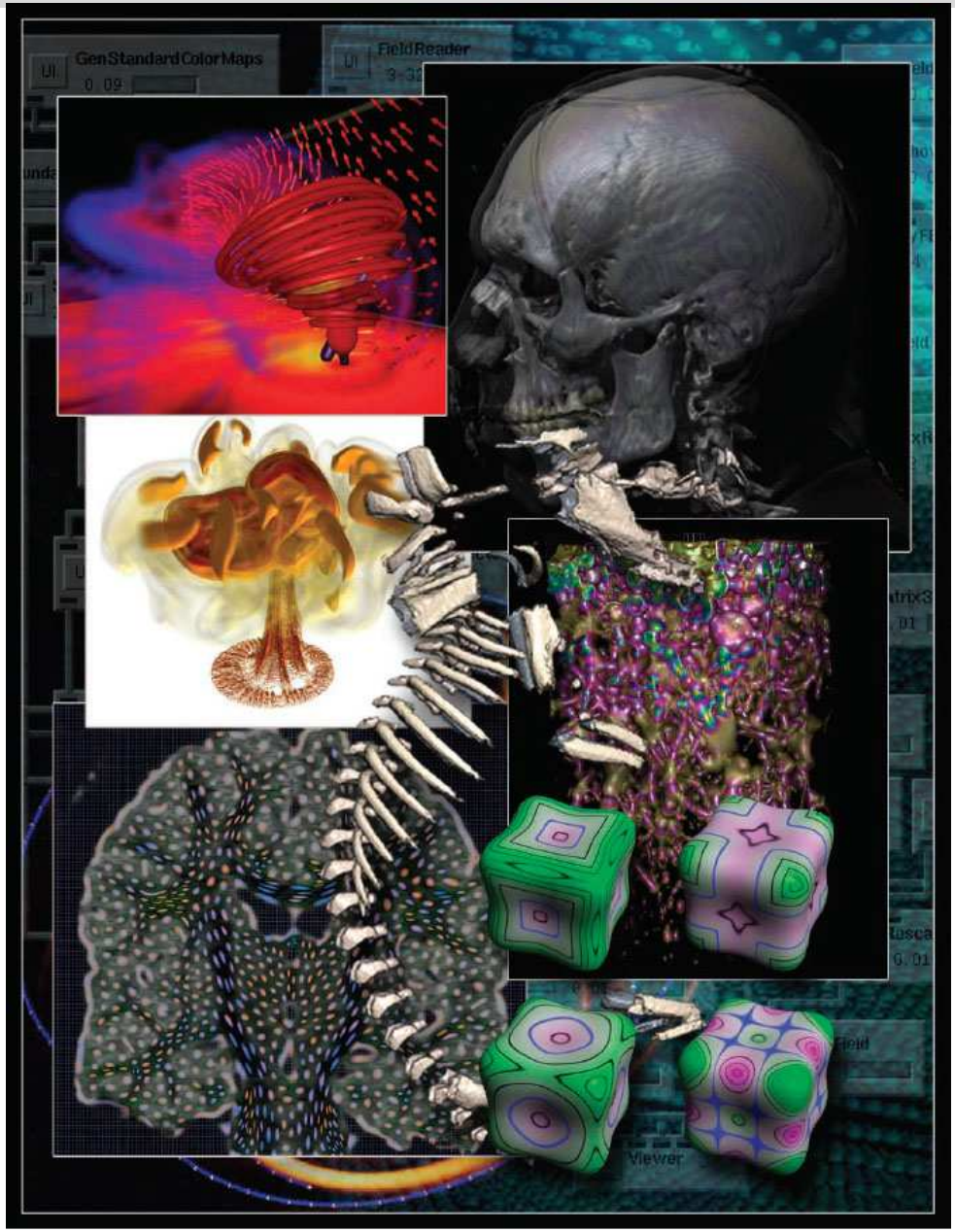
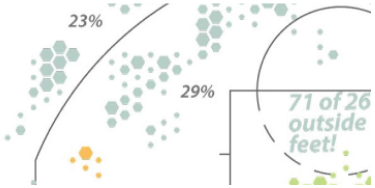
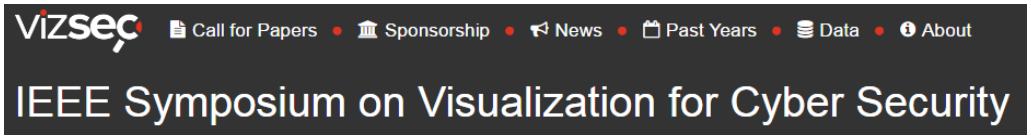


Image Source:
http://www.sci.utah.edu/the-institute/highlights/24-research-highlights/cibc-highlights/253-top-scientific-visualization-research-problems.html

Visualization in Data Science (VDS at IEEE VIS 2017)





IEEE VIS 2017 Arts Program

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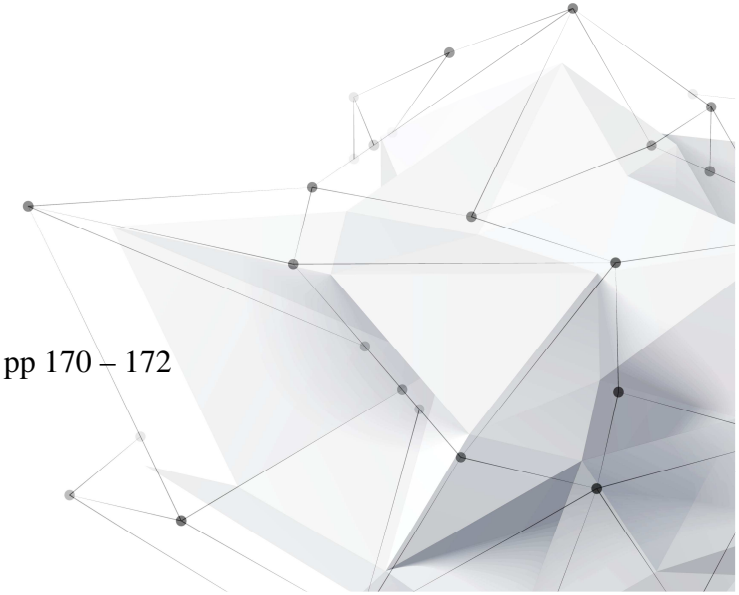
Data Visualization Process

High Level Overview

There are great subtleties involved in the collection of data and its conversion into information.



Ackoff, R. L. (1999) Ackoff's Best . New York: John Wiley & Sons, pp 170 – 172

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Data Visualization Process

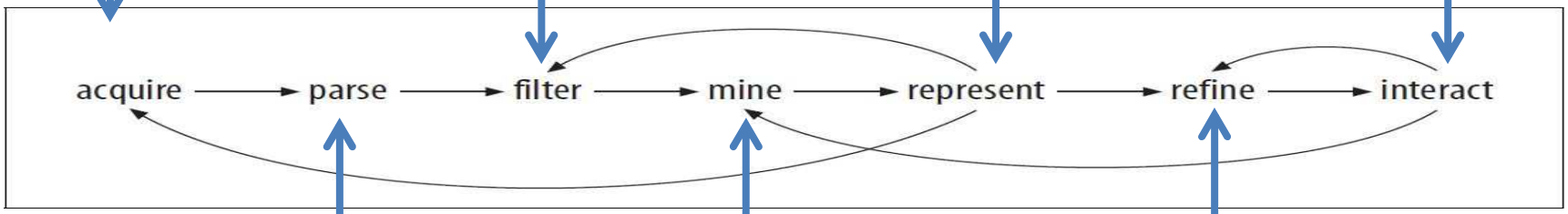
An iterative process

obtain the data

remove all but the data of interest

choose a basic visual model, such as a bar graph, list or tree

Add methods for manipulating the data or controlling what features are visible



provide structure

apply methods from statistics or data mining to discern patterns or place the data in mathematical context

improve the basic representation to make it clearer and more visually engaging

Adopted from Visualizing Data: Exploring and Explaining Data with the Processing Environment by Ben Fry, O'Reilly (p 15)

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Visualization Process

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

```
0265640 132304 138732 032051 037334 024721 015013 052226 001662
0265660 025537 064663 054606 043204 074076 124153 135216 126614
0265700 144210 056426 044700 042650 165230 137037 003655 006254
0265720 134453 124327 176005 027034 107614 170724 073702 067274
0265740 072451 007735 147620 061064 157435 113057 155356 114603
0265760 107204 102316 171451 046040 120223 001774 030477 046673
0266000 171317 116055 155117 130444 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 037026 037640 066171 123424
0266100 062701 032406 140000 165341 072410 100032 125455 056646
0266120 005716 071402 055672 132571 105645 170073 050376 072117
0266140 024451 007424 114200 077733 024434 012546 172404 102945
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 078216 002655
0266260 171466 126161 117155 065763 016177 014460 112765 055527
0266300 003767 175367 104754 036436 172172 150750 043643 145410
0266320 072074 000007 040627 070652 173011 002151 125132 140214
0266340 060115 014356 015164 067027 120206 070242 033065 131334
0266360 170601 170106 040437 127277 124446 136631 041462 116321
0266400 020243 005602 004146 121574 124651 006634 071331 102070
0266420 157504 160307 166330 074251 024520 124433 167273 030635
0266440 133614 106171 144160 010552 007365 026416 160716 100413
0266460 026630 007210 000630 121224 076033 140764 000737 003276
0266500 134060 042647 104475 110537 066716 104754 075447 112254
0266520 030374 144251 077734 015157 002513 173526 035531 150003
0266540 146207 015135 026446 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
```

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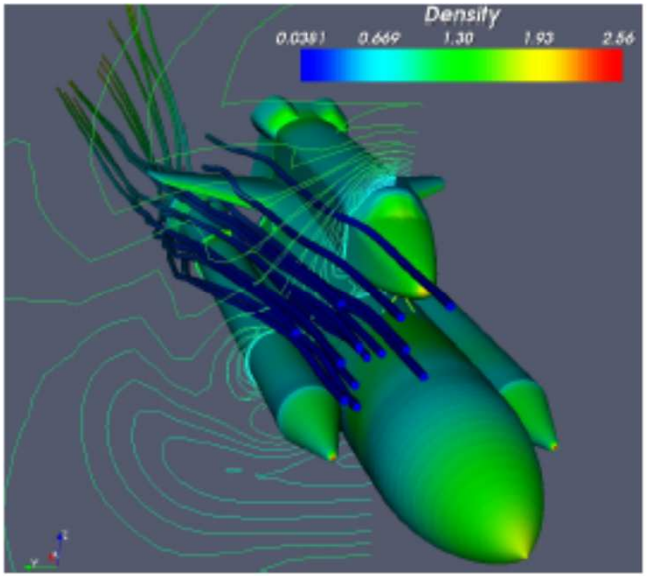
Adopted from The ParaView Tutorial, The Basics of Visualization, version 3.98

Visualization Process

There are several steps between raw data and a finished visualization

This is where the magic happens!



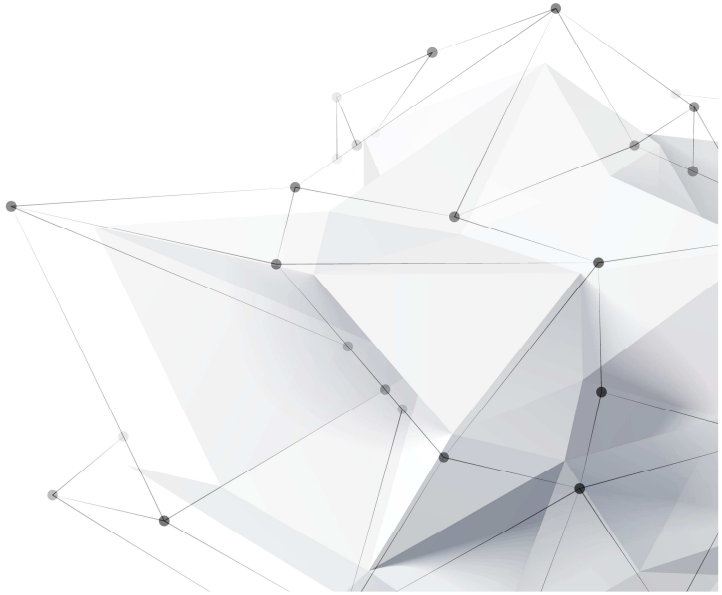
PURDUE POLYTECHNIC

Adopted from The ParaView Tutorial, The Basics of Visualization, version 3.98

Why do we care?

I just want a pretty picture!

PURDUE
POLYTECHNIC

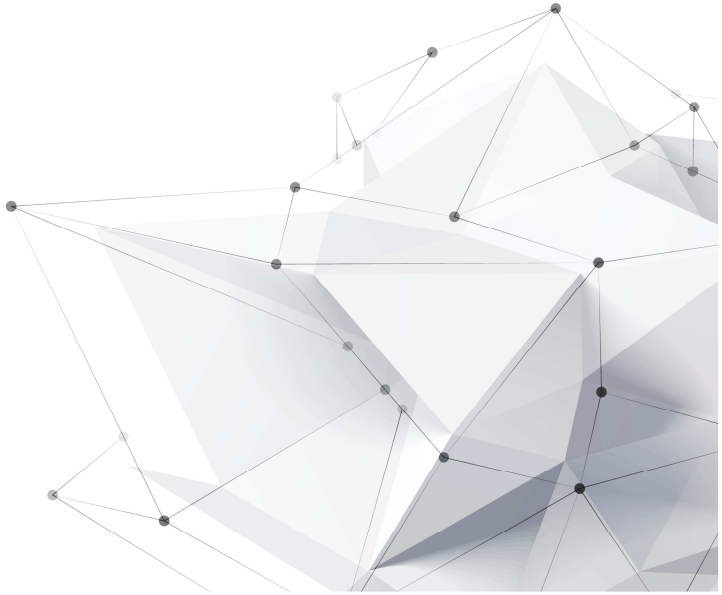


What does the pretty picture mean?

http://news.mit.edu/2015/automating-big-data-analysis-1016

PURDUE
POLYTECHNIC

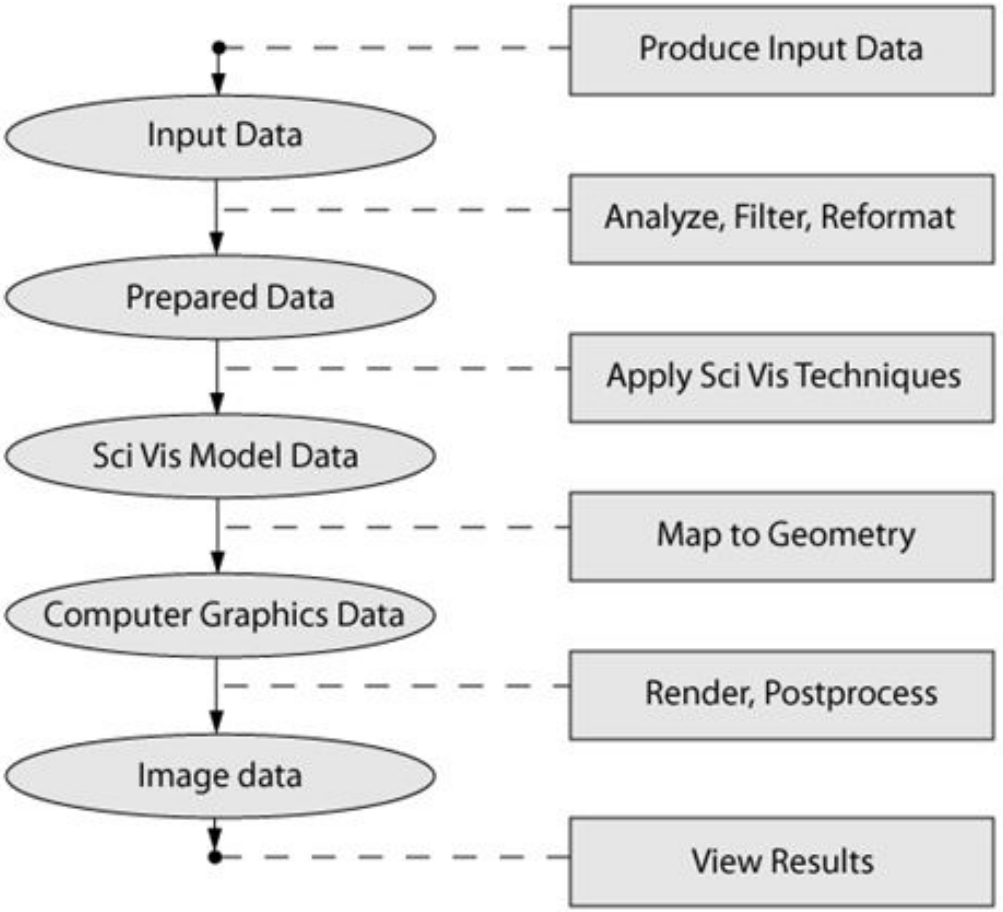
A Pretty Picture is Nothing without Meaning.



PURDUE
POLYTECHNIC

Scientific Visualization Pipeline

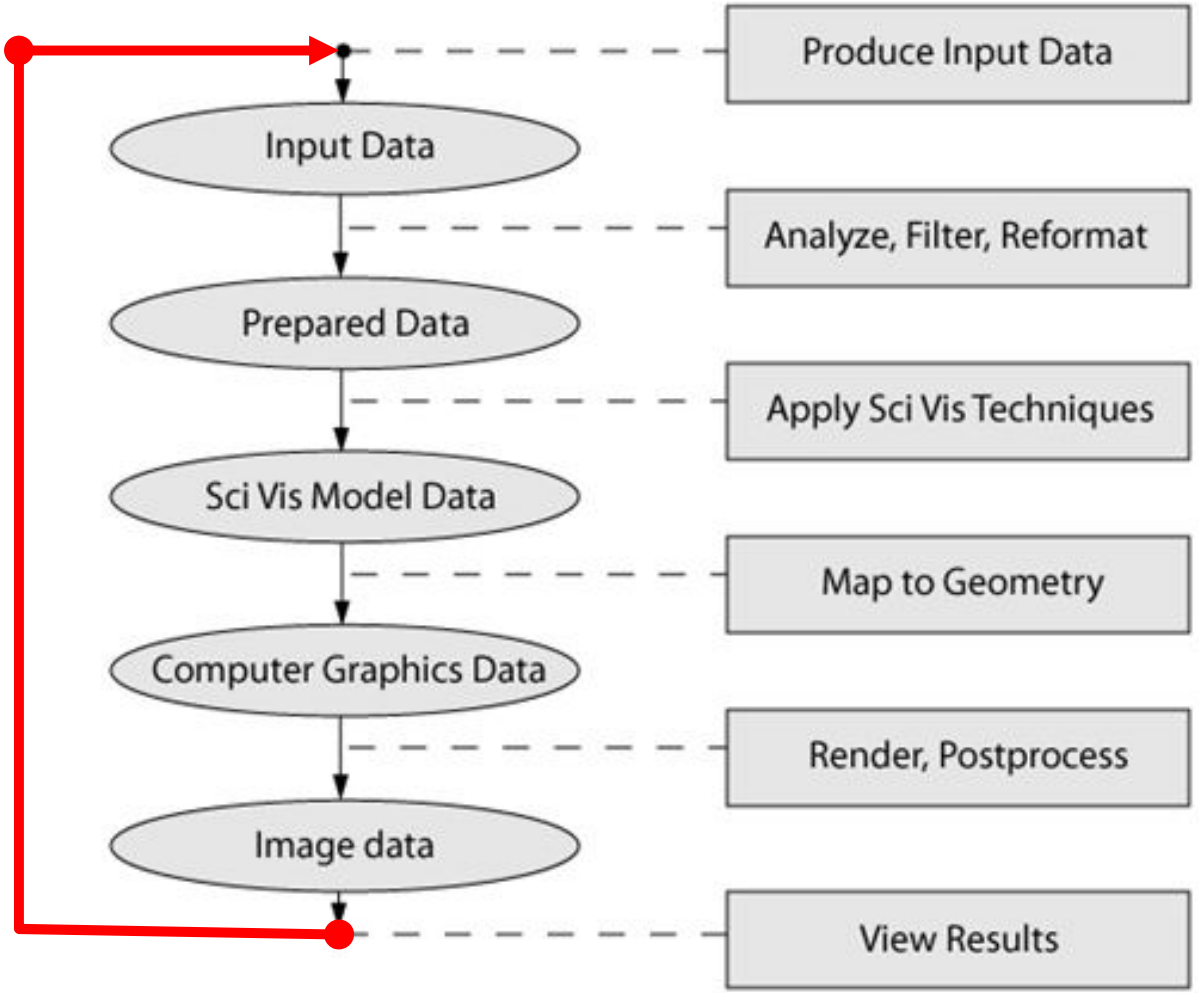
What's Missing?



PURDUE POLYTECHNIC

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

Scientific Visualization Pipeline



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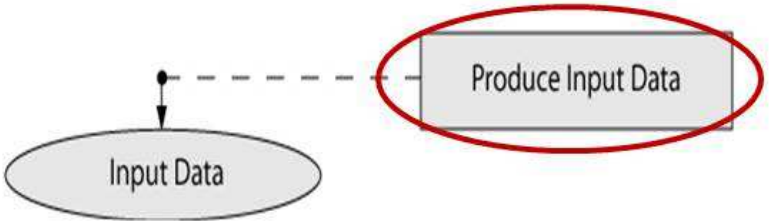
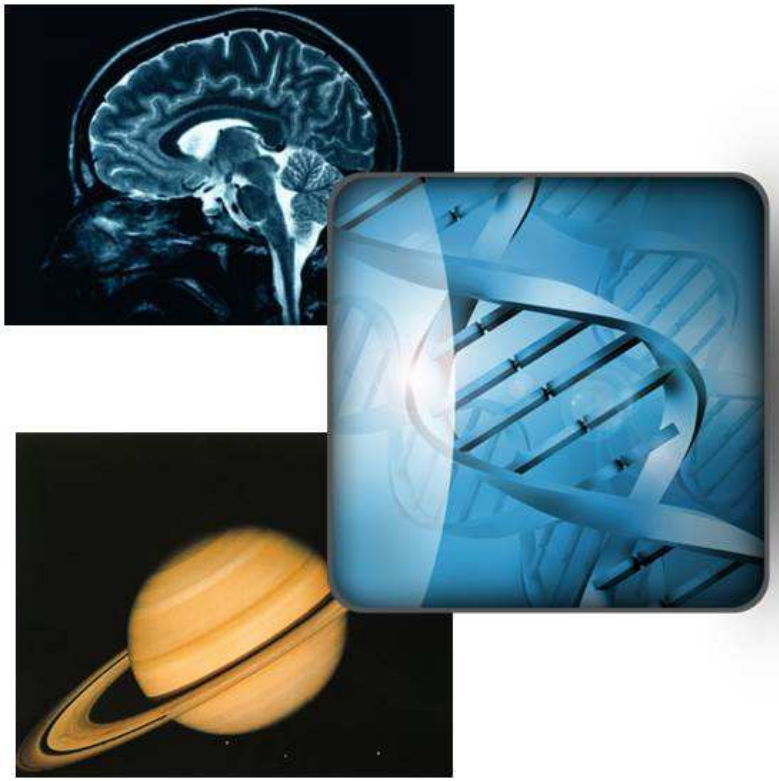
http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/

Scientific Visualization Pipeline: Step 1 . . .

Produce Data

- Simulated Data
- Images
- Numerical
- Some measured value
- Observed Phenomena





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

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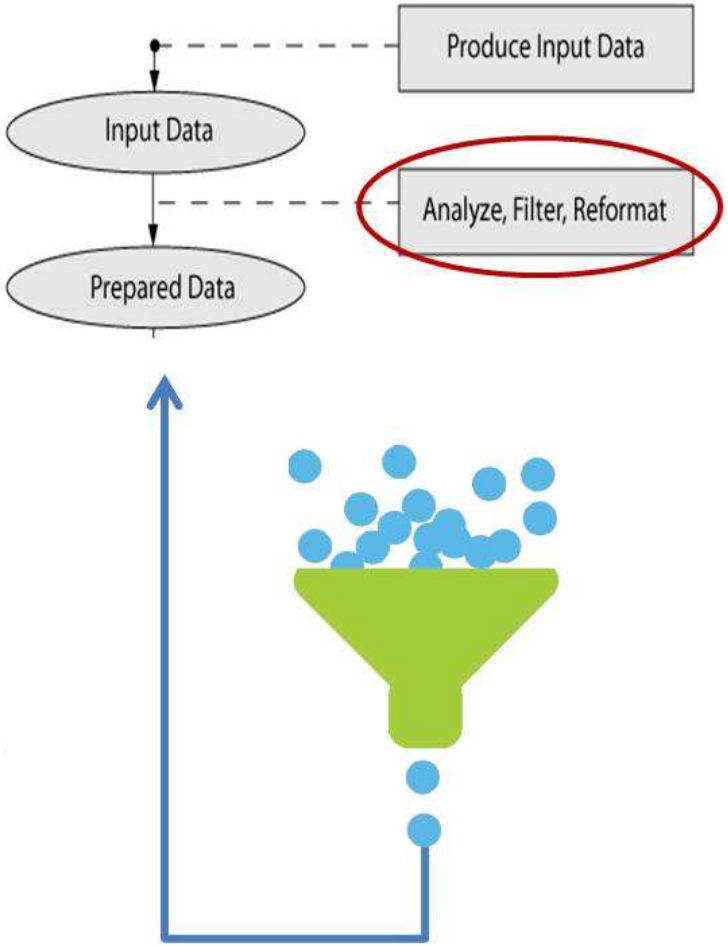
Scientific Visualization Pipeline: Step 2 . . .

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



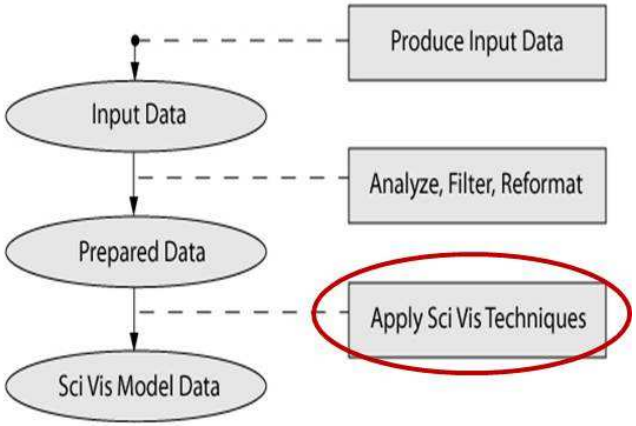
Adopted from
http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/

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

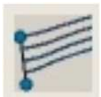


Contour

Clip

Threshold

Glyphs



Streamlines

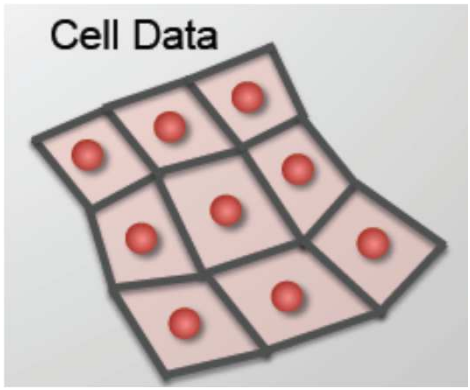
PURDUE POLYTECHNIC

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

Scientific Visualization Pipeline

Step 4 . . .

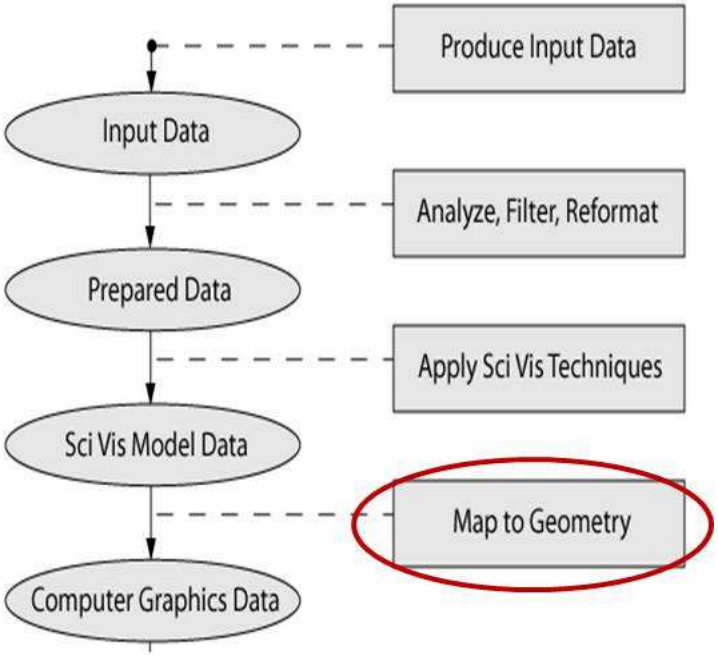
Map to Geometry

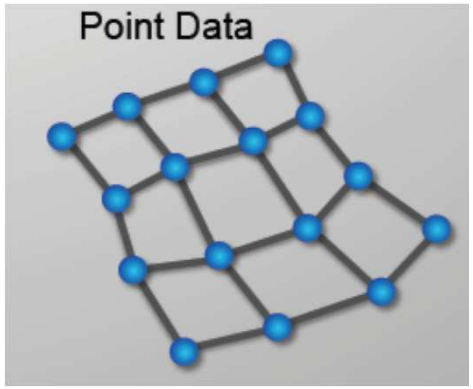


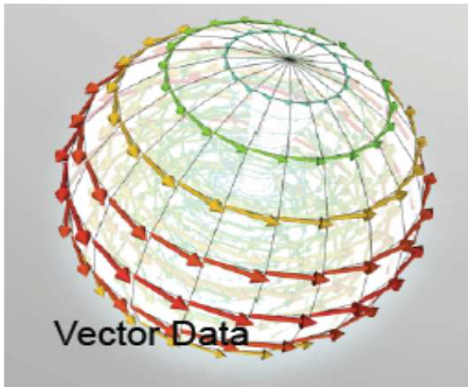
Scalars, vectors, tensors

1D, 2D, 3D

Mesh





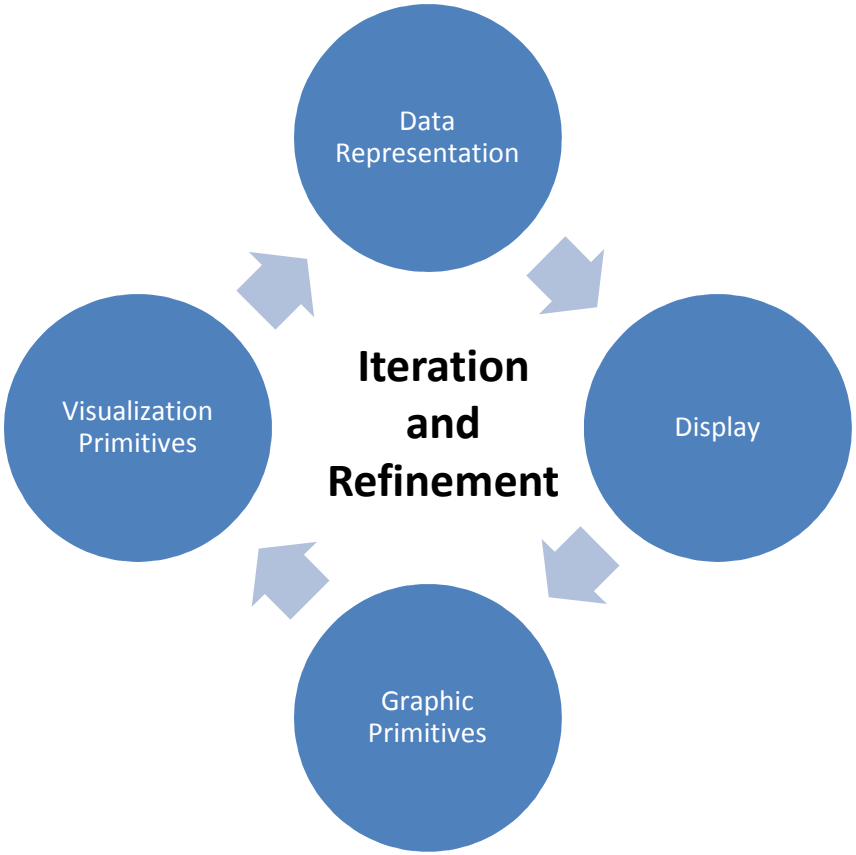


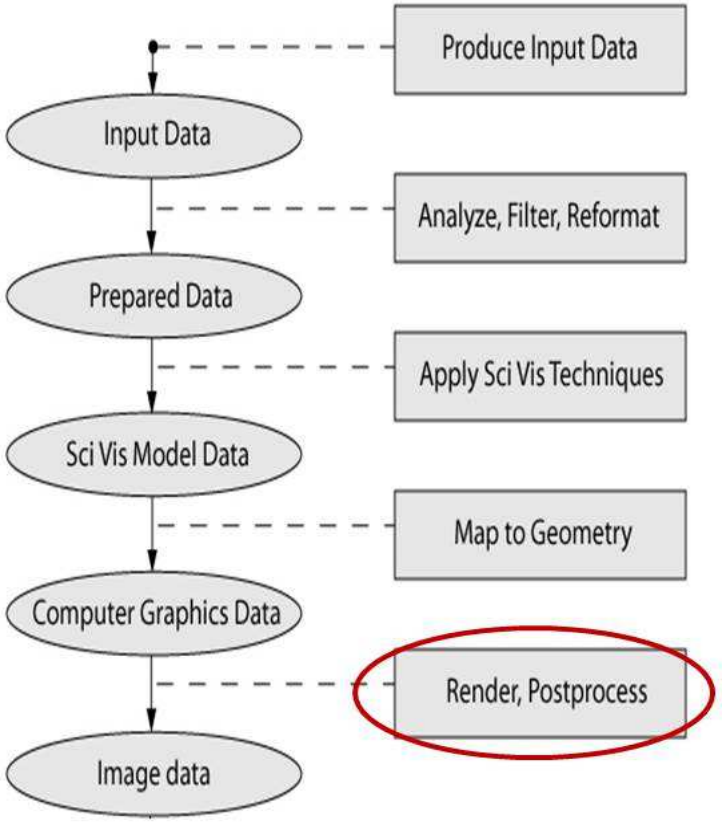
Adopted from
http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/

Scientific Visualization Pipeline:

Step 5 . . .

Render, Post Process

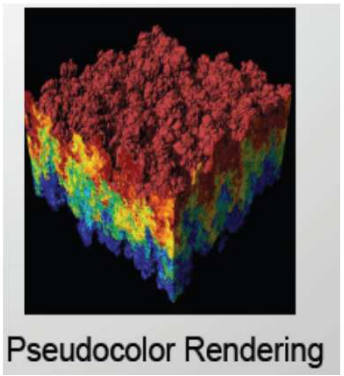




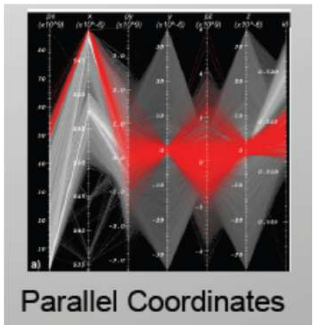
Adopted from
http://www.bu.edu/tech/research/training/tutorials/introduction-to-scientific-visualization-tutorial/the-scientific-visualization-pipeline/

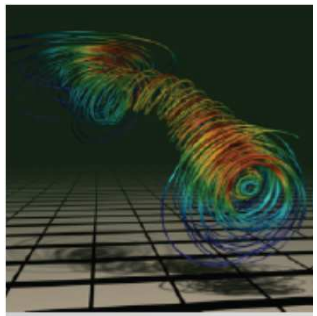
Scientific Visualization Pipeline: Step 6 . . .

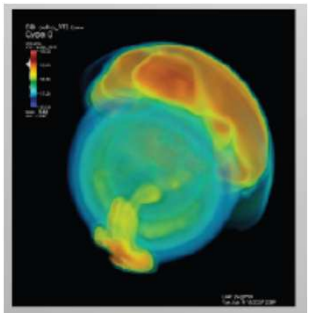
View Results

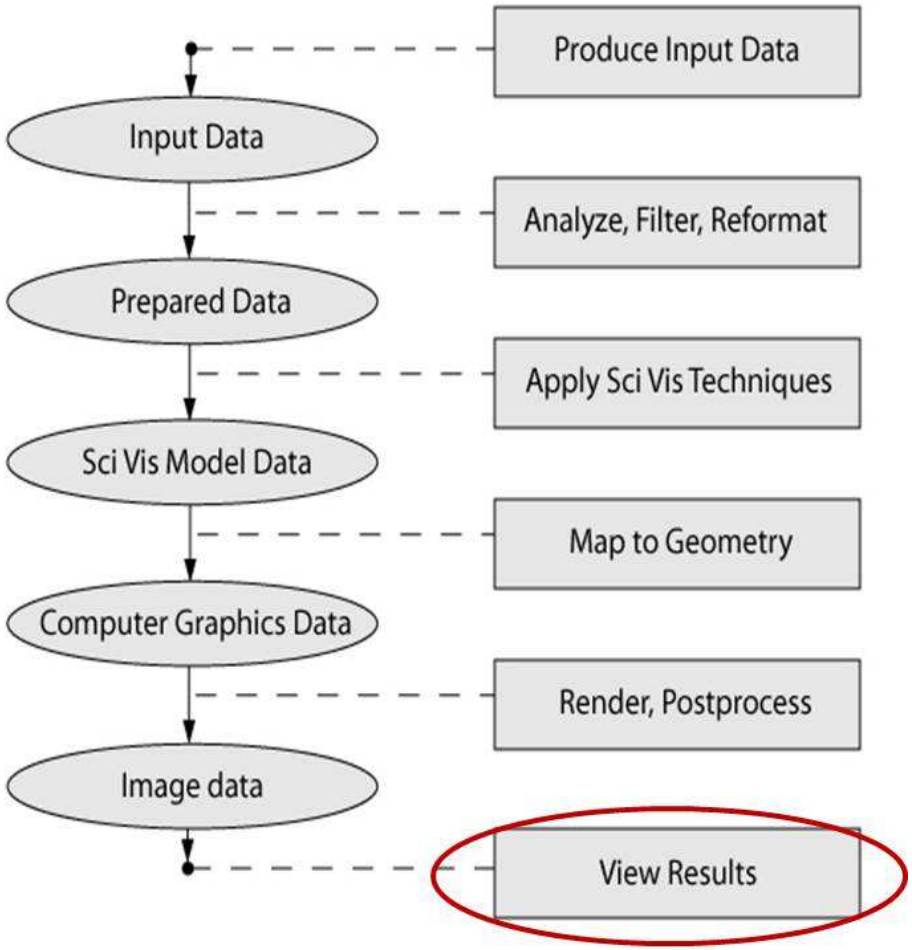

Pseudocolor Rendering

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/

Why Should I Care about Data Visualization?

Regardless of major, research interest, or academic background, at some point you will visualize some type of data.

~ Vetria Byrd, PhD

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POLYTECHNIC

WHY SHOULD YOU CARE?

There is a demand for

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

HPC wire

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

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. ~ Vetria Byrd, 2014

Engineering

Computer Science

Research

Physics

Industry

Non-STEM

The Arts

Biomedical Engineering

Athletics

Academia

Chemistry

Statistics

STEM

Social Media

Biology

PURDUE POLYTECHNIC

You've Got Data

Now What?

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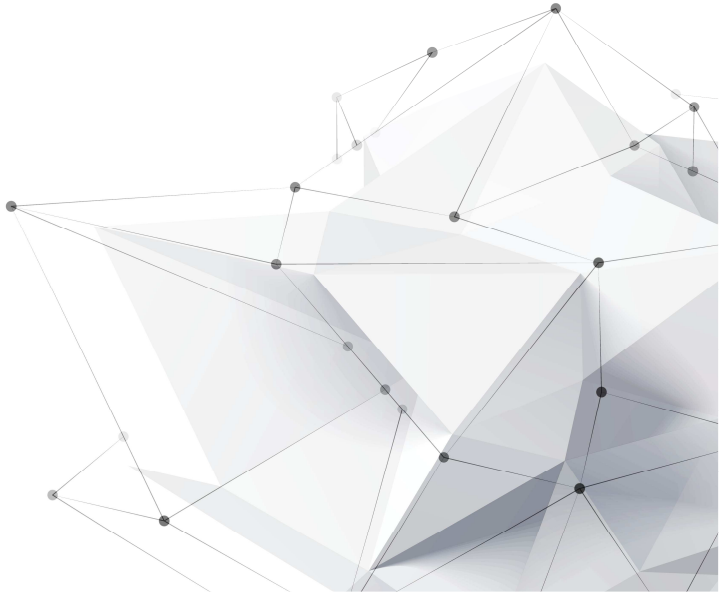


REMEMBER THE FOUR TYPES OF VISUALIZATIONS

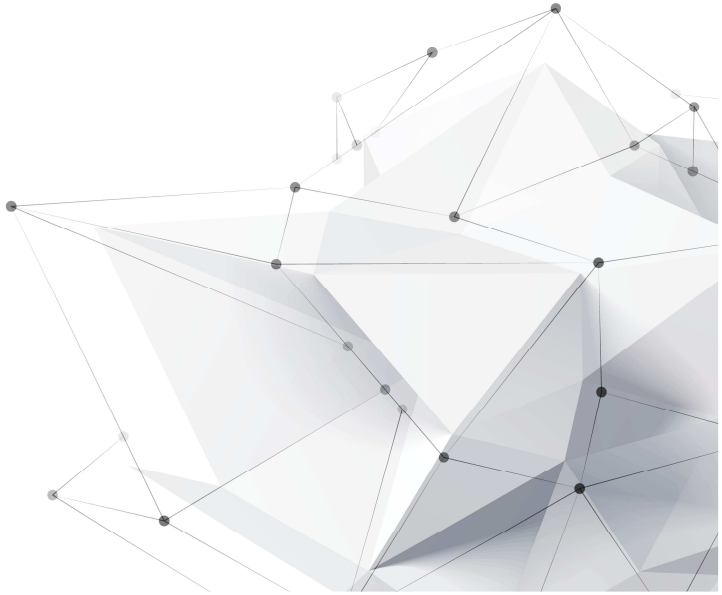
GEORGES GRINSTEIN (KEYNOTE PRESENTATION, VINCI 2016)

- **Exploratory**
  - Have no hypotheses about the data
  - Explore data interactively as undirected searches
- **Confirmatory**
  - Have specific hypotheses about the data
  - Goal-oriented examination of the hypotheses
- **Presentation**
  - Facts to be presented are fixed a priori
  - Select appropriate presentation techniques
- **Interactive**
  - Interactions with a pre-defined animation

PURDUE POLYTECHNIC

I just need a picture for my paper or poster.

PURDUE
POLYTECHNIC



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?

Starting Point: 38 best tools for data visualization
http://www.creativebloq.com/design-tools/data-visualization-712402

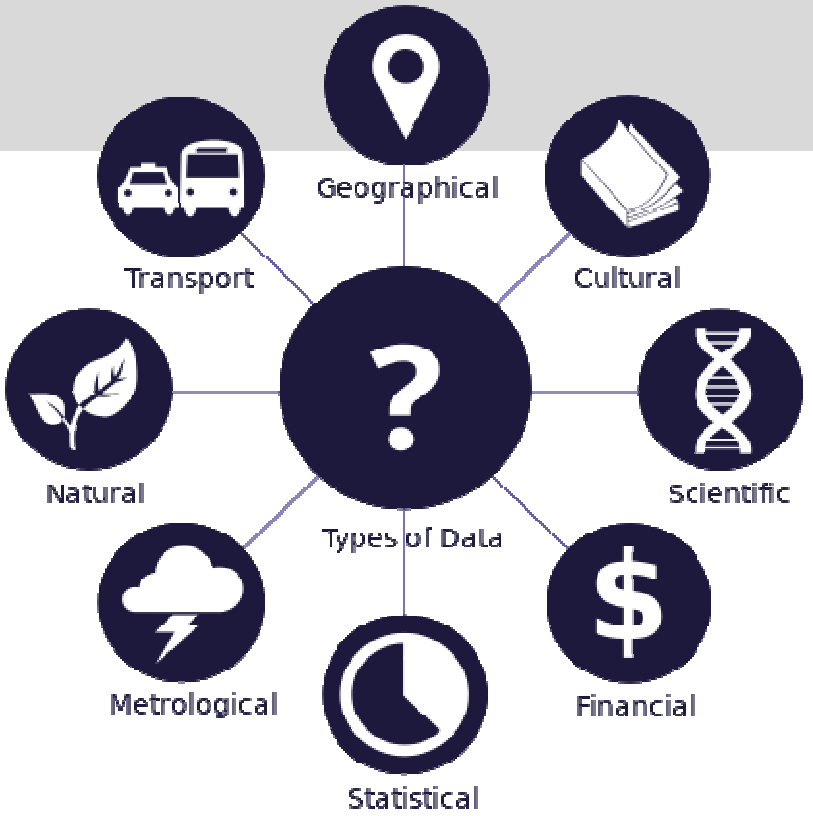
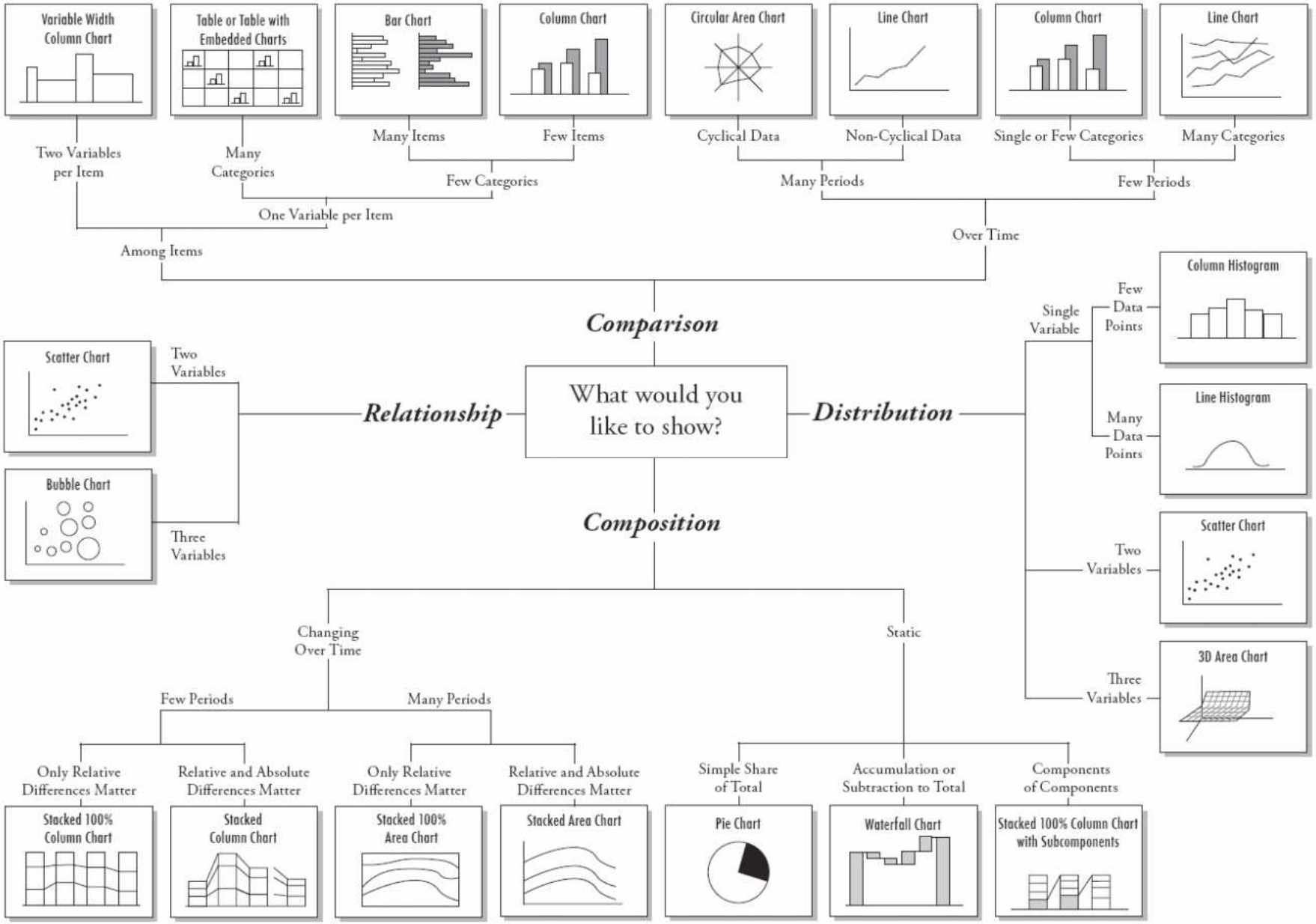


Image Source: Types of data. Translation of document hosted by João Batista Netoat
https://commons.wikimedia.org/wiki/File:Data_types_-_pt_br.svg

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

PURDUE POLYTECHNIC



https://www.labnol.org/software/find-right-chart-type-for-your-data/6523/

PURDUE POLYTECHNIC

I would like to program or create my own data visualization tool

PURDUE
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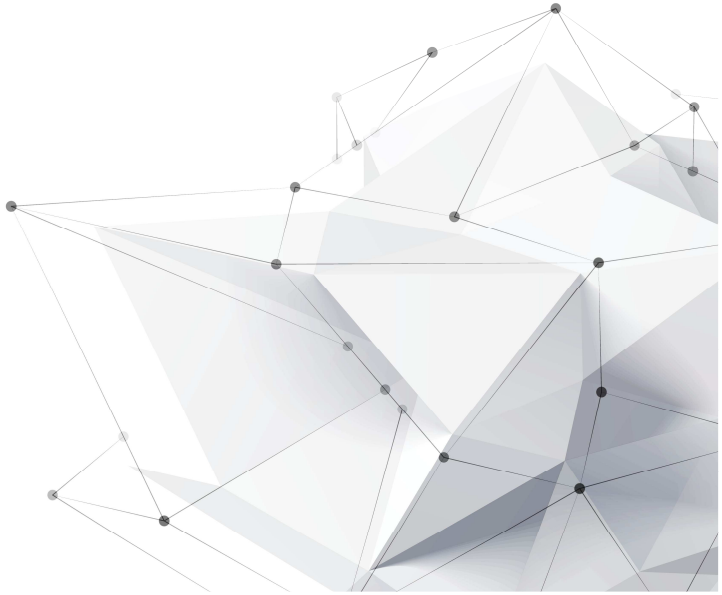

PROGRAMMING LANGUAGES FOR VISUALIZATION

5 Libraries for Building Data Visualizations

https://www.fastcompany.com/3029760/the-five-best-libraries-for-building-data-vizualizations

Which one is the best programming languages for data visualization?

https://www.quora.com/Which-one-is-the-best-programming-language-for-data-visualization

Data Visualization Basics with the R Programming Language

https://thenewstack.io/data-visualization-basics-r-programming-language/

PURDUE POLYTECHNIC

I am not a programmer but

I am interested in data visualization

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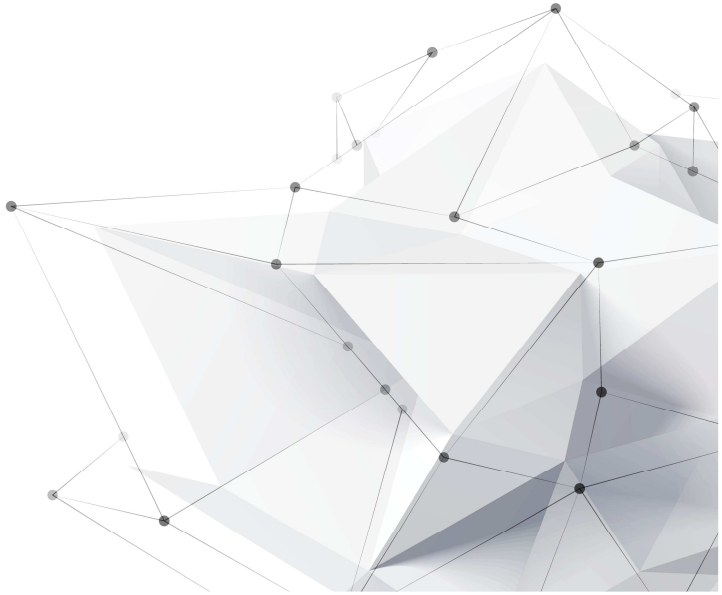

VISUALIZATION TOOLS

A STARTING POINT: OPEN SOURCE VISUALIZATION TOOLS

Information Visualization

- Gephi (https://gephi.org/)
- Tableau (not open source but free) https://www.tableau.com/products/desktop

Scientific Visualization

- ParaView (https://www.paraview.org/)
- VisIt (https://wci.llnl.gov/simulation/computer-codes/visit/)

Geo Visualization

- ARC GIS (https://www.arcgis.com/features/index.html)
- D3.js (https://d3js.org/)

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VISUALIZATION TOOLS

A STARTING POINT CONTINUED . . .

Civil Engineering Tools

http://guides.lib.purdue.edu/c.php?g=352179&p=3057468

Biological Visualization Tools

https://www.aiche.org/sbe/resources/resource-directory/software

Mathematics

http://visualizingmath.tumblr.com/

Data Visualization Basics with the R Programming Language

https://thenewstack.io/data-visualization-basics-r-programming-language/

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VISUALIZATION TOOLS

A STARTING POINT CONTINUED . . .

Interactive visualization tools:

https://constructive.co/insights/6-best-data-visualization-tools-2016-pt-1/

D3.js (https://d3js.org/)

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POLYTECHNIC

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.

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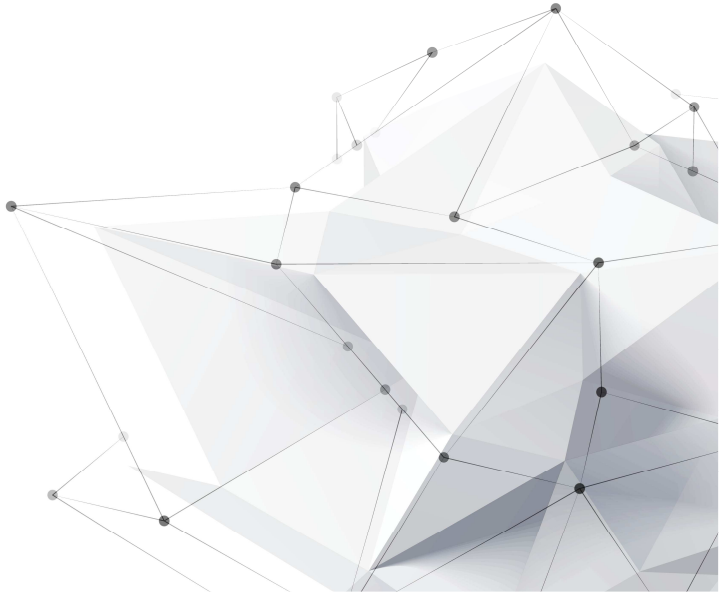
Data is Everywhere!



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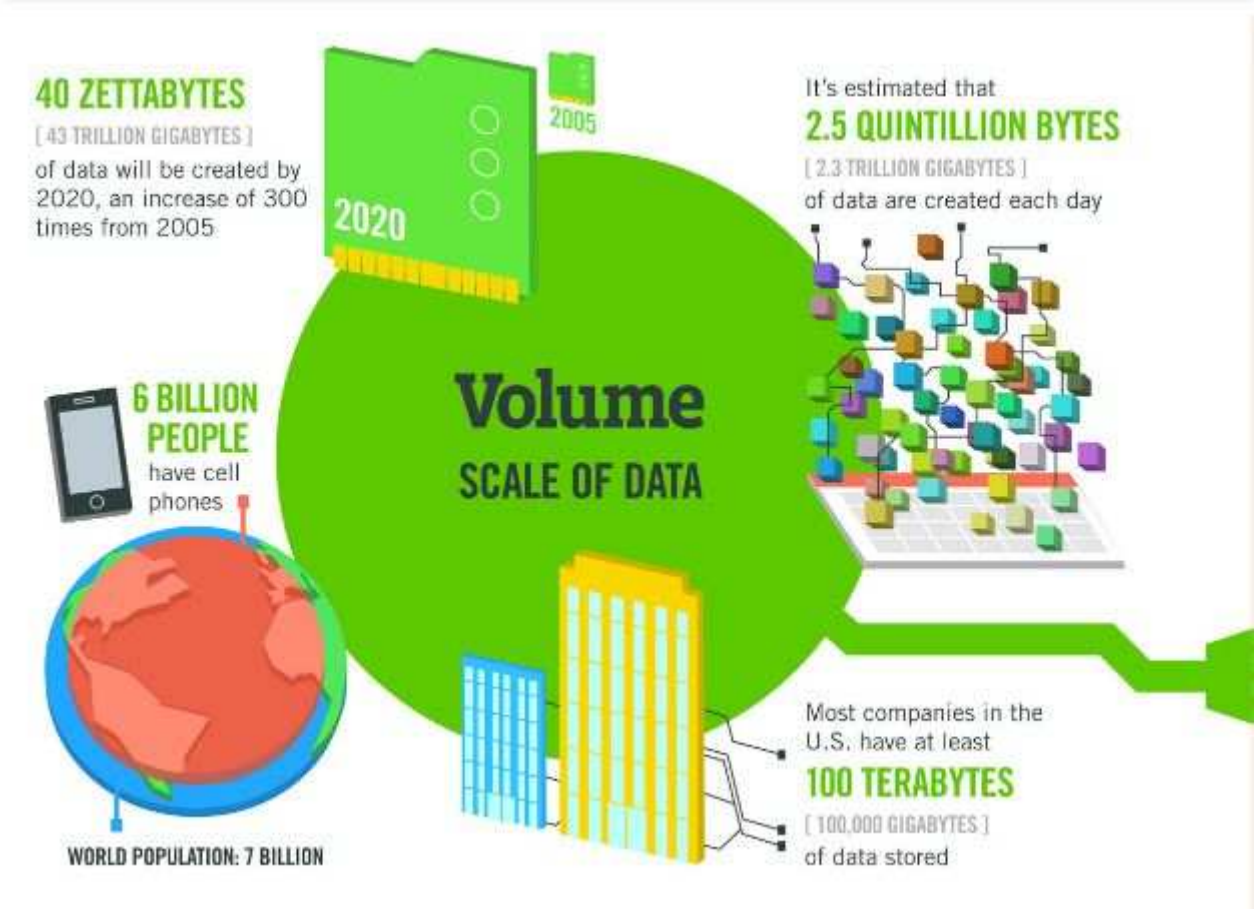
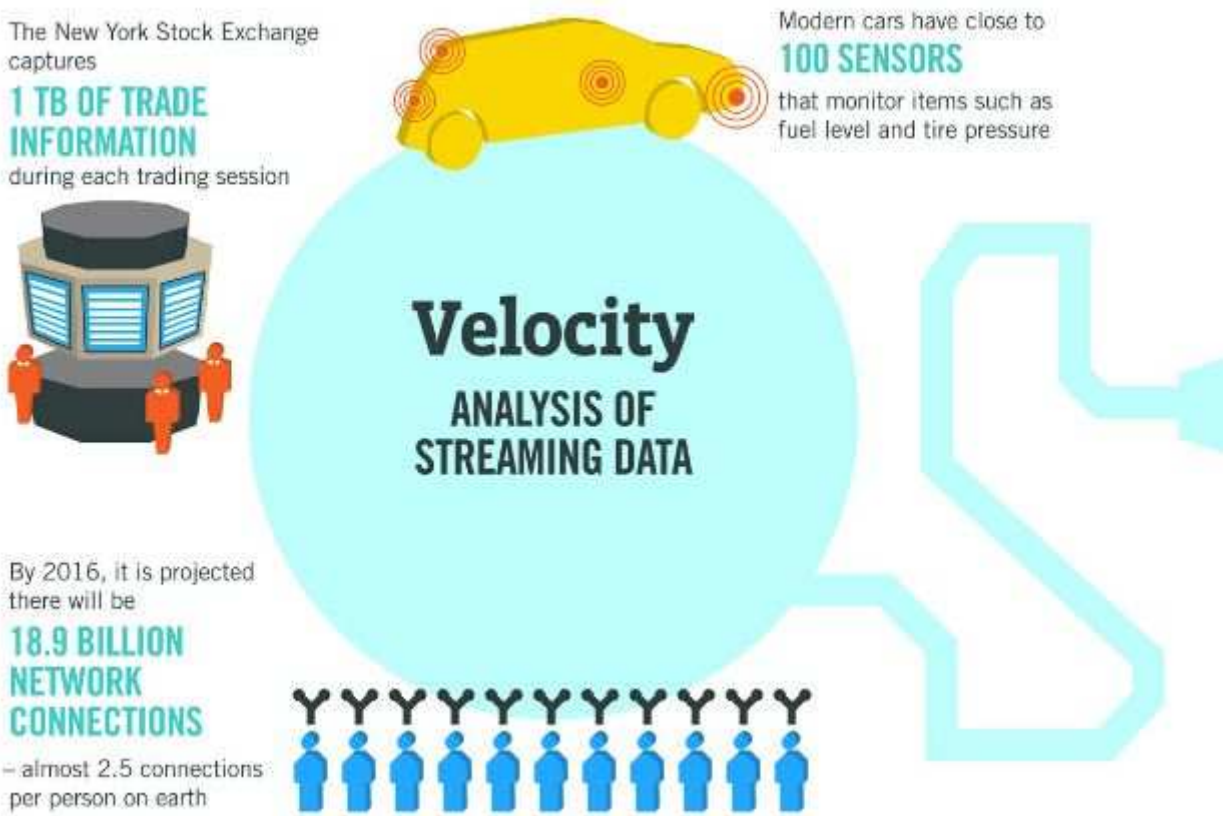
The Four V's of Big Data



https://www-01.ibm.com/software/data/bigdata/images/4-Vs-of-big-data.jpg

PURDUE POLYTECHNIC

The Four V's of Big Data



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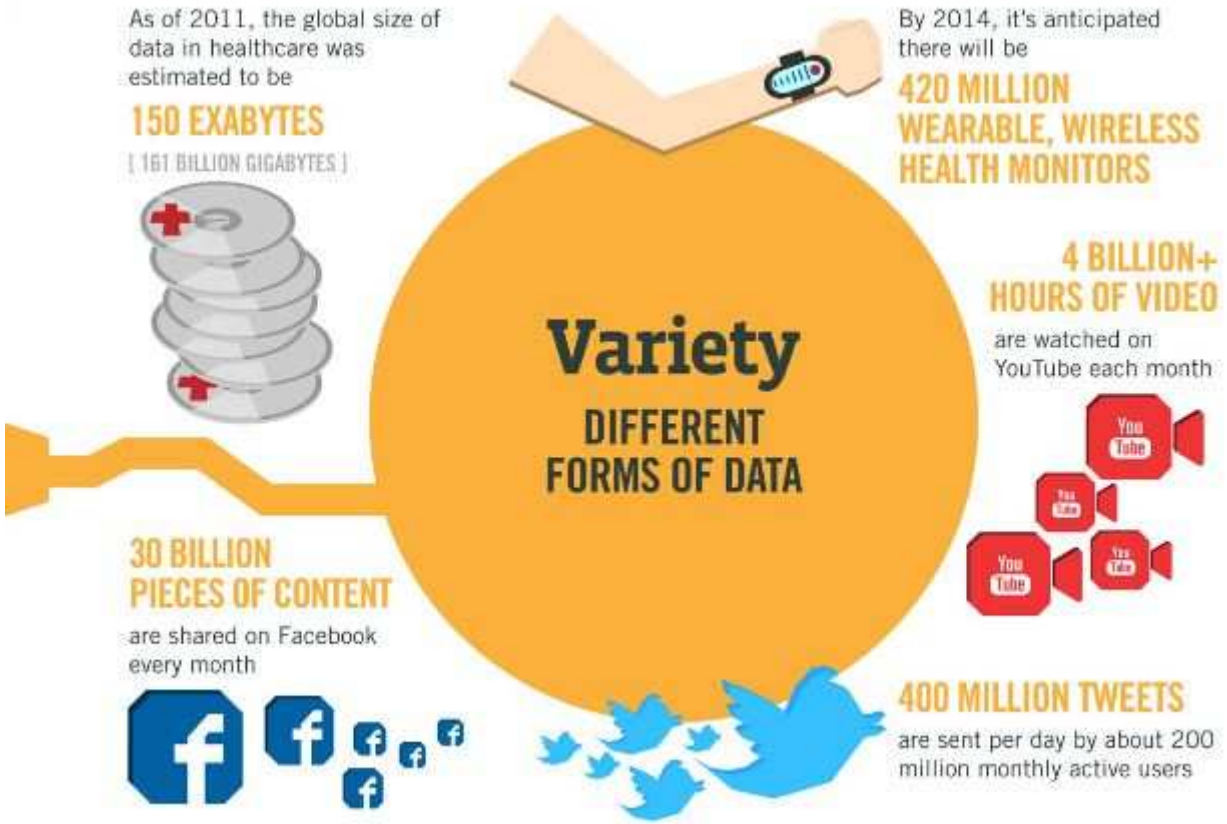
PURDUE POLYTECHNIC

The Four V's of Big Data



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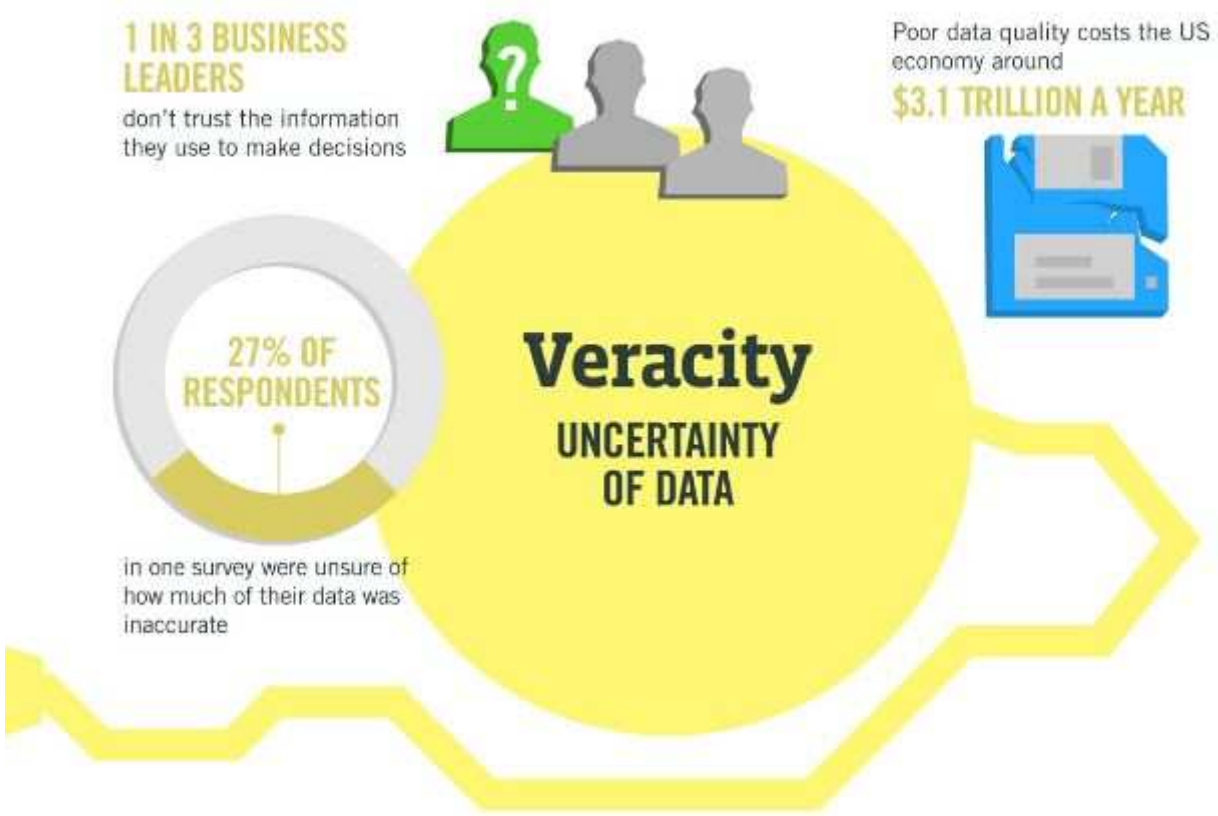
PURDUE POLYTECHNIC

The Four V's of Big Data



https://www-01.ibm.com/software/data/bigdata/images/4-Vs-of-big-data.jpg

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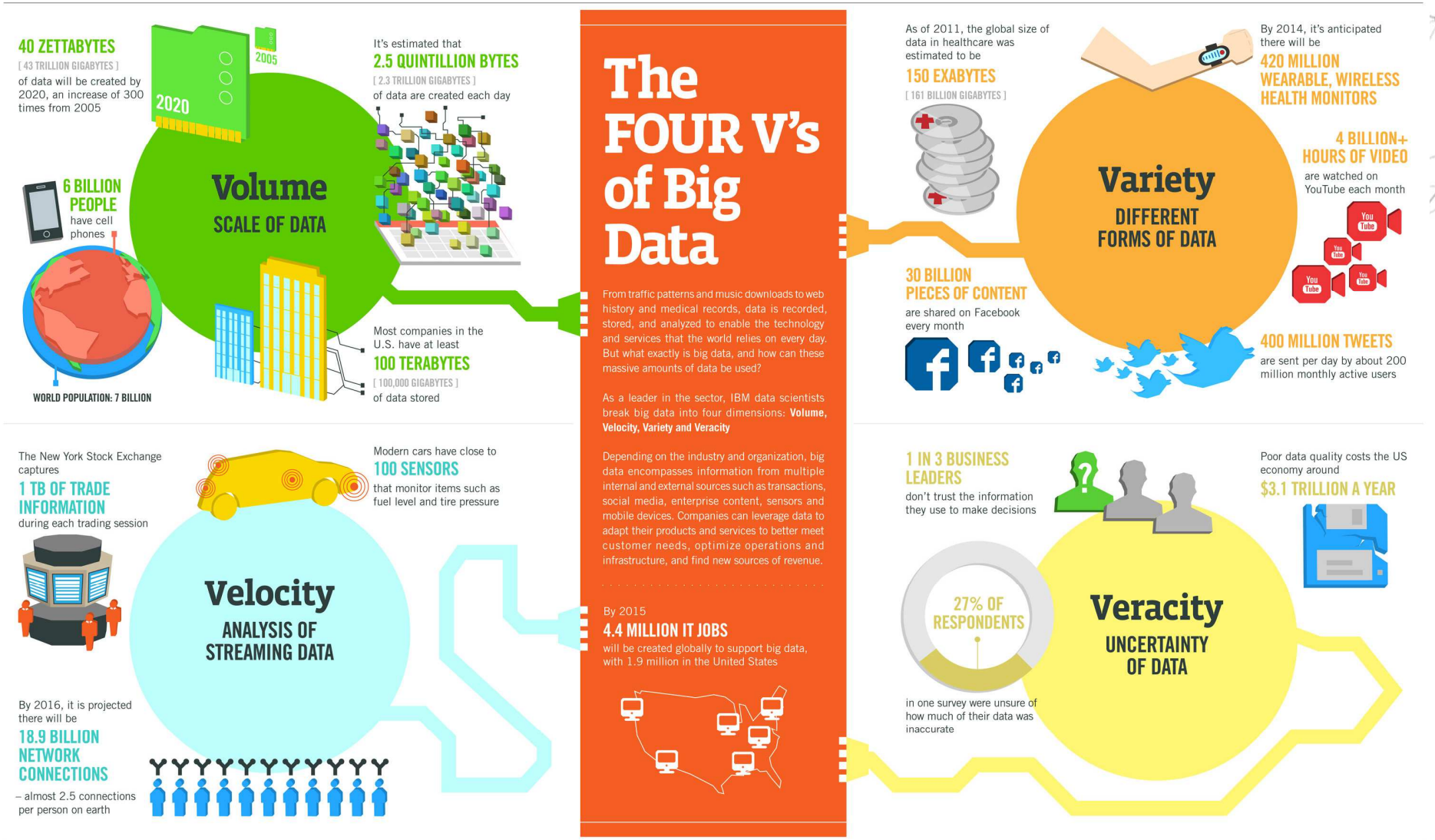
IBM Big Data Platform



https://www-01.ibm.com/software/data/bigdata/images/4-Vs-of-big-data.jpg

VISUALIZATION TOOLS FOR BIG DATA

THIS IS NOT AN EXHAUSTIVE LIST

- **Google charts** (https://developers.google.com/chart/) (Free) – display live data on your website
- **Tableau Desktop** (https://www.tableau.com/products/desktop) – 14 day free trial
- **D3** (https://d3js.org/) : Data Driven Document (Free): Javascript library for visualising big data
- **Fusion Chart** (http://www.fusioncharts.com/) - Javascript charting library for the web and mobile devices, spread across 120 countries with having clients such as Google, Intel, Microsoft and many others. However, you need a bit knowledge on Javascript for implementing it.
- **High Charts** (https://www.highcharts.com/) Highcharts is a charting library written purely in Javascript hence, a bit knowledge of Javascript is necessary for implementing this tool. It uses HTML5, SVG and VML for displaying charts across various browsers (from IE6+) and devices like android, iPhone etc.
- **Canvas** (http://canvasjs.com/)

A review of 20 big data visualization tools:
http://bigdata-madesimple.com/review-of-20-best-big-data-visualization-tools/

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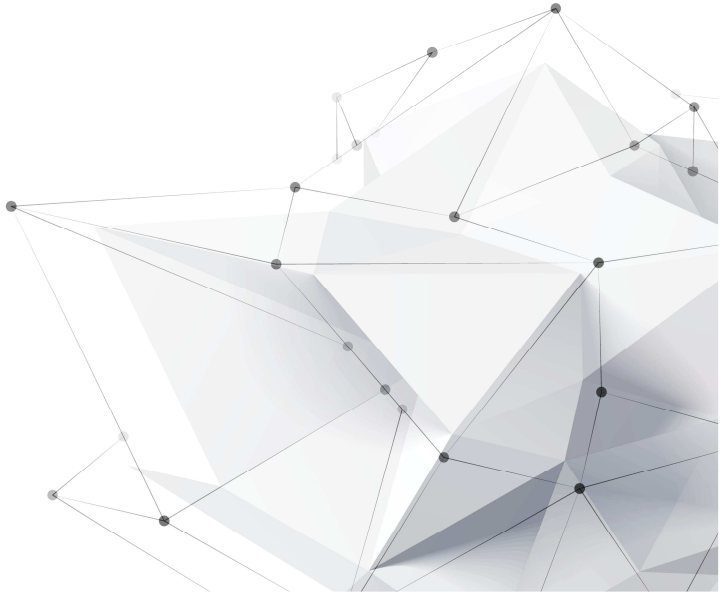
Why is Visualization Important?



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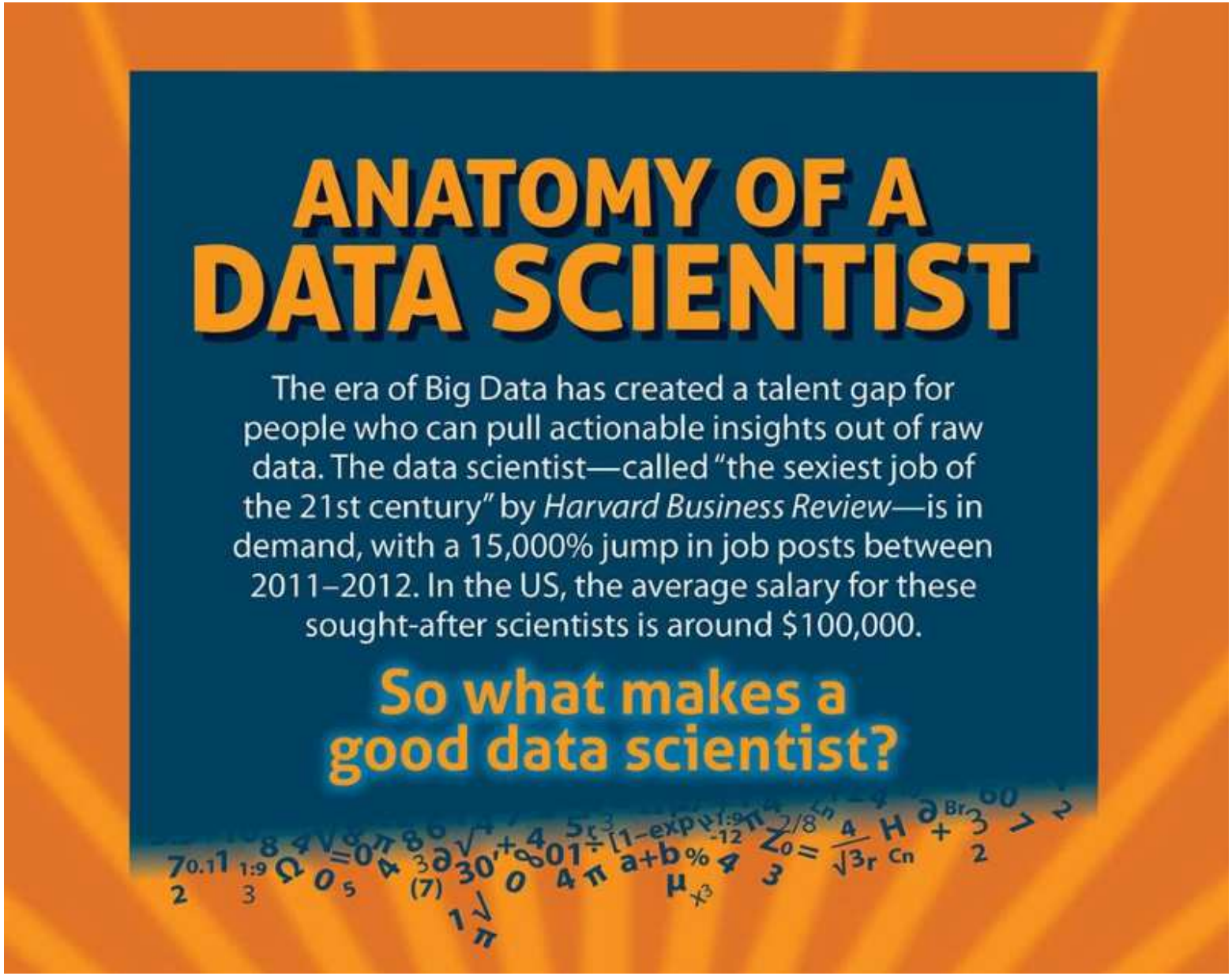

http://www.houghtoncdsa.org/liberal-arts-data-science-seriously/

PURDUE POLYTECHNIC

WHAT MAKES A GOOD DATA SCIENTIST?

- Degreed In Geek – It doesn't hurt to have a background and hands on experience in data visualization

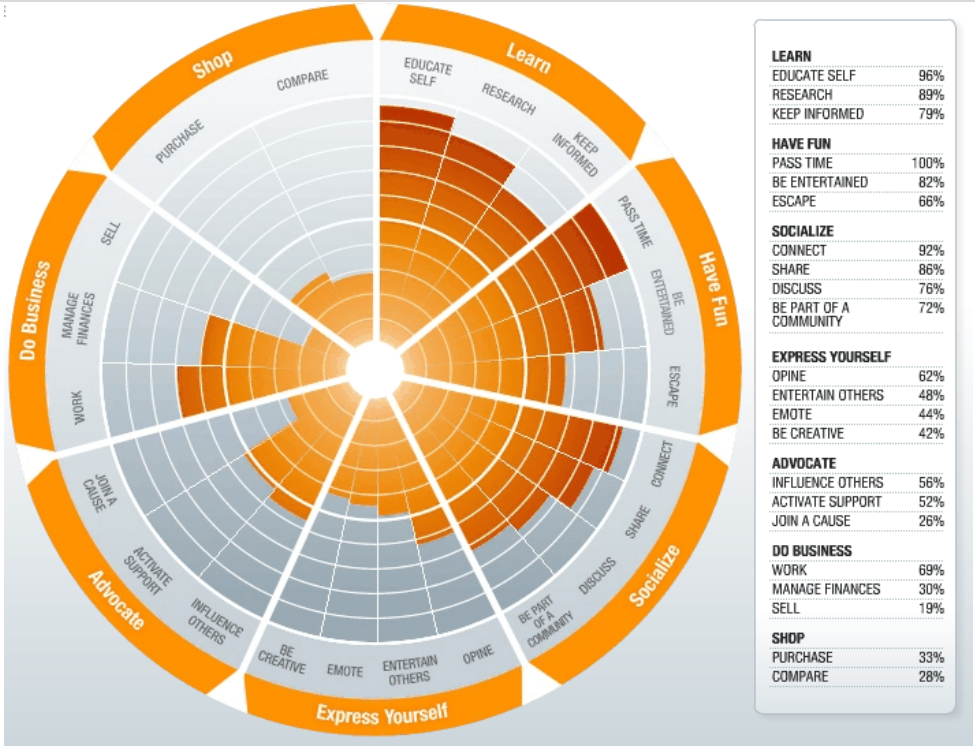

Image Source: https://www.pinterest.com/pin/213076626089856136/

http://www.houghtoncdsa.org/liberal-arts-data-science-seriously/

Sources:
www.indeed.com/jobtrends?q=%22Data+Scientist%22&l=%5D&relative=1
http://management.fortune.cnn.com/2013/05/10/big-data-jobs/
http://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century/ar/1
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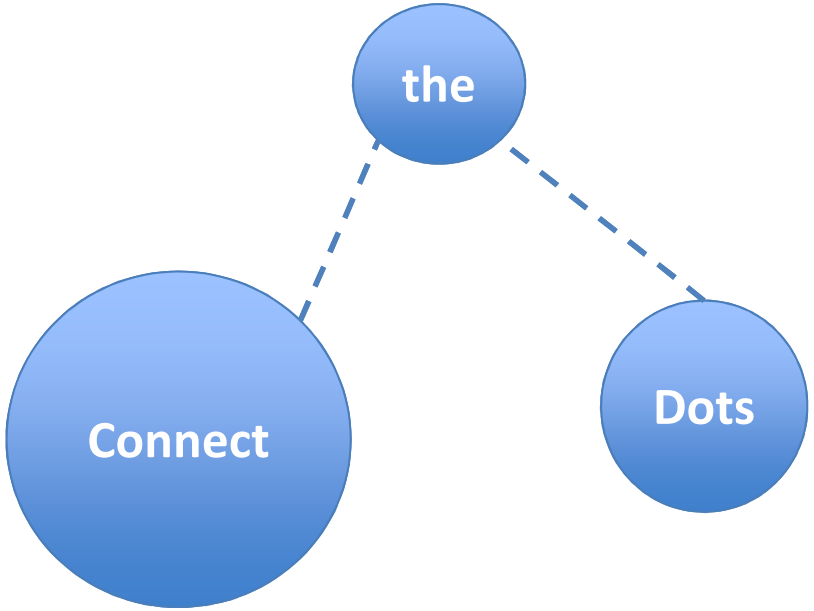
www.indeed.com/salary?q1=data+scientist&l1=&tm=1
www.payscale.com/research/US/Job=Data_Scientist_%2F_Engineer/Salary

PURDUE POLYTECHNIC

WHAT MAKES A GOOD DATA SCIENTIST?

- Problem Solving Prowess – A problem solver at heart who's able to devise creative solutions to real-world problems.
- Knows how to define those problems precisely, spot elusive patterns and connect the dots



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WHAT MAKES A GOOD DATA SCIENTIST?

- Mathlete
- Strong math skills are table stakes

Do NOT let this scare you!

http://ignatiansolidarity.net/blog/2015/06/22/jv-reflects-a-picture-is-worth-a-thousand-words/

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WHAT MAKES A GOOD DATA SCIENTIST?

- Suit-Able – Has the know-how and finesse to be a business leader.
- Today, data scientists can lead from the backroom to the boardroom

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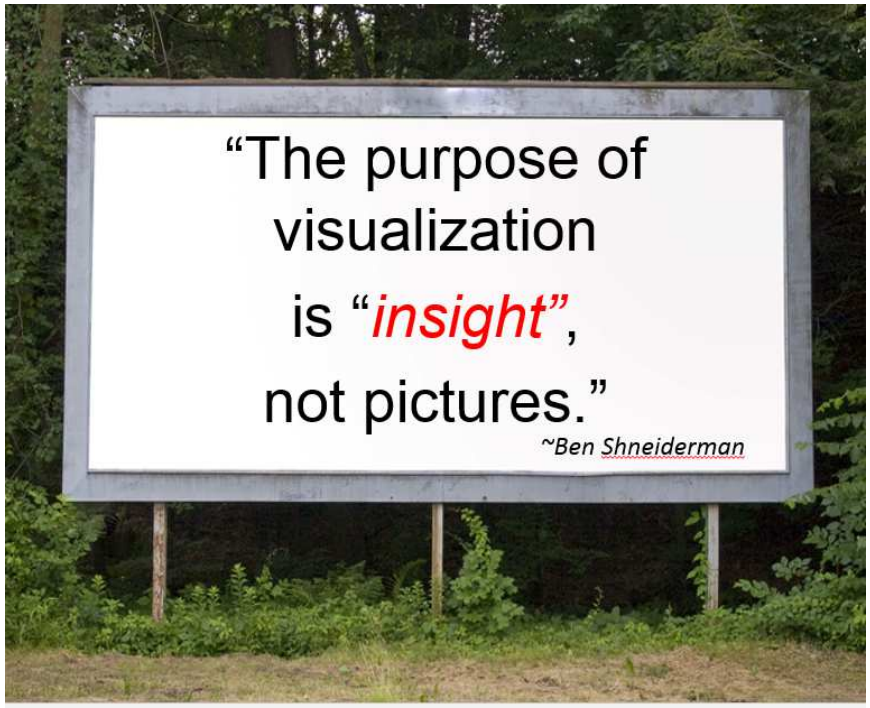
WHAT MAKES A GOOD DATA SCIENTIST?

- Insight Whisperer – Can develop unique insights, apply them to solve problems and explain them to people without overwhelming them



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www.payscale.com/research/US/Job=Data_Scientist_%2F_Engineer/Salary

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WHAT MAKES A GOOD DATA SCIENTIST?

- Quantastic – successful data scientists come not only from math backgrounds, but also from many other fields.
- They have programming skills or . . .
- The ability to learn programming languages and represent concepts via computer code

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www.payscale.com/research/US/Job=Data_Scientist_%2F_Engineer/Salary

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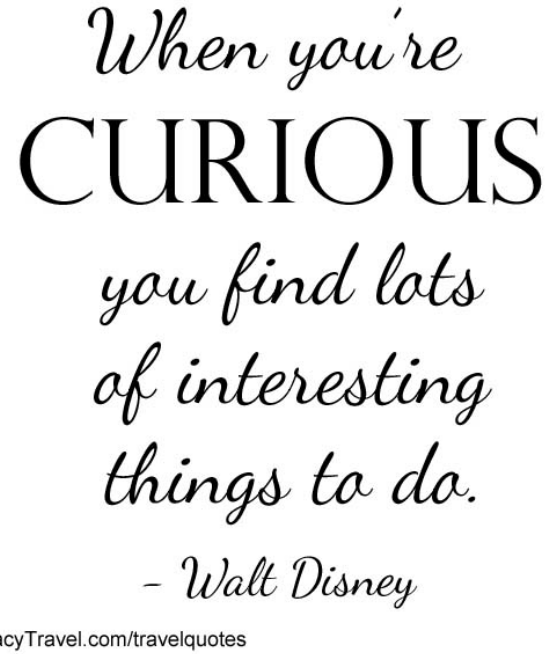
WHAT MAKES A GOOD DATA SCIENTIST?

- Curiouser and Curiouser – Critical Thinking and a relentlessly inquisitive nature are at the center of an analytic mindset



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WHAT MAKES A GOOD DATA SCIENTIST?

- Agile and Adaptive – versatile enough to apply their expertise to multiple industries, from retail to banking, insurance to government, healthcare to airlines

The possibilities are endless!

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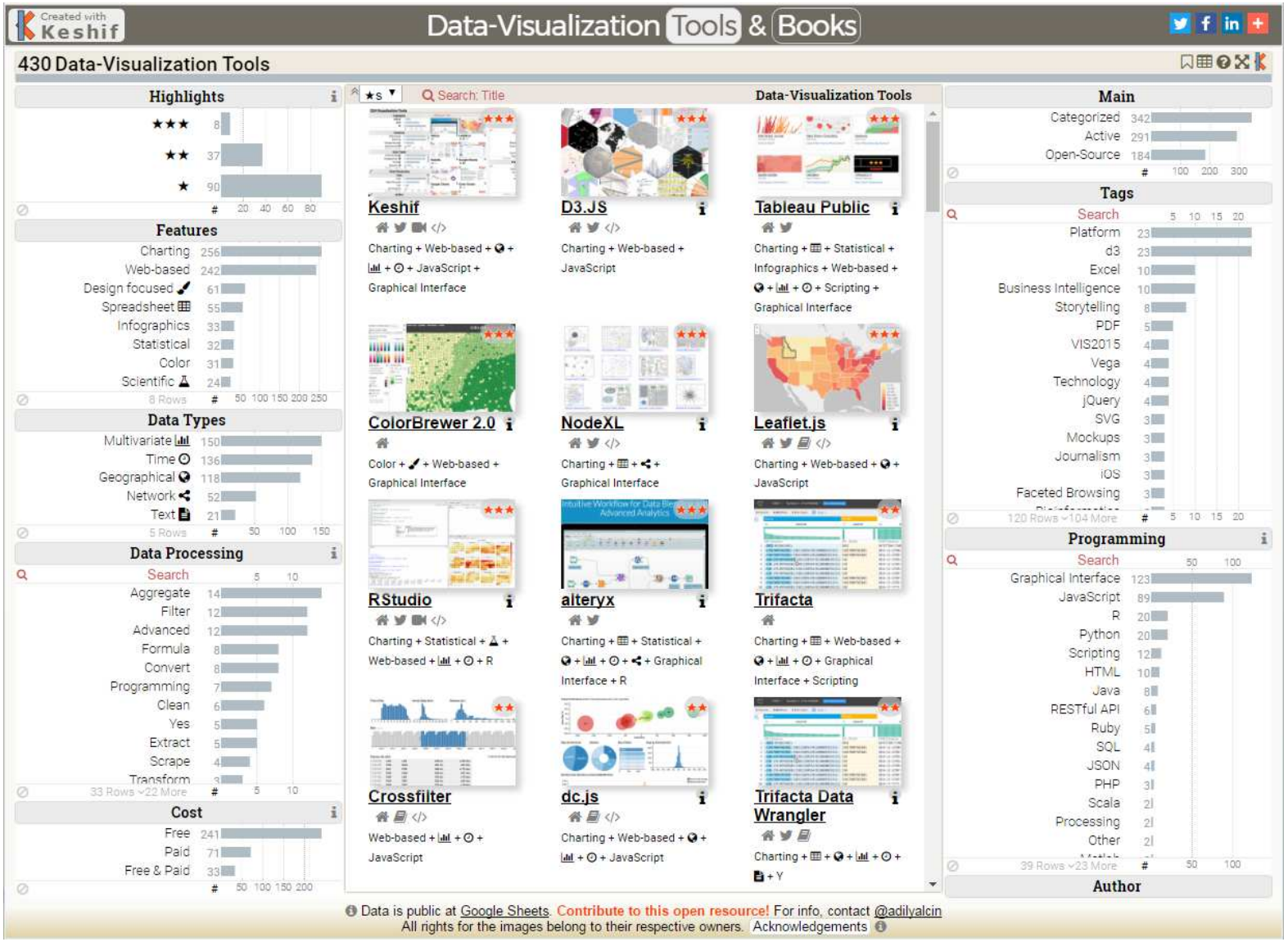
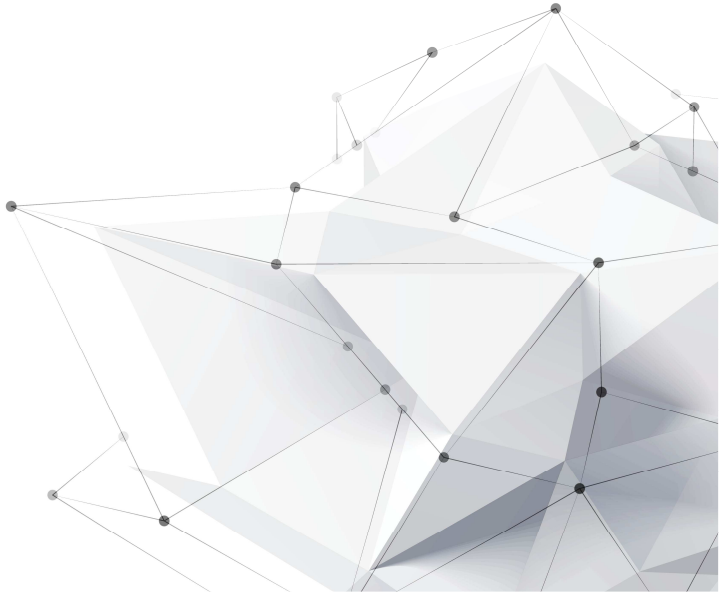
WANT MORE?

https://keshif.me/demo/VisTools?utm_content=26335725&utm_medium=social&utm_source=twitter



Visualization is a Process

- Your 1st visualization will not be your last
- The 1st visualization tool you use will not be your last



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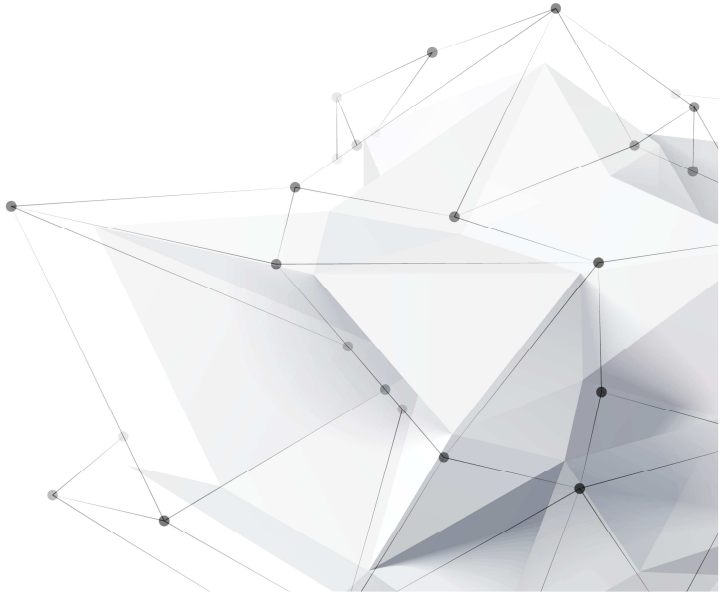
The purpose of visualization is

“Insight”



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Questions?

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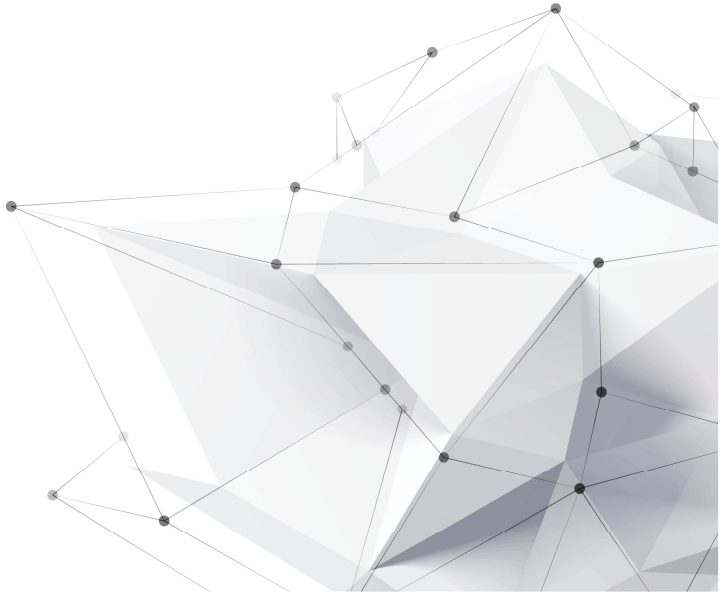

Questions?

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