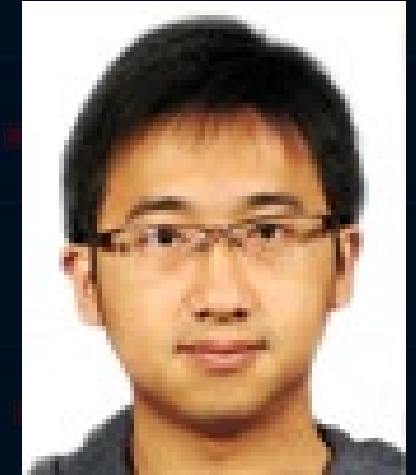


Visual Artificial Intelligence

Katy Börner @katycns & Yingnan Ju

Intelligent Systems Engineering
Cyberinfrastructure for Network Science Center
Luddy School of Informatics, Computing, and Engineering
Indiana University Network Science Institute (IUNI)
Indiana University, Bloomington, IN, USA



CSCI B551 Guest Lecture

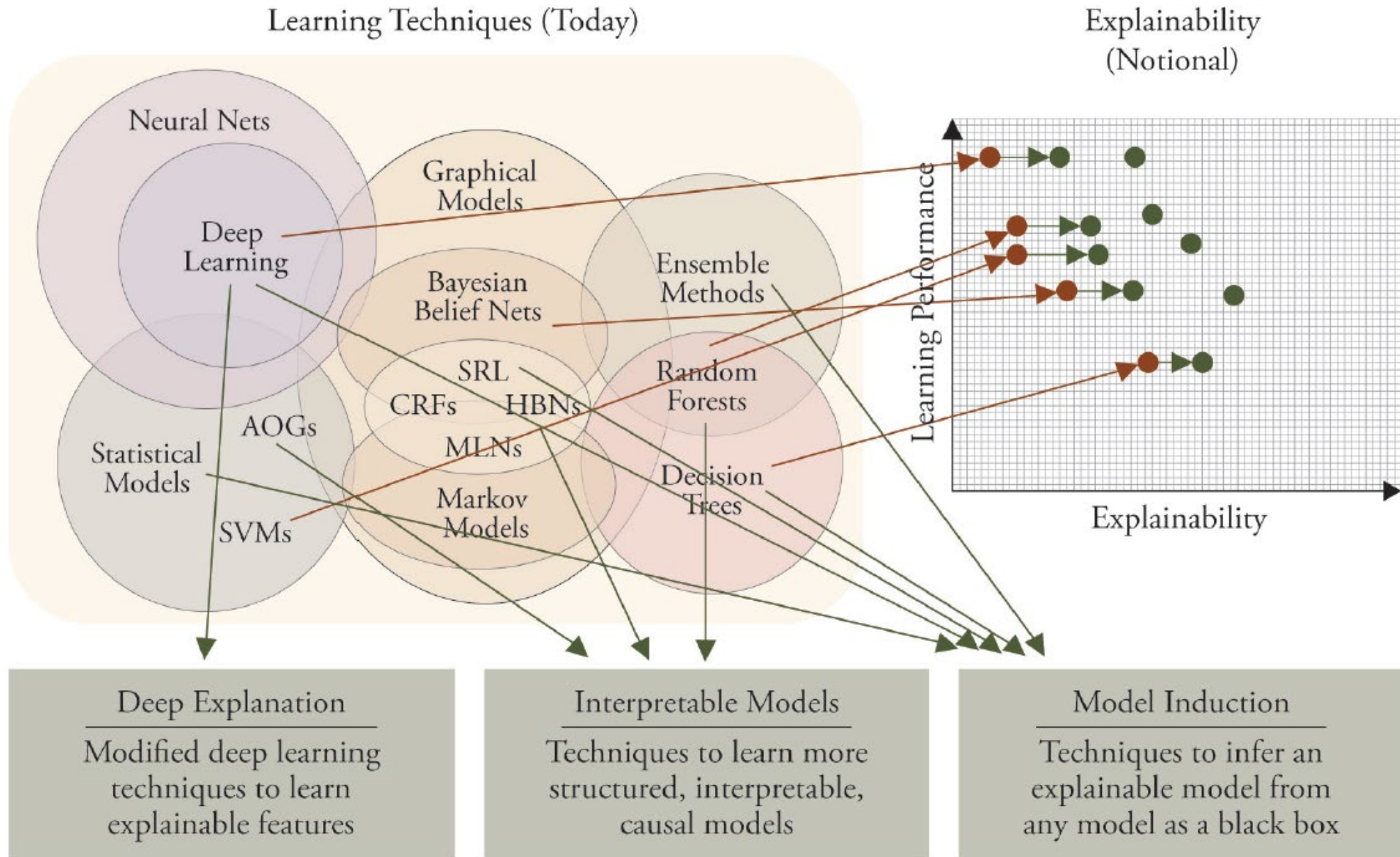
March 25, 2021



Visualizations of ML Algorithms



Motivation

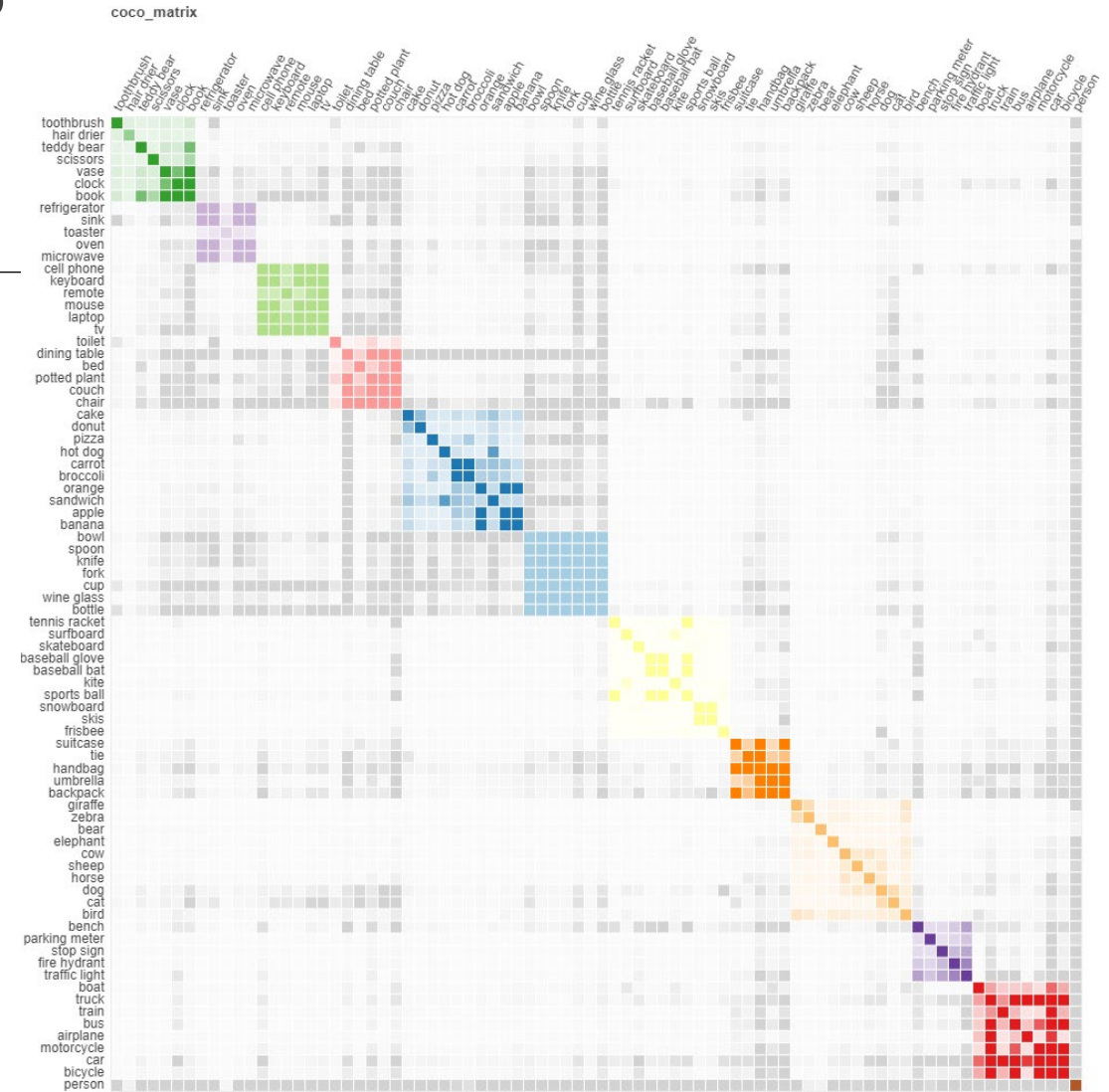
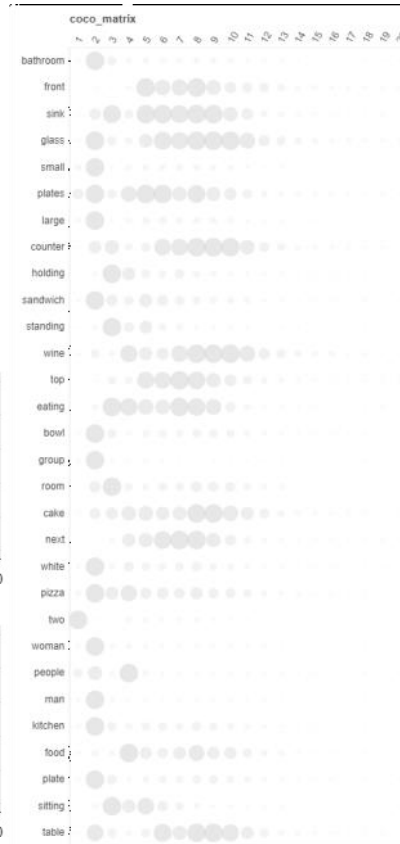
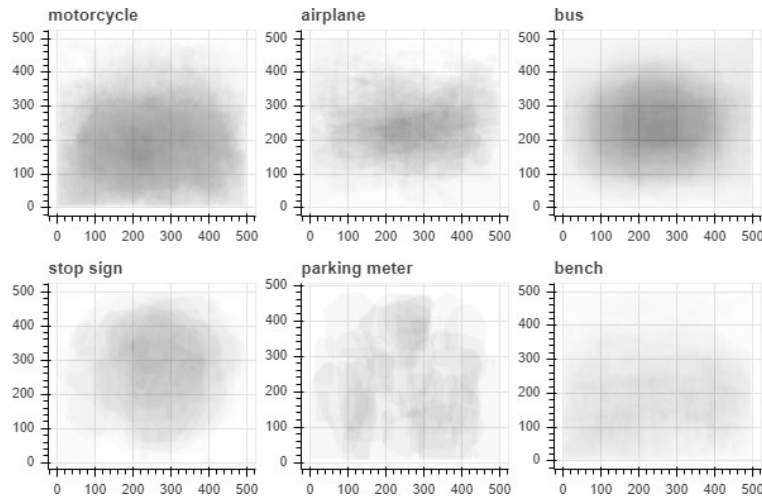
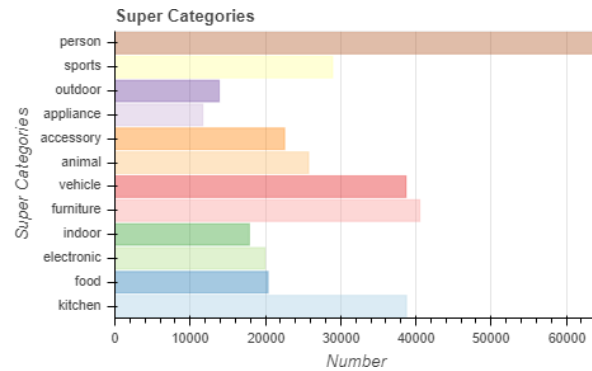


Five Visualization Tasks

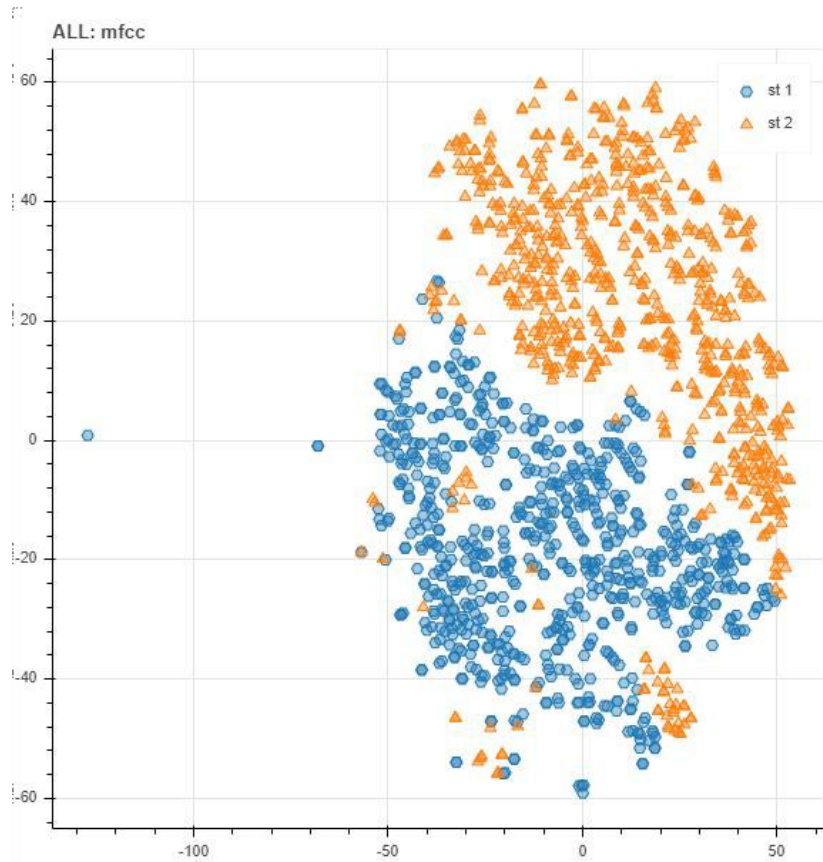
1. ML Data
2. ML Structure
3. ML Features
4. ML Learning Process
5. ML Prediction Results



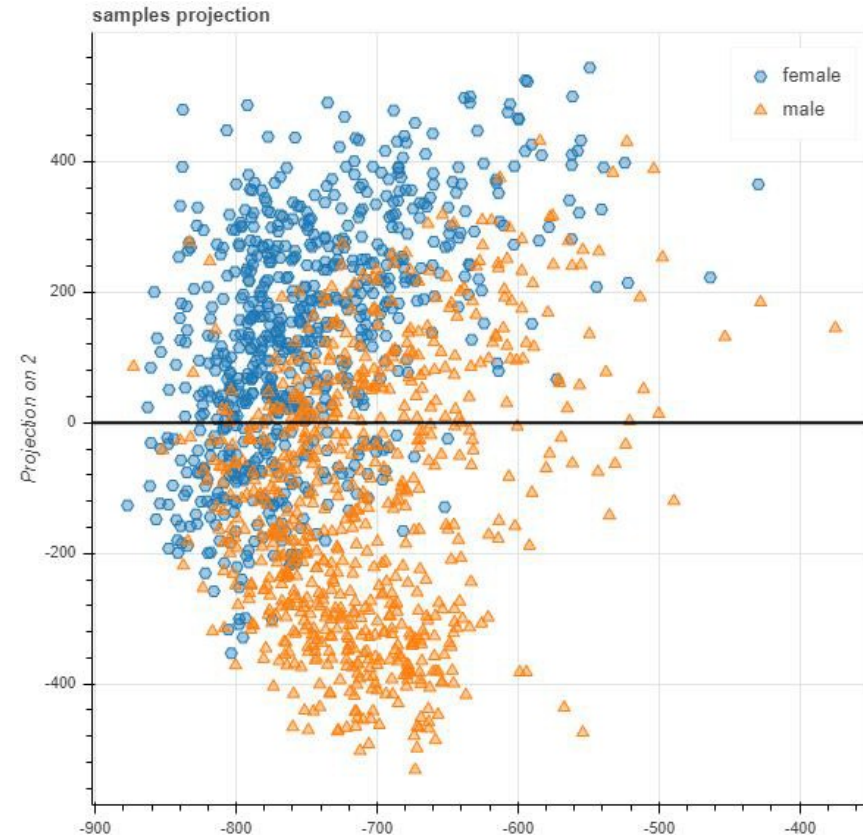
Visualizations of Datasets



Visualization of Data, e.g., embedding space



t-SNE



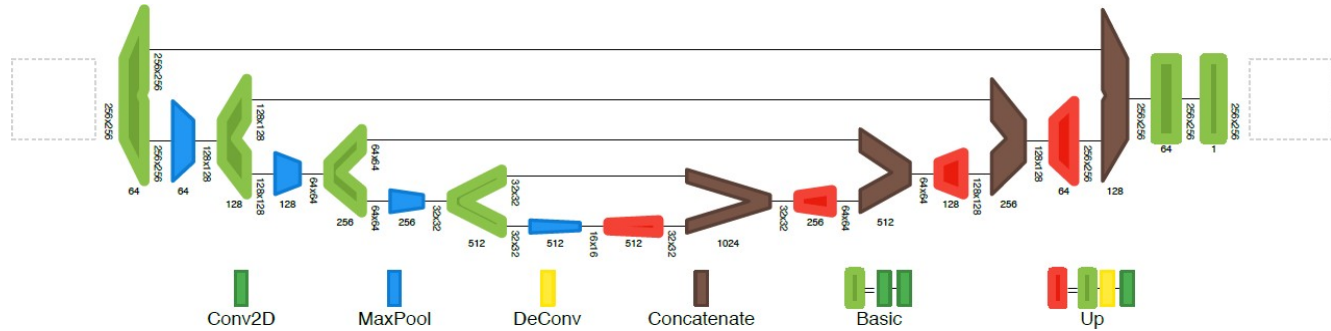
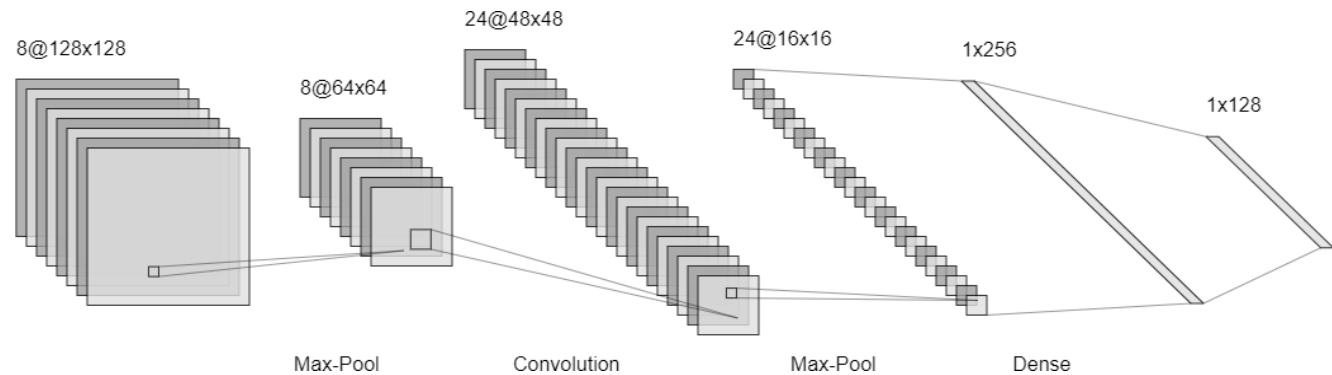
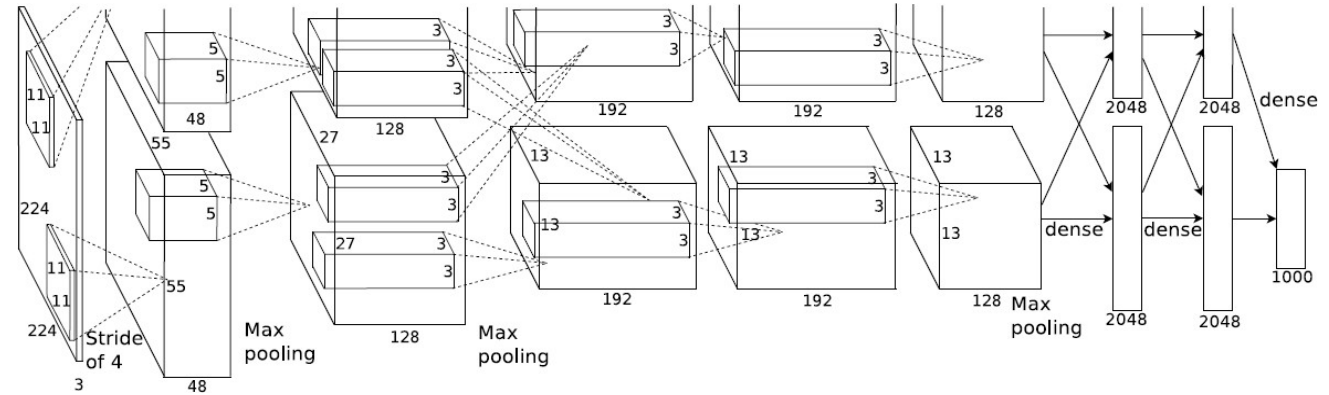
SVD

Visualization of NN Structure

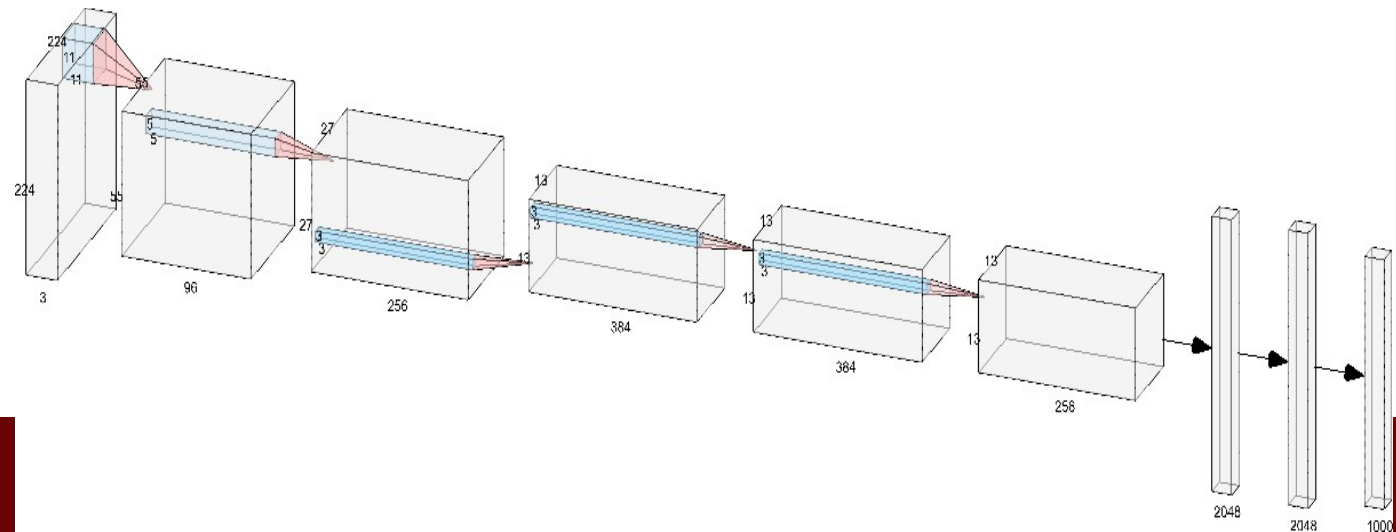
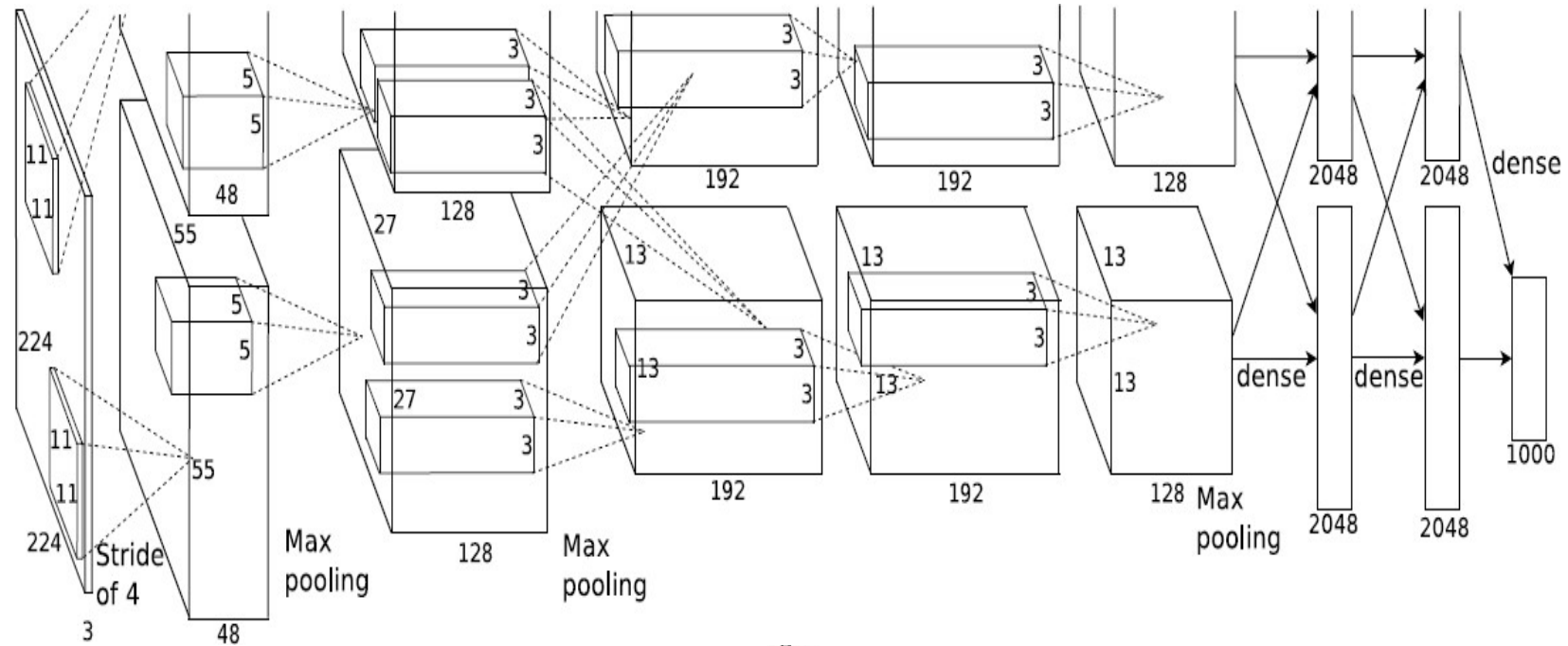
AlexNet Style

LeNet Style

Net2Vis Style



Visualization of NN model structures



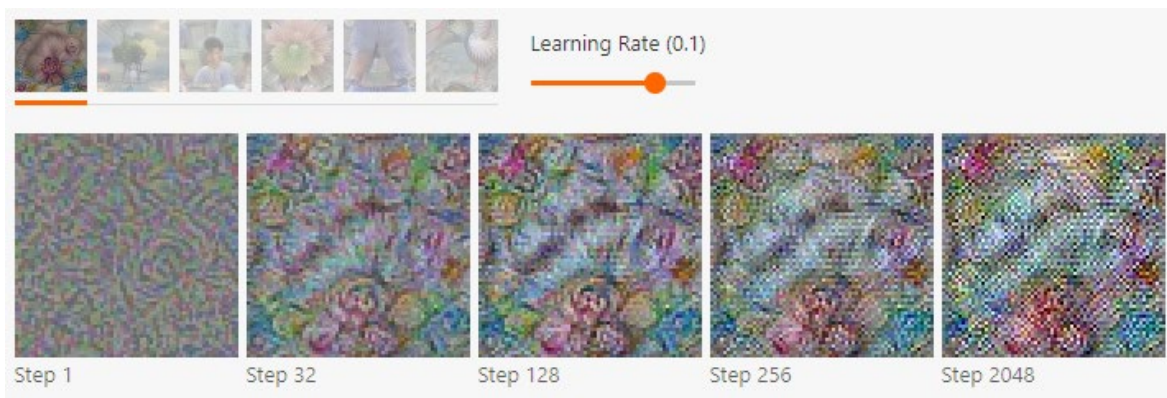
Visualization of NN Learning

Olah, C., Mordvintsev, A., & Schubert, L. (2017). Feature visualization. Distill, 2(11), e7.

<https://distill.pub/2017/feature-visualization/>

Interaction between Neurons
Customized hyperparameter



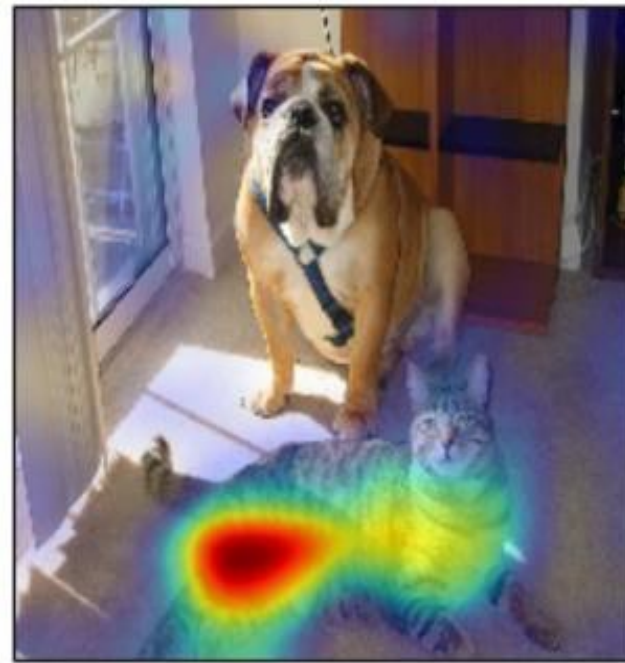


Visualization of Results, e.g., activation map

Grad-CAM



Original Image

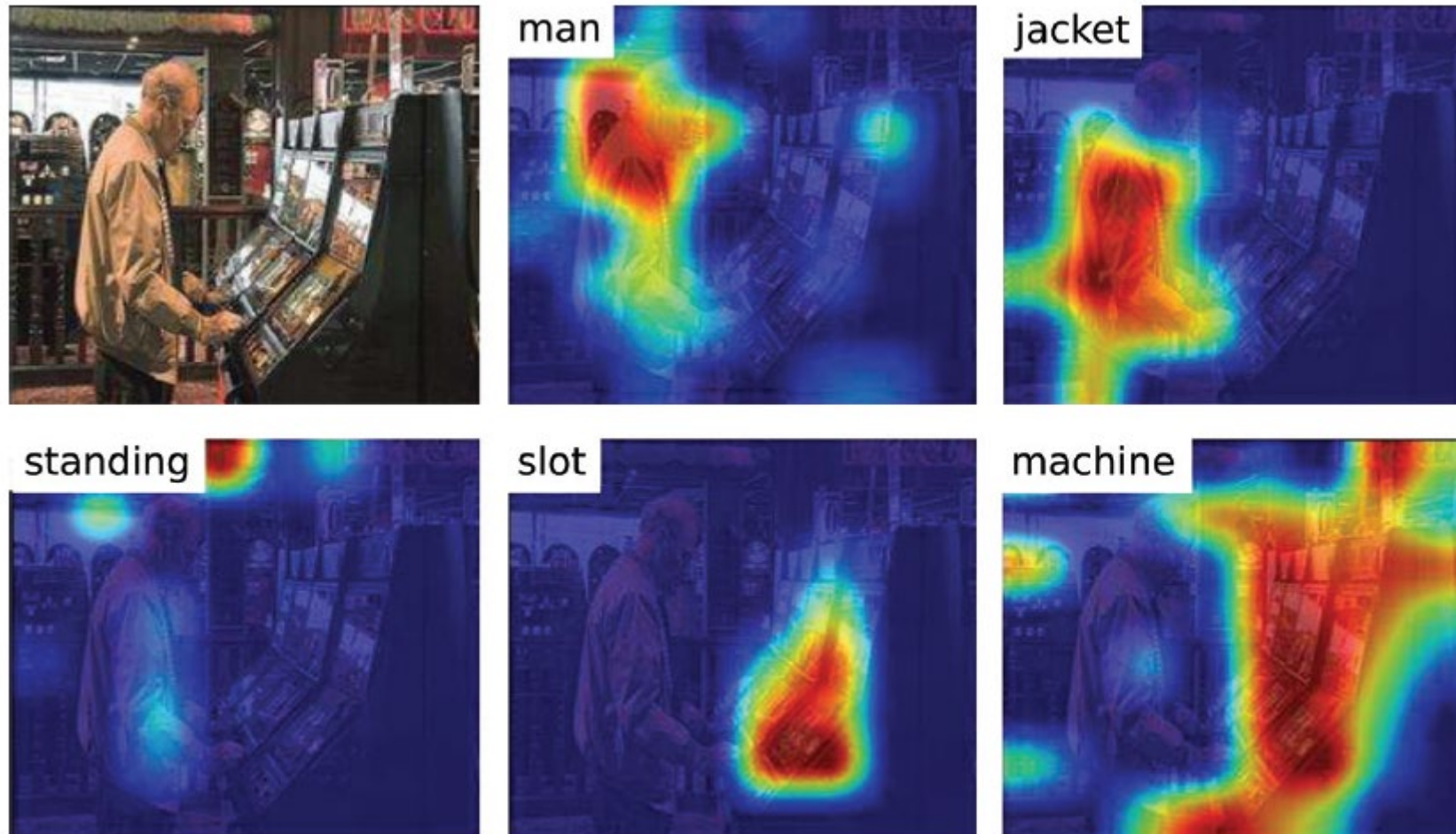


Grad-CAM 'Cat'



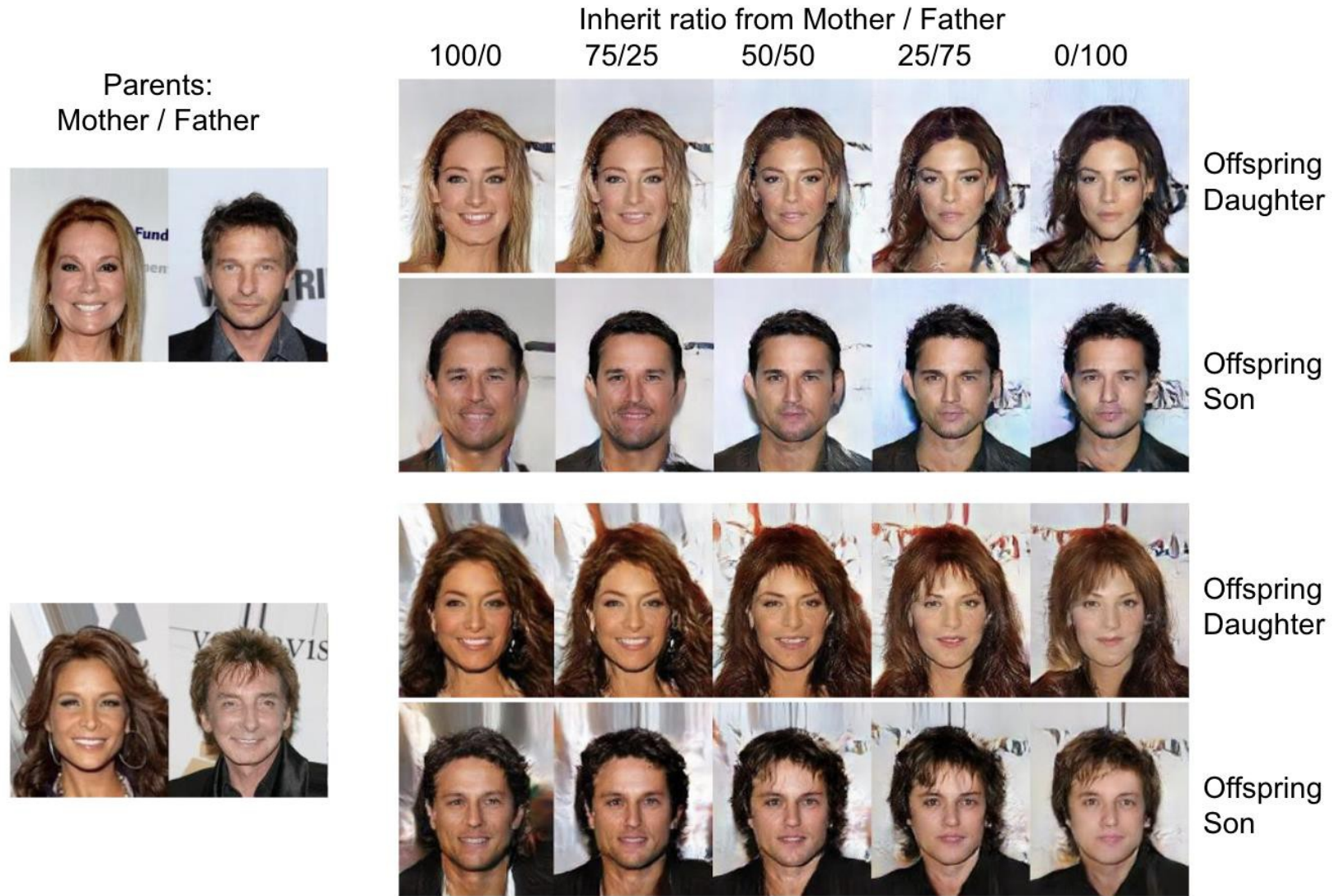
Grad-CAM 'Dog'

Visualization of Results, e.g., activation map

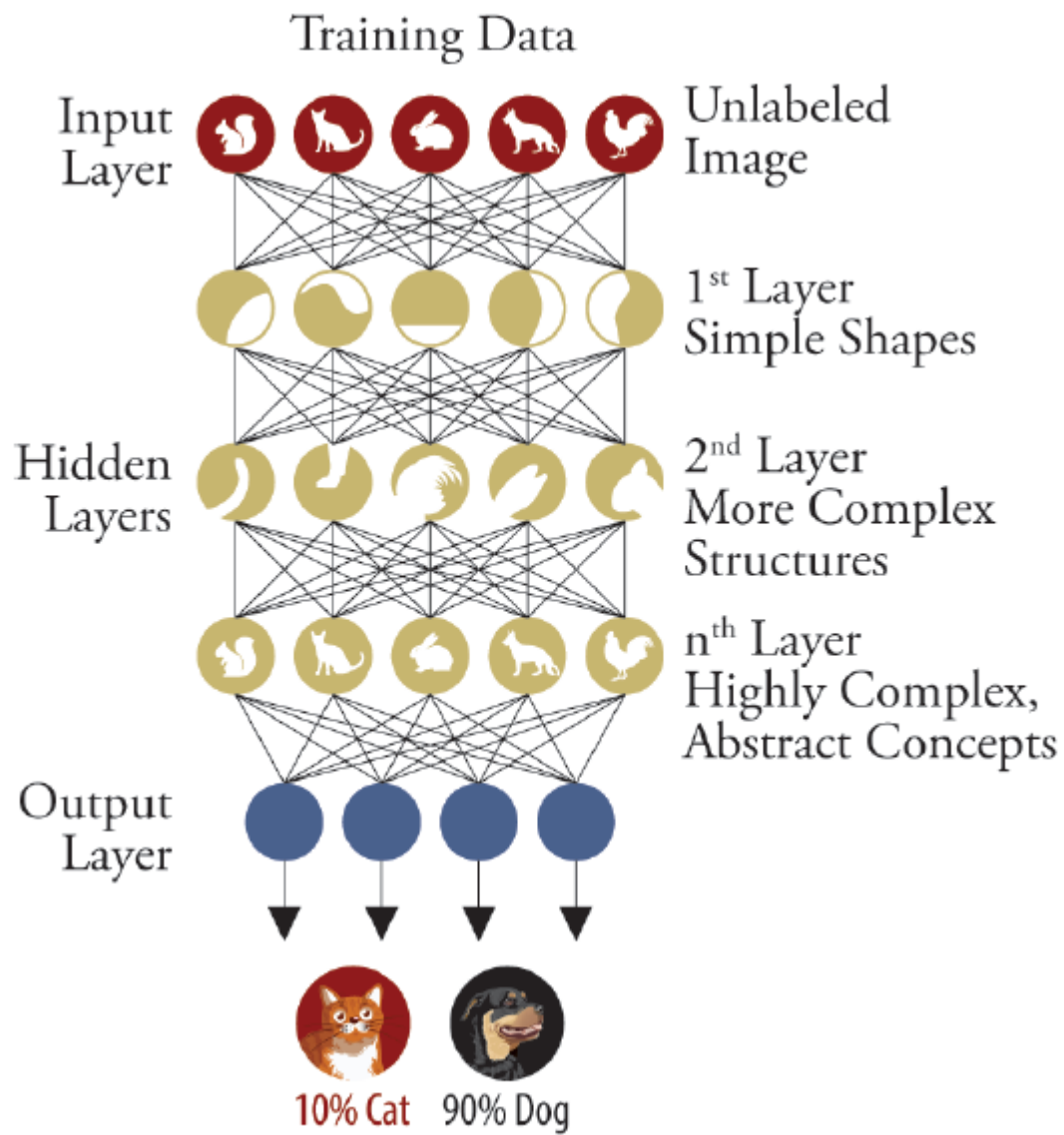


A man in a jacket is standing at the slot machine

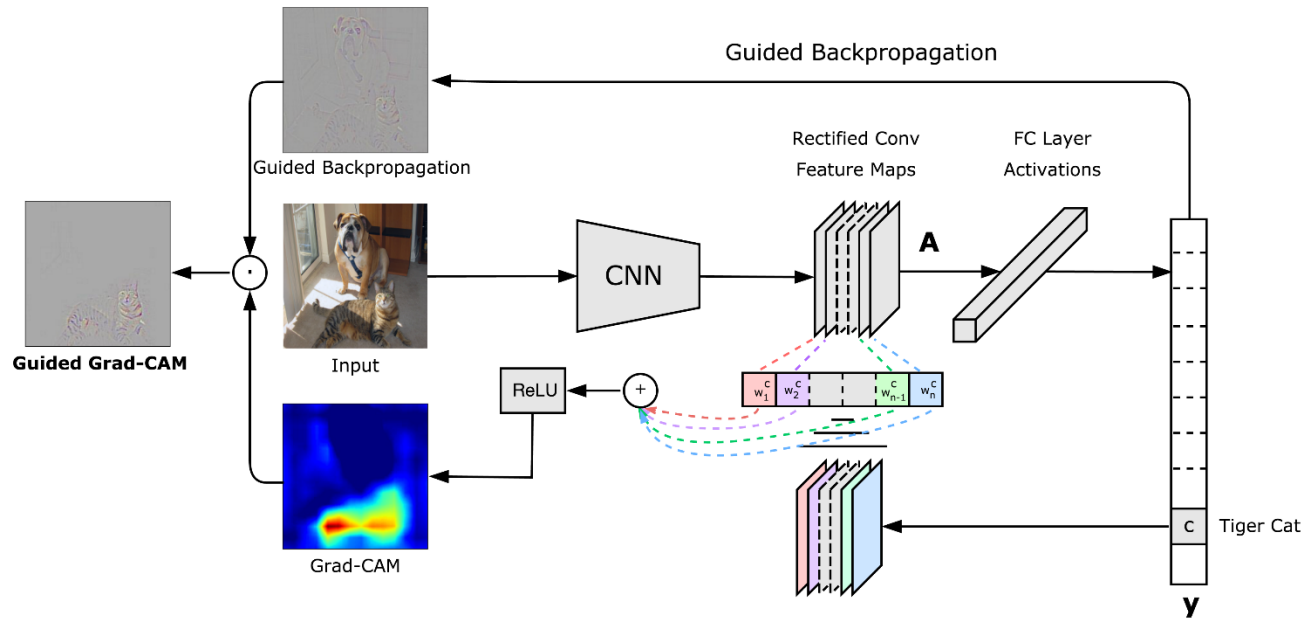
Generation of Training/Test Data



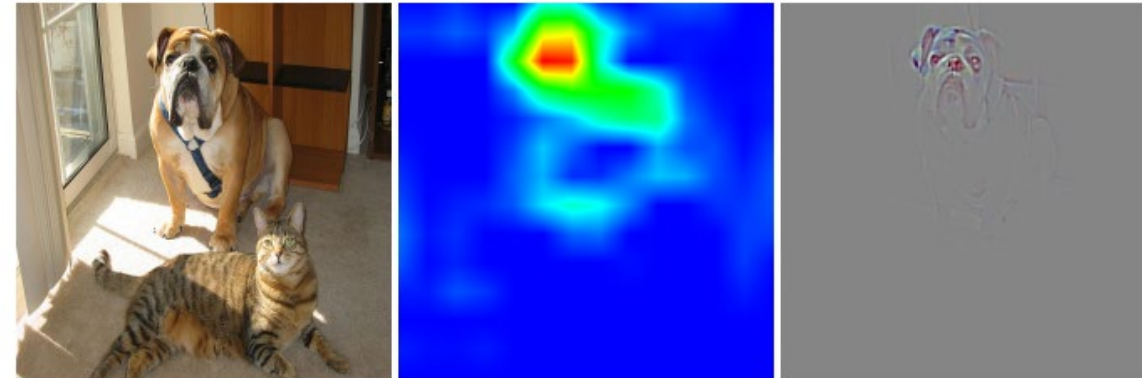
Conceptual Drawings



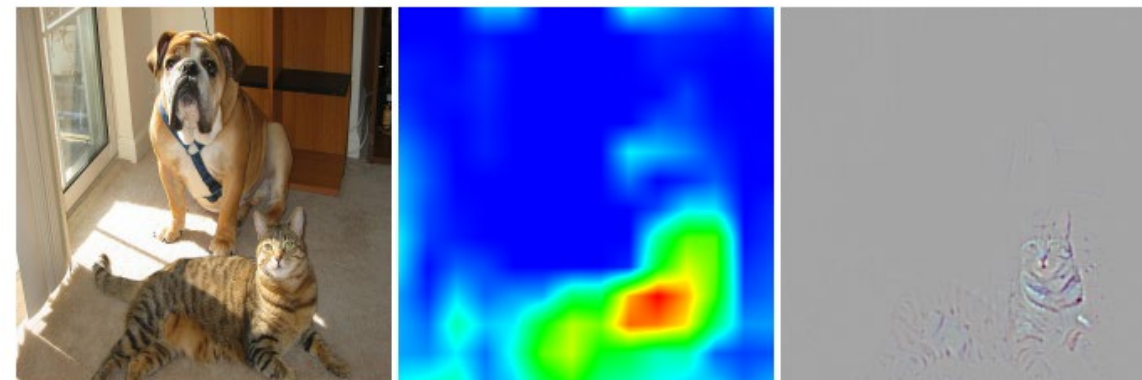
Combi: Structure and Result



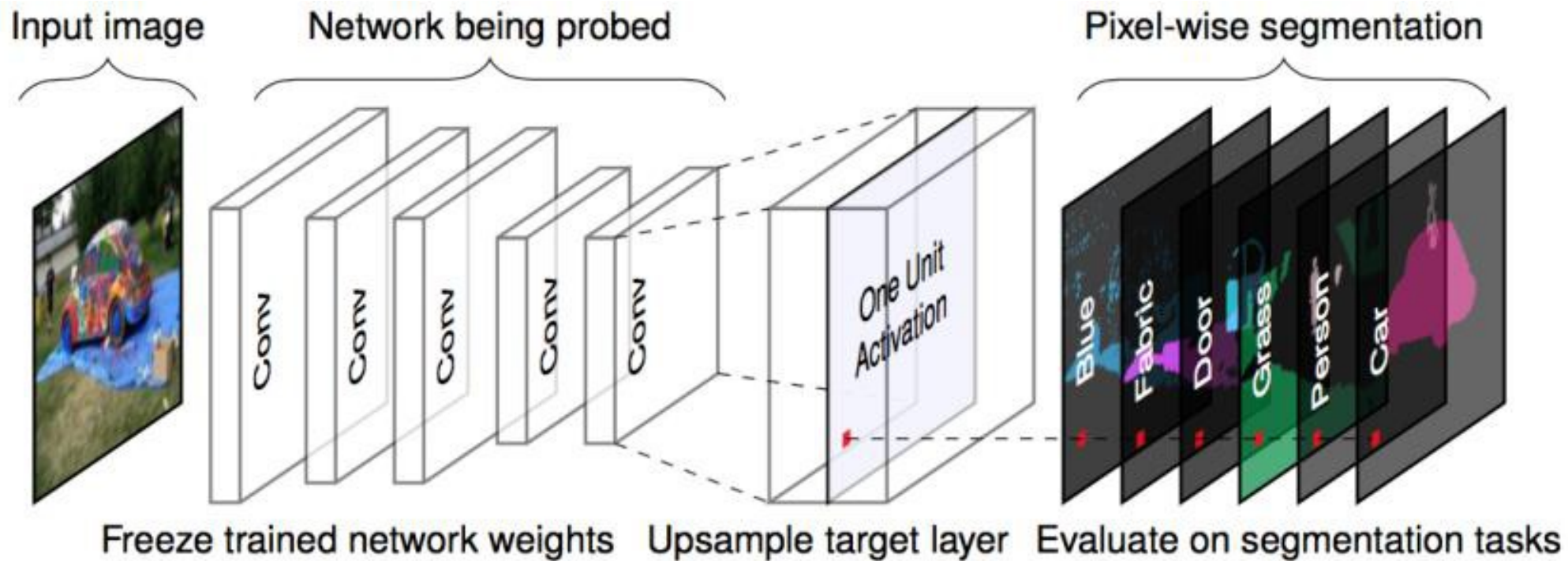
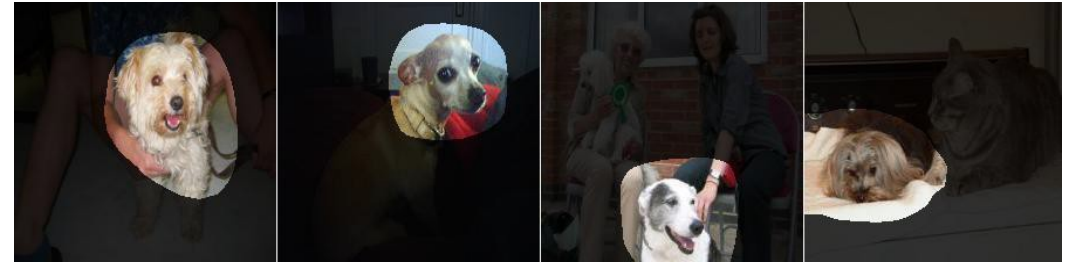
What animal? Dog



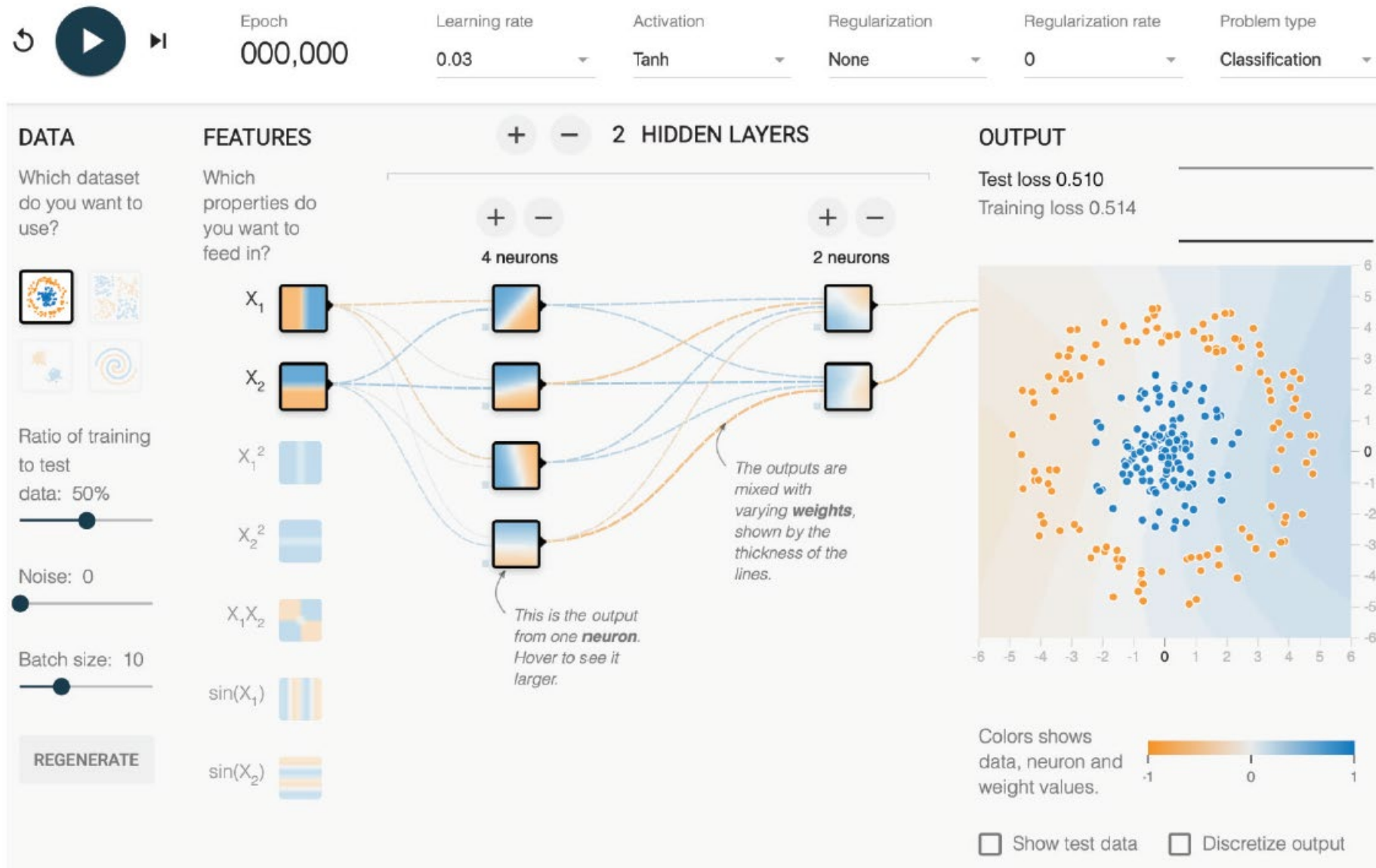
What animal? Cat



Combi: Structure and Result

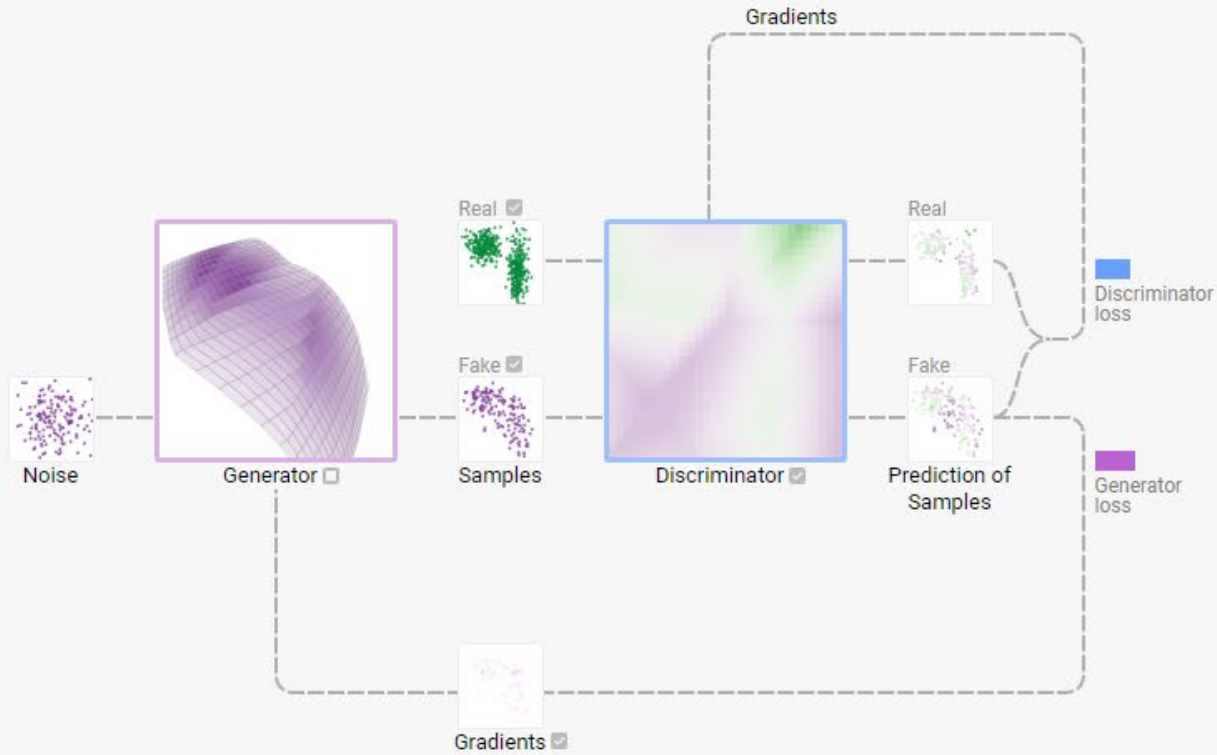


Combi: Structure and Result

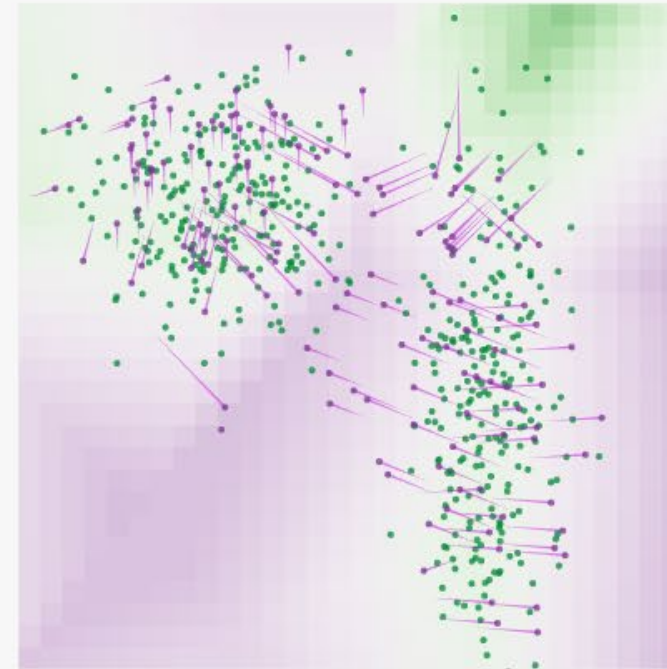




MODEL OVERVIEW GRAPH



LAYERED DISTRIBUTIONS



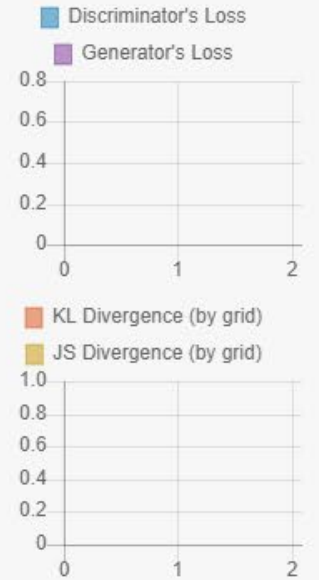
Each dot is a 2D data sample: **real samples**; **fake samples**.

Background colors of grid cells represent **discriminator**'s classifications. Samples in **green regions** are likely to be real; those in **purple regions** likely fake.

Manifold represents **generator**'s transformation results from noise space. Opacity encodes density: darker purple means more samples in smaller area.

Pink lines from fake samples represent **gradients** for generator.
/ This sample needs to move upper right to decrease generator's loss.

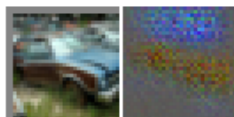
METRICS



input (32x32x3)

max activation: 0.42156, min: -0.45295
max gradient: 0.07001, min: -0.03894

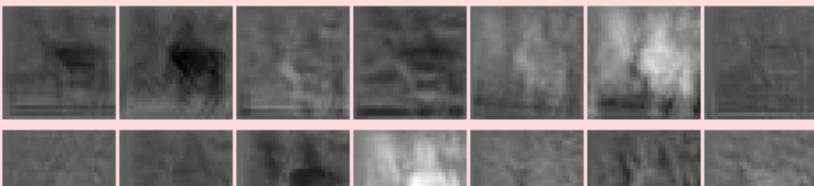
Activations:



conv (32x32x16)

filter size 5x5x3, stride 1
max activation: 0.78039, min: -0.42474
max gradient: 0.02009, min: -0.01871
parameters: 16x5x5x3+16 = 1216

Activations:



relu (32x32x16)

max activation: 1.10583, min: 0
max gradient: 0.0318, min: -0.03817

Activations:



pool (16x16x16)

pooling size 2x2, stride 2
max activation: 0.99044, min: 0
max gradient: 0.0323, min: -0.03395

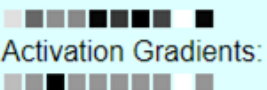
Activations:



fc (1x1x10)

max activation: 0.99332, min: -7.08355
max gradient: 0.6911, min: -0.98016
parameters: 10x320+10 = 3210

Activations:



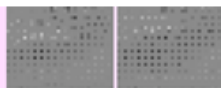
Activation Gradients:



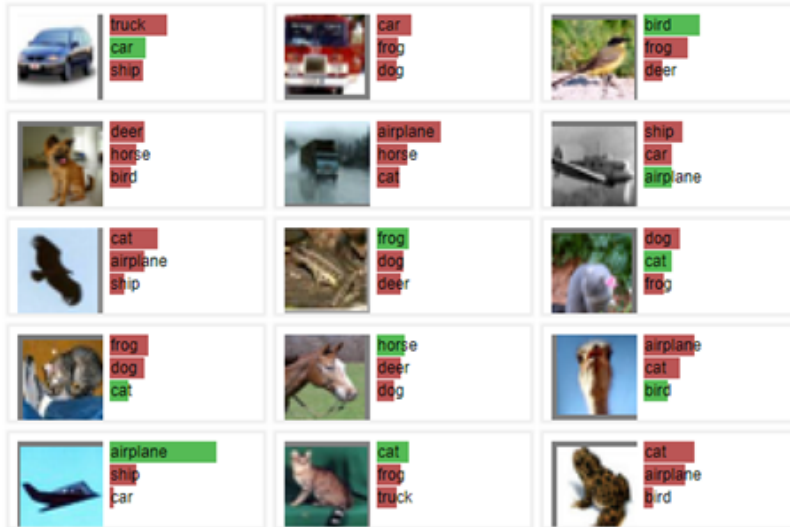
softmax (1x1x10)

max activation: 0.6911, min: 0.00021
max gradient: 0, min: 0

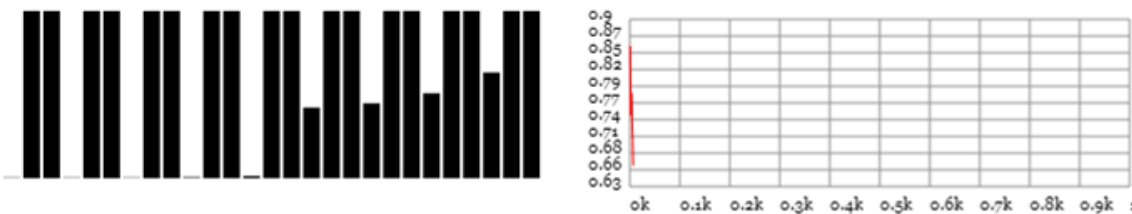
Activations:



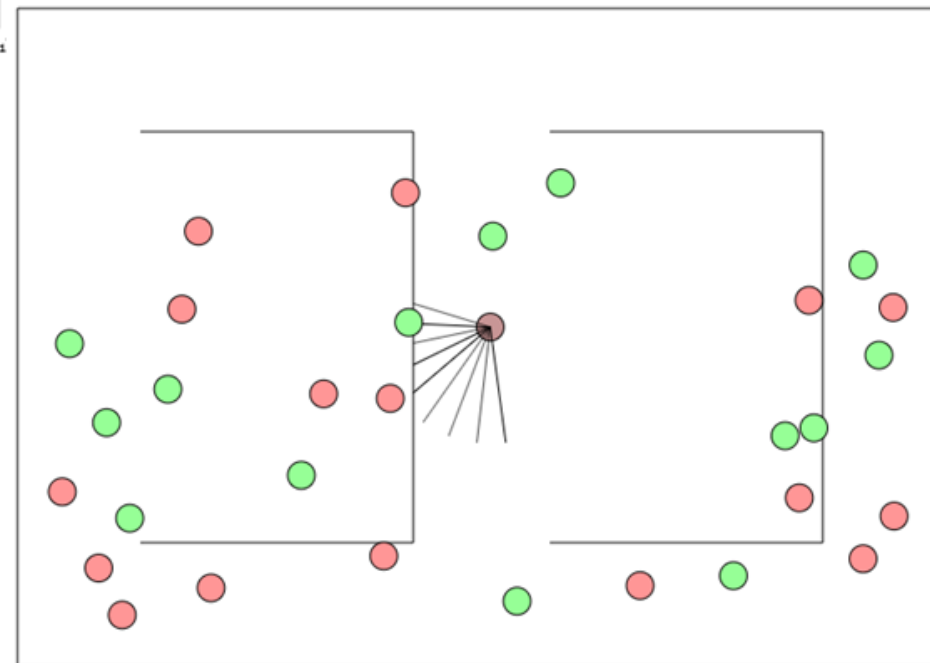
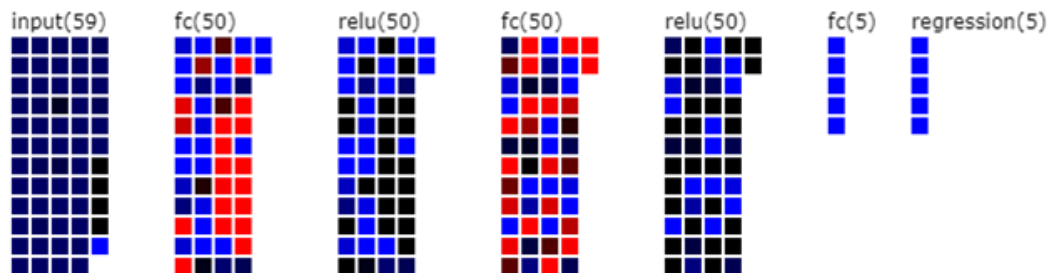
test accuracy based on last 200 test images: 0.3263888888888889



Left: Current input state (quite a useless thing to look at). **Right:** Average reward over time (this should go up as agent becomes better on average at collecting rewards)



Value Function Approximating Neural Network:



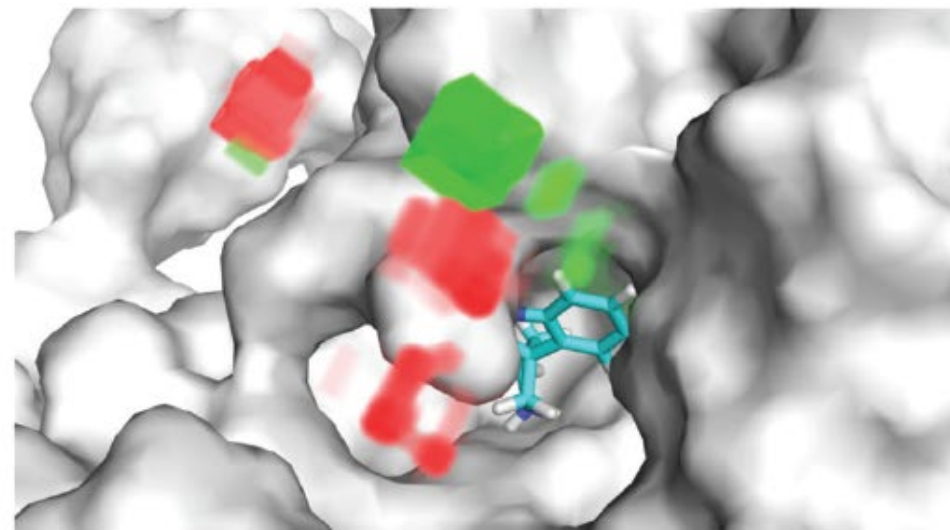
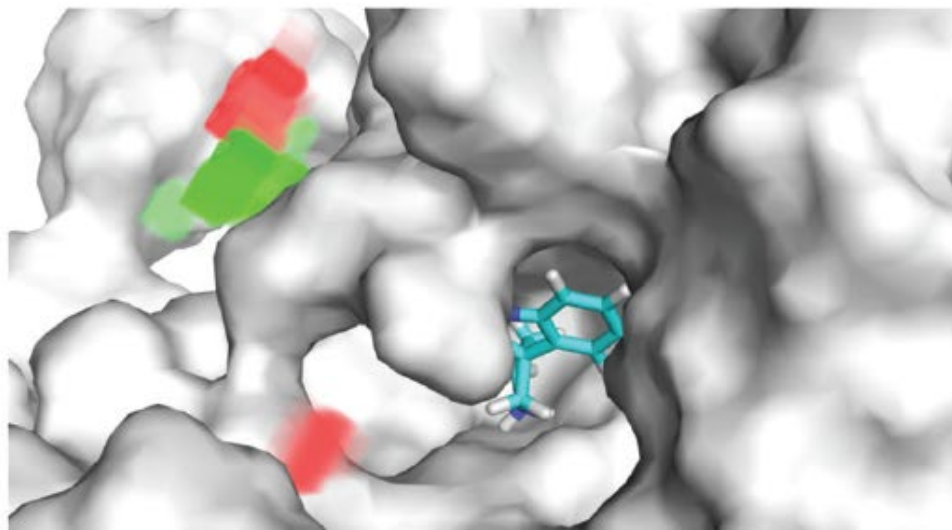
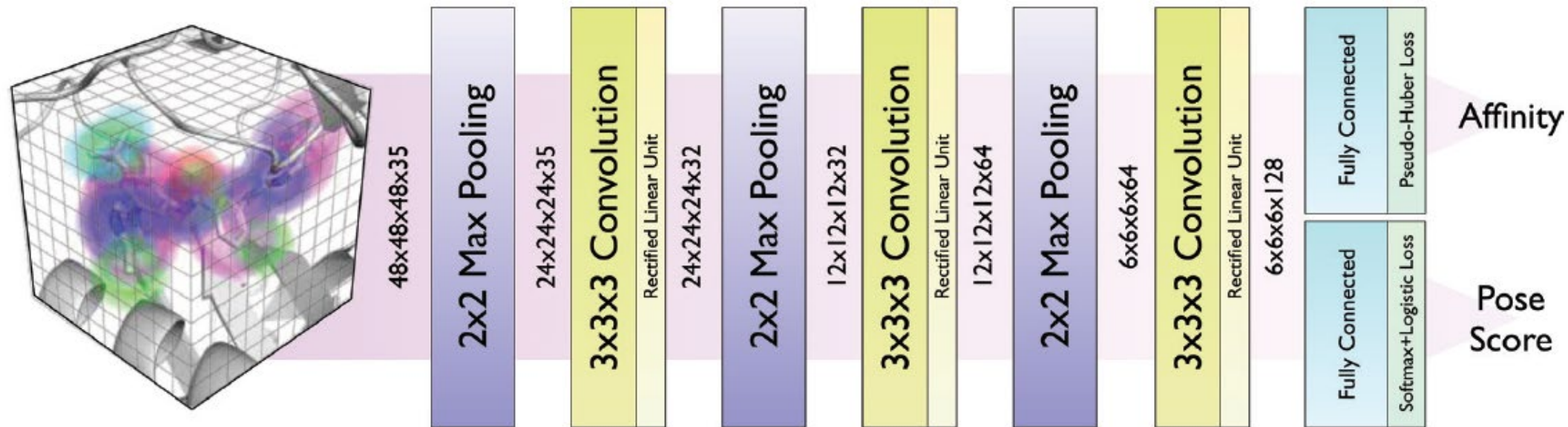
experience replay size: 2499
exploration epsilon: 1
age: 2501
average Q-learning loss: 0.12960280841138744
smooth-ish reward: 0.7649640075954809

Controls

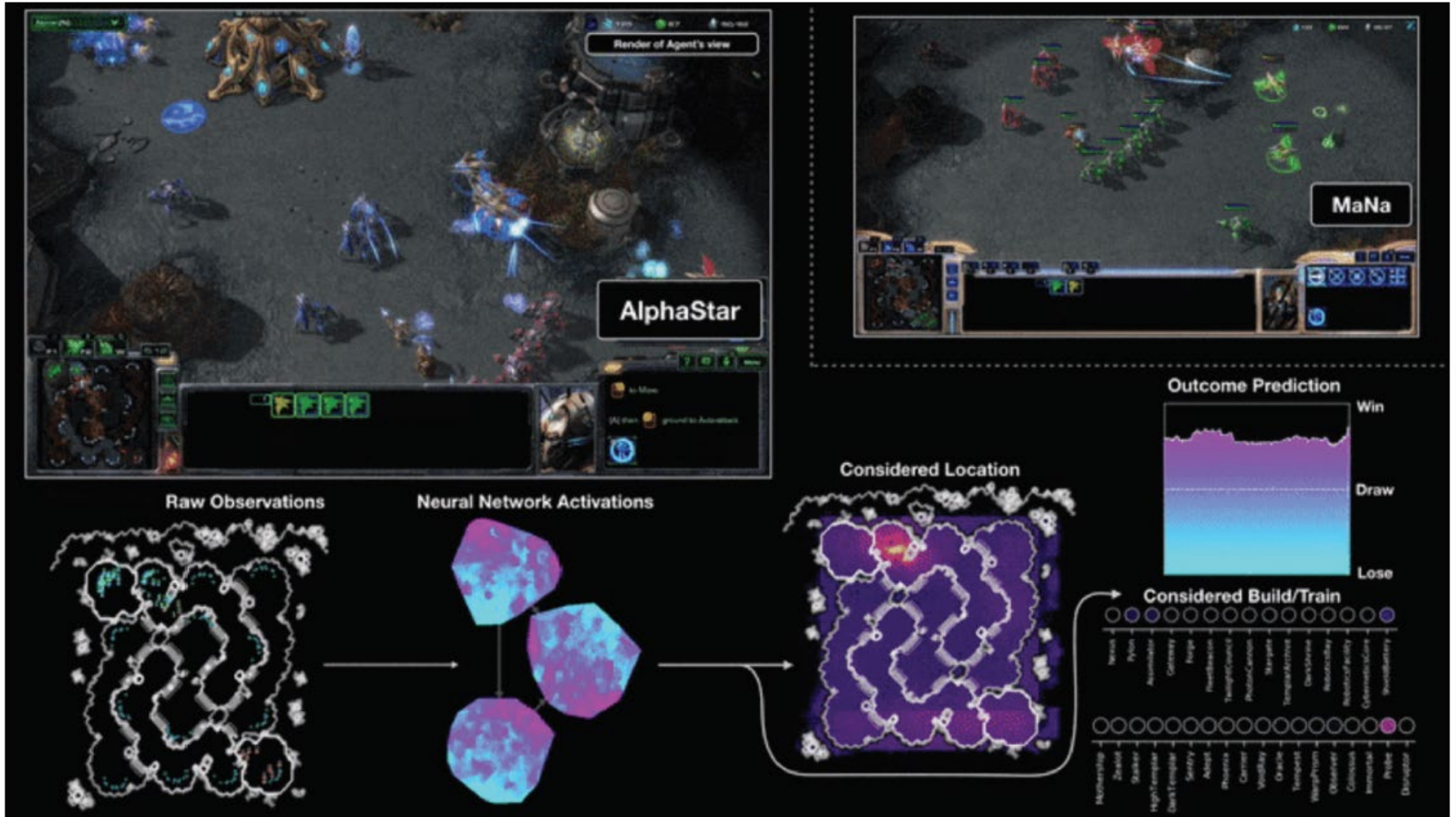
Go very fast Go fast Go normal speed Go slow
Start Learning Stop Learning



Combi: Structure and Result



Combi: Structure and Result



Data Visualization Literacy Framework

Börner, Katy, Andreas Bueckle, and Michael Ginda. 2019. Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *PNAS*, 116 (6) 1857-1864.



Data Visualization Literacy (DVL)

Data visualization literacy (ability to read, make, and explain data visualizations) requires:

- literacy (ability to read and write text in titles, axis labels, legends, etc.),
- visual literacy (ability to find, interpret, evaluate, use, and create images and visual media), and
- mathematical literacy (ability to formulate, employ, and interpret math in a variety of contexts).

Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important to strategically approach local and global issues.

DVL Framework: Desirable Properties

- Most existing frameworks focus on **READING**. We believe that much expertise is gained from also **CONSTRUCTING** data visualizations.
- Reading and constructing data visualizations needs to take human perception and cognition into account.
- Frameworks should build on and consolidate prior work in cartography, psychology, cognitive science, statistics, scientific visualization, data visualization, learning sciences, etc. in support of a de facto standard.
- Theoretically grounded + practically useful + easy to learn/use.
- Highly modular and extendable.

DVL Framework: Development Process

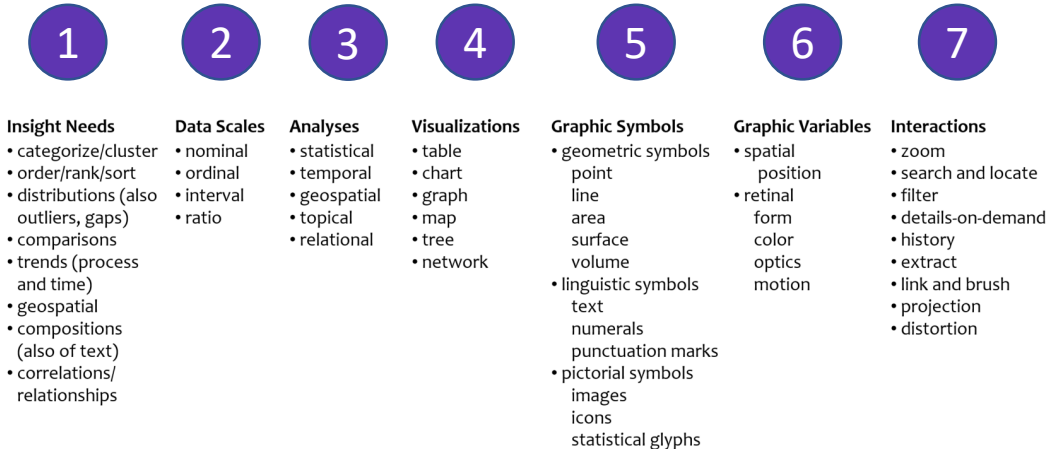
- The initial DVL-FW was developed via an extensive literature review.
- The resulting DVL-FW typology, process model, exercises, and assessments were then tested in the *Information Visualization* course taught for more than 17 years at Indiana University. More than 8,500 students enrolled in the IVMOOC version (<http://ivmooc.cns.iu.edu>) over the last six years.
- The FW was further refined using feedback gained from constructing and interpreting data visualizations for 100+ real-world client projects.
- Data on student engagement, performance, and feedback guided the continuous improvement of the DVL-FW typology, process model, and exercises for defining, teaching, and assessing DVL.
- The DVL-FW used in this course supports the systematic construction and interpretation of data visualizations.

Data Visualization Literacy Framework (DVL-FW)

Consists of two parts:

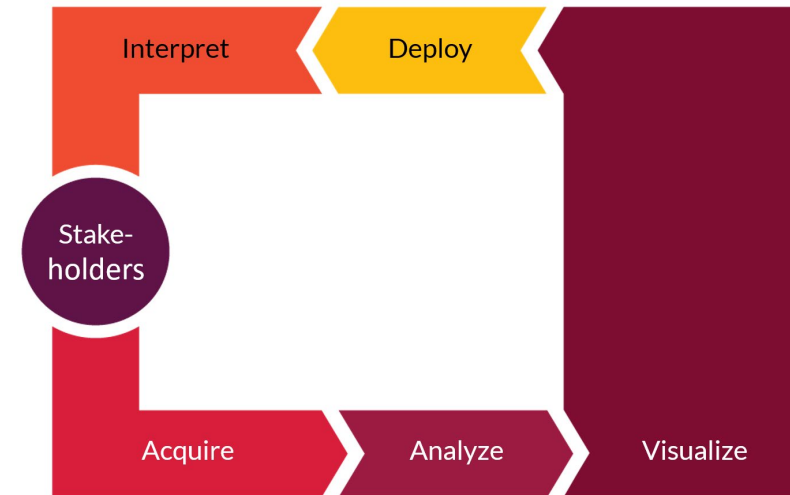
DVL Typology

Defines 7 types with 4-17 members each.



DVL Workflow Process

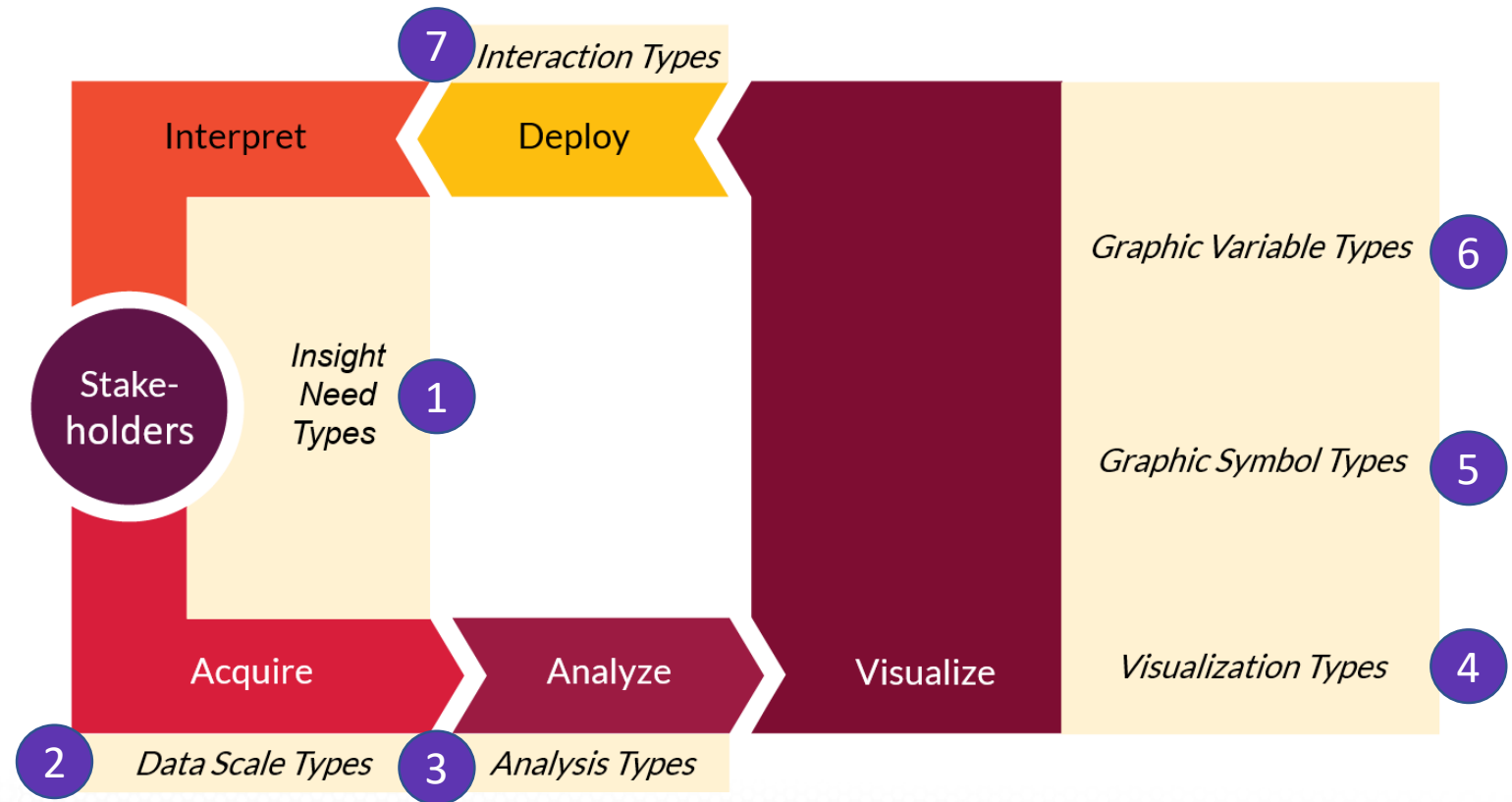
Defines 5 steps required to render data into insights.

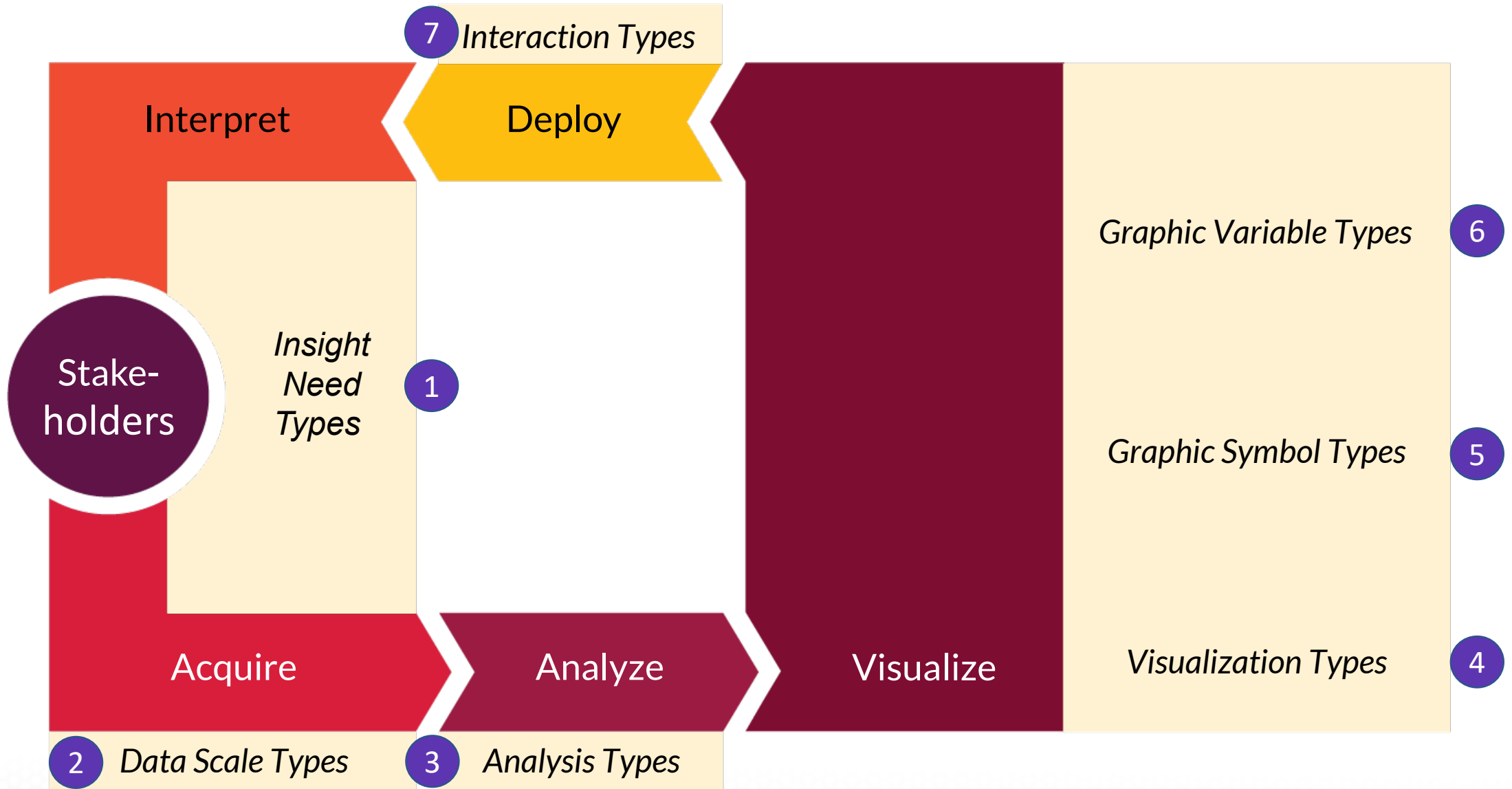


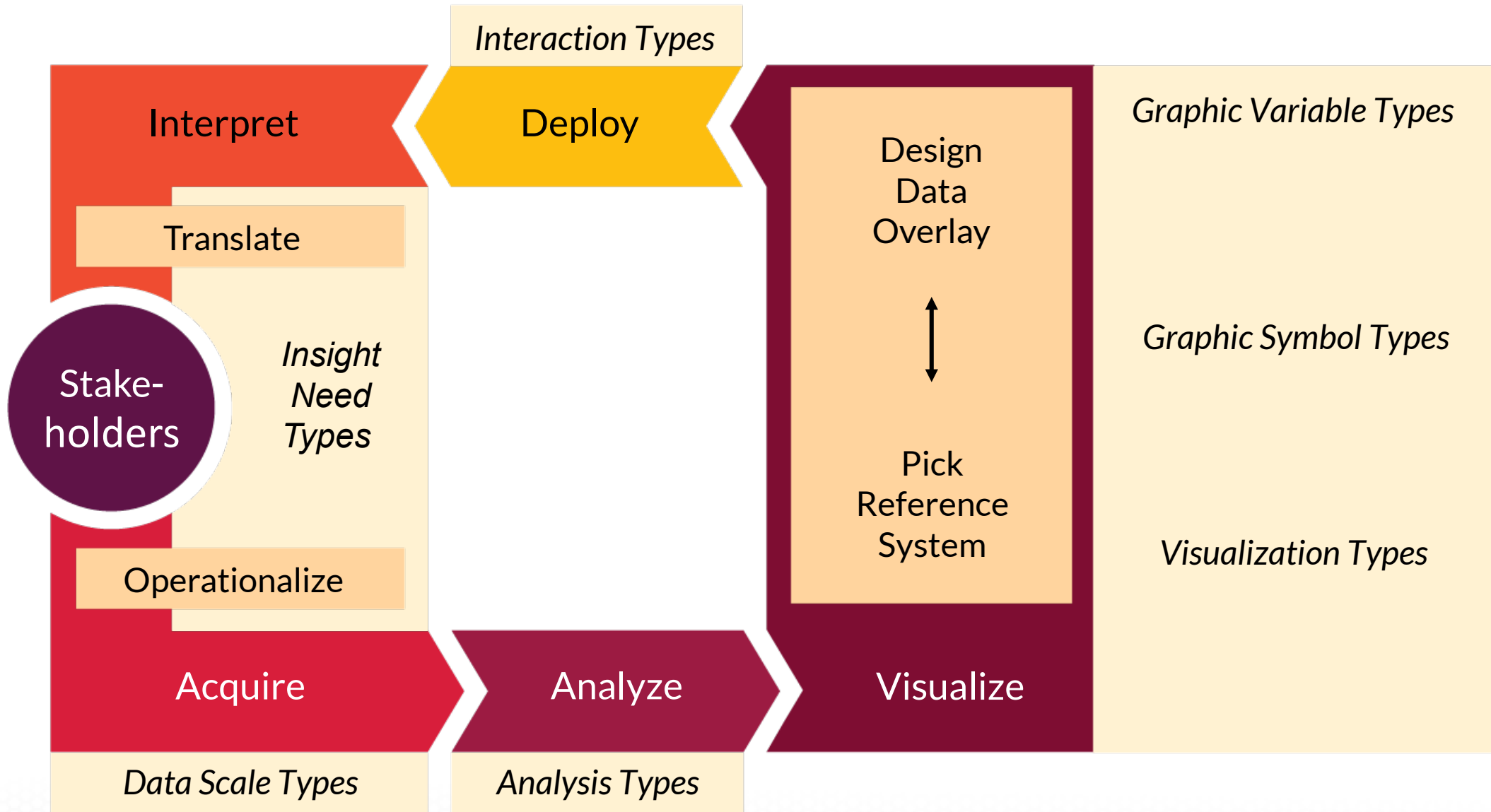
Data Visualization Literacy Framework (DVL-FW)

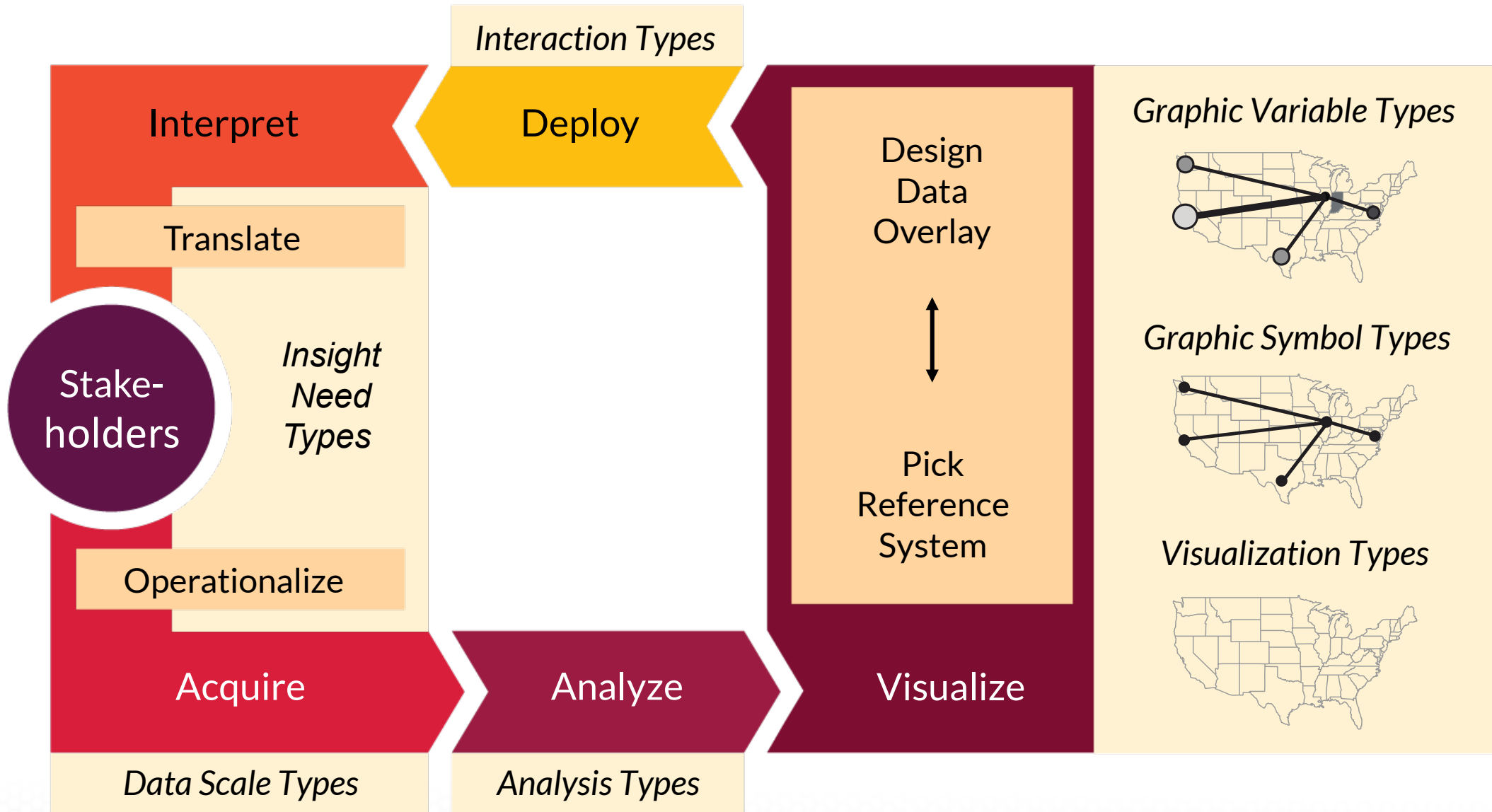
Consists of two parts *that are interlinked*:

**DVL Typology +
DVL Workflow Process**









Data Visualization Literacy Framework (DVL-FW)

Implemented in Make-A-Vis (MAV) to support learning via horizontal transfer, scaffolding, hands-on learning, etc.

☰ Make-A-Vis
i

Data

ISI Publications: (CSV) Preprocessed-wos

Title	Authors	Journal	Year	#Cites
Total Records: 562				

Journals: (from ISI Publications)

Name	#Papers	#Cites	First Year	Last Year
BMC EVOL BIOL	1	7	2006	2006
FEBS J	2	0	2005	2005
NAT PHYS	3	18	2005	2006

Total Records: 562

Make Visualization

Select Visualization Type

Scatter Graph

Temporal Bar Graph

Geomap

Scimap

Done

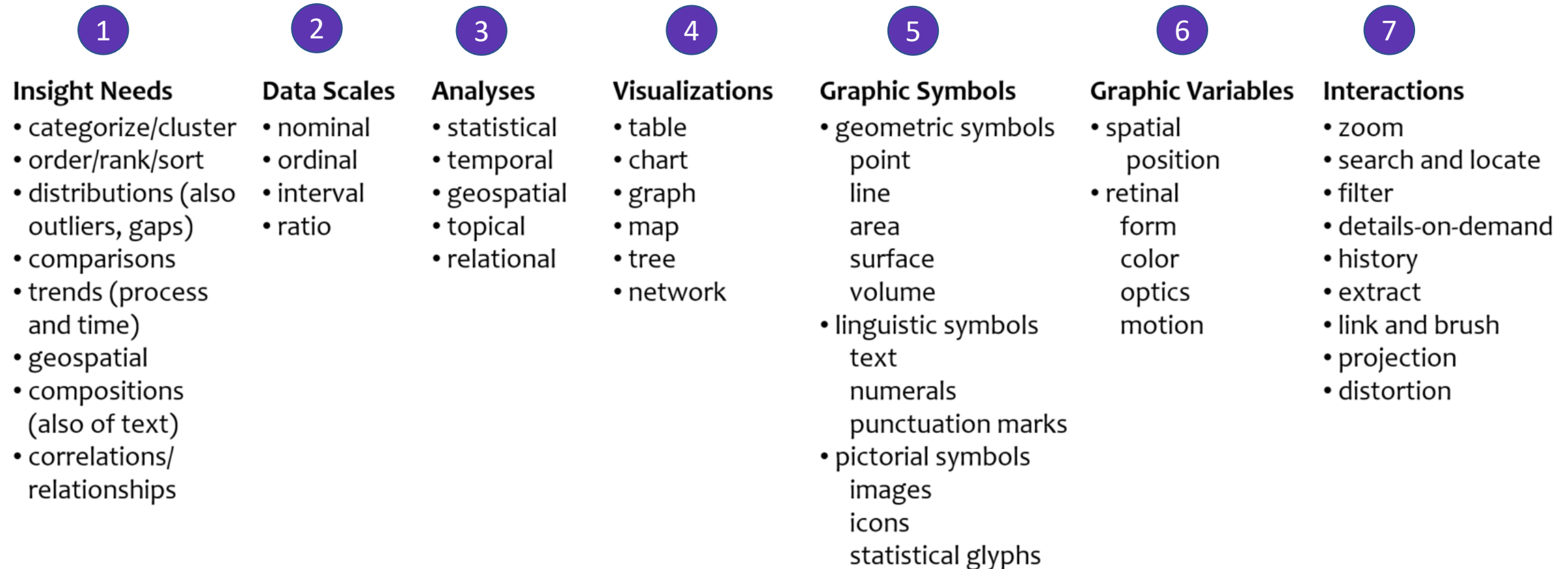
Temporal Bar Graph

4

5

6

Typology of the Data Visualization Literacy Framework



Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 25.

Typology of the Data Visualization Literacy Framework

1

Insight Needs

- categorize/cluster
- order/rank/sort
- distributions (also outliers, gaps)
- comparisons
- trends (process and time)
- geospatial
- compositions (also of text)
- correlations/relationships

Data Scales

- nominal
- ordinal
- interval
- ratio

Analyses

- statistical
- temporal
- geospatial
- topical
- relational

Visualizations

- table
- chart
- graph
- map
- tree
- network

Graphic Symbols

- geometric symbols
 - point
 - line
 - area
 - surface
 - volume
- linguistic symbols
 - text
 - numerals
 - punctuation marks
- pictorial symbols
 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
- retinal
 - form
 - color
 - optics
 - motion

Interactions

- zoom
- search and locate
- filter
- details-on-demand
- history
- extract
- link and brush
- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 26-27.

Bertin, 1967	Wehrend & Lewis, 1996	Few, 2004	Yau, 2011	Rendgen & Wiedemann, 2012	Frankel, 2012	Tool: Many Eyes	Tool: Chart Chooser	Börner, 2014
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to- whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships

Typology of the Data Visualization Literacy Framework

4

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- categorize/cluster
- order/rank/sort
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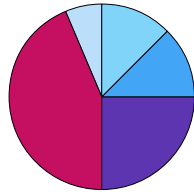
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- details-on-demand
- history
- extract
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- projection
- distortion

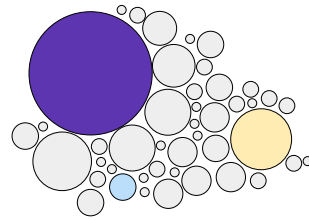
Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 30-31.

Visualization Types

Chart

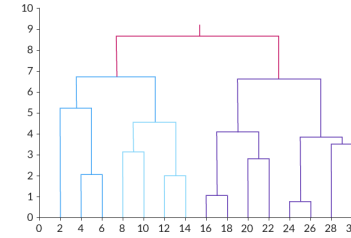


Pie Chart

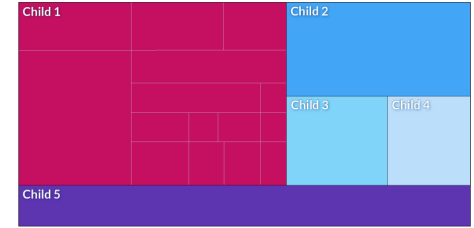


Bubble Chart

Tree

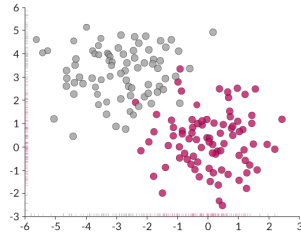


Dendrogram

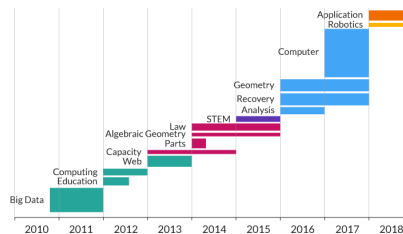


Tree Map

Graph

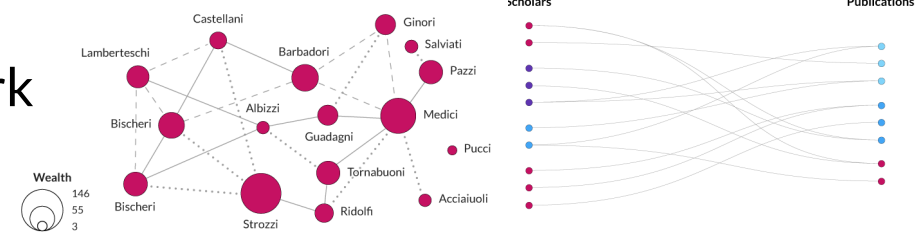


Scatter Graph



Temporal Bar Graph

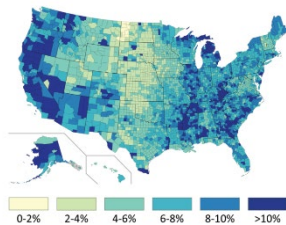
Network



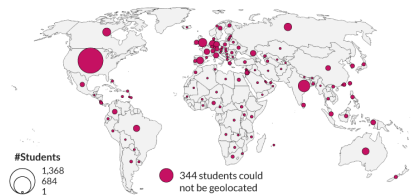
Force-Directed Network Layout

Bimodal Network Layout

Map



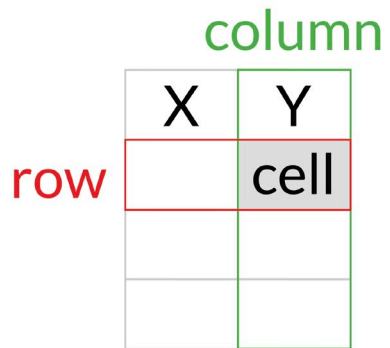
Choropleth Map



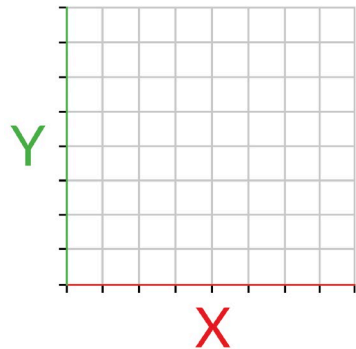
Proportional Symbol Map

Visualize: Reference Systems

Table
columns by rows



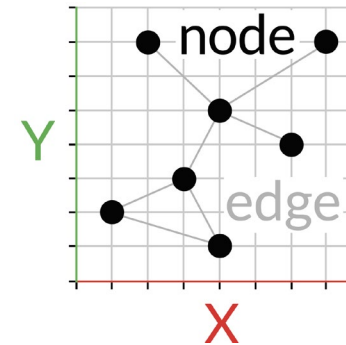
Graph
x-y coordinates



Map
latitude/
longitude



Network
local similarity

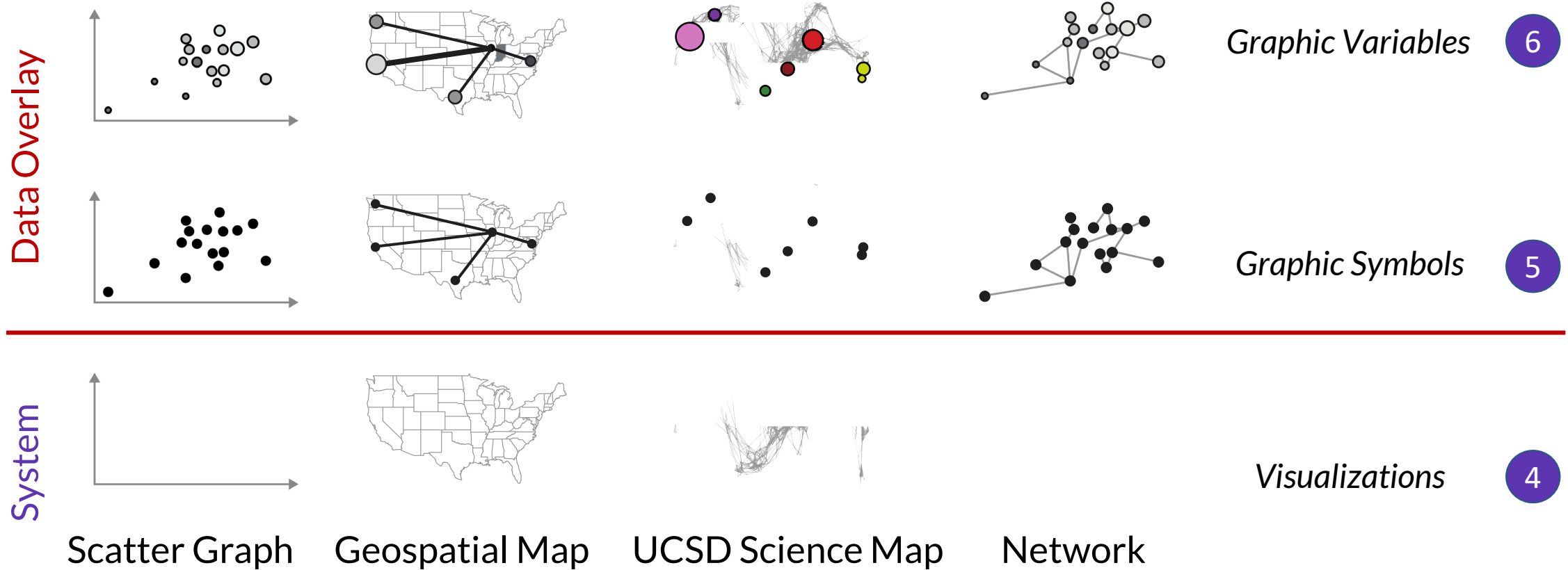


4

Visualization Types

- table
- chart
- graph
- map
- network layout

Visualize: Reference Systems, Graphic Symbols and Variables



Typology of the Data Visualization Literacy Framework

5

Insight Needs

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 - punctuation marks
- pictorial symbols
 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
- retinal
 - form
 - color
 - optics
 - motion

Interactions

- zoom
- search and locate
- filter
- details-on-demand
- history
- extract
- link and brush
- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 32-33.

Typology of the Data Visualization Literacy Framework

6

Insight Needs

- categorize/cluster
- order/rank/sort
- distributions (also outliers, gaps)
- comparisons
- trends (process and time)
- geospatial
- compositions (also of text)
- correlations/relationships

Data Scales

- nominal
- ordinal
- interval
- ratio

Analyses

- statistical
- temporal
- geospatial
- topical
- relational

Visualizations

- table
- chart
- graph
- map
- tree
- network

Graphic Symbols

- geometric symbols
 - point
 - line
 - area
 - surface
 - volume
- linguistic symbols
 - text
 - numerals
 - punctuation marks
- pictorial symbols
 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
- retinal
 - form
 - color
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 - motion

Interactions

- zoom
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- history
- extract
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- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 34-35.

Graphic Variable Types

Position: x, y; possibly z

Form:

- Size
- Shape
- Rotation (Orientation)

Color:

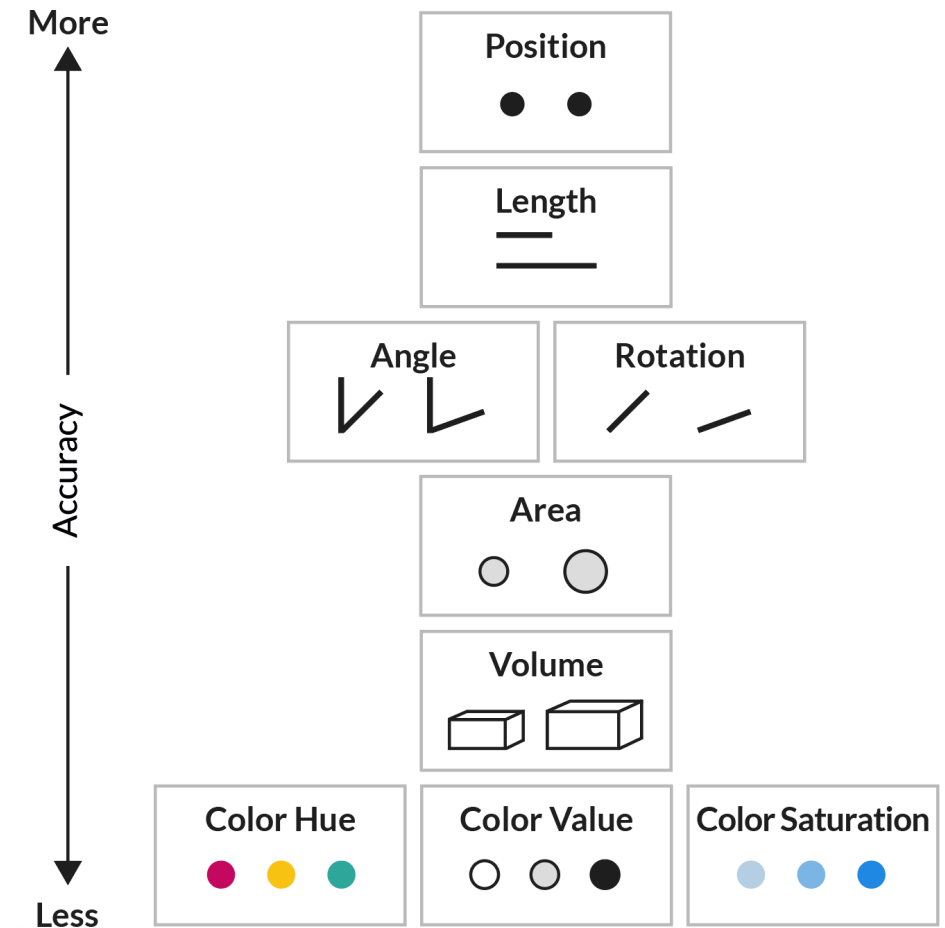
- Value (Lightness)
- Hue (Tint)
- Saturation (Intensity)



Optics: Blur, Transparency, Shading, Stereoscopic Depth

Texture: Spacing, Granularity, Pattern, Orientation, Gradient

Motion: Speed, Velocity, Rhythm



Graphic Symbol Types

			Geometric Symbols		Linguistic Symbols	Pictorial Symbols
			Point	Line		
Spatial	Position	X Y				
		Retinal	Form	Size		
Shape					Text Text Text	
Color	Value				Text Text Text	
	Hue				Text Text Text	
	Saturation				Text Text Text	
Texture	Granularity					
	Pattern					
Motion Optics	Blur				Text Text Text	
	Speed					

Graphic Variable Types

See *Atlas of Knowledge* pages 36-39 for complete table.

Qualitative

Also called:
Categorical Attributes
Identity Channels

Quantitative

Also called:
Ordered Attributes
Magnitude Channels

Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols					Linguistic Symbols Text, Numerals, Punctuation Marks					Pictorial Symbols Images, Icons, Statistical Glyphs					
			Point	Line	Area	Surface	Volume											
Spatial	x	quantitative																
	y	quantitative																
	z	quantitative																
Retinal	Form	Size	quantitative	NA (Not Applicable)														
		Shape	qualitative	NA														
		Rotation	quantitative	NA														
		Curvature	quantitative	NA														
	Angle	quantitative	NA															
	Closure	quantitative	NA															
	Value	quantitative																
	Color	Hue	qualitative															
Saturation	quantitative																	
Retinal	Texture	Spacing	quantitative															
		Granularity	quantitative															
		Pattern	qualitative															
		Orientation	quantitative	NA														
		Gradient	quantitative															
	Optics	Blur	quantitative															
		Transparency	quantitative															
		Shading	quantitative															
	Motion	Stereoscopic Depth	quantitative	Point in foreground .. background	Line in foreground .. background	Area in foreground .. background	Surface in foreground .. background	Volume in foreground .. background	Text in foreground .. background					Icons in foreground .. background				
		Speed	quantitative															
Velocity		quantitative																
Rhythm	quantitative	Blinking point slow .. fast	Blinking line slow .. fast	Blinking area slow .. fast	Blinking surface slow .. fast	Blinking volume slow .. fast	Blinking text slow .. fast					Blinking icons slow .. fast						

See Atlas of Knowledge pages 36-39 for complete table.

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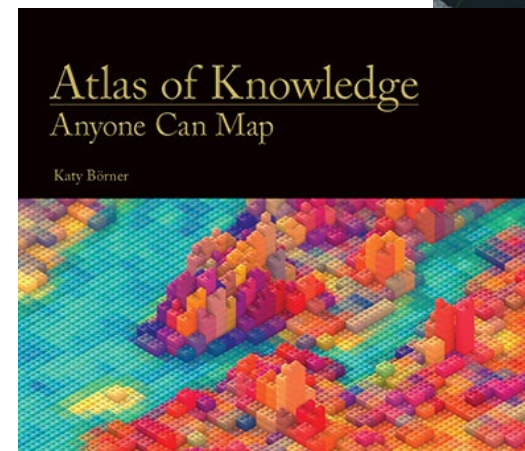
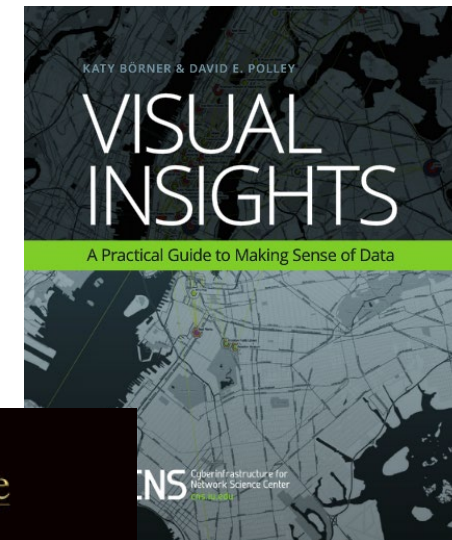
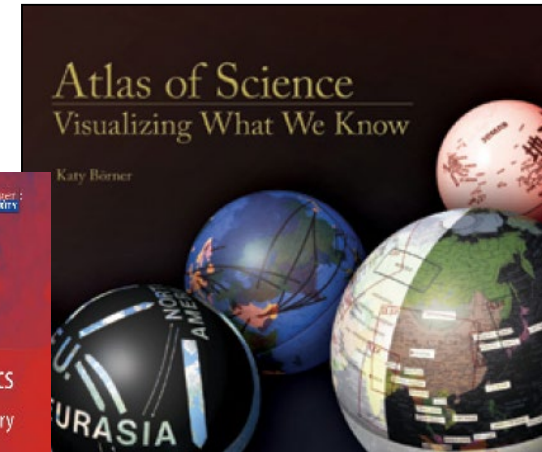
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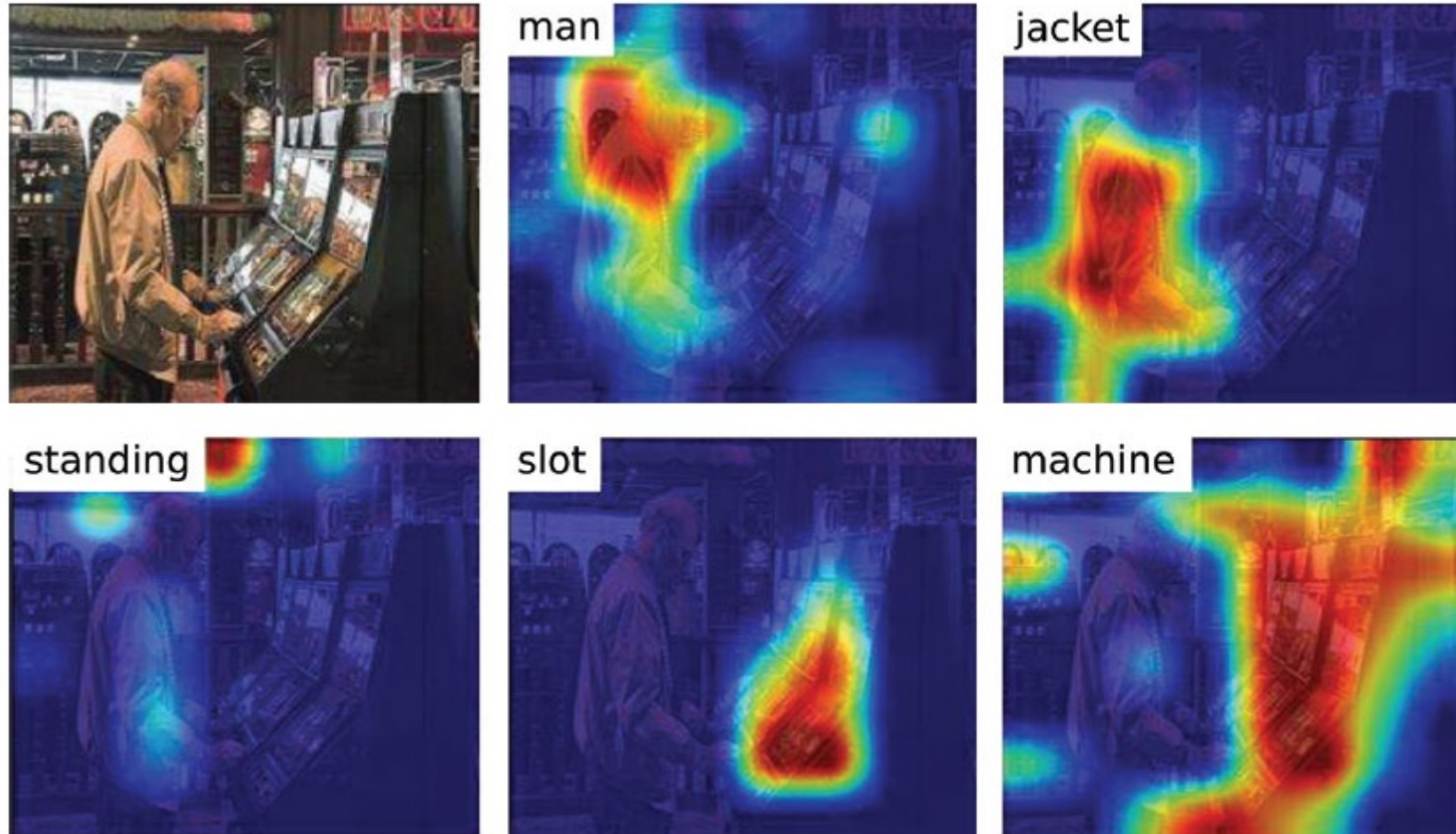
Börner, Katy (2015) **Atlas of Knowledge: Anyone Can Map**. The MIT Press. <http://scimaps.org/atlas2>



Data Visualization Literacy Framework Applied to ML Algorithms



Visualization of Results, e.g., activation map

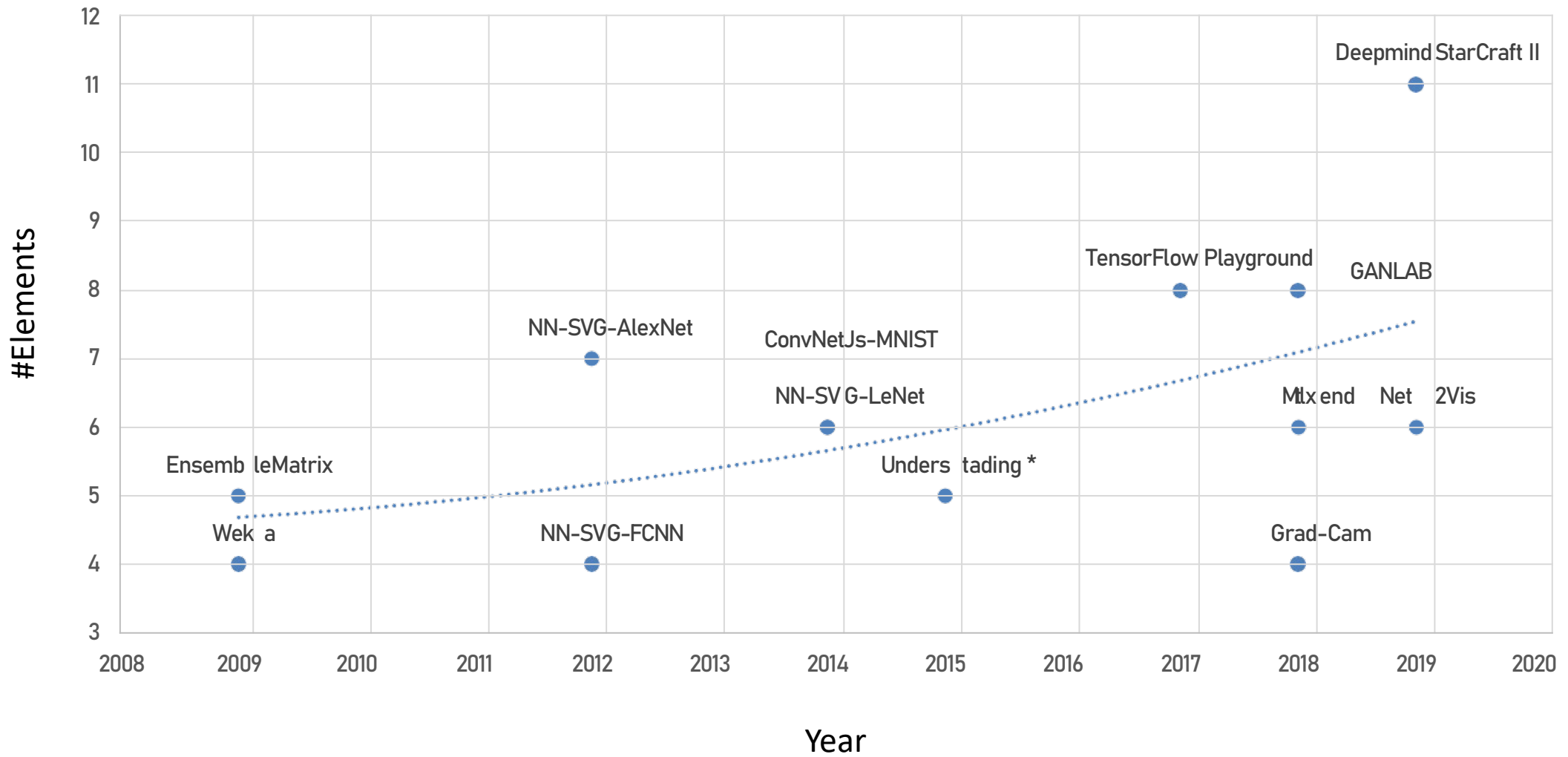


A man in a jacket is standing at the slot machine

Related Work	Graphic Symbols									Graphic Variables			Total
	Point	Line	Area	Surface	Volume	Text	Numerals	Images	Icons	Position	Form	Color	
<i>Net2Vis</i>		X	X			X	X			X		X	6
<i>NN-SVG-FCNN</i>	X	X								X		X	4
<i>NN-SVG-LeNet</i>		X	X			X	X			X		X	6
<i>NN-SVG-AlexNet</i>		X	X		X	X	X			X		X	7
<i>Understading *</i>			X			X		X		X		X	5
<i>ConvNetJs-MNIST</i>			X			X	X	X		X		X	6
<i>TensorFlow Playground</i>	X	X	X	X		X			X	X		X	8
<i>GANlab</i>	X	X	X	X		X			X	X		X	8
<i>Grad-Cam</i>				X				X		X		X	4
<i>Deepmind StarCraft II</i>	X	X	X	X		X	X	X	X	X	X	X	11
<i>Mlxtend</i>	X		X			X	X			X		X	6
<i>Weka</i>			X				X			X		X	4
<i>EnsembleMatrix</i>	X		X			X				X		X	5

* "Understading" = "Understanding neural networks through deep visualization (Yosinski et al., 2015)"





Q&A

