Data Visualization (CSCI 627/490)

Multiple Views

Dr. David Koop





Interaction Overview



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[Munzner (ill. Maguire), 2014]





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Sorting & Slope Graphs: LineUp

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4.	Princeton University	United States	100 (1)		90.7 (0.91) 73.08 (0.73) 85.5 (0.86)	0.94
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6.	University of California, Berkeley (UCB)	United States						
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10.	University of Pennsylvania	United States						
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12.	University of Michigan	United States						
13.	Johns Hopkins University	United States						
14.	New York University (NYU)	United States						
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17.	University of California, Los Angeles (UCLA)	United States						
18.	Northwestern University	United States						
19.	University of Illinois at Urbana-Champaign	United States						
20.	Brown University	United States						
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22.	University of Texas at Austin	United States						
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24.	Georgia Institute of Technology	United States						
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26.	Ohio State University	United States						
27.	University of Pittsburgh	United States						

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[Gratzl et al., 2013]









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Animated Transitions









Animated Transitions











• User Preferences: Staged animation > animation > static transitions



- Animation improves graphical perception
- Staging is better (do axis rescaling before value changes)
- Avoid axis rescaling when possible











Selection

- Selection is often used to initiate other changes
- User needs to select something to drive the next change
- What can be a selection target?
 - Items, links, attributes, (views)
- How?
 - mouse click, mouse hover, touch
 - keyboard modifiers, right/left mouse click, force
- Selection modes:
 - Single, multiple
 - Contiguous?





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Highlighting

- Selection is the user action
- Feedback is important!
- How? Change selected item's visual encoding
 - Change color: want to achieve visual popout
 - Add outline mark: allows original color to be preserved

_ _ _ _ _

- Change size (line width)
- Add motion: marching ants

(II)	Contacts
	Dashboard
Aa	Dictionary
- 😵	Dropbox
8	DVD Player
3	Emacs
-0	FaceTime
Æ	FileZilla
8	Firefox







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Interaction Latency

- The Effects of Interactive Latency on Exploratory Visual Analysis, Z. Liu and J. Heer, 2014
- Brush & link, select, pan, zoom



- 500ms added latency causes significant cost - decreases user activity and dataset coverage - reduces rate of observations, generalizations, and hypotheses







Navigation

→ Item Reduction



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→ Attribute Reduction



→ Cut

→ Slice



→ Project



[Munzner (ill. Maguire), 2014]



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Geometric vs. Semantic Zooming

- Geometric zoom: like a camera



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• Semantic zoom: visual appearance of objects can change at different scales







Assignment 4

- Corn & Soybean Production in Illinois
- Geospatial Visualizations & Treemap
 - Choose colormaps carefully
 - Add legend
- You may use D3 or Observable Plot
 - Part 1a: D3
 - Part 3 will require some D3 for treemap layout
- Due Friday

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Project Design

- Feedback available on Blackboard
- Work on turning your visualization ideas into designs
- Turn in:
 - Three Designs Sketches
 - One Bad Design
 - Be creative: <u>https://xeno.graphics/</u>
- Due Nov. 15







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- Why have just one visualization?
- Sometimes data is best examined in more than one view
 - Clutter/visual overload
 - Different attributes (cannot show all attributes in one view)
 - Different scales (task requires overview or detail)
 - Different encodings (no single encoding is optimal for all tasks)
- Eyes Beat Memory (Ch. 6)
 - Aiding working memory:
 side-by-side/layers > animated > jump cuts
 - Showing all visual elements at once \rightarrow don't need to remember





- Big questions:
 - How to partition display or layer views?
 - How to coordinate views (e.g. navigation, selection)?
 - What data is shared?

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ews? rigation, selection)?





Design Space of Composite Visualization

- Composite visualization views (CVVs)
 - Includes Coordinated multiple views (CMV)
 - + More!
- Design Patterns:
 - Juxtaposition: side-by-side
 - Superimposition: layers
 - Overloading: vis meshed with another
 - Nesting: vis inside a vis (recursive vis)
 - Integration: "merge" views + links

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Composite Visualization Techniques



(a) Juxtaposed views.





(b) Integrated views.



(c) Superimposed views.







Juxtaposition



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Juxtaposition



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Juxtaposition Guidelines

- Benefits:
 - without interference
 - Easy to implement
- Drawbacks:
 - objects are selected
- combined.

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- The component visualizations are independent and can be composed

- Implicit visual linking is not always easy to see, particularly when multiple

- Space is divided between the views, yielding less space for each view

• Applications: Use for heterogeneous datasets consisting of many different types of data, or for where different independent visualizations need to be

[W. Javed and N. Elmqvist, 2012]







Integration









Integration



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[VisLink, Collins and Carpendale, 2007]









Integration









Integration Guidelines

- Benefits:
 - components
 - separate
- Drawbacks:
 - Extra visual clutter added to the overall view
 - Display space is split between the views
 - Some dependencies exist between views to allow for the visual linking
- Applications: Use for heterogeneous datasets where correlation and comparisons between views is particularly important.

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- Easy to perceive one-to-one and one-to-many relations between items in

- Visualizations are less independent compared to juxtaposed views, but still



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Superimposition



is composed of:

Ireland

Portugal

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Superimposition



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[GeoSpace, I. Lokuge and S. Ishizaki, 1995]









Superimposition Guidelines

- Benefits:
 - Allows direct comparison in the same visual space.
- Drawbacks:
 - May cause occlusion and high visual clutter.
 - The client visualization must share the same spatial mapping as the host visualization.
- Applications: In settings where comparison is common, or where the component visualization views need to be as large as possible (potentially the entire available space).

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[W. Javed and N. Elmqvist, 2012]





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Overloading













Overloading



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[Links on Treemaps, J.-D. Fekete et al., 2003]









Overloading Guidelines

- Benefits:
 - as the host visualization
 - This also yield more flexibility and control over visual clutter
- Drawbacks:
 - Visual clutter is increased
 - Visual design dependencies between components are significant
- yield a compact (and complex) result.

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- The client visualization does not have to share the same coordinate space

Applications: Situations where one visualization can be folded into another to

[W. Javed and N. Elmqvist, 2012]









Nesting

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Nesting



Nesting Guidelines

- Benefits:
 - Very compact representation
 - Easy correlation
- Drawbacks:
 - Limited space for the client visualizations
 - Clutter is high
 - Visual design dependencies are high
- Applications: Situations that call for augmenting a particular visual representation with additional mapping

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[W. Javed and N. Elmqvist, 2012]



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Design Space

- Visualizations: the techniques or idioms used
- Spatial relation: relationship between visual structures in display space
- Data relation: visual relationship between items in different views
 - None: No relation
 - Item-item: One-to-one
 - Item-group: One-to-many
 - Item-dimension: Item in one view is a scale in another













Summary

Technique	Visualization A	Visualization B	Spatial Relation	Data Relation
ComVis [24] (Figure 2)	any	any	juxtapose	none
Improvise [39] (Figure 3)	any	any	juxtapose	none
Jigsaw [36]	any	any	juxtapose	none
Snap-Together [30]	any	any	juxtapose	none
semantic substrates [34] (Figure 4)	node-link	node-link	juxtapose	item-item
VisLink [11] (Figure 5)	radial graph	node-link	juxtapose	item-item
Napoleon's March on Moscow [37]	time line view	area visualization	juxtapose	item-item
Mapgets [38] (Figure 6)	map	text	superimpose	item-item
GeoSpace [22] (Figure 7)	map	bar graph	superimpose	item-item
3D GIS [8]	map	glyphs	superimpose	item-item
Scatter Plots in Parallel Coordinates [45] (Figure 8)	parallel coordinate	scatterplot	overload	item-dimensior
Graph links on treemaps [14] (Figure 9)	treemap	node-link	overload	item-item
SparkClouds [21]	tag cloud	line graph	overload	item-item
ZAME [13] (Figure 10)	matrix	glyphs	nested	item-group
NodeTrix [17] (Figure 11)	node-link	matrix	nested	item-group
TimeMatrix [44]	matrix	glyphs	nested	item-group
GPUVis [25]	Scatterplot	glyphs	nested	item-group

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[W. Javed and N. Elmqvist, 2012]











Summary (Scatterplot + Bar Chart)



(a) Juxtaposed views.







(b) Integrated views.



(c) Superimposed views.









- Facet (noun and verb)
 - particular aspect or feature of something
 - to split
- Partition visualization into views/layers
 - Either juxtapose (side-by-side), superimpose (layer), nest, etc.
 - Depends on data and encoding
 - Generally, superimposing does not scale as well
 - Multiple views eats display space (either large screens or small visualizations)







→ Share Encoding: Same/Different

→ Linked Highlighting



→ Share Data: All/Subset/None



Share Navigation



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[Munzner (ill. Maguire), 2014]





Multiform



r 🛛 🗵	Counties			'ø' 🗵	Cities	4 0 X
	Name	Area Po	pul Ce	Ce	Name	County Pop
	Montmorency MI Muskegon MI	0.167	10315 23.90 70200 12.90	02.08	Allen Park Bellefonte	MI Wayne County 29376 A PA Centre County 6395
	Newaygo MI Oakland MI	0.248	47874 12.80	02.75	Belleville Birch Run	MI Wayne County 3997 MI Saginaw County 1653
	Oceana MI	0.157	26873 14.00	02.66	Centre Hall Chesaning	PA Centre County 1079 MI Saginaw County 2548
	Ogemaw MI Ontonagon MI	0.168	7818 21.60	02.49 01.57	Dearborn Dearborn	MI Wayne County 97775
	Osceola MI Osceola MI	0.167	23197 14.20 9418 20.20	02.53	Detroit	MI Wayne County 951270
	Otsego MI	0.155	23301 13.70	02.59	Ecorse Flat Rock	MI Wayne County 11229 MI Wayne County 8488
C. M.K. h.I.	Presque Isle MI	0.164 2	14411 22.30	04.53	Frankenmuth Garden City	MI Saginaw County 4838
The 2 Con mil	Roscommon MI Saginaw MI	0.170	25469 23.80 10039 13.50	02.64	Gibraltar	MI Wayne County 4264
4 Show	Saint Clair MI	0.207 1	64235 12.20	03.88	Grosse Pointe Grosse Pointe Farms	MI Wayne County 5670 MI Wayne County 9764
$+ \Box \downarrow \uparrow \downarrow$	Sanilac MI	0.146	44547 15.40	03.34	Grosse Pointe Park	MI Wayne County 12443
The for the the	Schoolcraft MI Shiawassee MI	0.370	8903 18.60 71687 12.00	01.66	Grosse Pointe Woods	MI Wayne County 17080
	Tuscola MI	0.234	58266 12.80	02.91	Hamtramok Harper Woods	MI Wayne County 22976 MI Wayne County 14254
and sugar	Washtenaw MI	0.204 3	22895 08.10	04.62	Highland Park Howard	MI Wayne County 16746 PA Centre County 699
and the man	Wayne MI Wexford MI	0.174 20	61162 12.10 30484 14.00	07.61	Inkster	MI Wayne County 30115
STREET H	OH	0.990	30484 00.00	00.00	Lincoln Park Livonia	MI Wayne County 40008 MI Wayne County 100545
	Adams OH Allen OH	0.158	08473 14.20	02.62	Melvindale	MI Wayne County 10735 MI Saninaw County 782
and the second second second	Ashland OH Ashtabula OH	0.118	52523 13.90 02728 14.70	03.34	Miesburg	PA Centre County 1187
	Athens OH	0.138	62223 09.30	03.33	Milheim	PA Centre County 749 MI Wavne County 6459
	Belmont OH	0.111	46611 14.40 70226 18.20	03.28		
	Brown OH Butler OH	0.133	42285 11.60 32807 10.70	03.05	Airports & Se	eaplane Bases 🗗 🗹 🖄
	Carroll OH	0.110	28836 14.20	02.92	Name	En., County
	Clark OH	0.110 1	44742 14.70	04.36	D Detroit Metropolita	n Wa 1698 MI Wayne Co 🔺
	Clermont OH Clinton OH	0.124 1	77977 09.40 40543 12.20	04.45	M MBS International DET Detroit City	294483 MI Saginaw
	Columbiana OH	0.148 1	12075 15.00	03.81	U University Park	126945 PA Centre Co 3046 MI Wayne Co.
	Crawford OH	0.136	46966 15.20	03.29	The Willow Part	Solo IVI Wayne Co
	Cuyahoga OH Darke OH	0.129 13	93978 15.60 53309 15.30	07.43		
	Dofiance OH	0.116	20500 42.00	02.42		
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Sequential Seq	uential Non-Gray	•			M M M M M M M M M M M M M M M M M M M	tuno Anno Anno Anno Anno Anno
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					way Way	Way Way Way Way
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			MI	Allen Pa	* 1.41 0.07 0.12 0.2	0 0.18 5.50 0.12 0.06 5.55 0.05
			Wayne Cour PA	Bellefont	8	
			Centre Cour	ty Pop. 639	5 6.66 5.53 5.60 5.8	0 5.77 0.10 5.54 5.65 0.15 5.57
			MI Wayne Cour	Bellevil Ity Pop. 399	e 1.34 0.34 0.25 0.1	5 0.13 5.76 0.31 0.22 5.80 0.29
Show See			MI	Birch Ru	n 0.26 1.22 1.24 1.0	1 1.05 6.37 1.27 1.14 6.42 1.20
			PA	Centre Ha		
Counties	Countie	es	Centre Cour	ty Pop. 107	9 6.77 5.63 5.70 5.9	0 5.88 0.20 5.64 5.75 0.18 5.67
Cities	Cities		Saginaw Co	unty Pop. 254	9 0.35 1.37 1.36 1.12	2 1.16 6.64 1.40 1.27 6.70 1.34
Roads	Roads		MI Waxaa Car	Dearbor	1.37 0.11 0.19 0.2	2 0.21 5.49 0.18 0.12 5.53 0.11
Dellace de		da	MI D	Dearborn Heigh	IS 1 31 0 17 0 20 0 1	3 0 13 5 58 0 22 0 10 5 62 0 15
Railroads	Railroa	as	Wayne Cour	ty Pop. 5826	4 1.31 0.17 0.20 0.1	3 0.13 5.56 0.22 0.10 5.63 0.15
Airports	Airport	S	Wayne Cour	ty Pop. 95127	0 1.44 0.16 0.27 0.3	5 0.34 5.36 0.23 0.24 5.41 0.19
.00 🔽 Urban Area	as 🗌 🗌 States		MI Wayne Cour	Ecore ty Pop. 1122	e 1.46 0.03 0.14 0.2	7 0.24 5.44 0.11 0.12 5.48 0.06









Multiform Views

- The same data visualized in different ways
- Does not need to be a totally different encoding (all choices need not be disjoint), e.g. horizontal positions could be the same
- One view becomes cluttered with too many attributes
- Consumes more screen space
- Allows greater separability between channels







Small Multiples

• Same encoding, but different data in each view (e.g. SPLOM)











Interaction with Multiform & Small Multiples

- Key interaction with multiform and small multiples: **brushing**
 - also called linked highlighting
- views

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• Want to understand correspondences between representation in the different







Brushing











Schneiderman's Mantra

- Visual Information-Seeking Mantra [B. Schneiderman, 1996]:
 - Overview first
 - Zoom and filter (Chapter 13)
 - Details on demand
- Goal of the overview is to **summarize** all of the data
- layer
 - May be permanent: side-by-side
 - May be a popup layer: often opaque or separated
- (see textbook Ch. 6.7)

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• Want specific **details** about some aspect(s) of the data, need another view/





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Overview-Detail View











Overview-Detail (Different Encoding)











Overview-Detail (with Zoom-Filter)

- Detail involves some subset of the full dataset Involves user selection or filtering of some type
- How question: includes facet
- Examples:
 - Maps: partition into two views with same encoding, overview-detail
 - overview+detail of expenditures

- UC Trends: partition into multiple views, coordinated with linked highlighting,







Multiform & Small Multiples (Cerebral)













Navigation across multiple views

- Often navigation in one view updates navigation in another • Example: Maps: overview shifts as you move around in detail view Selections in one view may trigger selections in another









Partition into Side-by-Side Views



Superimpose Layers



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Partitioned Views

- Split dataset into groups and visualize each group
- Extremes: one item per group, one group for all items
- Can be a hierarchy
 - Order: which splits are more "related"?
 - Which attributes are used to split? usually categorical









Glyphs, Views, and Regions

- Glyphs are composed of multiple marks
- Views are a contiguous region of space
- A region is usually associated with a group of data
- Blurry lines of distinction between them







Example: Grouped Bar Chart



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65 Years and Over 45 to 64 Years 25 to 44 Years 18 to 24 Years 14 to 17 Years 5 to 13 Years Under 5 Years





















Matrix Alignment & Recursive Subdivision

- Matrix Alignment:
 - regions are placed in a matrix alignment
 - splits go to rows and columns
 - main-effects ordering: use summary statistic to determine order of categorical attribute
- Recursive subdivision:
 - Designed for exploration
 - Involves hierarchy
 - User drives the ways data is broken down in recursive manner

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Example: Trellis Matrix Alignment



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Barley Yield (bushels/acre)











Recursive Subdivision





Example: HiVE System



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[Slingsby et al., 2009]

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