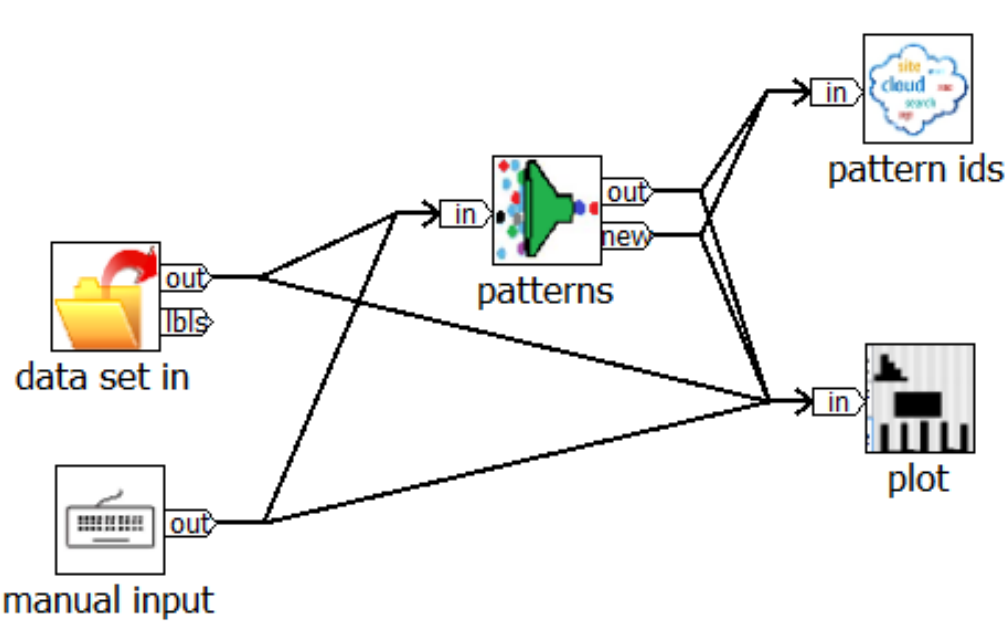
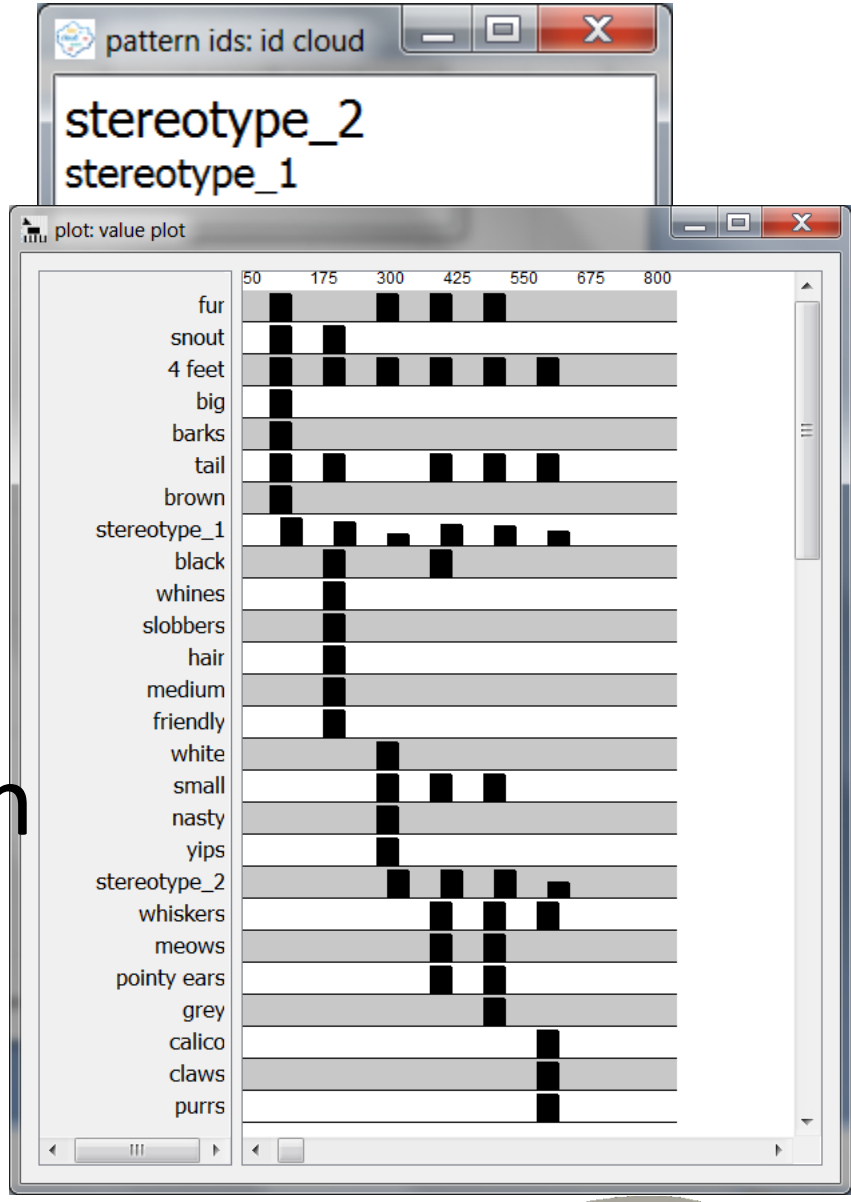




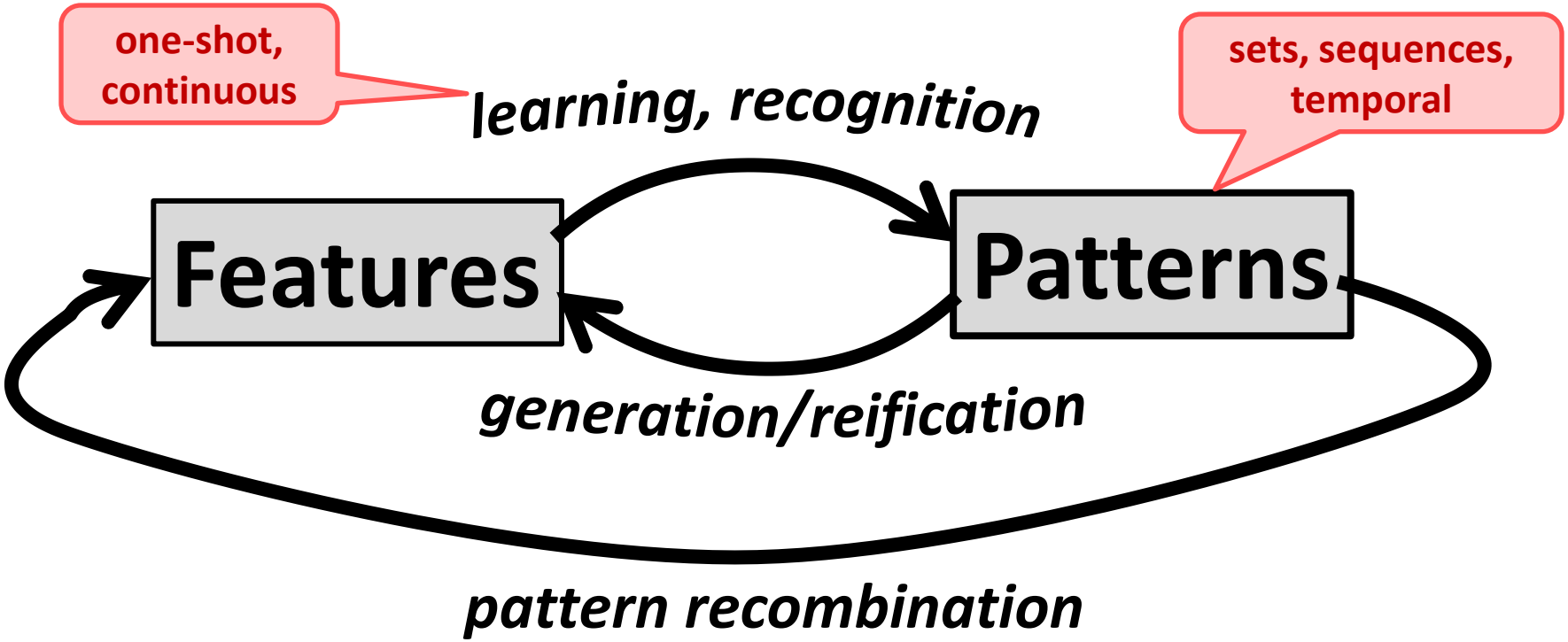
Which Features Matter How Much When

Memory Patterns and Learning in NeurOS

Lee Scheffler, Cognitivity

Cognitivity™
www.cognitivity.technology

What This Is All About



cascades/layers/meshes of patterns

Cognitivity™
www.cognitivity.technology

Approach

(Braitenberg: "...downhill invention...")

Build, run and improve cognitive functions
by interconnecting
reusable biologically inspired components

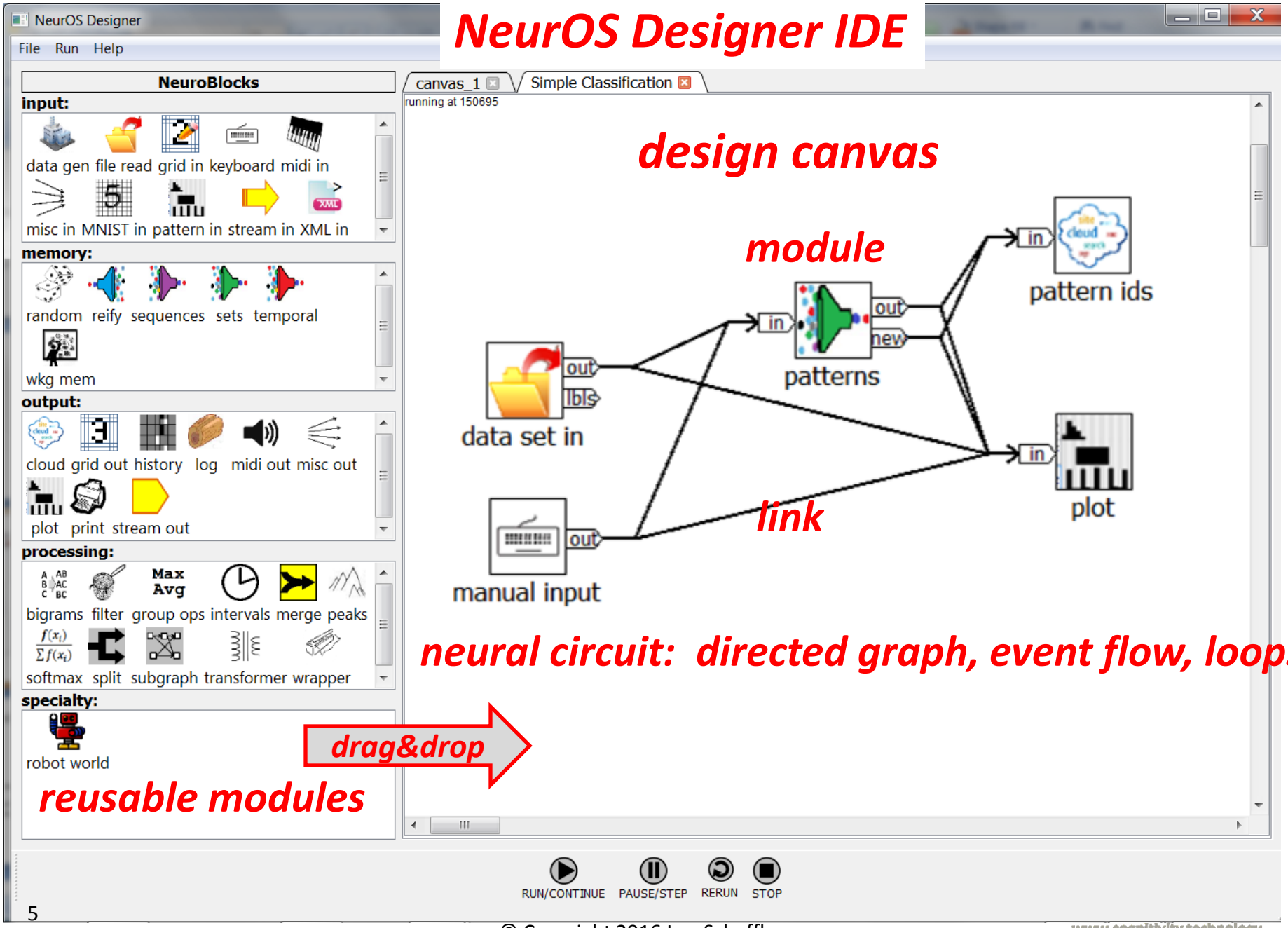
Open, integrative, NOT one-size-fits-all

Cognitivity™
www.cognitivity.technology

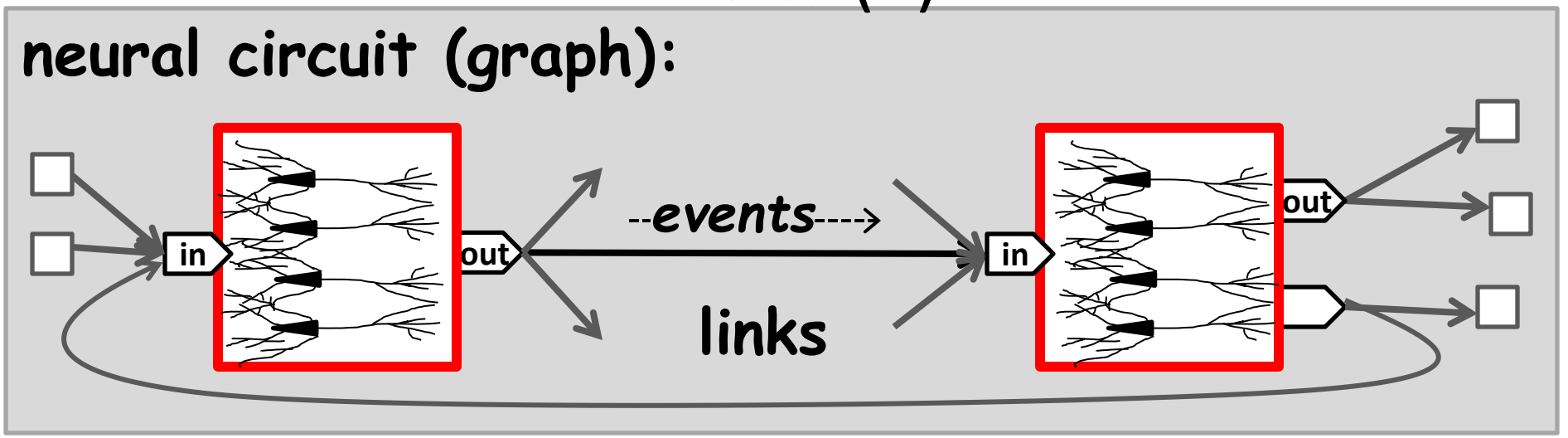
Talk Overview

- Brief tour of NeurOS/NeuroBlocks
- **Memory patterns**
  - **Sets, Sequences, Temporal**
  - **Reification**
- Example cognitive functions
  - unsupervised learning
  - concurrent exemplars & stereotypes
  - prediction
  - layers of patterns
  - labels as synonyms (supervised learning)
  - imagination
  - context disambiguation
  - attention

NeurOS Designer IDE



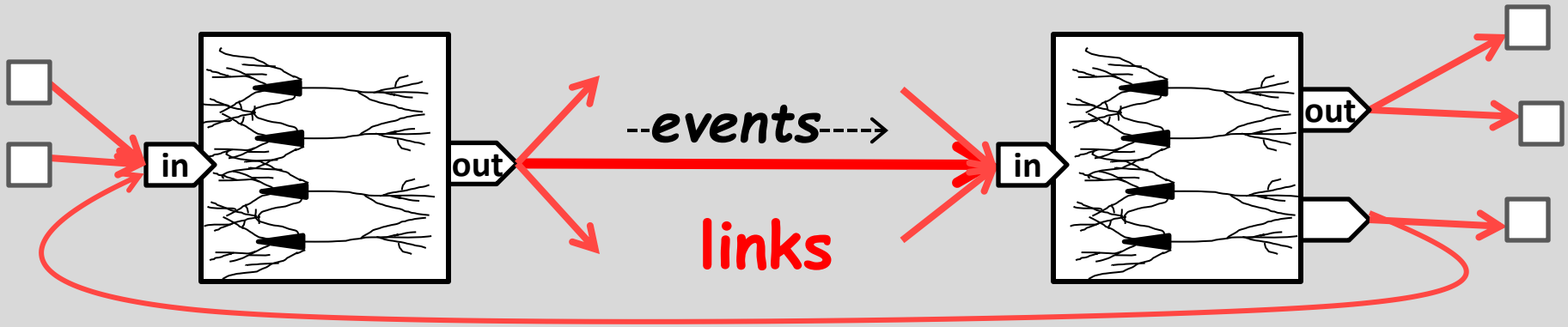
Basics (1)



module	Group/layer of neurons with similar function; state
link	Mulitiplexed event signal path: axons of multiple neurons
neural circuit	Directed signal flow graph, loops, nestable sub-graphs
event	New spiking rate of a neuron

Basics (2)

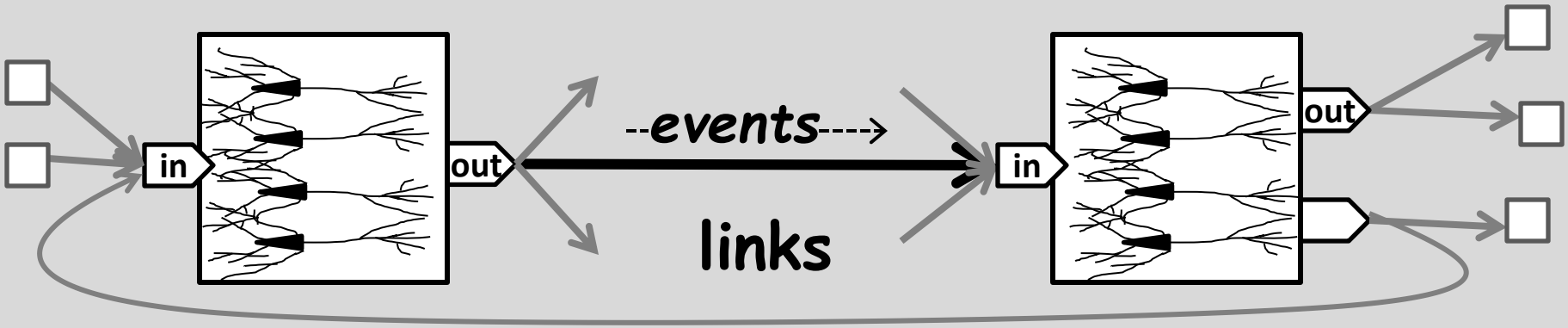
neural circuit (graph):



module	Group/layer of neurons with similar function; state
link	Mulitiplexed event signal path: axons of multiple neurons
neural circuit	Directed signal flow graph, loops, nestable sub-graphs
event	New spiking rate of a neuron

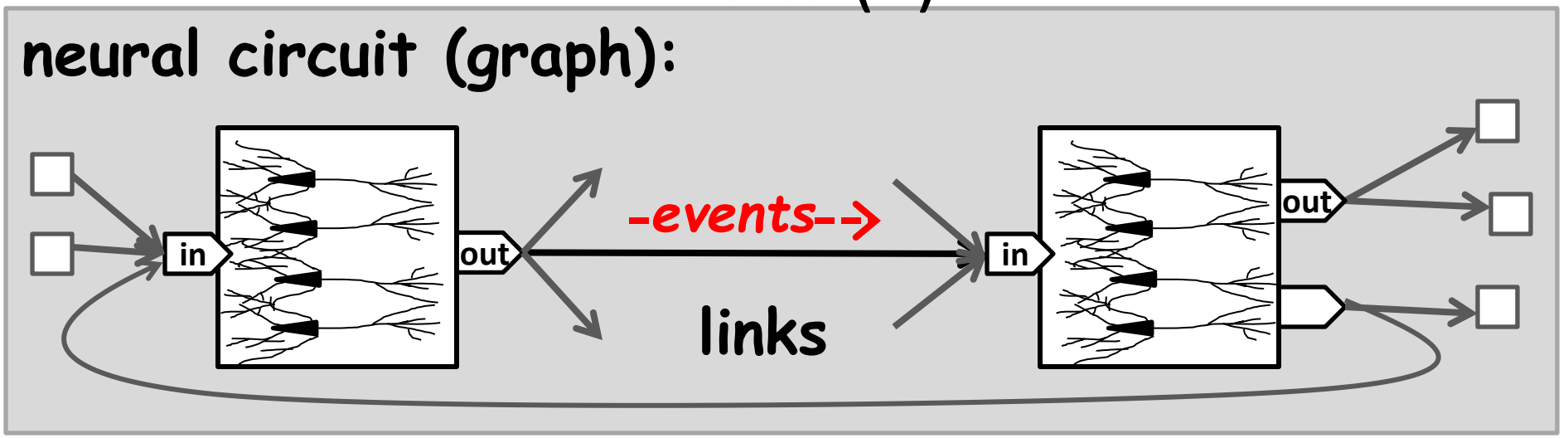
Basics (3)

neural circuit (graph):



module	Group/layer of neurons with similar function; state
link	Mulitiplexed event signal path: axons of multiple neurons
neural circuit	Directed signal flow graph, loops, nestable sub-graphs
event	New spiking rate of a neuron

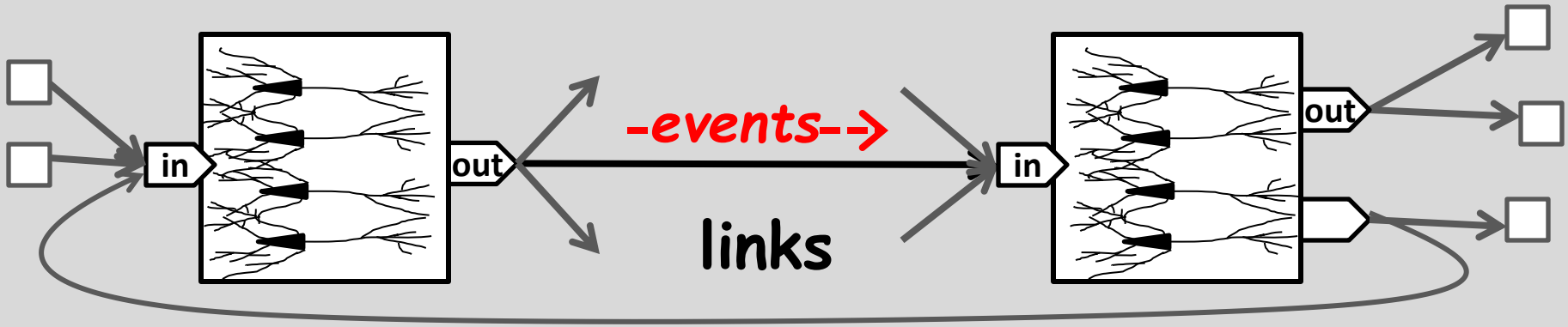
Basics (4)

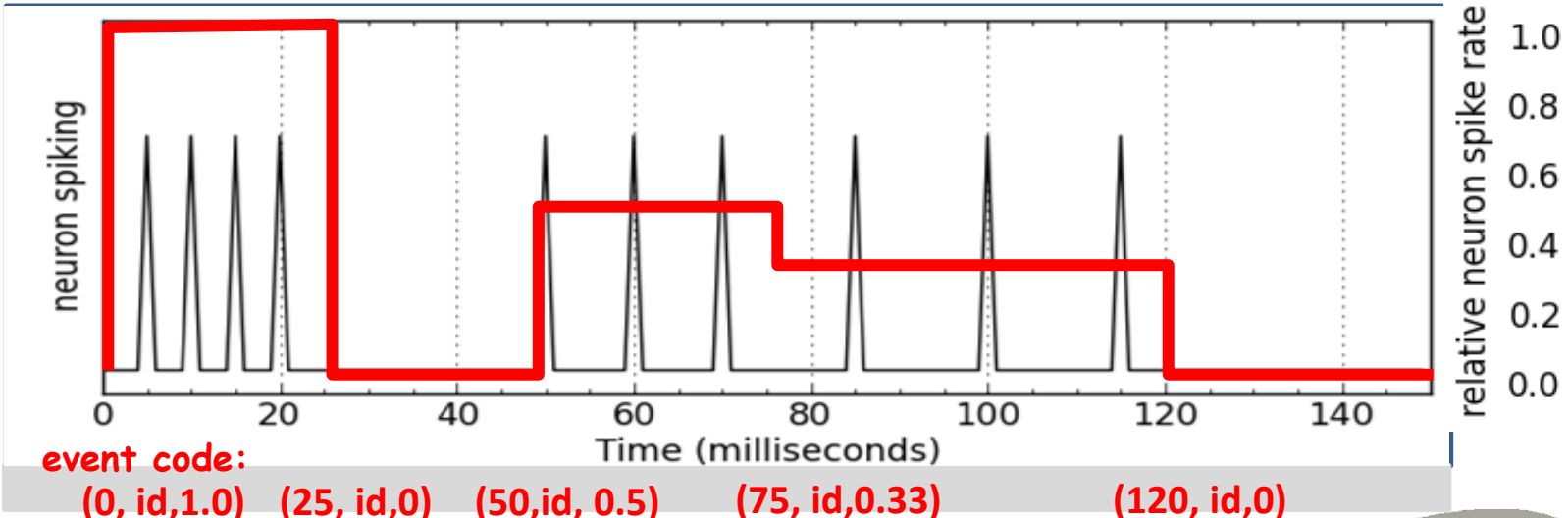


module	Group/layer of neurons with similar function; state
link	Mulitiplexed event signal path: axons of multiple neurons
neural circuit	Directed signal flow graph, loops, nestable sub-graphs
event	New spiking rate of a neuron

Basics (5)

neural circuit (graph):

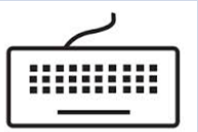
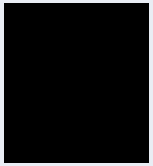
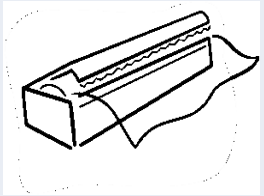
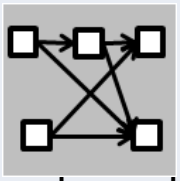
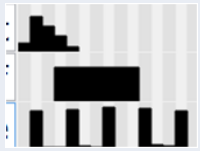
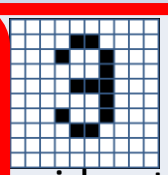
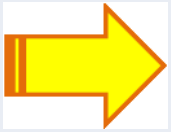




event code:

(0, id,1.0) (25, id,0) (50,id, 0.5) (75, id,0.33) (120, id,0)

Module Types

inputs (senses)	 keyboard  file in  temporal pattern in  grid in  data gen  stream in  MIDI in
processing	 filter  transformer  group ops  wrapper  subgraph
memory	 working memory  set patterns  sequence patterns  temporal patterns  pattern reify
outputs (actions, effectors)	 print  plot  cloud  grid out  stream out  log  MIDI out

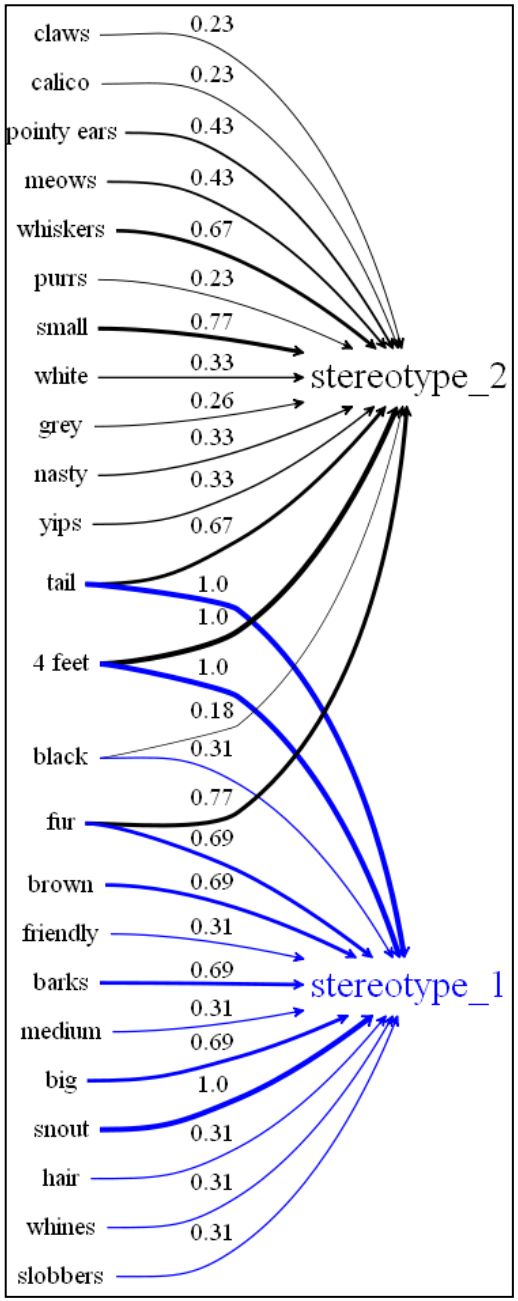
Long-Term Memory: Feature Patterns

- **Feature**: any distinct concept at any level of abstraction
  - any distinct neural (axonal) signal
  - spiking rate of a neuron
- **Pattern**: collection of weighted features
  - like a neuron or neuron assembly
  - optional expected value, time distributions
  - *no predefinition of input feature space*
- **Matching (recognition)**: sum of weight-value products
  - normalized, difference/error tolerant
  - output is a relative spiking rate reflecting match confidence
- **Pattern space**: collection of patterns
  - managed/accessed by one or more Modules
- Cascaded/layered patterns of patterns
  - a pattern is a feature

NOT neural networks!

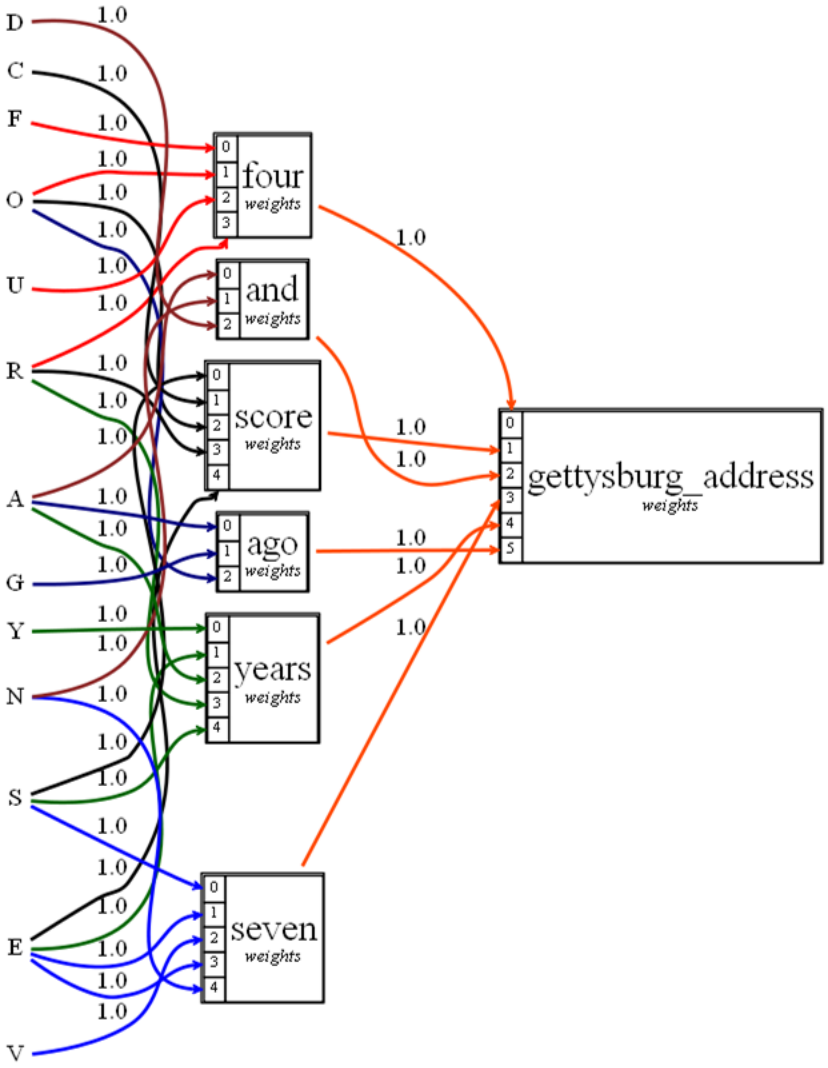
Memory Pattern/Module Types

Sets	Concurrent feature collections in any order Semantic range: any/OR, a few, some, many, most, all/AND
Sequences	Time-independent sequences of features Parameters for non-exact sequence matching
Temporal Sequences	Time-relative sequences of multiple features Parameters for non-exact matching, speed range
Reify	Inverse: generate pattern features e.g., prediction, feedback, imagination



	stereotype_1	stereotype_2
brown	**0.69**	
friendly	0.31	
barks	**0.69**	
medium	0.31	
fur	**0.69**	**0.77**
big	**0.69**	
hair	0.31	
4 feet	**1.0**	**1.0**
slobbers	0.31	
black	0.31	0.18
whines	0.31	
snout	**1.0**	
tail	**1.0**	**0.67**
meows		0.43
yips		0.33
claws		0.23
pointy ears		0.43
calico		0.23
purrs		0.23
whiskers		**0.67**
small		**0.77**
nasty		0.33
white		0.33
grey		0.26

Pattern Examples



Learning Rules

- Compute and emit **match scores** for all (relevant) patterns in pattern space
  - these patterns are features too!
- If some pattern match score exceeds **novelty threshold**, ***update*** best matching pattern:
  - adjust feature weights; anneal over repetition
  - add/remove features
- Otherwise, ***create*** a new pattern
- ***Forget*** patterns which rarely/never match

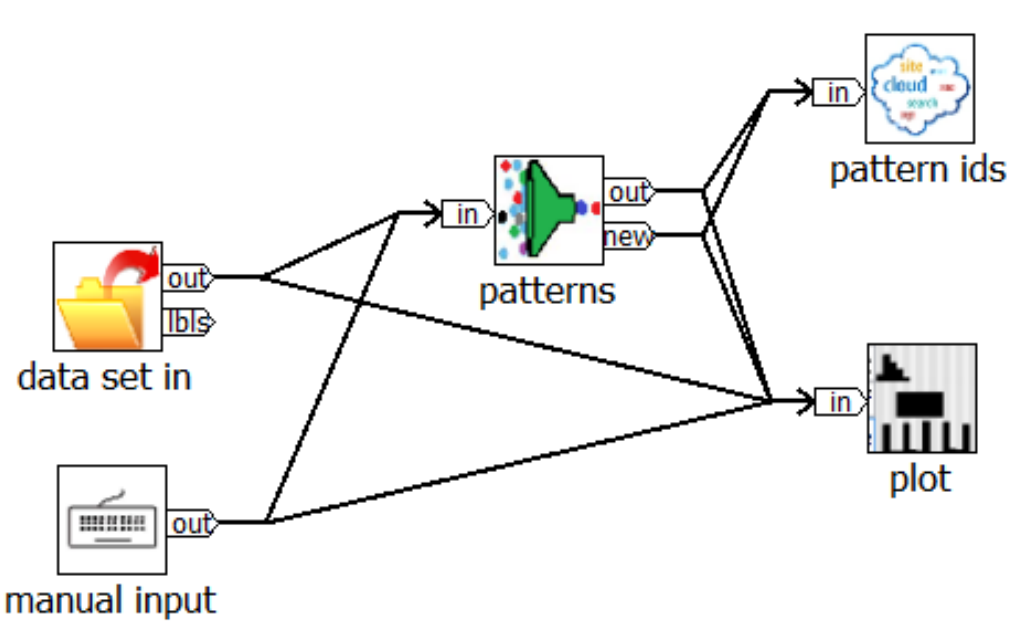
Cognitive Function Examples

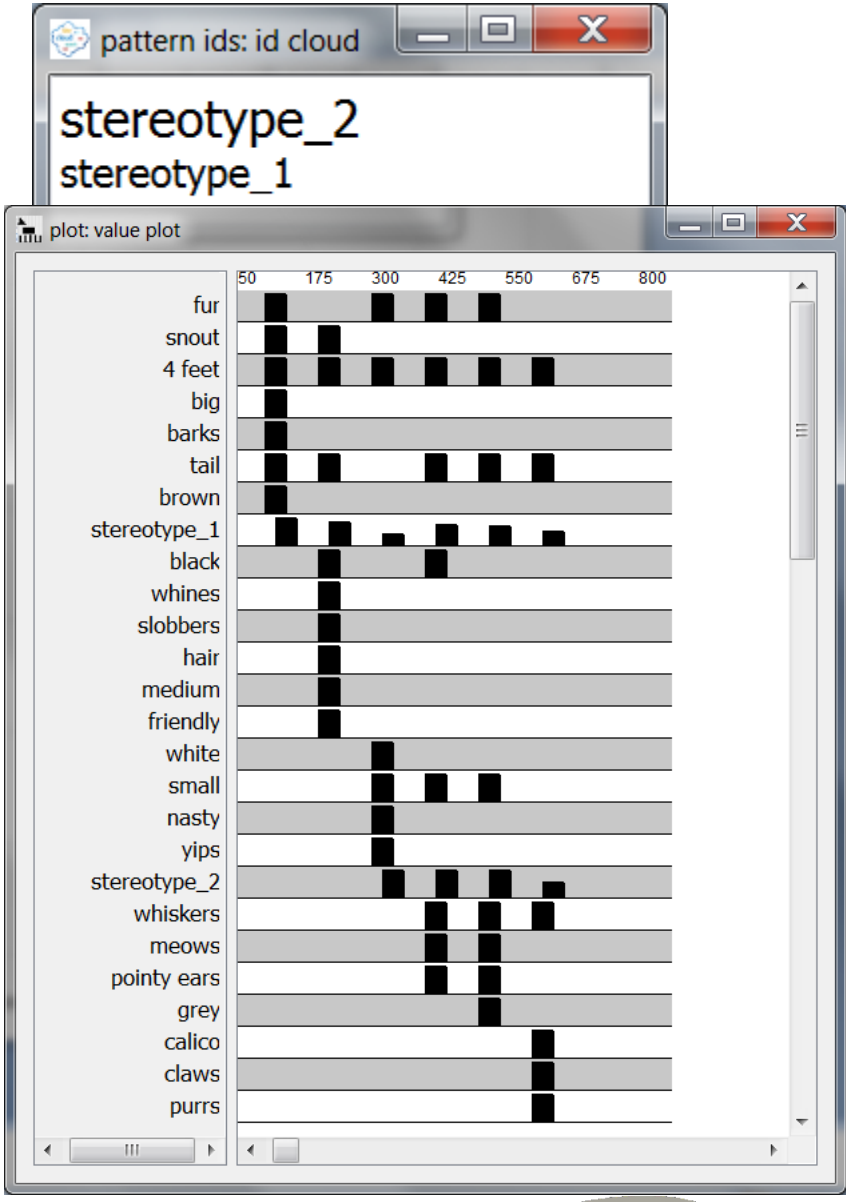
- unsupervised learning
- concurrent exemplars & stereotypes
- prediction
- layers of patterns
- labels as synonyms (supervised learning)
- imagination
- context disambiguation
- attention

Unlabeled Data

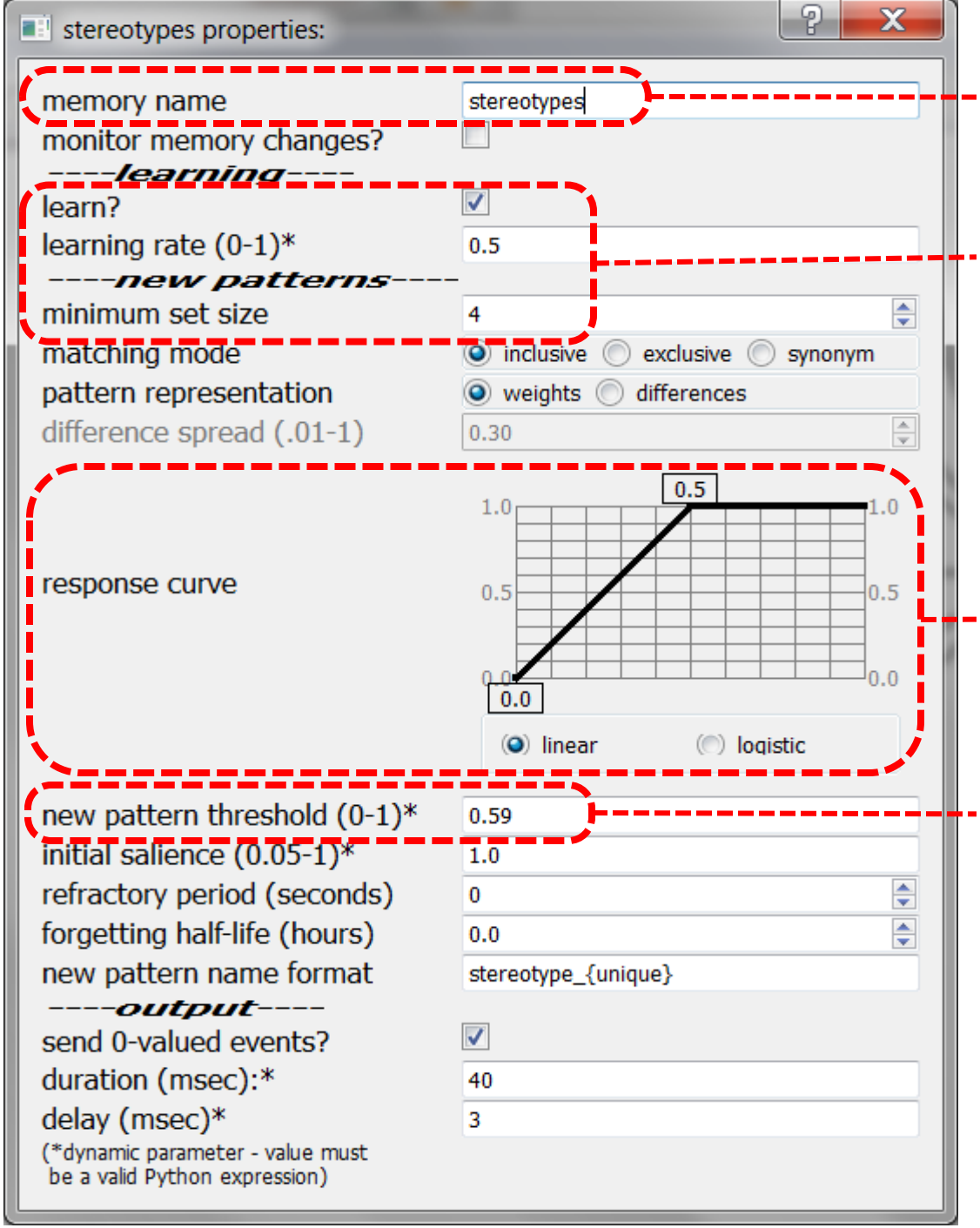
fur, snout, barks, big, 4 feet, brown, tail
hair, snout, whines, medium, 4 feet, black, tail, friendly, slobbers
fur, yips, small, 4 feet, white, nasty
fur, tail, small, black, 4 feet, pointy ears, meows, whiskers
fur, tail, small, grey, 4 feet, pointy ears, meows, whiskers
tail, calico, purrs, 4 feet, whiskers, claws

Small dataset, one-shot/continuous incremental learning





Unsupervised Learning



pattern space

learning controls

match score normalization
(some/many semantic)

novelty threshold

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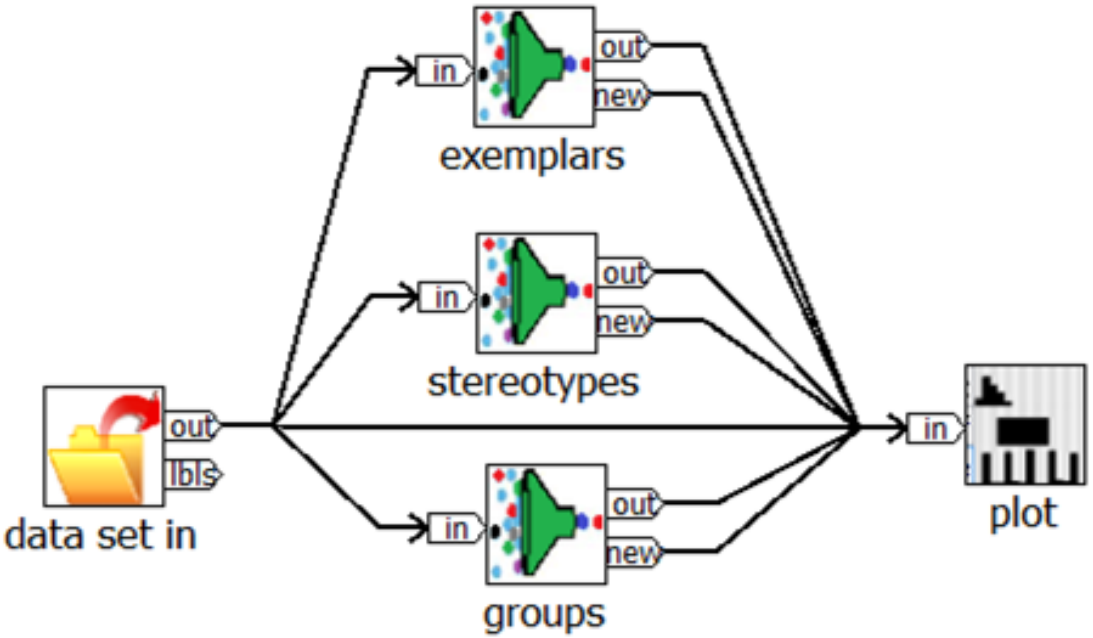
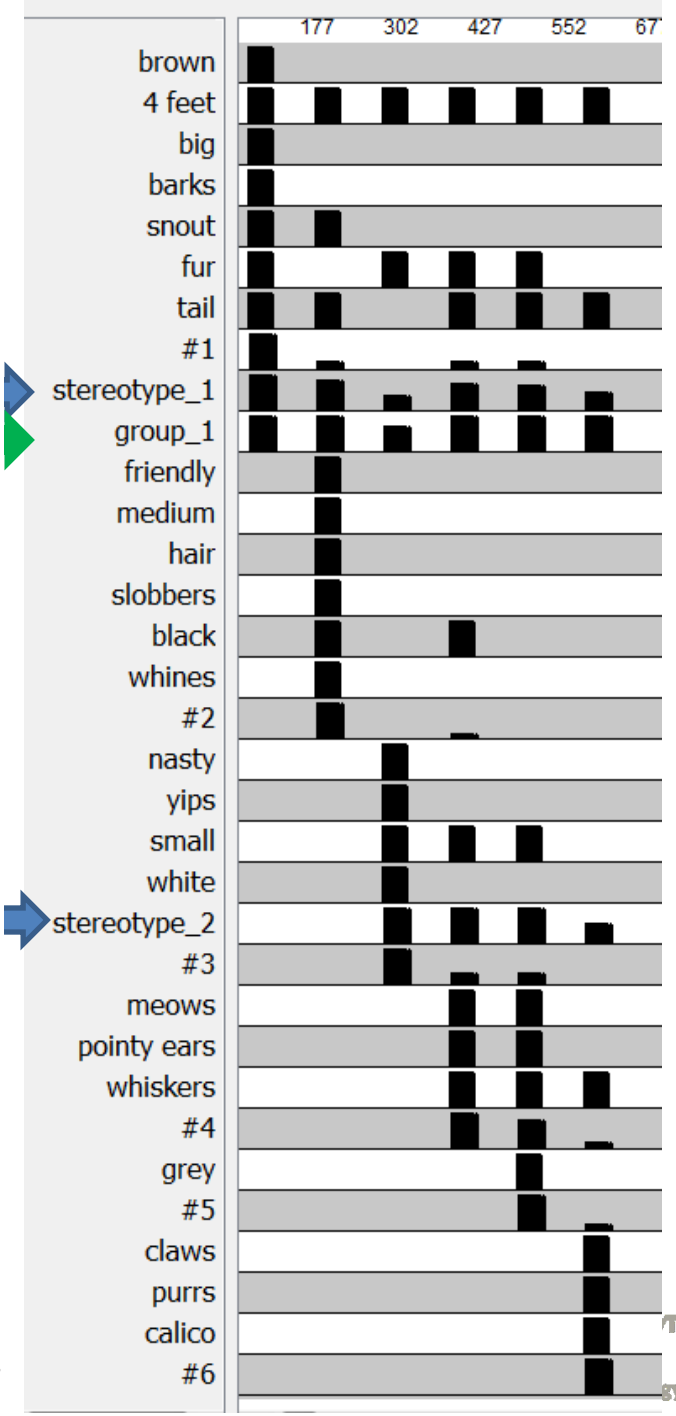
	exemplars						stereotypes		
novelty:	*0.9*						*0.59*		*0.5*
curve min-max:	*0.25 - 1*						*0 - 0.5*		*0 - 0.3*
pattern id:	#1	#2	#3	#4	#5	#6	stereotype_1	stereotype_2	group_1
4 feet	1	1	1	1	1	1	1	1	1
barks	1						0.69		0.14
big	1						0.69		0.14
black		1		1			0.31	0.18	0.22
brown	1						0.69		0.14
calico						1		0.23	0.33
claws						1		0.23	0.33
friendly		1					0.31		
fur	1		1	1	1	1	0.69	0.77	0.59
grey					1			0.26	0.22
hair		1					0.31		
medium		1					0.31		
meows				1	1			0.43	0.37
nasty			1					0.33	
pointy ears				1	1			0.43	0.37
purrs						1		0.23	0.33
slobbers		1					0.31		
small			1	1	1			0.77	0.45
snout	1	1					1		0.22
tail	1	1		1	1	1	1	0.67	0.92
whines		1					0.31		
whiskers				1	1	1		0.67	0.7
white			1					0.33	
yips			1					0.33	

Pattern Match Scores

curve min-max:	*0.25 - 1*						*0 - 0.5*		*0 - 0.3*
pattern id:	#1	#2	#3	#4	#5	#6	stereotype_1	stereotype_2	group_1
fur, barks, tail	0.24						0.62	0.42	0.85
small, meows, whiskers				0.17	0.17			0.54	0.78
small, meows, whiskers, black				0.33	0.17		0.08	0.60	0.9
big, brown, barks, tail	0.43						0.8	0.19	0.69

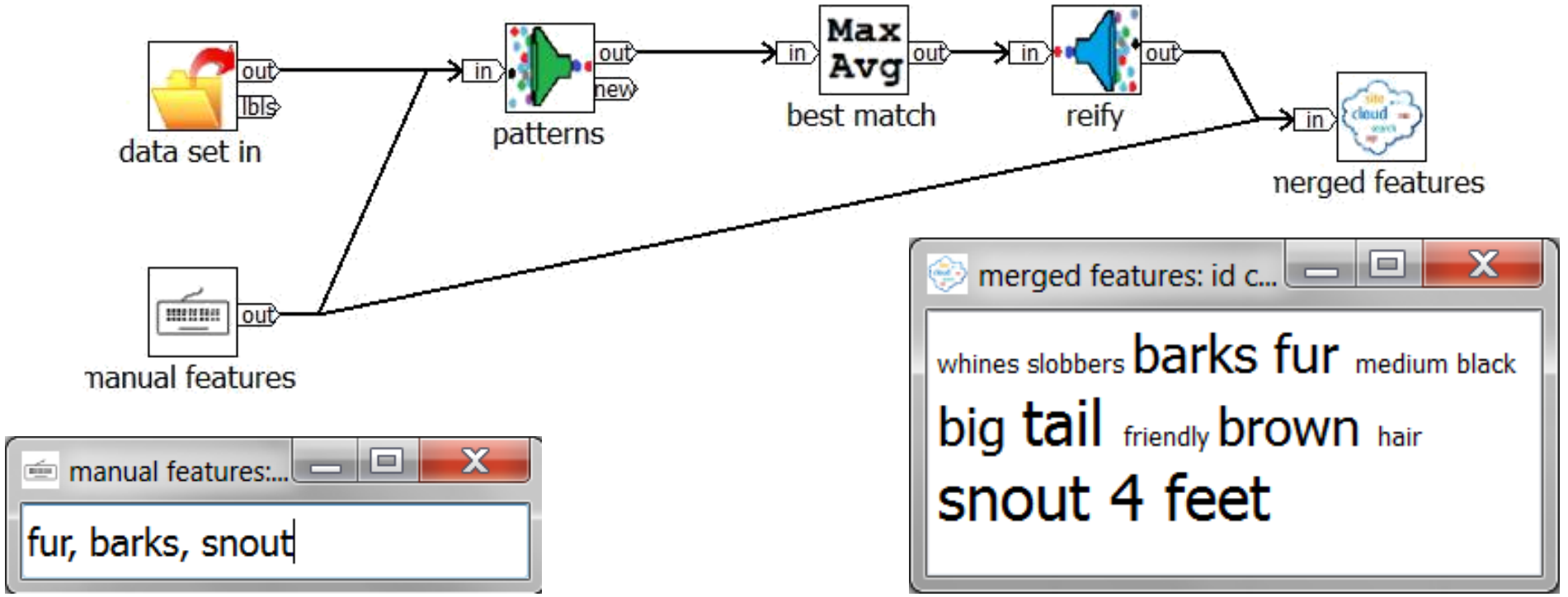
Concurrent Exemplars & Stereotypes



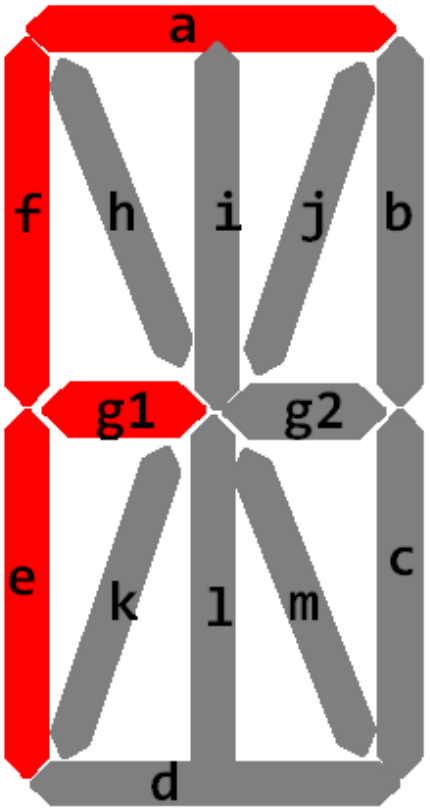


Prediction

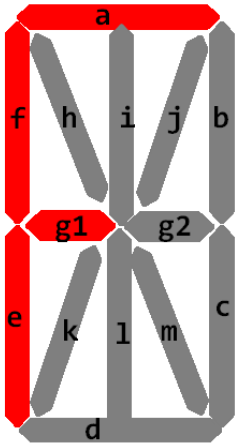
Partial features ➔ pattern recognition ➔ regeneration of missing features



Layers of Patterns



F = {a,e,f,g1}



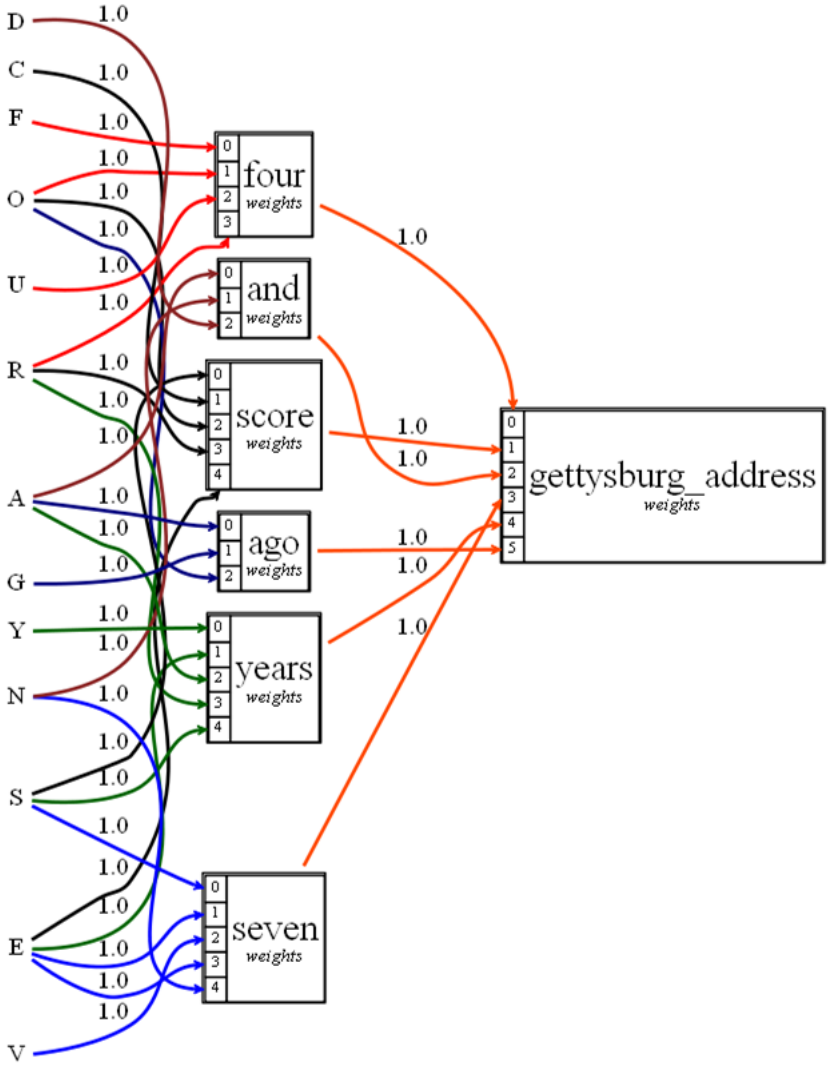
F = {a,e,f,g1}

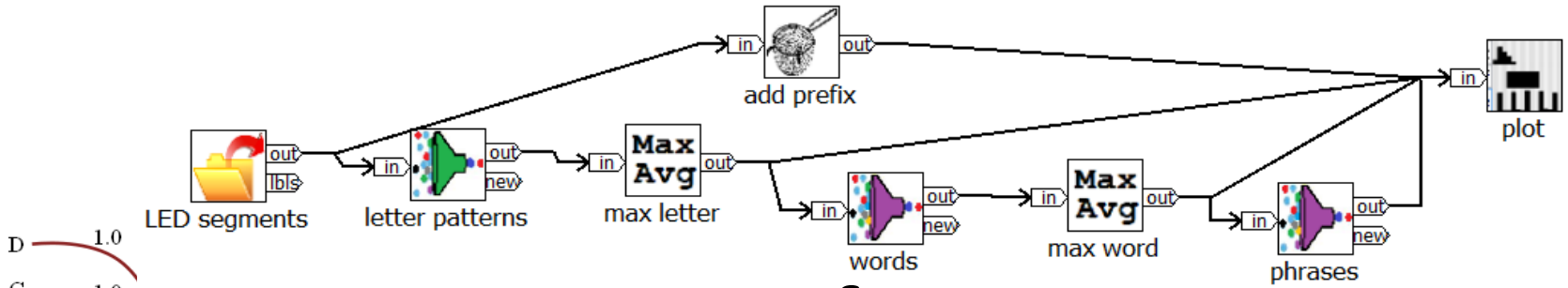
Layers of Patterns

letter

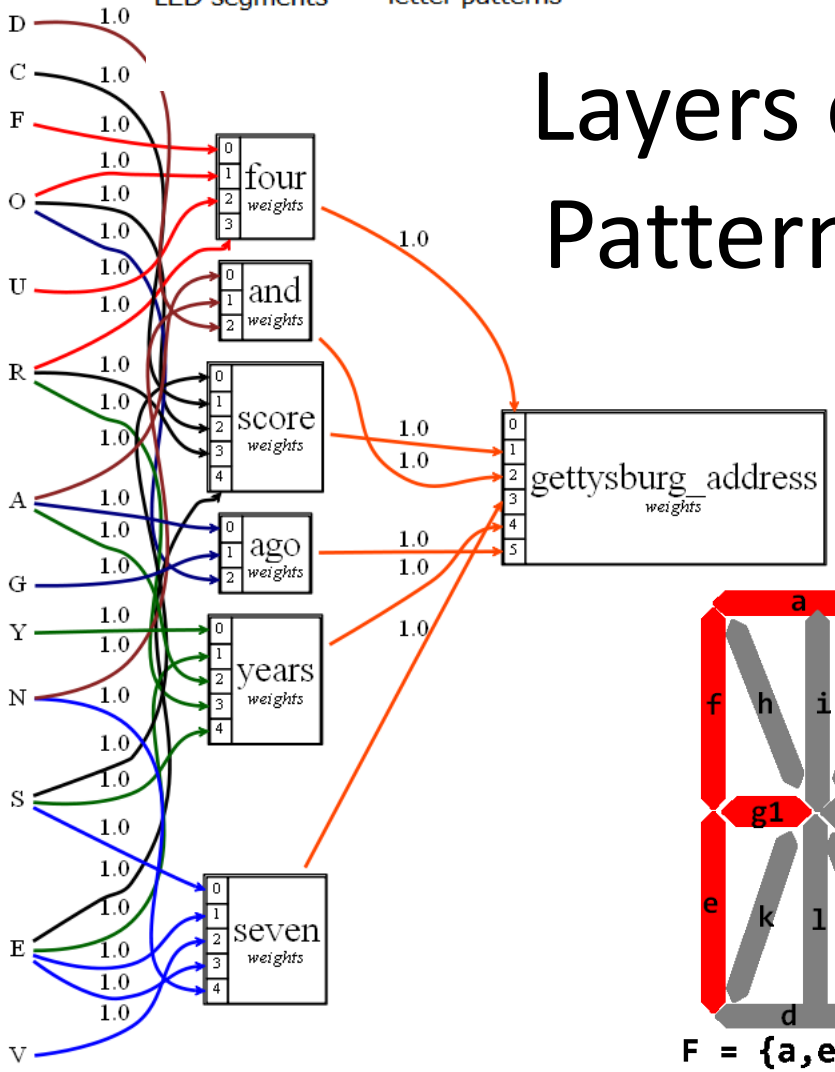
LED segment

	A	C	D	E	F	G	N	O	R	S	U	V	Y
c	1.0		1.0			1.0	1.0	1.0		1.0	1.0		
b	1.0		1.0				1.0	1.0	1.0		1.0		1.0
a	1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	1.0			
f	1.0	1.0		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
e	1.0	1.0		1.0	1.0	1.0	1.0	1.0	1.0		1.0	1.0	
g2	1.0			1.0		1.0			1.0	1.0			1.0
g1	1.0			1.0	1.0				1.0	1.0			1.0
d		1.0	1.0	1.0		1.0		1.0		1.0	1.0		
i			1.0										
l			1.0										1.0
h							1.0						
m							1.0		1.0				
k												1.0	
j												1.0	





Layers of Patterns



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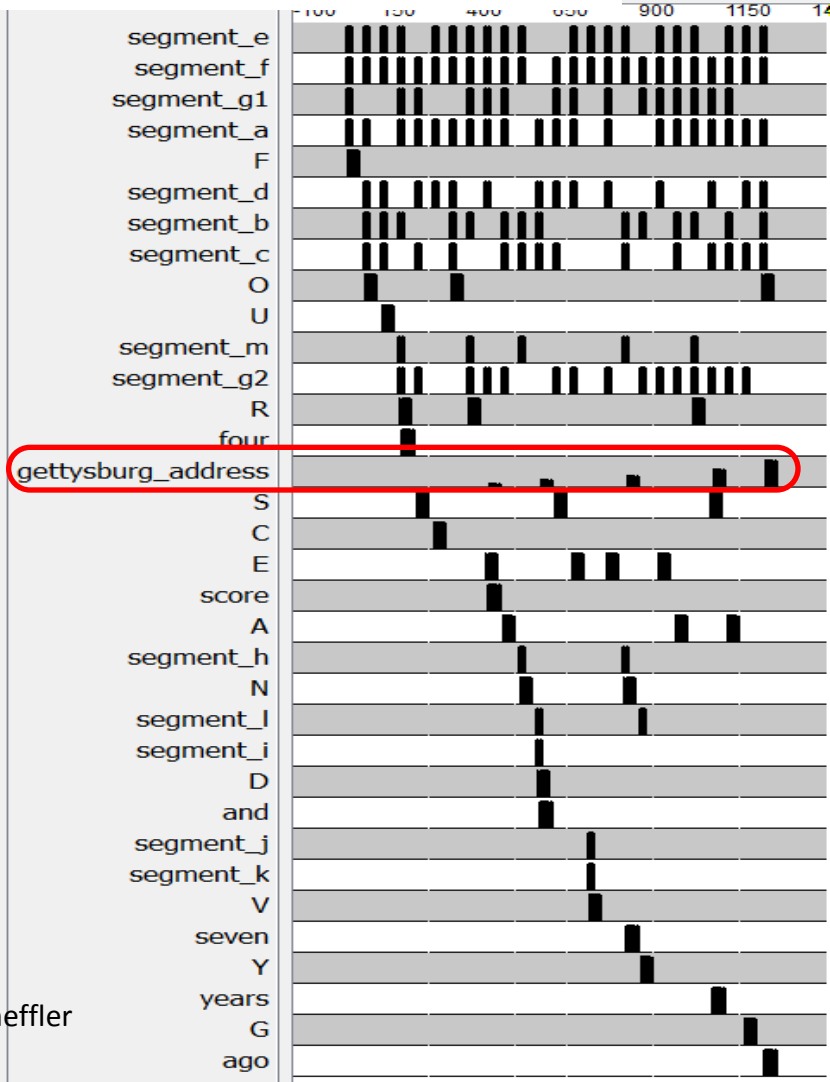
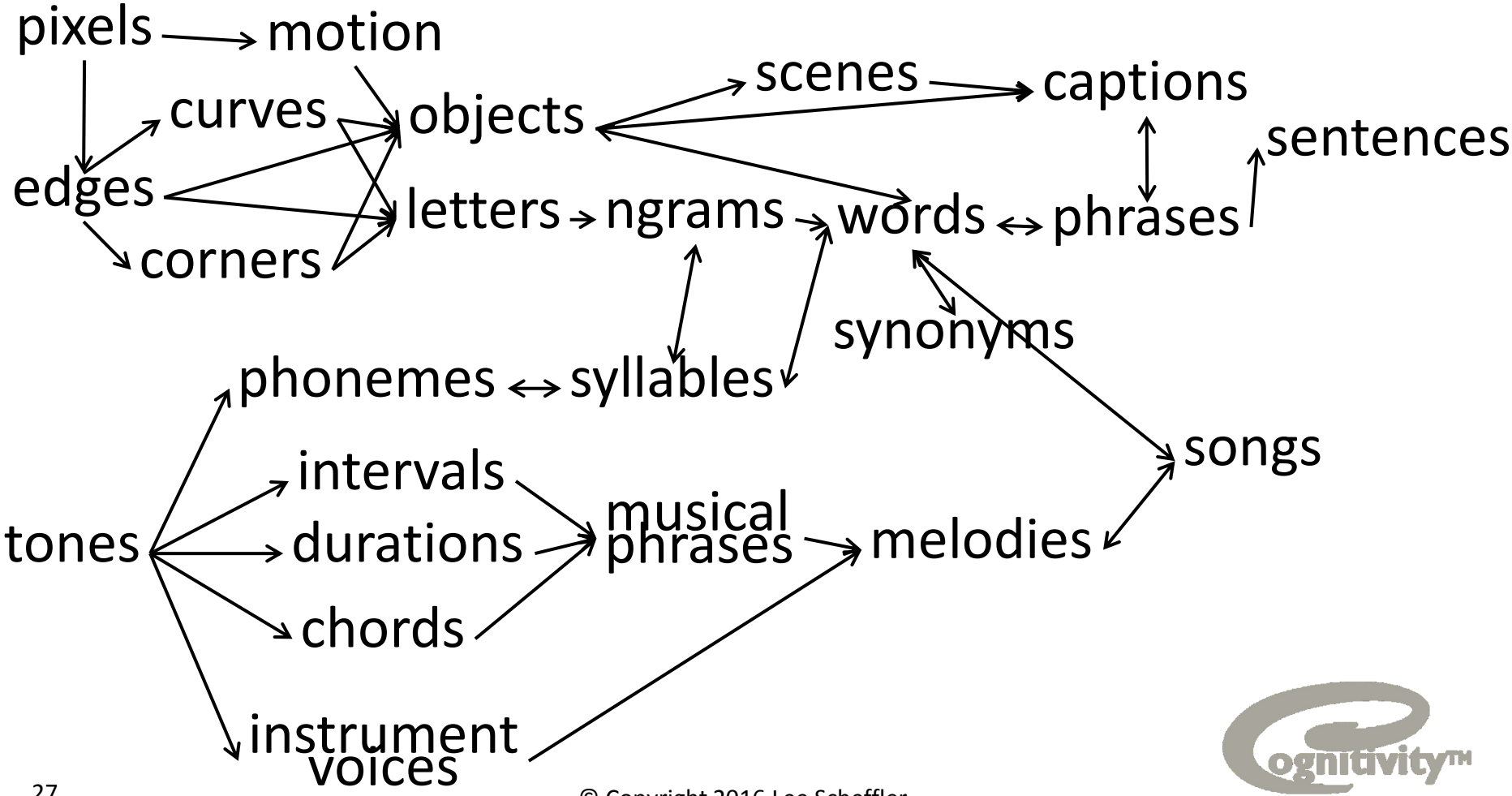


Layers of Pattern Recombination

(including bi-directionality)



Labeled Data

dog = fur, snout, barks, big, 4 feet, brown, tail
dog = hair,snout,whines,medium,4 feet,black,tail,friendly,slobbers
dog = fur, yips, small, 4 feet, white, nasty
cat = fur, tail, small, black, 4 feet, pointy ears, meows, whiskers
cat = fur, tail, small, grey, 4 feet, pointy ears, meows, whiskers
cat = tail, calico, purrs, 4 feet, whiskers, claws

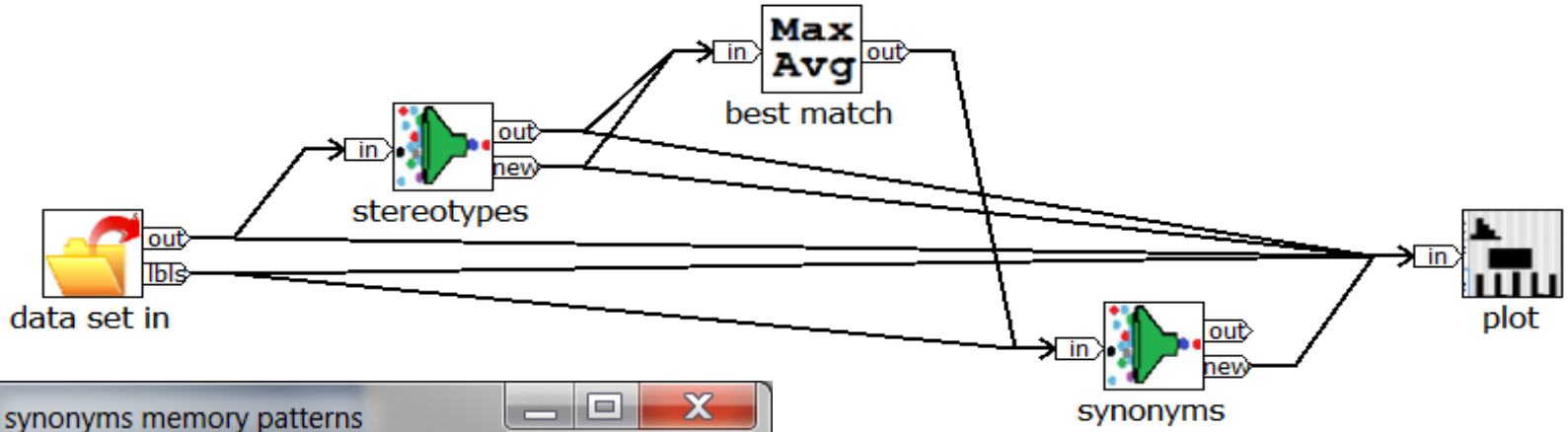
Labeled Data

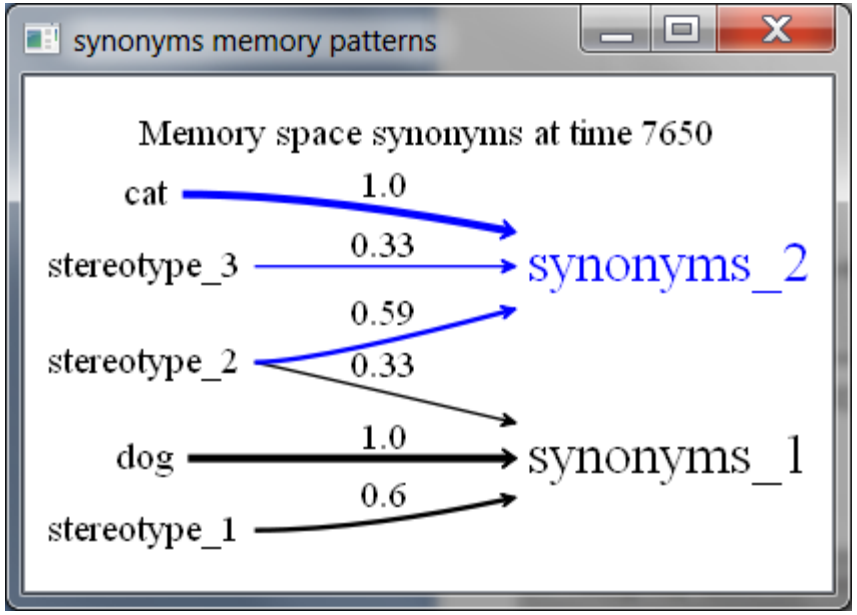
dog = fur, snout, barks, big, 4 feet, brown, tail
dog = hair,snout,whines,medium,4 feet,black,tail,friendly,slobbers

dog = fur, yips, small, 4 feet, white, nasty
cat = fur, tail, small, black, 4 feet, pointy ears, meows, whiskers
cat = fur, tail, small, grey, 4 feet, pointy ears, meows, whiskers

cat = tail, calico, purrs, 4 feet, whiskers, claws

Labels as Synonyms
(Supervised Learning)

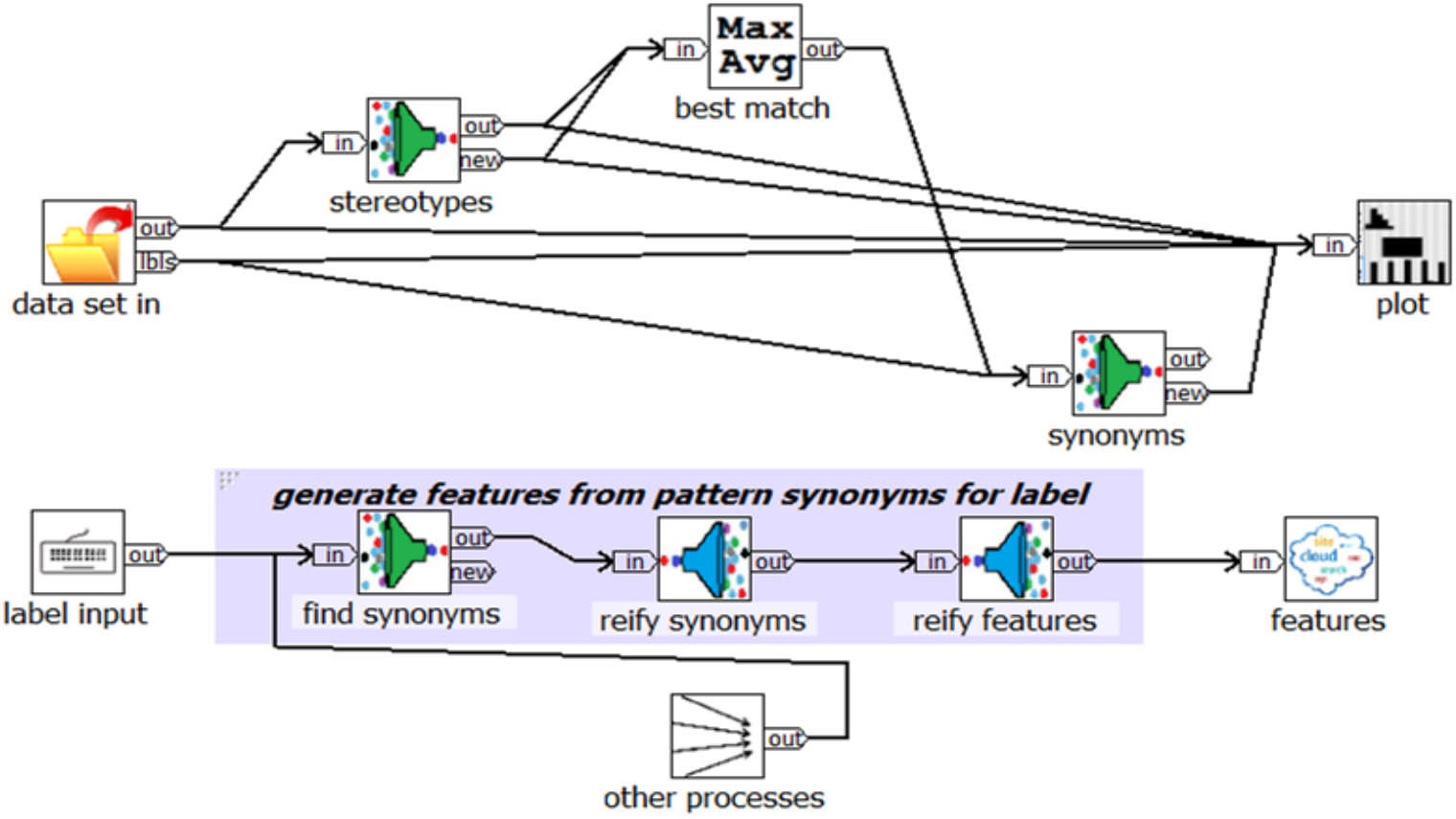




synonyms memory pa...

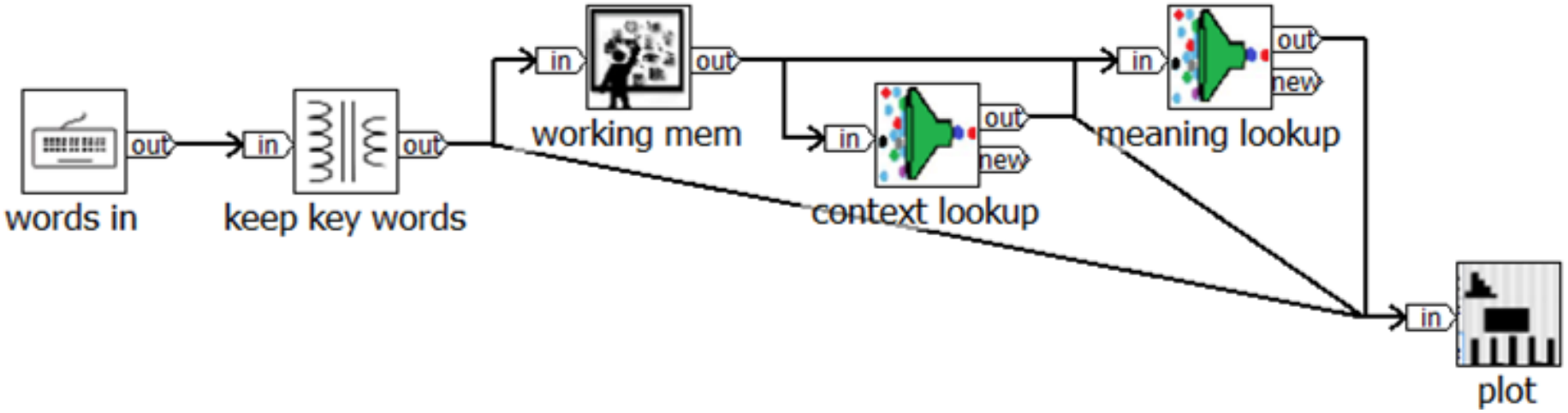
	synonyms_1	synonyms_2
stereotype_2	0.33	0.59
stereotype_1	0.6	
dog	**1.0**	
cat		**1.0**
stereotype_3		0.33

Imagination



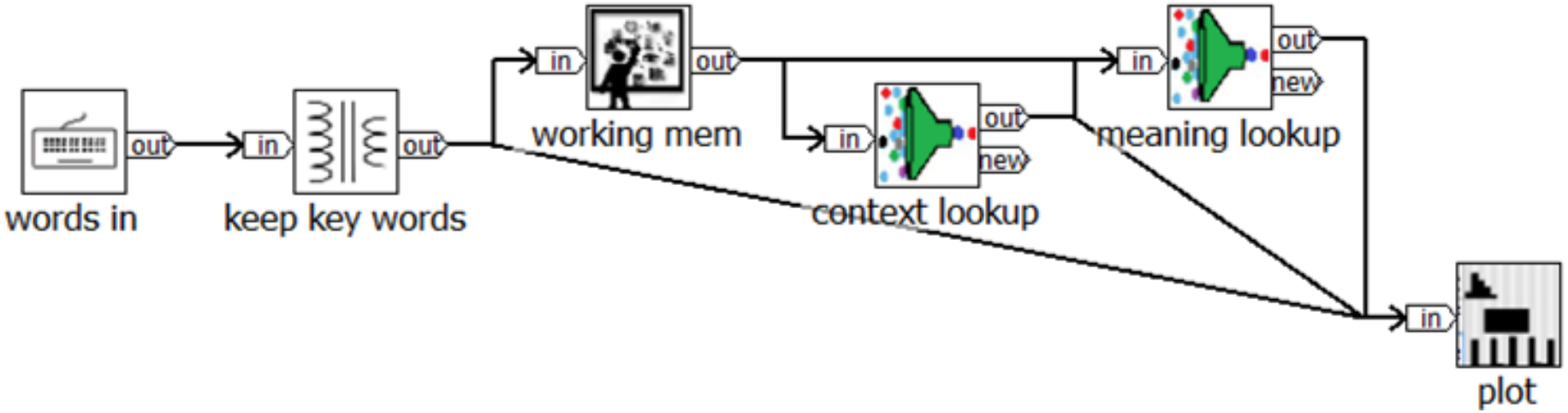
Context Disambiguation

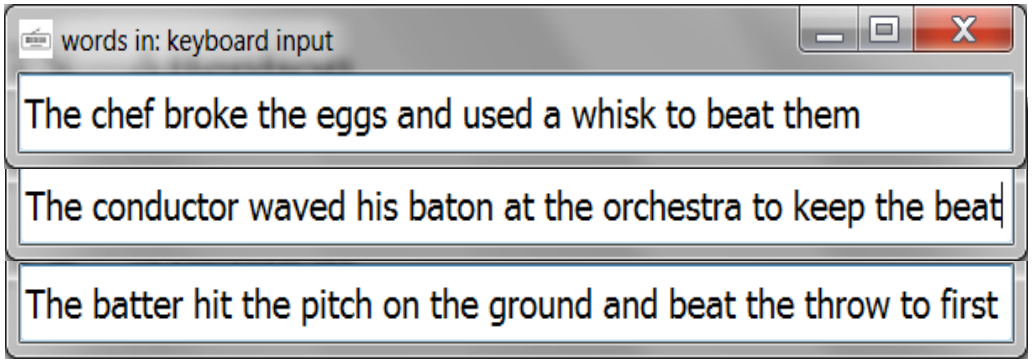
sports_context = batter, hit, ground, throw, ball, strike, out, safe, pitch, beat, score, single, double, triple
music_context = conductor, orchestra, chorus, baton, pitch, beat, score, arpeggio, chord, key, note
cooking_context = chef, kitchen, eggs, flour, spatula, beat, pan, pot, batter



Context Disambiguation

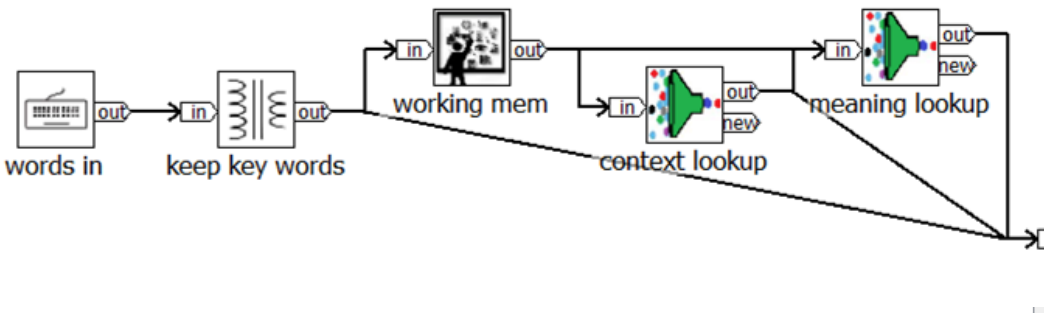
sports_context = batter, hit, ground, throw, ball, strike, out, safe, pitch, beat, score, single, double, triple
music_context = conductor, orchestra, chorus, baton, pitch, beat, score, arpeggio, chord, key, note
cooking_context = chef, kitchen, eggs, flour, spatula, beat, pan, pot, batter

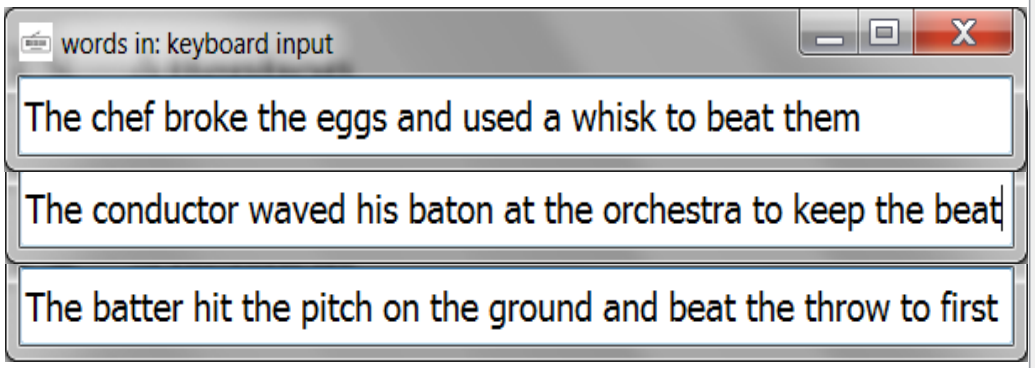


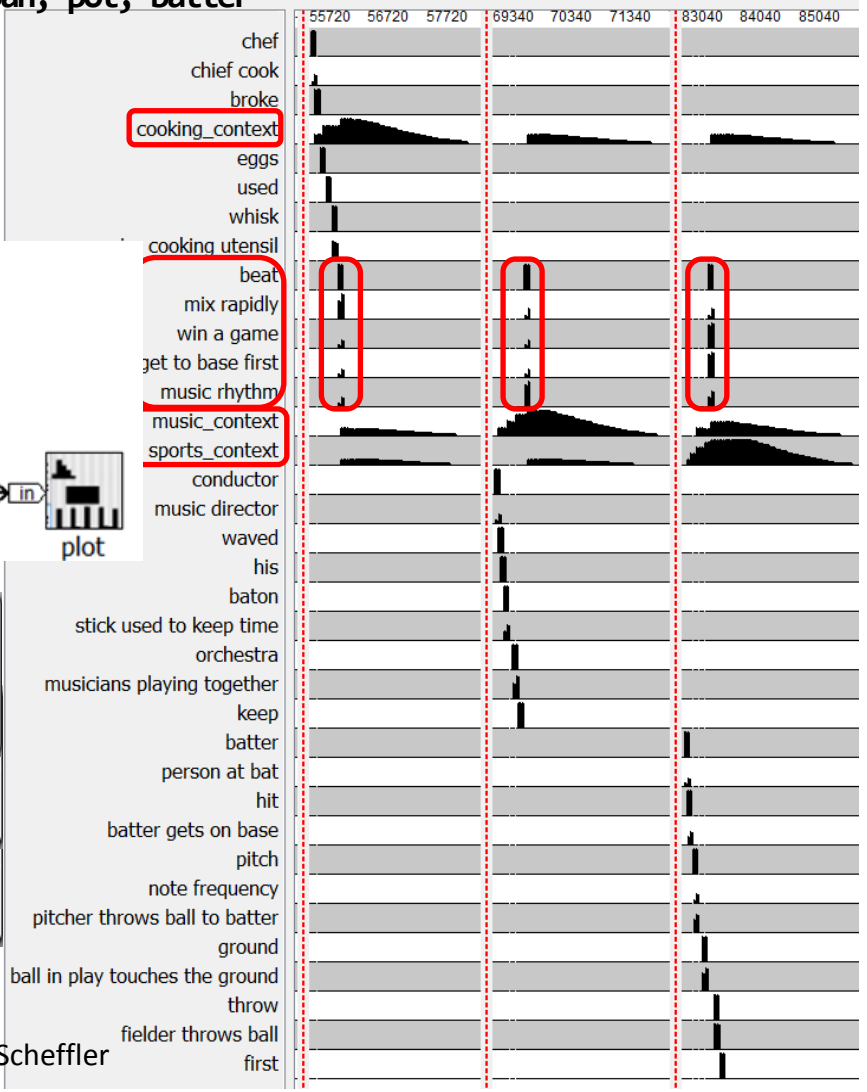


Context Disambiguation

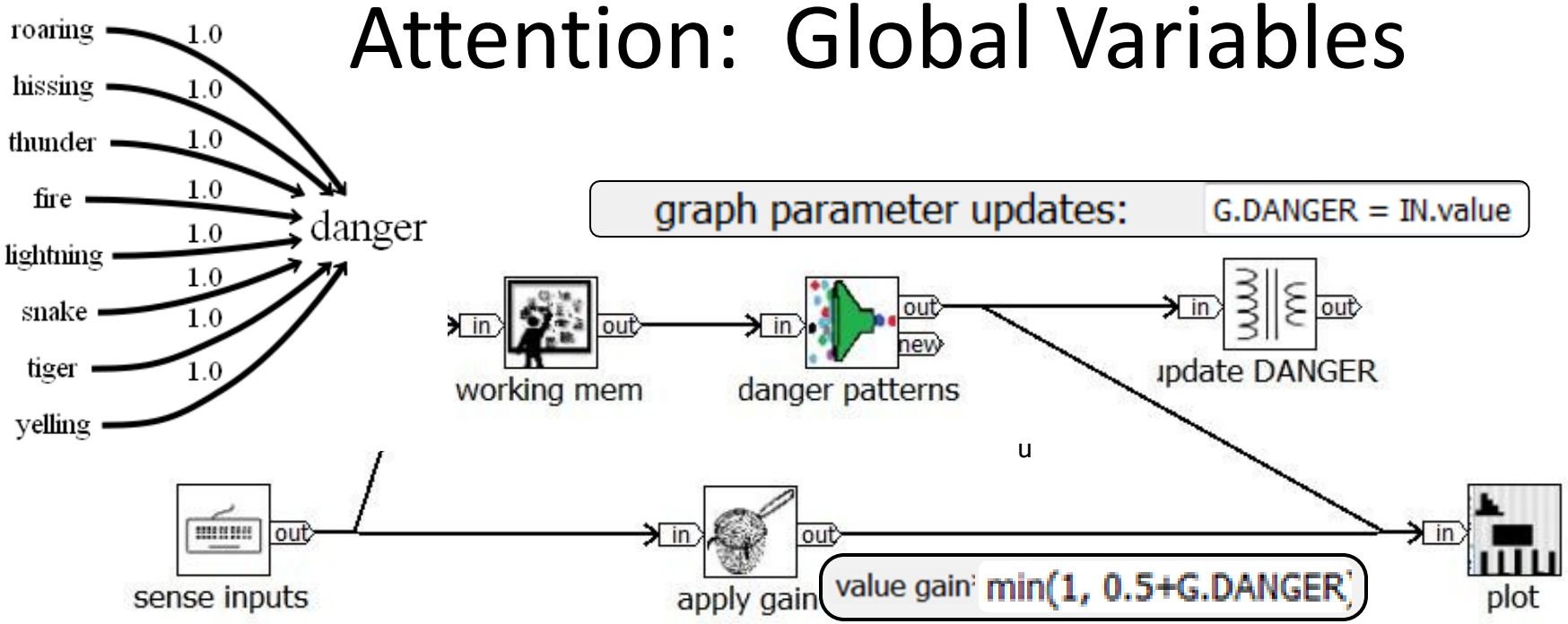
sports_context = batter, hit, ground, throw, ball, strike, out, safe, pitch, beat, score, single, double, triple
music_context = conductor, orchestra, chorus, baton, pitch, beat, score, arpeggio, chord, key, note
cooking_context = chef, kitchen, eggs, flour, spatula, beat, pan, pot, batter



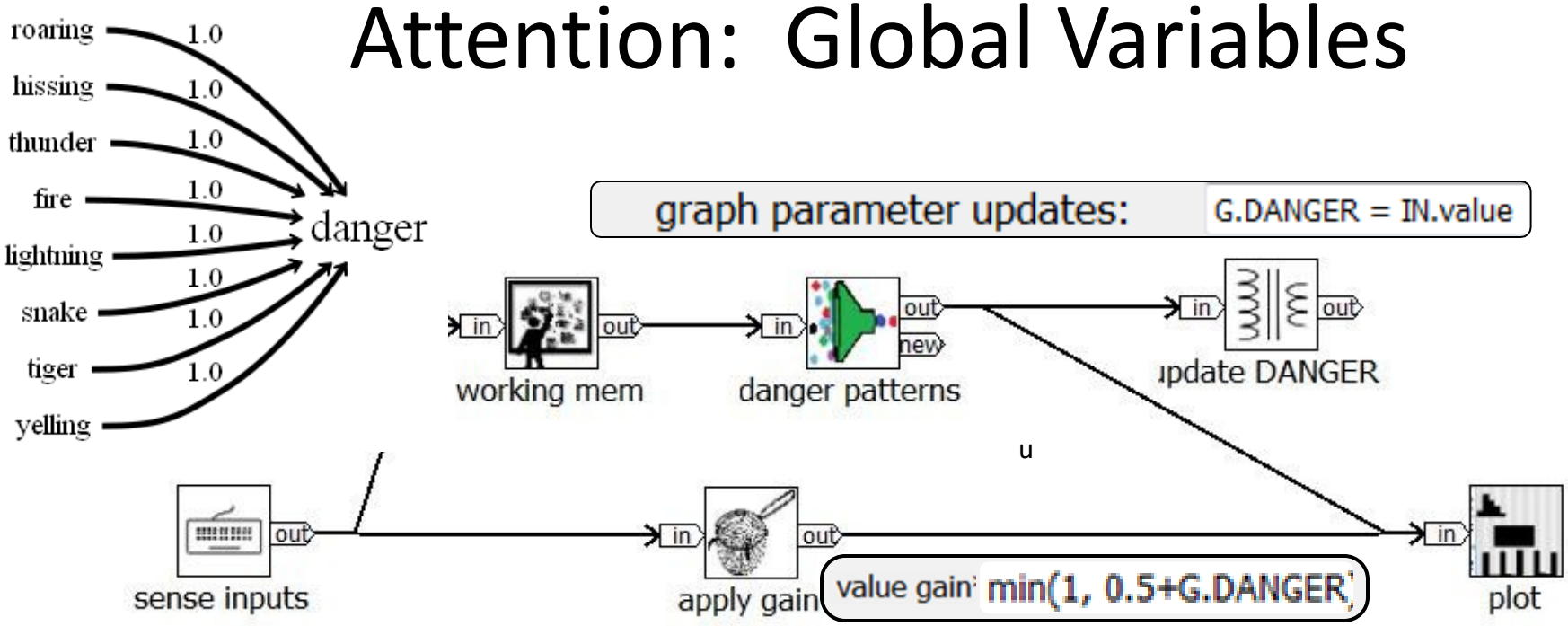




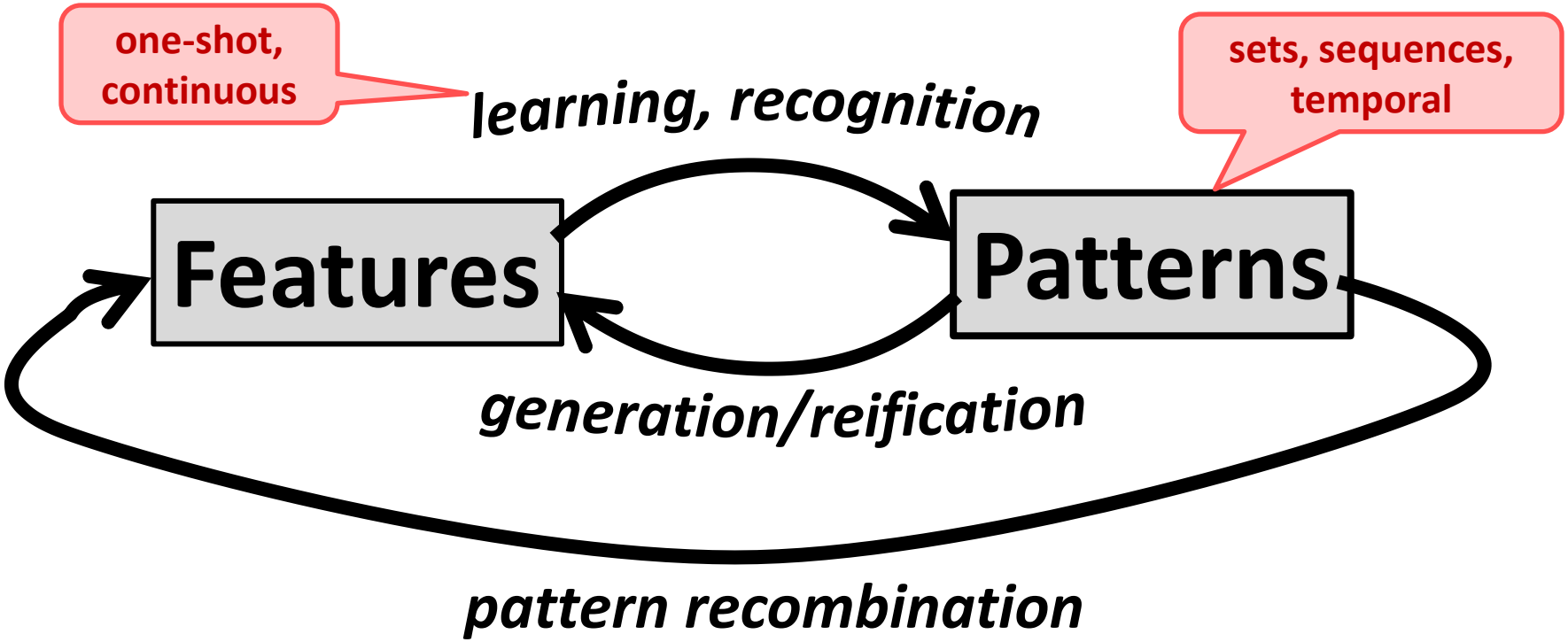
Attention: Global Variables



Attention: Global Variables

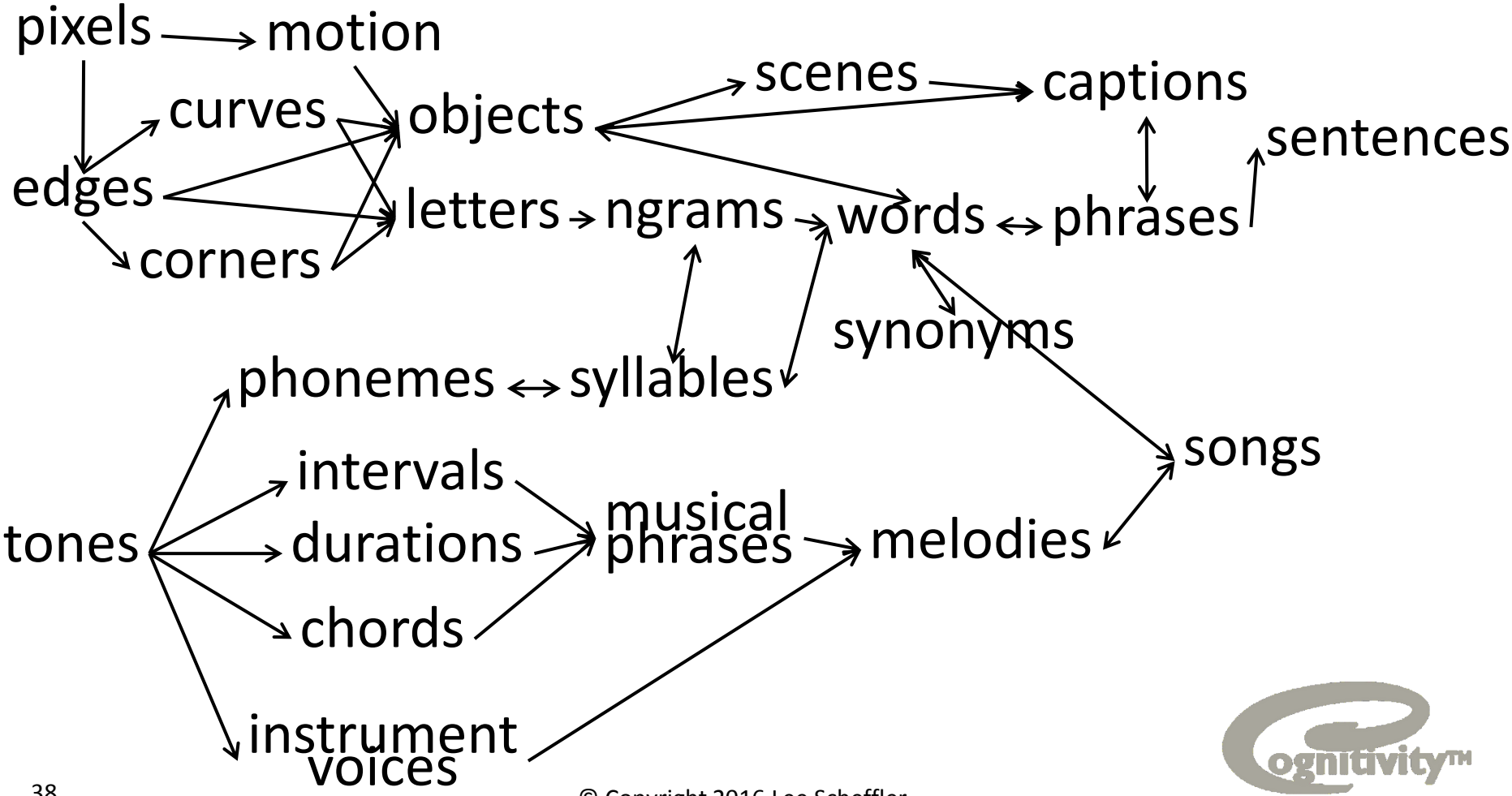


Summary and Conclusions

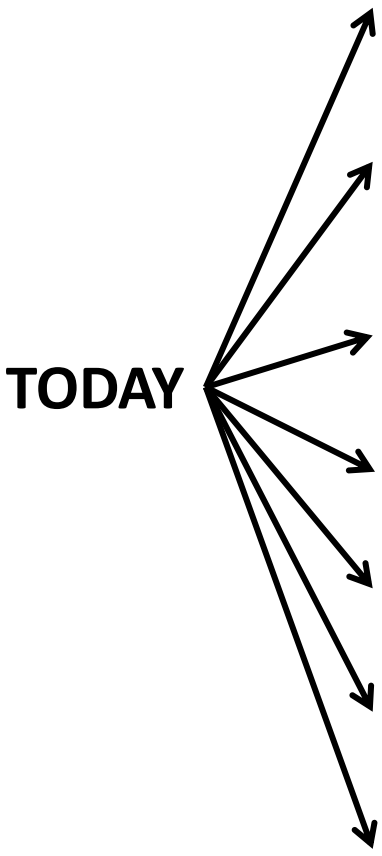


cascades/layers/meshes of patterns

Layers of Pattern Recombination (including bi-directionality)



NeurOS/NeuroBlocks Futures



development kit: GUI, modules, run-time

cognitive functions/systems: more, diverse, complex
"cognitive Olympics"

modules: inputs, outputs, memory, processing
external technology wrappers, custom modules

application areas: robotics, Internet of Things, ...

tools: improvements

platforms: ports, distributed systems, custom hardware

sharing: open ecosystem, modules, assemblies, apps

Thank You

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