Data Visualization (CSCI 490/680)

Sets

Dr. Maoyuan Sun (slides prepared by Dr. Koop)

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Announcements

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Project Design

- Start working on turning your visualization ideas into designs
- Sketch
- Options:
 - Try vastly different options
 - Refine an initial idea

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<u>Assignment 4</u>

- Create Choropleth Maps
 - Deal with projections and GeoJSON Data
 - Select appropriate colormaps
- [CS 680 Only] Part 3 is using other libraries, you only need to do one option
- Example image at the right is **not** a solution to Part 3, needs proper colormapping!





Set and Cluster Visualization

- Set and cluster visualization not covered in depth in the textbook
- Nice summary of set visualization in the following paper:
 - Visualizing Sets and Set-typed Data, B. Alsallakh et al., 2014
 - Also: <u>http://www.setviz.net</u>

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Sets

- A set is a collection of **unique** objects
 - Generally unordered
 - Example: S = {"apple", "pear", "orange"})
- What questions can we ask about sets?
 - Containment: Is some item x in s?
 - Intersection: what items are in both s and T?
 - Union: what items are in either s or T?
 - Difference: what items are in s but not T?

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Set-typed Data - Characteristics

- Set Algebra
 - Set operations, Cartesian product, power set, ...
- Set similarities
 - Similarity measures (Jaccard, Tversky, etc.)
- Element degree
 - exclusive set membership
- Dimensionality
 - 2ⁿ possible combinations
 - $2^{(2^n)}$ possible queries

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Set-typed Data - Representations

Boolean Attributes

			University of	/fh/// st.potten	
0	1	0	0	0	0
	0	1	1	0	0
	1	0	0	1	0
R	0	0	0	0	1
	1	0	0	0	0
2	0	0	1	0	0

Multi-valued Attribute







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Element-Set Tuples













Set-typed Data - Representations

Boolean Attributes

Adjacency Matrix







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Multi-valued Attribute

Adjacency List

Element-Set Tuples



Edge List











What are tasks with set data?

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[All of the following Slides from B. Alsallakh et al., 2014]



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Find elements based on their set memberships



Find elements with a specific set membership degree





Filter out elements based on their set membership degrees

Create a new set that contains certain elements

Find elements belonging to a specific set

Find sets containing a specific element

Filter out elements based on their set memberships



Find elements belonging to a specific set

Find elements based on their set memberships

Find elements with a specific set membership degree

Filter out elements based on their set memberships

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Create **a new set** that contains certain elements











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Find elements belonging to a specific set













Find elements belonging to















Find elements belonging to































Find sets containing a specific element













Find sets containing a specific element













Find s<mark>ets c</mark>ontaining



affiliations





a specific element







Find s<mark>ets c</mark>ontaining





affiliations





a specific element







Find s<mark>ets c</mark>ontaining





affiliations





a specific element


















Find elements based on their



set memberships









Find elements based on their







set memberships









Find elements based on their







set memberships





















Find elements with a specific set membership degree











Find elements with a specific set membership degree

2 affiliations









Find <mark>elements w</mark>ith





a specific set membership degree

2 affiliations





Find elements belonging to a specific set

Find elements based on their set memberships

Find elements with a specific set membership degree





-ind sets contain



Find elements based on their set memberships



Find elements with a specific set membership degree

Filter ou

Filter out elements based on their set memberships

Filter out elements based on their set membership degrees

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Find elements belonging to a specific set

Find sets containing a specific element





Element Attributes







Element Attributes









#

Find the **#** of sets in the set family



Analyze **Mo**







Analyze **exclusion relations**



Analyze https://www.intersection.relations



Find intersections between k sets

Find sets involved in certain intersection







Find the set with largest pairwise set intersections



Analyze set & set intersection cardinalities



Analyze and compare set similarities



Analyze and compare set exclusiveness



Highlight specific sets, subsets, or set relations









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set-theoretical operations



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Analyze set & set intersection cardinalities



InfoVis Visual Analytics Time-oriented Data Diagrams





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Analyze set & set intersection cardinalities









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InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams 51 15 15 25 60





InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams ^∕~⊙







InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams





InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams 51 15 15 25 60





InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams 5 1 1 5 15 25 60





InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams 51 15 15 25 60



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Analyze and compare set similarities



Analyze and compare set exclusiveness



Highlight specific sets, subsets, or set relations



Create **a new set** using set-theoretical operations





Element Attributes











Element Attributes



Find the attribute value of a certain element

Find the distribution of an attribute in a certain set or subset

Compare the attribute values of sets or set intersections

Analyze the set memberships for elements having certain attribute values

Create a new set out of elements having certain attribute values

Element Attributes



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Element Attributes

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Element Attributes





attribute value = female

InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams

Element Attributes



- set memberships = research areas



attribute value = female

InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams

Element Attributes



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InfoVis Visual Analytics (VA) Time-oriented Data (TD) Diagrams

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Element Attributes







Element Attributes



Techniques

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Venn Diagram



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Venn Diagram?

Trust Partnership Innovation Performance











Scalability

- How to show the intersection of four sets? 8?
- Euler Diagrams: only show intersections/containments that exist
- Still run into scalability issues



Ir sets? 8? tions/containments that exist









What about cardinality?

Area encoding



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Using glyphs



[B. Alsallakh et al., 2014]



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Venn Diagram Visualizations

show only required set relations



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show unwanted set relations



[B. Alsallakh et al., 2014]



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What if we don't worry so much about nice circles/ ellipses?





Compact Euler Diagrams: Use edges



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Compact Euler Diagrams: Use nesting













Euler Diagram Variants

use edges



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use a concentric layout









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Bubble Sets: Overlay set membership









Bubble Sets & Overlay Techniques

- Given spatial layout is determined by other attributes, want to show set containment without modifying spatial layout
- Idea of "spatial rights"
- Construct regions based on a potential field
- Draw using containment marks
- How do we compute these?





Bubble Sets & Overlay Techniques

- Given spatial layout is determined by other attributes, want to show set containment without modifying spatial layout
- Idea of "spatial rights"
- Construct regions based on a potential field
- Draw using containment marks
- How do we compute these?
 - Marching Squares!





KelpFusion



(a) Bubble Sets



(b) Kelp Diagrams

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(c) LineSets



(e) KelpFusion (medium)



[Meulemans et al., 2013]



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Overlays

Region-based



[Collins et al., 2009]



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Line-based

[Dinkla et al., 2012]

Glyph-based



[Itoh et al., 2009]









More...

Node-Link Visualizations



Matrix-based techniques



Aggregation-based techniques



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[via B. Alsallakh et al., 2014]

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More... Parallel Sets



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[Kosara et al., 2006, Example: J. Davies]









Clusters

- What is a cluster?
 - A grouping of objects (sets of objects)
 - Why is this not more precise?
- How do we determine if two items should be in the same cluster?









Clusters

- What is a cluster?
 - A grouping of objects (sets of objects)
 - Why is this not more precise?
- How do we determine if two items should be in the same cluster?
 - Distance
 - Relationships: Connectivity and Containment (Hierarchies)
 - Distributions









Clusters

- What is a cluster?
 - A grouping of objects (sets of objects)
 - Why is this not more precise?
- How do we determine if two items should be in the same cluster?
 - Distance
 - Relationships: Connectivity and Containment (Hierarchies)
 - Distributions
- Can an item be in more than one cluster?
 - Hard clustering: no
 - Soft (fuzzy) clustering: yes, for example, with likelihood of being in a cluster









Visualizing Clusters

- If a clustering algorithm assigns each data item to a cluster, we can treat this like set visualization
- If a spatial distance is used, this often means there is a no overlap (e.g. in 2D)
- What visual encodings could work?











Hierarchical Clustering



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Hierarchical Clustering

- Each item may belong to multiple groups, but groups are nested
- Data items are organized in a tree
- Creating hierarchical clusters:
 - Agglomerative: start with individuals and group
 - Divisive: start with one group and divide
- Any tree visualization method will work, but...
- ... generally containment marks used for clusters









Network Clusters











Network Clusters

- Create groups based on connectivity
- Layout may be important (or could be used to create clusters)
- How to create network clusters:
 - Idea: Low connectivity between groups induces cuts
 - potential intersection)
 - Can also use attribute information

- Example: group of friends from home and group of friends at college (and









Biclustering



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• Bicluster: network concept

• Given two groups, each node in one group is connected to every node in the other group (goes both directions)















Biset edge bundling (and grouping)



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[M. Sun et al., 2016]











Biset Edge Bundling

Mark Davis		City Computer Services Corp.
Shiela Watson		Empire State Vending Services
Steven Clark	- HA	New York Stock Exchange
Vincent Cortez		Border Patrol
Amalicio Guatemez	ACC HHI	University of Texas
Reg Harriss		contenting or result
Den Hassine		PBI
Anmed Yassin		American Airlines
Yasein Mosed		AMTRAK
Mukhtar Galab		Sprint
Faysal Goba		Penn Station NYC
Hani al Hallak		INS .
Bagwant Dhaliwal		Office Supplies Co.
Abdul Ramazi		Clark & Co
Sahim Albakri		First Union Bank
Muhammed bin Harazi		Talban
Clark Webster		CIA
Ziad al Shibh		Budnet Storane Linits
Omar Bakri Ostaria		Ai Osada
Contacto		A Gallon
Canada		MIS
Richard Reid		British Special Branch
Tawfiq al Adel	NAME AND	Sealink Container Corp.
Saled Khalad		US Post Office
Jeite Nijboer		Bush Intercontinental Airport
al Ahdal		Continental Airlines
bin Attash		Reagan National Airport
Hans Pakes		The Powhatan Company
Jamai Kalifa		Pentagon
Masood Yaser		Home Depot
Abu al Masri		Apex Paper Products Company
Ralph Goode		Arvan Nations
Abul Hassan Salman		Army CID
Clark Adams		Ruter Tourk Rental
Walana Wilson		Popular Franka
Marade Misser		Detri taraer
Karm bensaid		Coast Guard
Carl Louis		Passport Agency
Abdelhak Kherbane		U-haul
Hamid Alwan		Virginia National Bank
Alwan		United Connector
Abdulla Ramzi		United
Omar Clark		University of Virginia
Joseph Nizar		Select Gourmet Foods
Riduan bin Attash		First Union National Bank
Saleh al Ahdal		Pyramid Bank of Cairo
Saeed Khalad		Central Bank of Dubai
Jamil Musawi	/	Marvel Corporation
Muhammad Shamzi		German Intelligence
Vincent Lozario		American Diniomatic Mission Mis
Khallan Maulet		Prime real segmentable respect 198
Abobil of Marte		
Acour ai mada		

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Bicluster Reordering Problem



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(b)





Bicluster relationships as a graph











