

## Scalable Visualization for Information Discovery

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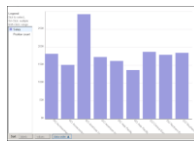
UNL CSCE 100

Oct 12, 2021

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### What is Visualization?

- **Communication** of **information** using **graphical** representations
- Everyday and everywhere
  - Bar chart in a newspaper
  - Subway map
  - Weather chart
  - Stock market analysis
  - ....

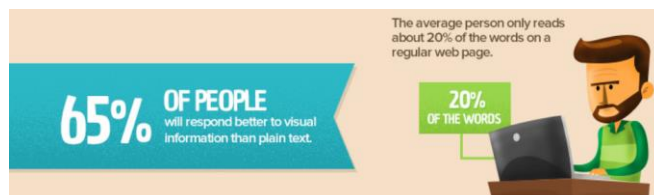
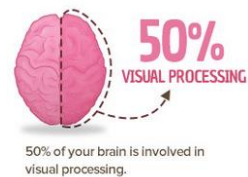
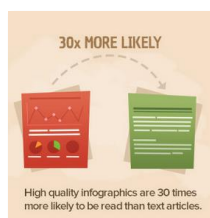


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## Why Visualization?

- Pictures have been used for communication since before the formalization of written language
- Our brain is well built for processing pictures
  - **Speed**
    - Image interpretation is performed in parallel
    - Text analysis is limited by sequential process of reading
    - One biological study estimates the transmission speed of the optic nerve at around 9Mb/sec
  - **Pattern matching**
    - Our visual system can quickly identify important patterns from massive data
      - E.g. face recognition from a large number of people

## Why Visualization?

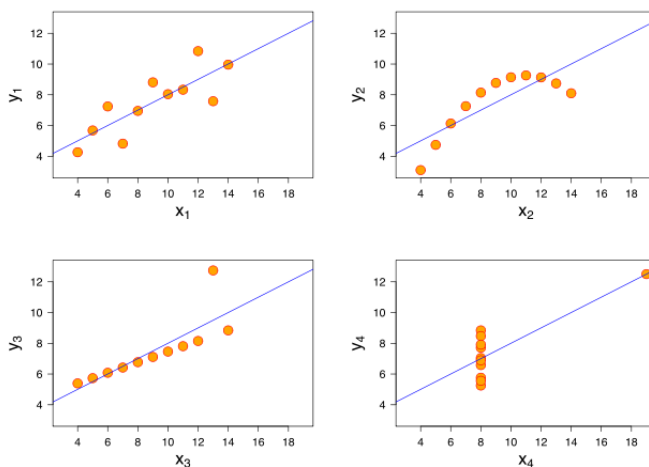


## A Classic Example

- Four data sets
  - Each containing a set of data points in  $(x, y)$

Property	Value
Mean of $x$ in each case	9 (exact)
Variance of $x$ in each case	11 (exact)
Mean of $y$ in each case	7.50 (to 2 decimal places)
Variance of $y$ in each case	4.122 or 4.127 (to 3 decimal places)
Correlation between $x$ and $y$ in each case	0.816 (to 3 decimal places)
Linear regression line in each case	$y = 3.00 + 0.500x$ (to 2 and 3 decimal places, respectively)

## Magic!

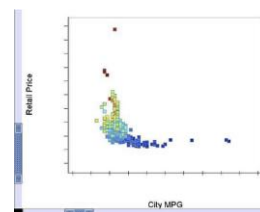
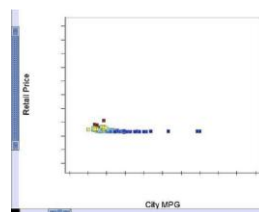
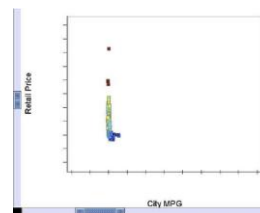
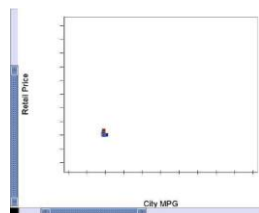


## Why is Visualization Challenging?



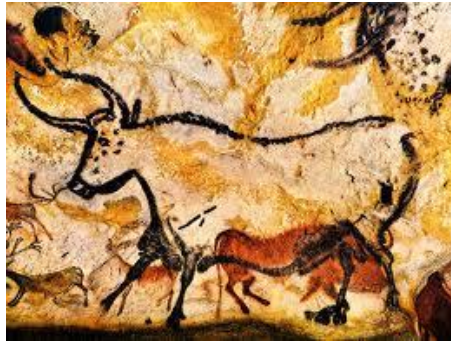
## Why is Visualization Challenging?

- The same data plotted with different scales is perceived dramatically differently.



### Early Visualization

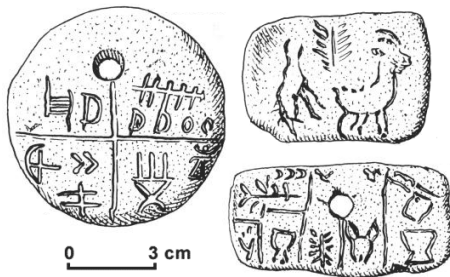
- Perhaps the first technique for **graphically** recording and presenting **information**



Cave paintings by early man approximately **30,000** years ago

### Early Visualization

- Early graphical writing



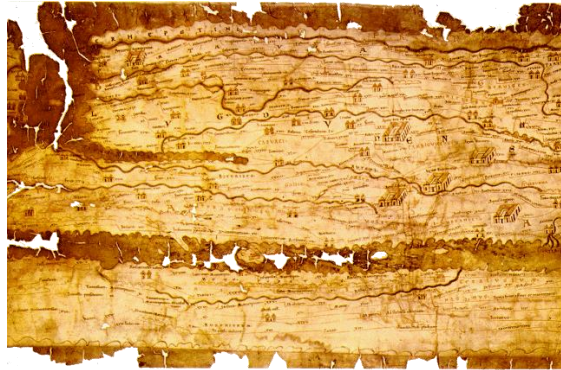
Tartaria Tablets, **5500BC**



Kish Tablet, **3500 BC**

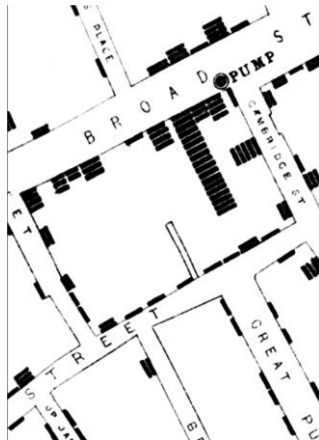
### Early Visualization

- Some necessary need for survival



Peutinger map: the road network in the Roman Empire.  
Created in **15<sup>th</sup> century** based on a **4<sup>th</sup>-century map**

### Early Visualization

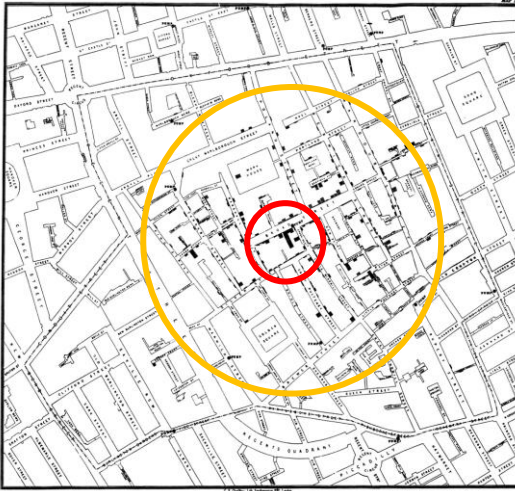


### Vis + Data Mining

A section of John Snow's map of the deaths from cholera in London in 1663.

**Each bar within the houses represents one deceased individual.**

## Early Visualization

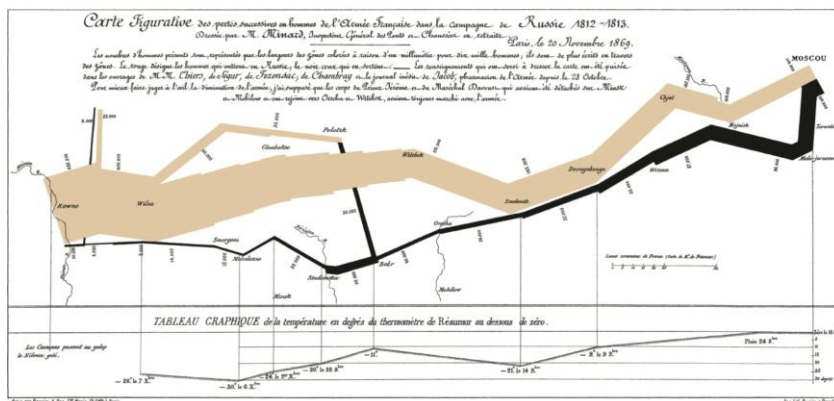


Overview map of the deaths from cholera in London in 1663.

Note the concentration around the Broad Street Water Pump.  
Note as well the outliers.

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## Early Visualization



Minard's map, showing Napoleon's march on Moscow. The width of the line conveys the size of the army at that location. Color indicates the direction of movement. The temperature is plotted at different points along the retreat at the bottom. (1869)

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## Early Visualization



Leonardo Da Vinci's study of the motion of the human arm (1510).

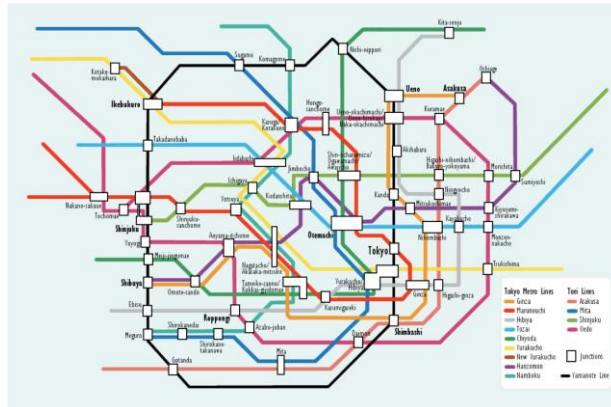
## Early Visualization



Leonardo Da Vinci's picture of water flow

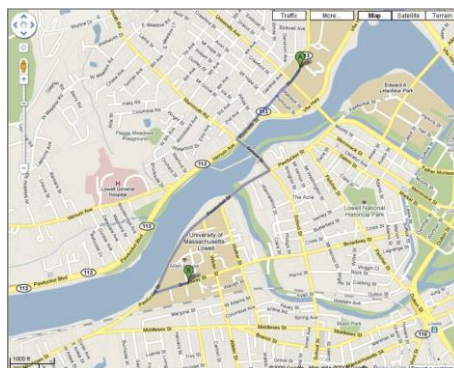
## Visualization Today

The Tokyo Underground map. A logical representation of the metro highlighting **qualitative** relationships between the stops.



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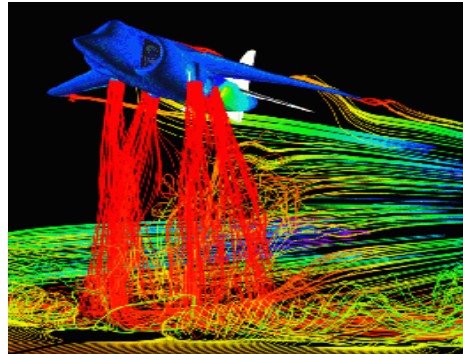
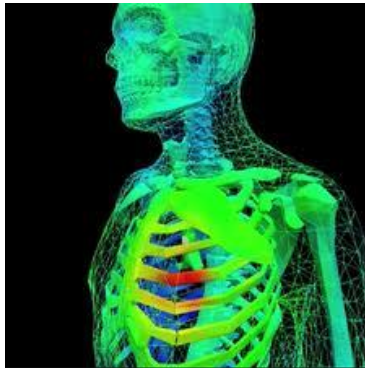
## Visualization Today



The google.com map directions from 198 Riverside St., Lowell, MA (UMass Lowell, North Campus) to 883 Broadway St., Lowell, MA (UMass Lowell, South Campus). Google.com maps provide graphical cues drawn on top of road maps to indicate driving directions from point A to point B.

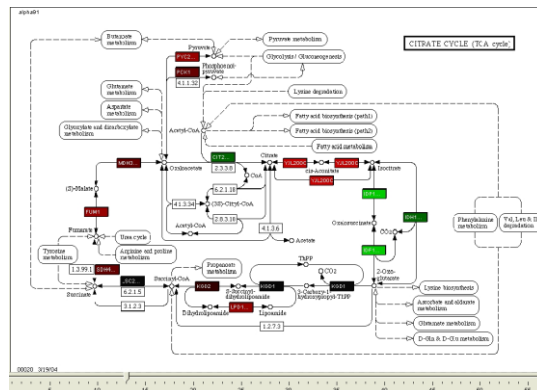
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## Visualization Today



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## Visualization Today

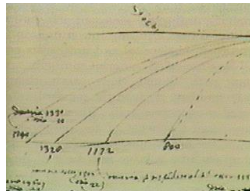
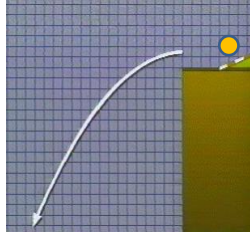
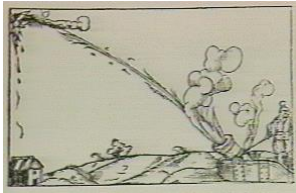


A pathway represented by a network with nodes representing genes and color the level of expression.

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## Why is visualization a necessity?

- Galileo's Analysis of Projectile Motion



Parabola

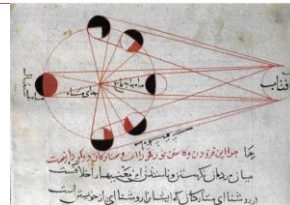
$$y = ax^2 + bx + c$$

<http://www.mcm.edu/academic/galileo/ars/arshtml/mathofmotion2.html>

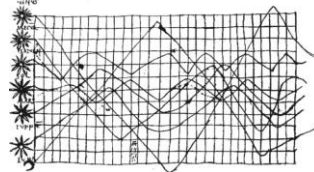
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## Why is visualization a necessity?

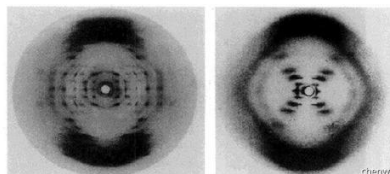
- Many many examples
  - Kepler's laws
  - Newton's laws
  - DNA structure
  - ... ..
  - Numerous scientific publications



Produced by Biruni circa 1030. Shows the phases of the moon in orbit.



Planetary motion.

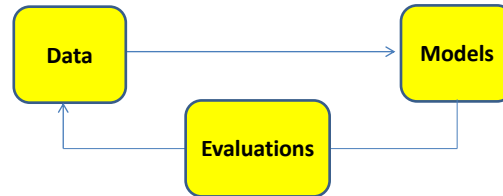


The x-ray diffraction image

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### Why is visualization a necessity?

- Human's Knowledge Discovery Pipeline



- Visualization
  - Can be used at every step of the KD pipeline
  - Often a part of this larger process
  - Tightly coupled with analysis

### Visualization vs. Computer Graphics

- Computer Graphics
  - Graphical objects and organization of graphic primitives
- Visualization
  - More than computer graphics
  - Based on the underlying data (spatial positions, populations, or physical measures)
  - Include aspects from numerous other disciplines
    - Human-computer interaction
    - Psychology for human perception
    - Databases
    - Statistics
    - Data mining
    - ...

## Visualization vs. Computer Graphics

- Computer Graphics
  - Creation of images and animations for **visual realism**
  - Video games, cartoons, advertisements, and movie special effects
- Visualization
  - Not emphasize visual realism, but **effective communication of information**
  - Many applications do not deal with physical objects

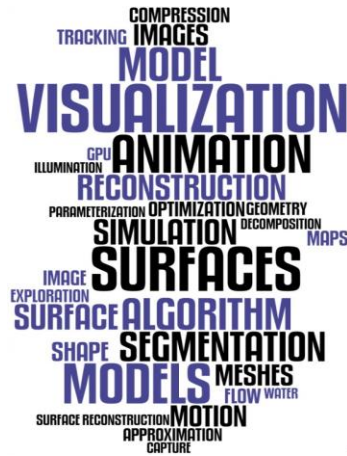
## Visualization vs. Computer Graphics

- Computer Graphics provides tools for visualization
  - Graphics-programming language
    - OpenGL, DirectX, Processing, Java3D
  - Underlying graphics Hardware
    - Intel, Nvidia or AMD graphics cards
  - Rendering process
    - Different shading
  - Output format
    - JPEG, TIFF, AVI, MPEG

## Visualization vs. Computer Graphics

- Paper keywords from Computer Graphics Forum

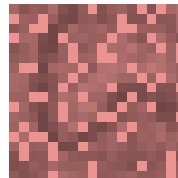
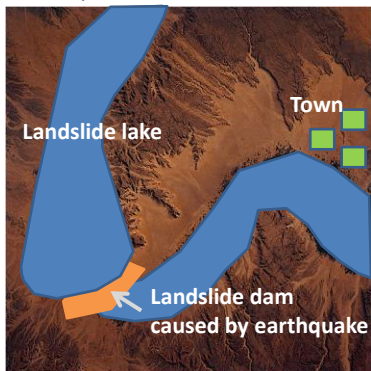
This image itself is a visualization. →



## Why is Visualization Challenging in Big Data Era?

- Big Data – **Dilemma**

Example: Landslide lake detection



**Coarser resolution:**  
missing details

**Finer resolution:**  
Finding the needle in a haystack



## Why is Visualization Challenging in Big Data Era?



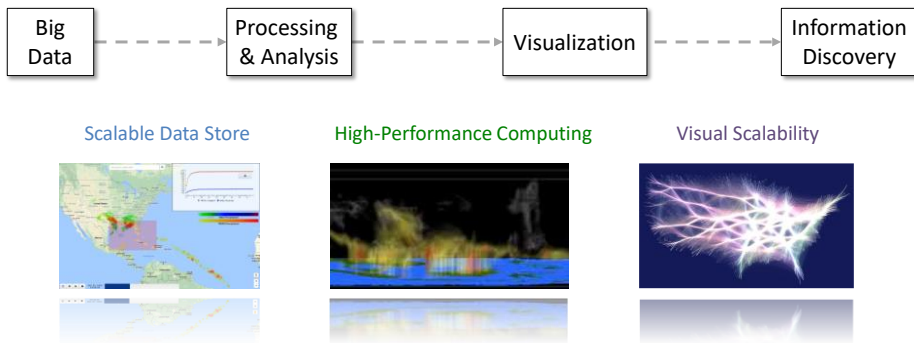
## Our Research Theme





## Our Research Theme

Holistically address every stage  
of a visualization pipeline



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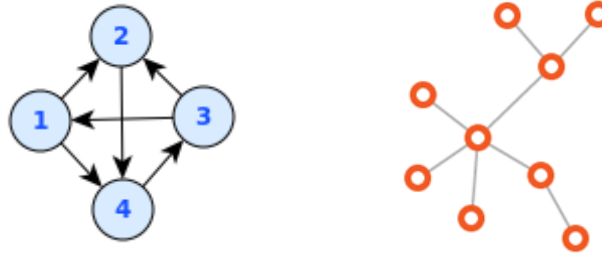
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## Visual Scalability

Massive Data vs. Limited Screen

Example: Traditional node-link diagram for network data

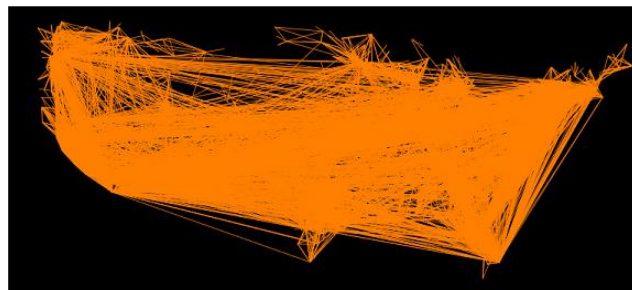


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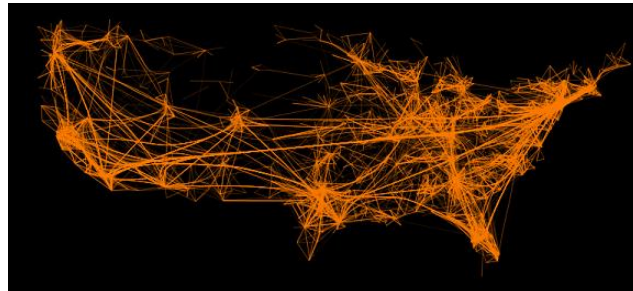


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## Visual Scalability

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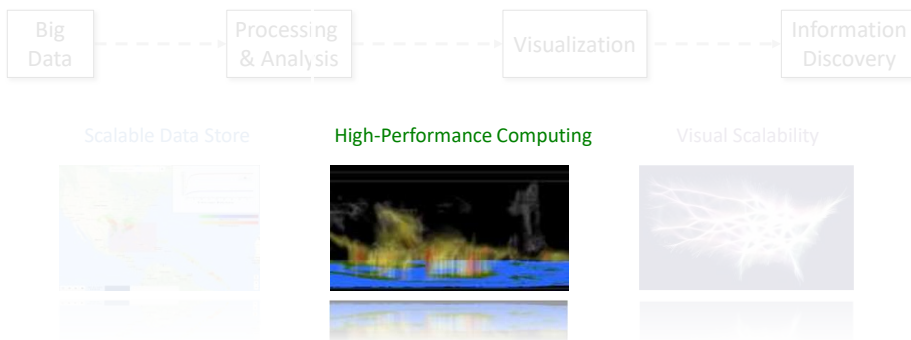
Our research: Edge bundling for network data



[Yves 2019]

## Our Research Theme

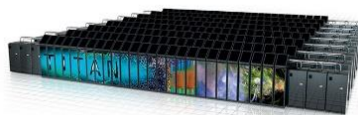
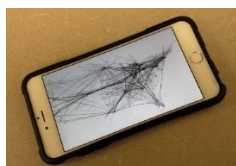
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## High-Performance Computing

Our research: Exploit high-performance compute technology

- Accelerate data processing
- Ensure **interactivity**

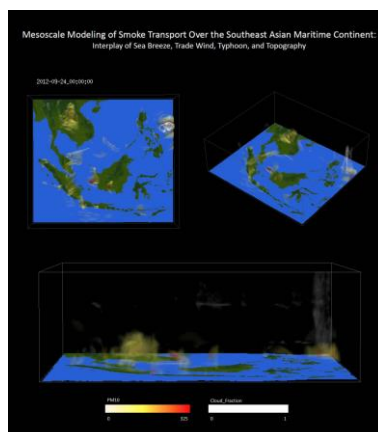


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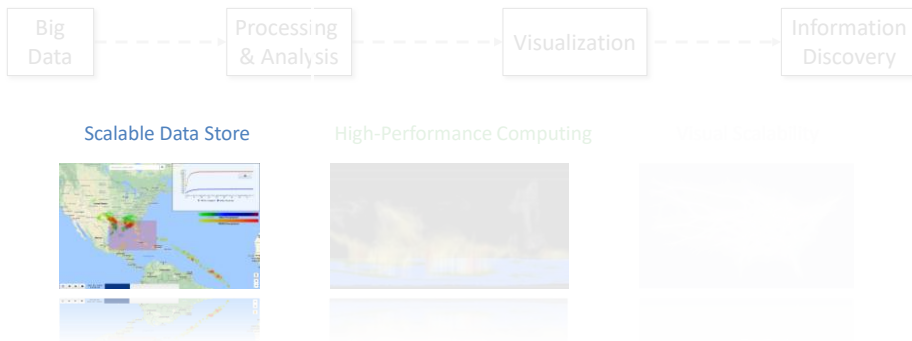


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## Our Research Theme

Holistically address every stage  
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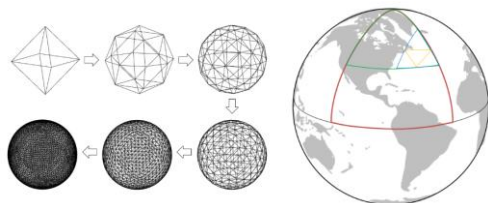
## Scalable Data Store

Our research: Design new distributed data indexing and placement solutions

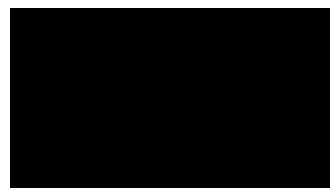
- **Petabytes and beyond**
- **Diverse data types and structures**  
(vector, raster, relation, binary, and text)
- **Complex data presentations**  
(shapefiles, images, tables and point clouds)

## Scalable Data Store

Our example work: SpatioTemporal Adaptive-Resolution Encoding (STARE)



[\[PAPER\]](#) [\[VIDEO\]](#)



## Our Research Theme

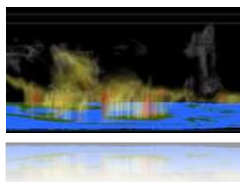
Lead to new scientific  
applications and discoveries



Scalable Data Store



High-Performance Computing



Visual Scalability



## Tweether: A Visualization Tool Displaying Correlation of Weather to Tweets



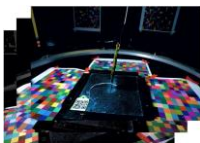
Tweether: A Visualization Tool Displaying Correlation of  
Weather (Grid Data) to Tweets (Point Data)

[PAPER]

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## Plant Phenotyping

Our research: Develop new imaging and 3D reconstruction  
systems to capture high-resolution dynamics of plant growth.



Multi-view images



3D reconstruction



Panicle segment



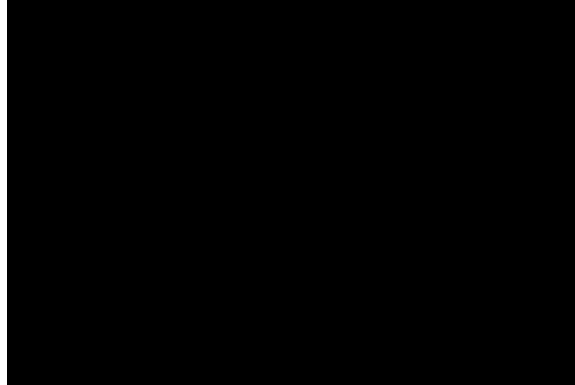
Trait extraction

[PAPER]

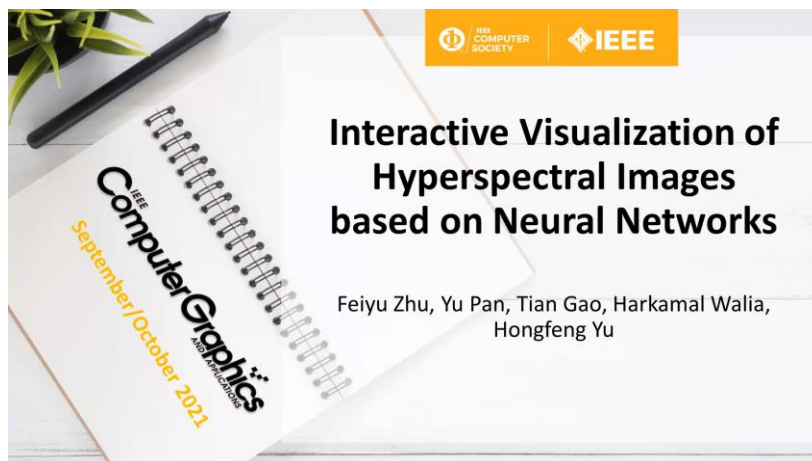
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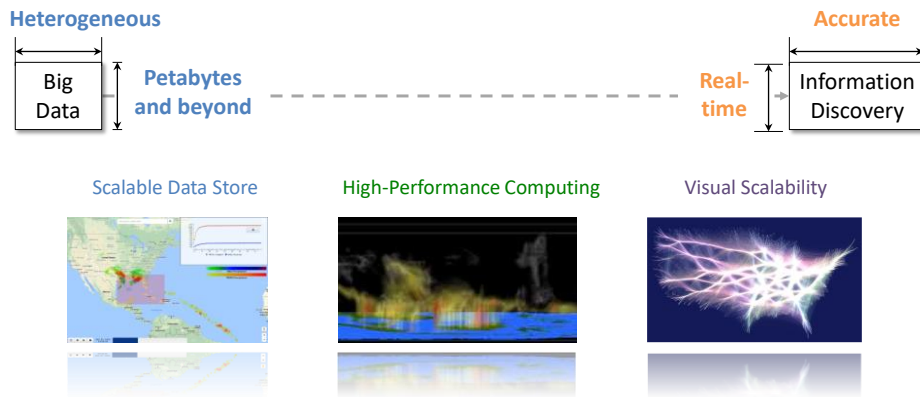
## Interactive Visualization of Hyperspectral Images based on Neural Networks



[\[PAPER\]](#) [\[VIDEO\]](#)



## Our Research Theme



Thank You!

