

# Data Types, Tasks, Visual Encodings

CS 7250 Spring 2020 *Prof. Cody Dunne Northeastern University* 

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# READING QUIZ

8 min



QUESTIONS?



PREVIOUSLY, ON CS 7250...





Note: these are all really important concepts when it comes time to coding your visualizations...!

# Visualization Building Blocks

## Channels :



![](_page_4_Picture_6.jpeg)

**Channels:** Expressiveness Types and Effectiveness Ranks Magnitude Channels: Ordered Attributes Position on common scale Position on unaligned scale Length (1D size) Tilt/angle Area (2D size) Depth (3D position)  $\rightarrow \bullet$ **} (** Color luminance Color saturation Curvature Volume (3D size)

![](_page_5_Figure_2.jpeg)

Same

Same

![](_page_5_Picture_4.jpeg)

# **Expressiveness and Effectiveness**

- Effectiveness principle: the importance of the attribute should match the salience of the channel; that is, its noticeability.

  - (i.e., encode most important attributes with highest ranked channels)
- Expressiveness principle: the visual encoding should express all of, and only, the information in the dataset attributes.
  - (i.e., data characteristics should match the channel)

![](_page_6_Picture_8.jpeg)

![](_page_6_Picture_9.jpeg)

# Data Types

# **DATASET** = collection of information that is the target of analysis

![](_page_7_Figure_2.jpeg)

→ Geometry (Spatial)

![](_page_7_Picture_4.jpeg)

![](_page_7_Picture_5.jpeg)

![](_page_7_Picture_6.jpeg)

NOW, ON CS 7250...

![](_page_8_Picture_2.jpeg)

![](_page_9_Figure_1.jpeg)

# Analysis

## What data is shown?

## Why is the user analyzing / viewing it?

How is the data presented?

![](_page_9_Picture_6.jpeg)

![](_page_10_Figure_1.jpeg)

## **DATA ABSTRACTION**

## **TASK ABSTRACTION**

VISUAL ENCODING

# Analysis

![](_page_10_Picture_7.jpeg)

![](_page_11_Figure_1.jpeg)

DATA ABSTRACTION

## **TASK ABSTRACTION**

VISUAL ENCODING

# Analysis

![](_page_11_Picture_7.jpeg)

## Learn what are data types and dataset types

- Learn what are attribute types
- Learn how to pick appropriate visual representations based on attribute type and perceptual properties

# GOALS FOR TODAY

![](_page_12_Picture_6.jpeg)

# Data Types

# **DATASET** = collection of information that is the target of analysis

![](_page_13_Figure_2.jpeg)

→ Geometry (Spatial)

![](_page_13_Picture_4.jpeg)

![](_page_13_Picture_5.jpeg)

![](_page_13_Picture_6.jpeg)

# Data Types

# **DATASET = collection of information that is the target of analysis**

![](_page_14_Figure_2.jpeg)

Fields

Grids

Positions

Attributes

Geometry

Items

Positions

Clusters, Sets, Lists

Items

![](_page_14_Picture_12.jpeg)

![](_page_14_Picture_13.jpeg)

# Attribute Types

# → Categorical

e.g., fruit (apple, pear, grape), colleges (CAMD, CCIS, COE)

## → Ordered

### → Ordinal

### → Quantitative (continuous)

![](_page_15_Picture_6.jpeg)

e.g., sizes (xs, s, m, l, xl), months (J, F, M)

e.g., lengths (1', 2.5', 5'), population

![](_page_15_Picture_9.jpeg)

![](_page_15_Picture_10.jpeg)

### Categorical

#### **Estimated Heat Accumulation**

![](_page_16_Figure_2.jpeg)

### Quantitative

100 zettajoules

![](_page_16_Picture_5.jpeg)

1980

![](_page_16_Figure_8.jpeg)

change.html

![](_page_16_Picture_10.jpeg)

![](_page_16_Picture_11.jpeg)

![](_page_17_Picture_0.jpeg)

![](_page_17_Picture_1.jpeg)

![](_page_17_Picture_2.jpeg)

![](_page_17_Picture_3.jpeg)

![](_page_18_Picture_0.jpeg)

Categorical

MiseryMap <sup>™</sup>Back to main site

### 236 DELAYS

between 3 PM and 7 PM (all cancellations today) (all delays today)

![](_page_18_Figure_4.jpeg)

## CANCELLATIONS

### Quantitative

![](_page_18_Picture_8.jpeg)

**Channels:** Expressiveness Types and Effectiveness Ranks Magnitude Channels: Ordered Attributes Position on common scale Position on unaligned scale Length (1D size) Tilt/angle Area (2D size) Depth (3D position)  $\rightarrow \bullet$ **} (** Color luminance Color saturation Curvature Volume (3D size)

![](_page_19_Figure_2.jpeg)

Same

Same

![](_page_19_Picture_4.jpeg)

#### Quantitative

Position Length Angle Slope Area Volume Density Color Saturation Color Hue Texture Connection Containment Shape

Figure 15: Ranking of Perceptual Tasks. The tasks shown in the gray boxes are not relevant to that type of data.

<u>Mackinlay (1986)</u>

![](_page_20_Picture_5.jpeg)

![](_page_20_Picture_6.jpeg)

![](_page_20_Picture_7.jpeg)

![](_page_21_Figure_1.jpeg)

Figure 15: Ranking of Perceptual Tasks. The tasks shown in the gray boxes are not relevant to that type of data.

#### (Categorical) Nominal

Mackinlay (1986)

![](_page_21_Picture_7.jpeg)

![](_page_21_Picture_8.jpeg)

![](_page_21_Picture_9.jpeg)

![](_page_22_Figure_1.jpeg)

Figure 16: Analysis of the Area Task.

- AREA
- Tuesday Wednesday Ο Hawk Jay O

![](_page_22_Picture_5.jpeg)

![](_page_22_Picture_6.jpeg)

![](_page_22_Picture_7.jpeg)

![](_page_23_Figure_1.jpeg)

type of data.

Nominal

Position Color Hue Texture Connection Containment Density Color Saturation Shape Length Angle Slope Area Volume

Figure 15: Ranking of Perceptual Tasks. The tasks shown in the gray boxes are not relevant to that

Mackinlay (1986)

![](_page_23_Picture_8.jpeg)

![](_page_23_Picture_9.jpeg)

![](_page_23_Picture_10.jpeg)

## DATA ABSTRACTION

![](_page_24_Figure_1.jpeg)

![](_page_24_Figure_4.jpeg)

![](_page_24_Figure_6.jpeg)

→ Geometry (Spatial)

![](_page_24_Figure_8.jpeg)

Dataset Availability

→ Static

![](_page_24_Figure_11.jpeg)

![](_page_24_Figure_12.jpeg)

![](_page_24_Picture_13.jpeg)

![](_page_24_Picture_14.jpeg)

![](_page_25_Picture_1.jpeg)

VISUAL ENCODING

# Analysis

## **DATA ABSTRACTION**

![](_page_25_Picture_8.jpeg)

# GOALS FOR TODAY

- Learn what "Tasks" are and why they are so important.
- Learn the differences between high, mid, and low level task classifications.
- Begin practicing how to classify tasks (key step in visualization design process!).

![](_page_26_Picture_4.jpeg)

## Why abstract?

Avoids domain specific terms thus easier to apply to other cases (broadly applicable results).

![](_page_27_Figure_3.jpeg)

		Why?
Station	S	Targets
		All Data
Present	→ Enjoy	→ Trends → Outliers → Features $\downarrow$ $\downarrow$ $\vdots$ $\downarrow$
		Attributes
et known	→ Derive → √√ Target unknown	<ul> <li>→ One → Many</li> <li>→ Distribution → Dependency → Correlation → Simi</li> <li>→ Extremes</li> </ul>
• Lookup	• . Browse	Network Data
•> Locate	< `.⊙. Explore	→ Topology
Compare	→ Summarize	<ul> <li>→ Paths</li> <li>→ Spatial Data</li> <li>→ Shape</li> <li>↓ ↓ ↓ ↓</li> <li>How?</li> </ul>

![](_page_27_Picture_5.jpeg)

![](_page_27_Picture_6.jpeg)

![](_page_27_Picture_7.jpeg)

## Why abstract?

Avoids domain specific terms thus easier to apply to other cases (broadly applicable results).

![](_page_28_Picture_3.jpeg)

542 x 279 10.1/17.8 Mb; 10/9 ms

1.1:853

## **Visualization Tools**

![](_page_28_Picture_5.jpeg)

![](_page_28_Picture_6.jpeg)

## Why abstract?

Avoids domain specific terms thus easier to apply to other cases (broadly applicable results).

![](_page_29_Figure_3.jpeg)

		Why?
Station	S	Targets
		All Data
Present	→ Enjoy	→ Trends → Outliers → Features $\downarrow$ $\downarrow$ $\vdots$ $\downarrow$
		Attributes
et known	→ Derive → √√ Target unknown	<ul> <li>→ One → Many</li> <li>→ Distribution → Dependency → Correlation → Simi</li> <li>→ Extremes</li> </ul>
• Lookup	• . Browse	Network Data
•> Locate	< `.⊙. Explore	→ Topology
Compare	→ Summarize	<ul> <li>→ Paths</li> <li>→ Spatial Data</li> <li>→ Shape</li> <li>↓ ↓ ↓ ↓</li> <li>How?</li> </ul>

![](_page_29_Picture_5.jpeg)

![](_page_29_Picture_6.jpeg)

![](_page_29_Picture_7.jpeg)

![](_page_30_Picture_0.jpeg)

Analyze  $( \rightarrow)$ 

### ACTIONS define user goals.

![](_page_30_Figure_3.jpeg)

### High-level

#### → Consume

![](_page_30_Figure_7.jpeg)

![](_page_30_Picture_8.jpeg)

![](_page_30_Figure_9.jpeg)

![](_page_30_Figure_10.jpeg)

#### → Produce

#### → Annotate

![](_page_30_Figure_13.jpeg)

→ Record

![](_page_30_Figure_15.jpeg)

→ Derive

![](_page_30_Picture_17.jpeg)

![](_page_30_Picture_18.jpeg)

![](_page_31_Picture_0.jpeg)

### ACTIONS define user goals.

![](_page_31_Figure_2.jpeg)

### **Original Data**

![](_page_31_Picture_4.jpeg)

![](_page_31_Figure_5.jpeg)

![](_page_31_Figure_6.jpeg)

#### trade balance = exports – imports

### **Derived** Data

![](_page_31_Picture_9.jpeg)

![](_page_31_Picture_10.jpeg)

![](_page_32_Picture_0.jpeg)

## ACTIONS define user goals. Mid-level

![](_page_32_Picture_2.jpeg)

	Target known	Target unknown
Location known	• • Lookup	• • • Browse
Location unknown	Locate	<b>Explore</b>

![](_page_32_Picture_4.jpeg)

![](_page_33_Picture_0.jpeg)

![](_page_33_Picture_1.jpeg)

![](_page_33_Picture_2.jpeg)

### → Search

		Target known	Target unkn
	Location known	• • Lookup	• • • Brow
Nort	Location unknown	Locate	K Exp
2			
Ruggles 💂			
+////			

![](_page_33_Figure_5.jpeg)

![](_page_33_Picture_6.jpeg)

![](_page_34_Picture_0.jpeg)

![](_page_34_Picture_1.jpeg)

![](_page_34_Picture_2.jpeg)

		Target known	Target unkr
	Location known	••• Lookup	• • • Bro
Nort	Location unknown	Locate	<b>COCO</b> Exp

### Ruggles 💂

## What is the address of Ryder hall?

![](_page_34_Figure_7.jpeg)

![](_page_34_Picture_8.jpeg)

![](_page_34_Picture_9.jpeg)

![](_page_35_Picture_0.jpeg)

![](_page_35_Picture_1.jpeg)

![](_page_35_Picture_2.jpeg)

Nort	Location unknown	Locate	<b>COLO</b> Exp
	Location known	• • Lookup	Bro
		Target known	Target unkr

## Where is Ryder Hall?

![](_page_35_Figure_6.jpeg)

![](_page_35_Picture_7.jpeg)

![](_page_36_Picture_0.jpeg)

![](_page_36_Picture_1.jpeg)

![](_page_36_Picture_2.jpeg)

		Target known	Target unkr
	Location known	• • • Lookup	• • • Bro
Nort	Location unknown	Locate	K OC -> Exp

## What buildings are near Ryder Hall?

![](_page_36_Figure_6.jpeg)

![](_page_36_Picture_7.jpeg)

![](_page_36_Picture_8.jpeg)

![](_page_37_Picture_0.jpeg)

![](_page_37_Picture_1.jpeg)

![](_page_37_Picture_2.jpeg)

		Target known	Target unkr
	Location known	• • Lookup	• • • Bro
Nort	Location unknown	<b>Cocol</b> Locate	K OX -> Exp

### Ruggles 💂

## What is south of Huntington Ave?

![](_page_37_Figure_7.jpeg)

![](_page_37_Picture_8.jpeg)

![](_page_37_Picture_9.jpeg)

![](_page_38_Picture_0.jpeg)

## ACTIONS define user goals. Low-level

![](_page_38_Picture_2.jpeg)

![](_page_38_Picture_3.jpeg)

multiple targets

![](_page_38_Figure_5.jpeg)

![](_page_38_Picture_6.jpeg)

![](_page_38_Picture_7.jpeg)

![](_page_39_Picture_0.jpeg)

![](_page_39_Picture_1.jpeg)

## **TARGETS** are aspects of the data interest that are interest to the user.

![](_page_39_Picture_3.jpeg)

➔ Topology

![](_page_39_Picture_5.jpeg)

 $\rightarrow$  Paths

![](_page_39_Picture_7.jpeg)

Spatial Data

→ Shape

![](_page_39_Picture_10.jpeg)

 $\bigstar + \bigcirc$ 

![](_page_39_Picture_17.jpeg)

![](_page_40_Picture_0.jpeg)

## ACTIONS define user goals.

![](_page_40_Figure_2.jpeg)

## Lots of other task taxonomies...!

![](_page_40_Picture_4.jpeg)

### High-level

![](_page_40_Figure_6.jpeg)

### Mid-level

Target known	Target unknown			
• • • Lookup	• Browse			
COLOCATE	<b>C O Explore</b>			

![](_page_40_Figure_9.jpeg)

![](_page_40_Picture_10.jpeg)

# Analytic Task Taxonomy Low-level

- Retrieve Value How long is the movie Gone with the Wind?
  - Filter What comedies have won awards?
- Compute Derived Value How many awards have MGM studio won in total?
  - Find Extremum What director/film has won the most awards?
    - **Sort** Rank movies by most number of awards.
  - **Determine Range** *What is the range of film lengths?*
- Characterize Distribution What is the age distribution of actors?
  - Find Anomalies
    - Cluster
    - Correlate
- Are there exceptions to the relationship between number of awards won and total movies made by an actor?
- Is there a cluster of typical film lengths?
- Is there a trend of increasing film length over the years? Amar et al., 2005

![](_page_41_Picture_15.jpeg)

![](_page_41_Picture_16.jpeg)

# AN EXAMPLE OF TASK ANALYSIS -> VISUALIZATION DESIGN

![](_page_42_Picture_1.jpeg)

![](_page_42_Picture_2.jpeg)

![](_page_42_Picture_3.jpeg)

### Hierarchical Task Analysis

### During a type 1 diabetes clinical visit with a Certified Diabetes Educator...

![](_page_43_Picture_2.jpeg)

+

![](_page_43_Picture_3.jpeg)

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![](_page_43_Picture_6.jpeg)

![](_page_43_Picture_7.jpeg)

![](_page_43_Picture_9.jpeg)

Zhang et al., 2018 44

![](_page_43_Picture_11.jpeg)

0.

![](_page_44_Figure_1.jpeg)

Develop a treatment plan and educate patients

#### <u>Zhang et al., 2018</u> 45

![](_page_44_Picture_5.jpeg)

![](_page_44_Picture_6.jpeg)

0.

![](_page_45_Figure_1.jpeg)

Task Specificity Increasing Develop a treatment plan and educate patients

![](_page_45_Picture_4.jpeg)

![](_page_45_Picture_5.jpeg)

## Design Requirements

- DR1. Composite Visualization of Integrated Data
- DR2. Visualization of Folded Temporal Data
- DR3. Align and Scale Temporal Data
- DR4. **Summary** Statistics

![](_page_46_Picture_7.jpeg)

![](_page_46_Picture_9.jpeg)

![](_page_46_Picture_10.jpeg)

![](_page_46_Picture_11.jpeg)

### Hierarchical Task Analysis

#### 14-Day Overview

![](_page_47_Figure_2.jpeg)

#### Detail View

### Task Abstraction

![](_page_47_Figure_5.jpeg)

### Design

### Summary **Statistics** Panel

Zhang et al., 2018 48

![](_page_47_Picture_9.jpeg)

![](_page_47_Picture_10.jpeg)

![](_page_47_Picture_11.jpeg)

# IN-CLASS EXERCISE: MOCK INTERVIEW, TASK ANALYSIS

![](_page_48_Picture_1.jpeg)

# Interview Advice

![](_page_49_Picture_1.jpeg)

- Have a designated note-taker and designated leader
- Be prepared. (Have some questions prepared in advance.)
- Start slow, safe, and personal.
- Coax, don't hammer.
- Make some questions open ended.
- Ask what you don't know.
- Let the interviewees wander a bit-but be careful.
- Listen, really listen.
- For software, look for "work arounds" and hacks.
- Make sure to write down your thoughts and impressions immediately after the interview.
- You are the visualization expert don't ask them what vis they want, don't think too early about what vis to build.

www.forbes.com/sites/shelisrael/2012/04/14/8-tips-on-conducting-great-interviews/+&cd=3&hl=en&ct=clnk&gl=us 50

![](_page_49_Picture_15.jpeg)

![](_page_49_Picture_16.jpeg)

![](_page_50_Picture_0.jpeg)

# Task Analysis

## **Visualization for Public Transit** Development

15m

### **INSTRUCTIONS:**

- Break-out into groups of ~3 people.
- Pretend you are transportation engineers, e.g., for the MBTA, City of Boston.
- Discuss the "domain tasks" and classify the tasks.
  - Save your notes for a later exercise!!!

Retrieve Value	How long is the movie Gone with the Wind?
Filter	What comedies have won awards?
Compute Derived Value	How many awards have MGM studio won in total?
Find Extremum	What director/film has won the most awards?
Sort	Rank movies by most number of awards.
Determine Range	What is the range of film lengths?
Characterize Distribution	What is the age distribution of actors?
Find Anomalies	Are there exceptions to the relationship between number of awards won ar movies made by an actor?
Cluster	Is there a cluster of typical film lengths?
Correlate	Is there a trend of increasing film length over the years?

and total

![](_page_50_Figure_10.jpeg)

**Actions** 

![](_page_51_Picture_1.jpeg)

# Analysis

## **DATA ABSTRACTION**

VISUAL ENCODING

![](_page_51_Picture_7.jpeg)

# GOALS FOR TODAY

• Learn about visual encodings, esp. arranging tables

Learn how to pick appropriate visual representations based on attribute type and perceptual properties

![](_page_52_Picture_6.jpeg)

## VISUAL ENCODING

![](_page_53_Figure_1.jpeg)

#### Now...

![](_page_53_Picture_3.jpeg)

![](_page_53_Picture_4.jpeg)

#### Marks: Marks as Items/Nodes Points → Lines $/ / \sim$ ••••

![](_page_54_Picture_2.jpeg)

→ Areas

**Marks as Links** 

→ Containment

→ Connection

# Visualization Building Blocks

### Channels:

![](_page_54_Figure_10.jpeg)

![](_page_54_Picture_11.jpeg)

**Channels:** Expressiveness Types and Effectiveness Ranks

![](_page_55_Figure_1.jpeg)

type of data.

Figure 15: Ranking of Perceptual Tasks. The tasks shown in the gray boxes are not relevant to that

Mackinlay (1986) Munzner's VAD 56

![](_page_55_Picture_6.jpeg)

![](_page_55_Picture_7.jpeg)

# IN-CLASS EXERCISE: ENCODINGS WORKSHEET

![](_page_56_Picture_1.jpeg)

# Encoding Match-up

![](_page_57_Figure_1.jpeg)

![](_page_57_Picture_2.jpeg)

# Encoding Match-up

![](_page_58_Figure_1.jpeg)

![](_page_58_Picture_2.jpeg)

![](_page_59_Figure_0.jpeg)

![](_page_59_Picture_1.jpeg)

# Arrange Tables

#### Separate, Order, Align Regions $(\rightarrow)$

→ Order → Separate

Key: an independent attribute that can be used as a unique index (Tableau Dimension) Value: a dependent attribute (i.e., cell in a table) (Tableau Measures)

## → Align

![](_page_60_Figure_5.jpeg)

→ Many Keys **Recursive Subdivision** 

![](_page_60_Figure_8.jpeg)

![](_page_60_Picture_9.jpeg)

![](_page_60_Picture_10.jpeg)

Categorical or Ordinal

Categorical Ordinal, or Quantitative

![](_page_60_Picture_13.jpeg)

![](_page_60_Picture_14.jpeg)

# Example Keys

Date	Precipitation	High Temperature
May 1, 2016	0"	60
May 2, 2016	0.3″	62
May 3, 2016	1″	55
May 4, 2016	0"	67
	e	

Кеу

Student	College	HW1 grade (out of 10)
John	COS	9
Jane	Khoury	10
June	Khoury	8
Joe	Khoury	8

![](_page_61_Figure_4.jpeg)

![](_page_62_Picture_0.jpeg)

# Arrange Tables - no key

SCATTER PLOT

![](_page_62_Picture_5.jpeg)

![](_page_63_Figure_0.jpeg)

### BAR CHART

# Arrange Tables - one key

![](_page_63_Picture_3.jpeg)

LINE GRAPH

![](_page_63_Picture_5.jpeg)

# Arrange Tables - two keys

![](_page_64_Picture_1.jpeg)

![](_page_64_Picture_3.jpeg)

Stacked Bar Chart

![](_page_64_Figure_5.jpeg)

ΗΕΑΤΜΑΡ

![](_page_64_Picture_7.jpeg)

### Arrange Tables - Two Keys (Network) $\rightarrow$ 2 Keys Les Misérables Co-occurrence Matrix

![](_page_65_Figure_2.jpeg)

Source: The Stanford GraphBase.

 Order: by Cluster

This matrix diagram visualizes character co-occurrences in Victor Hugo's Les Misérables.

Each colored cell represents two characters that appeared i the same chapter; darker cells indicate characters that cooccurred more frequently

Use the drop-down menu to reorder the matrix and explore the data.

Built with d3.js.

## https://bost.ocks.org/mike/miserables/

![](_page_65_Picture_14.jpeg)

67

## $\rightarrow$ 2 Keys Matrix

![](_page_66_Figure_2.jpeg)

#### HiGlass 🔀

HiGlass is a tool for exploring genomic contact matrices and tracks. Please take a look at the examples and documentation for a description of the ways that it can be configured to explore and compare contact matrices. To load private data, HiGlass can be run locally within a Docker container. The HiC data in the examples below is from Rao et al. (2014) [2].

A preprint of the paper describing HiGlass is available on bioRxiv [1].

#### **Single View**

![](_page_66_Figure_7.jpeg)

![](_page_66_Picture_8.jpeg)

# Arrange Tables - Two Keys (Network)

About Examples Docs 👩

http://higlass.io/

![](_page_66_Picture_13.jpeg)

![](_page_66_Picture_14.jpeg)