Information Visualization

Multiple Views

Dr. David Koop







D. Koop, CSCI 628, Fall 2021

Feature Visualization

Edges (layer conv2d0)

Textures (layer mixed3a)

D. Koop, CSCI 628, Fall 2021

Objects (layers mixed4d & mixed4e)

Northern Illinois University

Feature Vis by Optimization

- "[W]hat kind of input would cause a certain behavior"
- Start from random noise and iteratively tweak (using derivatives)

• What are the objectives? (Where are we going?) - Neuron, channel, layer (has DeepDream "interesting" objective

D. Koop, CSCI 628, Fall 2021

Step 48

Naive Optimization

Even if you carefully tune learning rate, you'll get noise.

Optimization results are enlarged to show detail and artifacts.

REPRODUCE IN A CO NOTEBOOK

Step 1

Step 32

D. Koop, CSCI 628, Fall 2021

Step 128

Step 256

Step 2048

The Building Blocks of Interpretability

The Building Blocks of Interpretability

Interpretability techniques are normally studied in isolation. We explore the powerful interfaces that arise when you combine them and the rich structure of this combinatorial space.

CHOOSE AN INPUT IMAGE

For instance, by combining feature visualization (what is a neuron looking for?) with attribution (how does it affect the output?), we can explore how the network decides between labels like Labrador retriever and tiger cat.

CHANNELS THAT MOST SUPPORT ...

LABRADOR RETRIEVER

feature visualization of channel hover for attribution maps →			
net evidence	1.63	1.51	
for "Labrador retriever"	1.22	1.24	
for "tiger cat"	-0.40	-0.27	

D. Koop, CSCI 628, Fall 2021

Several floppy ear detectors seem to be mportant when distinguishing dogs, whereas pointy ears are used to classify "tiger cat".

1.32 0.13

TIGER CAT

Feature Vis + Attribution

D. Koop, CSCI 628, Fall 2021

Spatial Attribution with Saliency Maps

INPUT IMAGE

OUTPUT CLASSES

_abrador Retriever	
Golden Retriever	
Tennis Ball	1
Rhodesian Ridgeback	
Appenzeller	

mixed3a

mixed4a

D. Koop, CSCI 628, Fall 2021

OUTPUT FACTORS

Labrador Retriever	Tiger	
Golden Retriever	Tiger Cat	
Beagle	Lynx	
Kuvasz	Collie	
Redbone	Border Collie	

mixed4d

853	Party in	-	123	53	1000	CEN	1993	2652	1623	822	123	1738	KOM
	Kana I		Sec.			K3	834		250		392	193	10
						8		128	85	2	×	M	
								5			251		
												8	
		** 1			8								
			N C	121	192	1		R		C	ŷ.	51	
					20		8	21					
							M	5				502	
17		2						3 2					
81	8			22	63	EZ			5		×	×.	
	83												2
			10		-		195		101		12	252	200

mixed5a

Channel Attribution

INPUT IMAGE

OUTPUT CLASSES

Labrador Retriever	
Golden Retriever	
Tennis Ball	I
Rhodesian Ridge	
Appenzeller	

TOP CHANNELS SUPPORTING LABRADOR RETRIEVER

Showing 3 of **512**

Showing 3 of 480

• • •

Showing 3 of 508

D. Koop, CSCI 628, Fall 2021

[C. Olah et al.]

Showing 3 of 512

Factoring into Neuron Groups

INPUT IMAGE

By using non-negative matrix factorization we can reduce the large number of neurons to a small set of groups that concisely summarize the story of the network.

NEURON GROUPS based on matrix factorization of mixed4d layer

EFFECT of neuron groups on output classes

Labrador retriever	2.249	3.755	-1.193	-1.141	1.117	-1.892
beagle	3.298	0.599	-0.110	-0.356	-0.133	-2.618
tiger cat	-0.350	-0.994	-1.607	0.116	0.248	0.205
lynx	0.111	-0.642	-0.057	0.117	1.120	0.152
tennis ball	0.920	1.336	0.152	-0.885	1.227	-0.480

D. Koop, CSCI 628, Fall 2021

ACTIVATIONS of neuron groups

6 groups

Adding InfoVis

INPUT IMAGE

To understand multiple layers together, we would like each layer's factorization to be "compatible"—to have the groups of earlier layers naturally compose into the groups of later layers. This is also something we can optimize the factorization for.

- positive influence
- negative influence

D. Koop, CSCI 628, Fall 2021

Schedule

- Critique for Thursday
- Progress Reports next Tuesday

- 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

D. Koop, CSCI 628, Fall 2021

Northern Illinois University

D. Koop, CSCI 628, Fall 2021

[Munzner (ill. Maguire), 2014]

Multiform

D. Koop, CSCI 628, Fall 2021

r 🔤 🗵	Counties			'ø' 🗵	Cities	· 특 집 🗵
	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 Oscoda 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
A A	Tuscola MI	0.234	58266 12.80	02.91	Hamtramok Harper Woods	MI Wayne County 22976 MI Wayne County 14254
and sugars	Washtenaw MI	0.204 3	22895 08.10	04.62	Highland Park Howard	MI Wayne County 16746
and the man	Wayne MI Wexford MI	0.174 20	61162 12.10 30484 14.00	07.61	Inkster	MI Wayne County 30115
STANDA 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 Saginaw 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 Wayne 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 222571 MI Wayne Co
	Columbiana OH	0.148 1	12075 15.00	03.81	U University Park	126945 PA Centre Co 3046 ML Wayne Co.
	Crawford OH	0.136	46966 15.20	03.29	The Willow Non	Solo mi mayie 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	<u> </u>	
🗗 🖉 🔣 📔 🗖 Color Schem	ne 🔅		City-	City Distar	ices	r₫ ×
Sequential Seq	uential Non-Gray	•			M M M M M M M M M M M M M M M M M M M	anno Anno Anno Anno Anno Anno Anno Anno
					aw o aw	me de
		E.			agin Way	Way Way Way Way Way
					0 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	36 68 84 m 57 22
					179 179 280 125 125 125	ne 190 190 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 195 0 190 19
					Pop. Vvya Pop. Vest	Pop. Pop. Pop. Pop. Pop.
			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	Reliefont	6	
			Centre Cour	ty Pop. 639	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 ty 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 Street			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
		da	MI D	Dearborn Heigh	s 1 31 0 17 0 20 0 4	3 0 13 5 59 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

• Want to understand correspondences between representation in the different

Brushing

Shneiderman's Mantra

- Visual Information-Seeking Mantra [B. Shneiderman, 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)

D. Koop, CSCI 628, Fall 2021

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

Overview-Detail View

Overview-Detail (Different Encoding)

EXPENDITURES BY FUNCTION (BAR & DONUT)

D. Koop, CSCI 628, Fall 2021

FIVE-YEAR TREND

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

D. Koop, CSCI 628, Fall 2021

Northern Illinois University

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

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

Example: Trellis Matrix Alignment

D. Koop, CSCI 628, Fall 2021

Barley Yield (bushels/acre)

Newham Example: HiVE System

Westminster

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

D. Koop, CSCI 628, Fall 2021

 $|\otimes_{jux} \mathbf{B}| = |\mathbf{A} \mathbf{B}|$ $\bigotimes_{sup} \mathbf{B} = \mathbf{A} \mathbf{B}$ $\bigotimes_{\text{ovl}} \mathbf{B} = \mathbf{A} \mathbf{B}$ A $\bigotimes_{nst} B$ $\bigotimes_{int} B$

Northern Illinois University

Composite Visualization Techniques

(a) Juxtaposed views.

(b) Integrated views.

(c) Superimposed views.

Juxtaposition

D. Koop, CSCI 628, Fall 2021

NIU

Northern Illinois University

Juxtaposition

D. Koop, CSCI 628, Fall 2021

Northern Illinois University

Juxtaposition Guidelines

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

D. Koop, CSCI 628, Fall 2021

- 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

D. Koop, CSCI 628, Fall 2021

[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.

D. Koop, CSCI 628, Fall 2021

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

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

Northern Illinois University

Superimposition

is composed of:

Ireland

Portugal

D. Koop, CSCI 628, Fall 2021

Northern Illinois University

Superimposition

D. Koop, CSCI 628, Fall 2021

[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).

[W. Javed and N. Elmqvist, 2012]

Overloading

Nesting

	Desps 512	Fusnu 1971	Glovi_375)	Haein 162	Haein 162	HelpJ_156	Helpy_156	Helpy_156	Lacia_156	Leixy 509;	Lisin_1680	Lisin_1680	Meslo_134	Meslo_134	Meslo 134	Meslo_134	Meslo_134	Meslo_134	Meslo_134	Meslo_134	Metac_200	Metth_156	Oceih_231	Oceih 230	Oniye_399:	Oniye_399:
	45218	03582	21137	72305	73641	11941	45555	46184	72305	54889	10534	1504	70759	73259	73305	74097	74622	75817	75942	74014	90100	78506	00619	98332	38976	38620
Meslo_13470759					L.	-	1	_				h,	14	L.	Ц		ι.		b.			4		Ы		
Meslo_13473259					Ц	L.	s.	l.	k e	4	-	1		-	1							L.		Ч		
Meslo_13473305	-					-	1	Į.			1		Ц			Ŀ.	L.	Ц	d.					4		
Meslo_13474097							Ш	L.		ų		LI.			L.	J.									L.	
Meslo_13474622	-					1	1	ų.	1	Ц	-	_		Į.	Ч		l,	u)		- 1		1		Ч		
Meslo_134/581/		-		-		Ŀ		L.							Ц	1	L.	4	5			H.		1	1	
Mesio_13470942	-				н			÷	1	Ŀ,					Ч		1	Ч	4		Н	-	1		Ŀ	ų
Mesio_134/4014 Metao_20000400	h			-		1		h		÷					H					ł	2					
Metac_20090100	-									h											ł,					
Death 23400840	h																	Н					H			
Oceih_23100019	┝									H.			H										H			
Onive_20030032	۲				H									۲									H			
Onive_39938620					Н													Н					H		H	
Pasmu 15601990					Н																		۲			
Pasmu 15603594								1	Ť.	r.	1	2			T	1				i.						
Aartu 15888162																		Ľ						T		
Acine 50085668																										
Aartu 16119640																										
Aartu 15891435		1																								
Agrtu 15887957									L																	
Agrtu_15888729																										
Agrtu_15890417																										
Agrtu_15890732		11		L																						
Agrtu_15891761																										
Agrtu_16119689				4	Ц																					
Agrtu_15890737				L					Ŀ																	
Agrtu_15891743							_																			
Agrtu_15891779							4																			
Agrtu_15891829	Ц.																									
Agrtu_16119287	h,													4			J.		-	ų						-
Arcfu_11499199						Ц		-		-				d,			-					÷	4			-
Bacsu_16080435							Ļ							-				1				þ.	μ			
Bacsu_16080423							d.		+	L.	L.	4		ы			L.		ы			ļ.	4			
Biflo_23465528					H	L.	-	Ļ		ļ		ъ.				i.	-					H				
Borbr_33601144										h		j.	μ			-			Ц	h		۲				
Borbr 23804054								H									H			-			H			
Borbr 22802204								P.															h			
Borbr 22802522																							h			
Braia 27379200					H																		H			
Braia 27370004								۲		H					H			۲								
Braia 27384500								H		H																H
Braia 27382025					h			L.															H			
Braia 27382710																										
Braia 27378421					H					٦	۲							t				H				
Brume 17988945																			Ŀ							
Camje 15792248																										T
Close 15803888																			h.,							
	•																									

D. Koop, CSCI 628, Fall 2021

Northern Illinois University

Nesting

Nesting Guidlines

- 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

D. Koop, CSCI 628, Fall 2021

[W. Javed and N. Elmqvist, 2012]

Northern Illinois University

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

D. Koop, CSCI 628, Fall 2021

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-dimension
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

D. Koop, CSCI 628, Fall 2021

[W. Javed and N. Elmqvist, 2012]

Summary (Scatterplot + Bar Chart)

(a) Juxtaposed views.

(b) Integrated views.

(c) Superimposed views.

What about large displays, multiple devices, or virtual/augmented reality?

Visualization on Devices other than Personal Computers

VisTiles

[Langner, Horak, and Dachselt, VIS 2017]

[Horak, Badam, Elmqvist, and Dachselt, CHI 2018]

D. Koop, CSCI 628, Fall 2021

Now: Large Wall-sized Displays

More data

More views

More users

Northern Illinois University

Large Display Interactions and Movement

Collaboration Styles

[Isenberg, Fisher, Morris, Inkpen, Czerwinski, VAST 2010]

Territoriality and Formations

[Azad, Ruiz, Vogel, Hancock, and Lank, DIS 2012]

D. Koop, CSCI 628, Fall 2021

Proximity to the display

Up Close and Personal [Jakobsen and Hornbæk, TOCHI 2014]

User Study on User Movement

∧ Themed Exploration Phase

D. Koop, CSCI 628, Fall 2021

Open Exploration Phase

[R. Langner et al.]

Vistribute

Vistribute: Distributing Interactive Visualizations in Dynamic Multi-Device Setups

Tom Horak, Andreas Mathisen, Clemens N. Klokmose, Raimund Dachselt, Niklas Elmqvist

ACM CHI 2019 Glasgow, Scotland, UK

Vistribute

Vistribute: Distributing Interactive Visualizations in Dynamic Multi-Device Setups

Tom Horak, Andreas Mathisen, Clemens N. Klokmose, Raimund Dachselt, Niklas Elmqvist

ACM CHI 2019 Glasgow, Scotland, UK

MARVIS: Mobile Devices & Augmented Reality

MARVIS Combining Mobile Devices and Augmented Reality for Visual Data Analysis

Ricardo Langner langner@acm.org Marc Satkowski msatkowski@acm.org

D. Koop, CSCI 628, Fall 2021

Wolfgang Büschel

bueschel@acm.org

Raimund Dachselt dachselt@acm.org

MARVIS: Mobile Devices & Augmented Reality

MARVIS Combining Mobile Devices and Augmented Reality for Visual Data Analysis

Ricardo Langner langner@acm.org Marc Satkowski msatkowski@acm.org

D. Koop, CSCI 628, Fall 2021

Wolfgang Büschel

bueschel@acm.org

Raimund Dachselt dachselt@acm.org

Using Tablets and Augmented Reality

OVERVIEW+DETAIL

Using AR for adapting different Overview+Detail and Focus+Context techniques. (a) A typical map overview; (b) Marginal histograms around the mobile device; (c) 3D visualization of a Matrix Cube; (d) Navigation support by an off-screen coordinate origin; (e) Zoomed in bar chart with fisheye-style continuation; (f) Mobile device as a detailed lens into a larger map;

D. Koop, CSCI 628, Fall 2021

FOCUS+CONTEXT & SEAMLESS VISUALIZATION EXTENSION

Using Tablets and Augmented Reality

Using AR for Alternative Visualization Views, Separated Visualization User Interface Components, and Superimposed 3D Visualizations. (a) SPLOM shows alternative scatterplots configurations; (b) Distributed views of a dashboard; (c) Tilted AR views; (d) Off-loaded legend and menus; (e) Continuous 3D track above a map; (f) 3D wall visualization aligned to a map;

Using Tablets and Augmented Reality

Using AR for *Relations Between Visualizations*, *Combination of* Visualizations, and Multi-User Support. (a) Linking and brushing supported by curved AR connections; (b) Ribbons between devices indicate the relative proportions; (c) Icon meta-visualizations reveal view relations; (d) AR bar chart summarizes calculated differences between views; (e) Merging two views in AR; (f) Personal and shared areas for collaborative activities;

