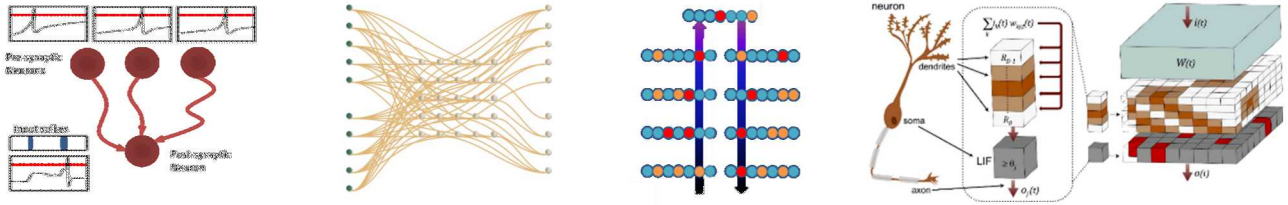
SAND2019-8625C

Neural Inspired Approaches to Enabling Autonomy



PRESENTED BY

Srideep Musuvathy

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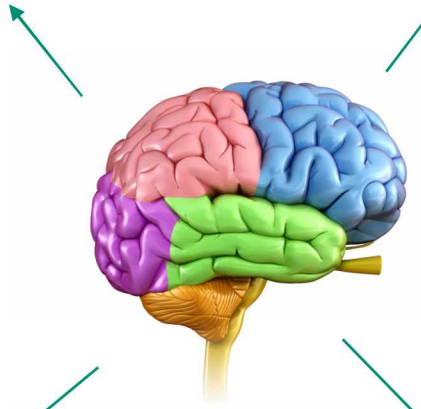
Autonomy

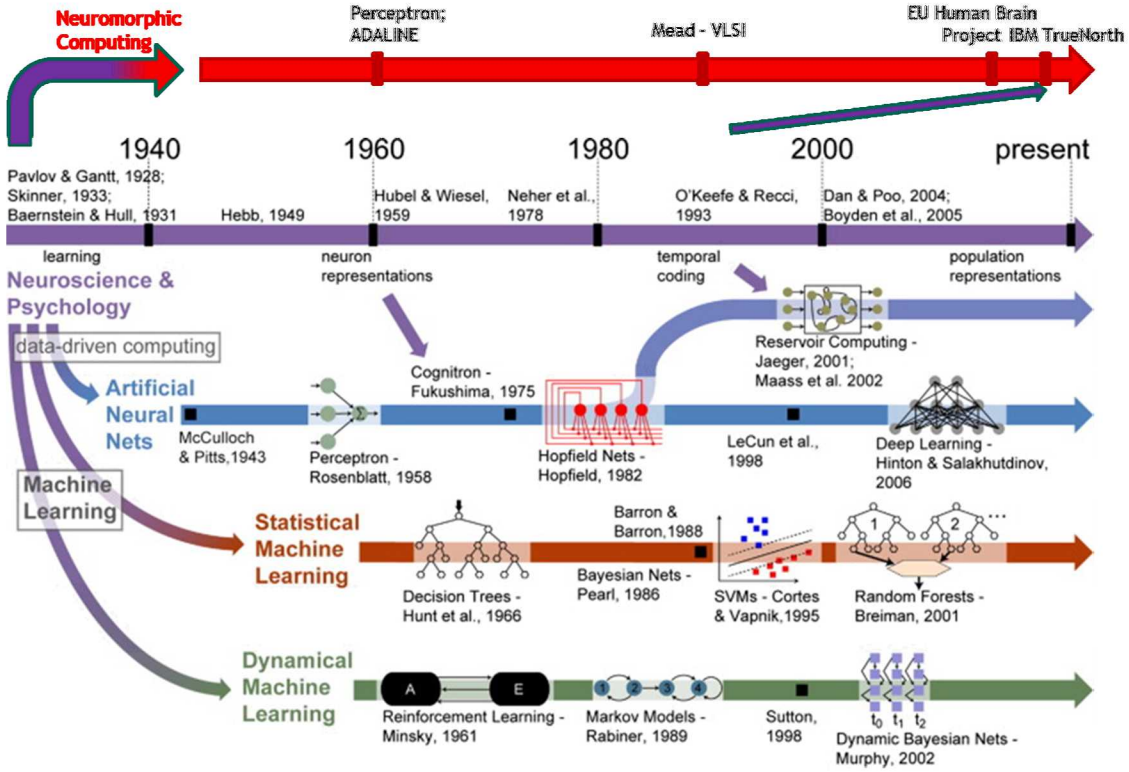
Introduction

Perception, Navigation, and Control



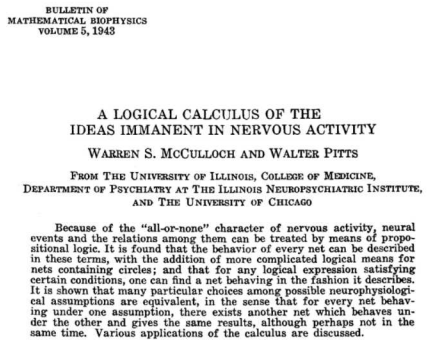
What is neural-inspired?

- Inspired by neural architectures in the brain
- Non von Neumann
  - Co-located memory and processing
- May be spiking
- Parallel processing by simple elements
- Low power, robust, adaptive
- No definition!



James, et al., BICA 2017

Not a New idea…



BULLETIN OF
MATHEMATICAL BIOPHYSICS
VOLUME 5, 1943

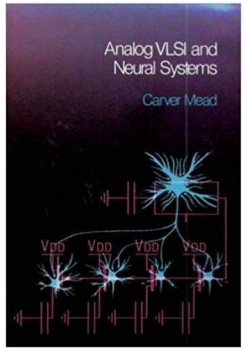
A LOGICAL CALCULUS OF THE
IDEAS IMMANENT IN NERVOUS ACTIVITY

WARREN S. MCCULLOCH AND WALTER PITTS

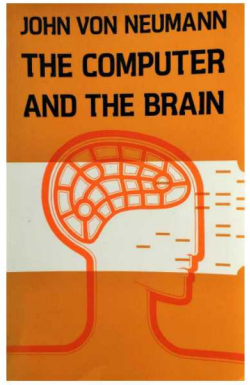
FROM THE UNIVERSITY OF ILLINOIS, COLLEGE OF MEDICINE,
DEPARTMENT OF PSYCHIATRY AT THE ILLINOIS NEUROPSYCHIATRIC INSTITUTE,
AND THE UNIVERSITY OF CHICAGO

Because of the "all-or-none" character of nervous activity, neural events and the relations among them can be treated by means of propositional logic. It is found that the behavior of every net can be described in these terms, with the addition of more complicated logical means for nets containing circles; and that for any logical expression satisfying certain conditions, one can find a net behaving in the fashion it describes. It is shown that many particular choices among possible neurophysiological assumptions are equivalent, in the sense that for every net behaving under one assumption, there exists another net which behaves under the other and gives the same results, although perhaps not in the same time. Various applications of the calculus are discussed.

McCulloh & Pitts, 1943



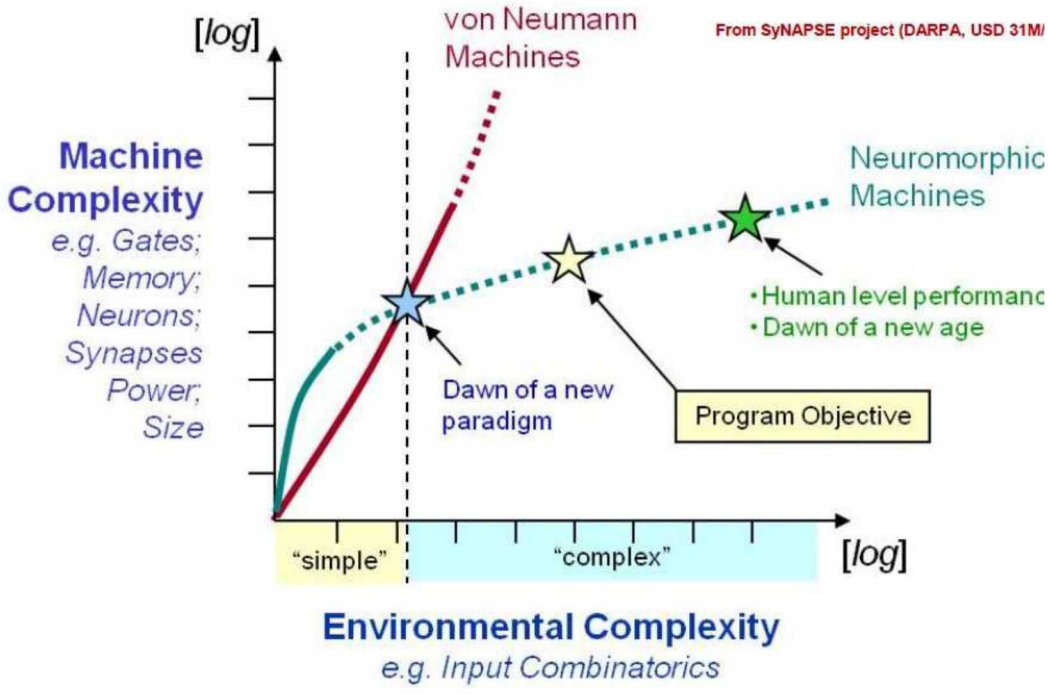
Mead, 1989



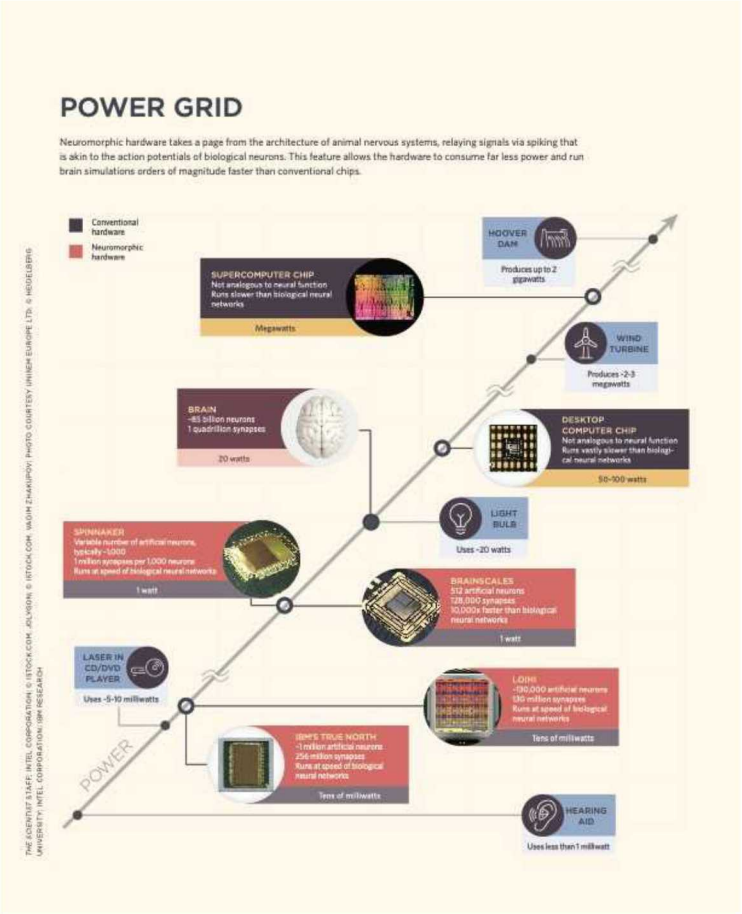
Neumann, 1958

Neural Inspired hardware

Benefits of a Neural Inspired Approach



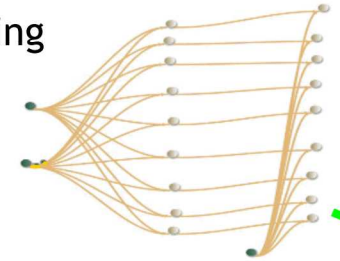
The Register, August 2011



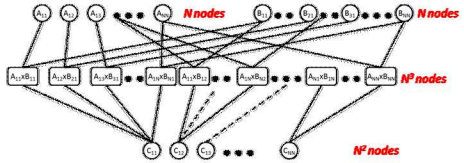
The Scientist, May 2019

Impacting Broad Areas of Computation

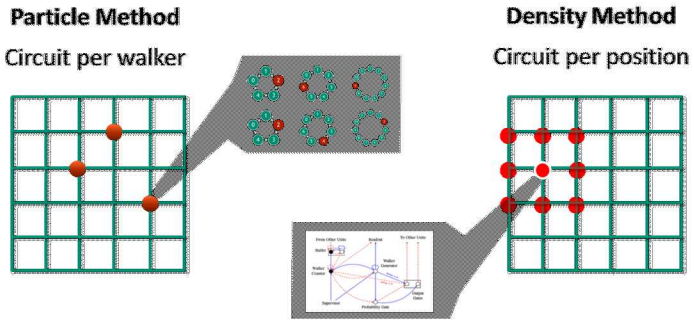
Pattern Matching



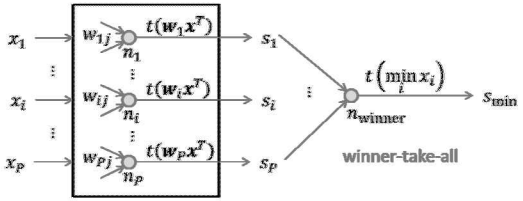
Linear Algebra

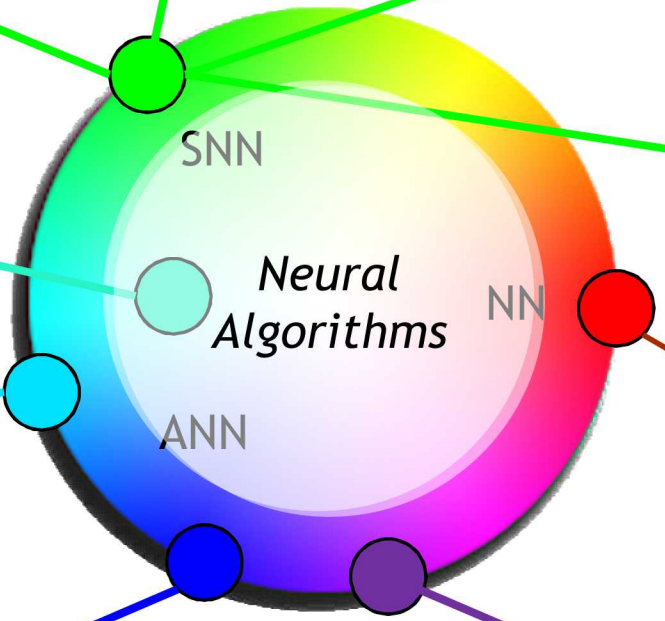


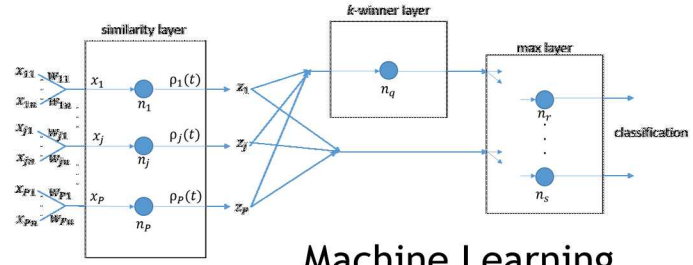
Scientific Computing



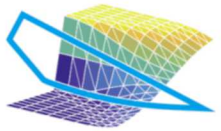
Optimizations



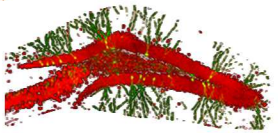




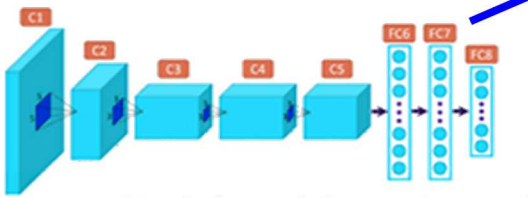
Machine Learning



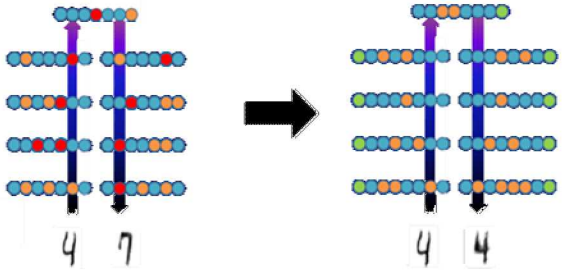
WHETSTONE



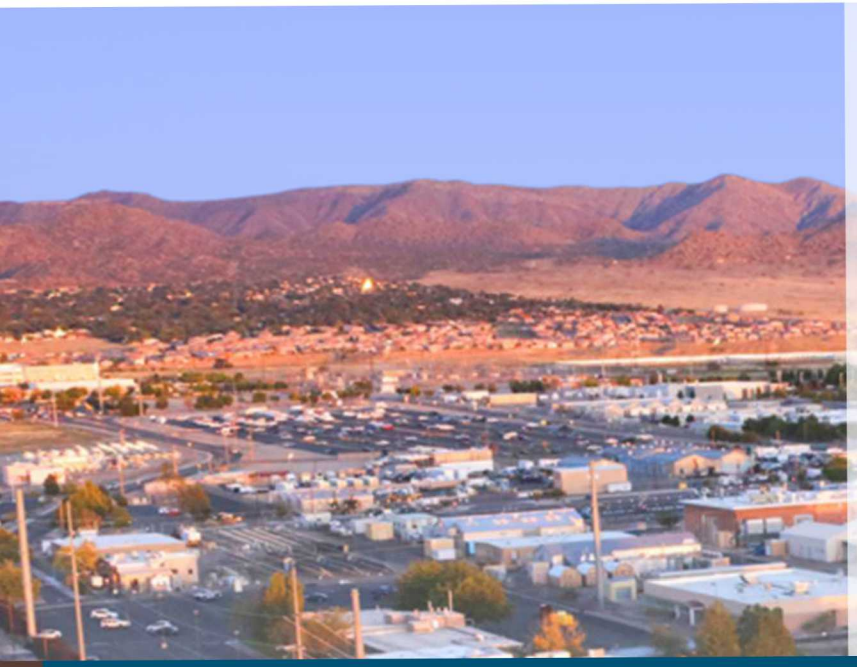
Intelligent Storage



Context Modulated Deep Learning



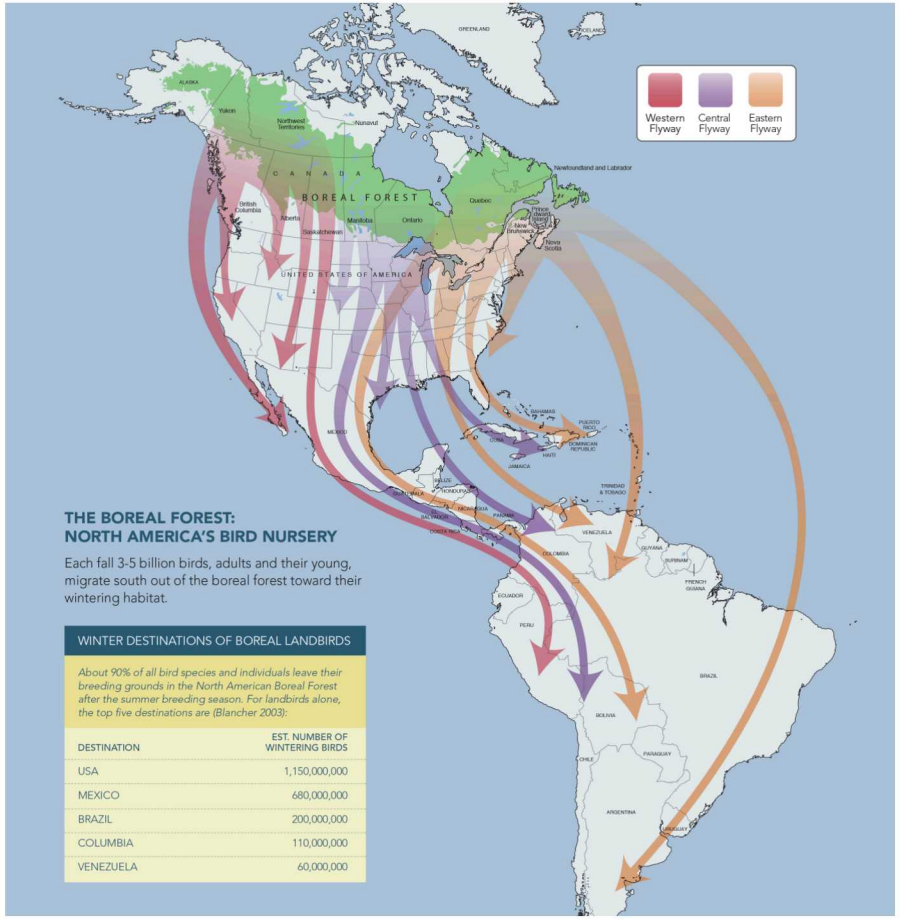
Adaptive Deep Learning



SLAM

A Neural Inspired Approach

Bird Migration



Radio Canada and boreal songbird initiative, 2014

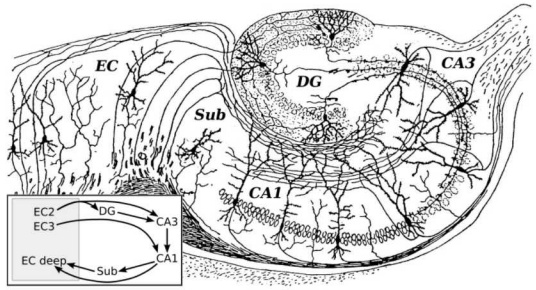
Rodent Navigation

No GPS!

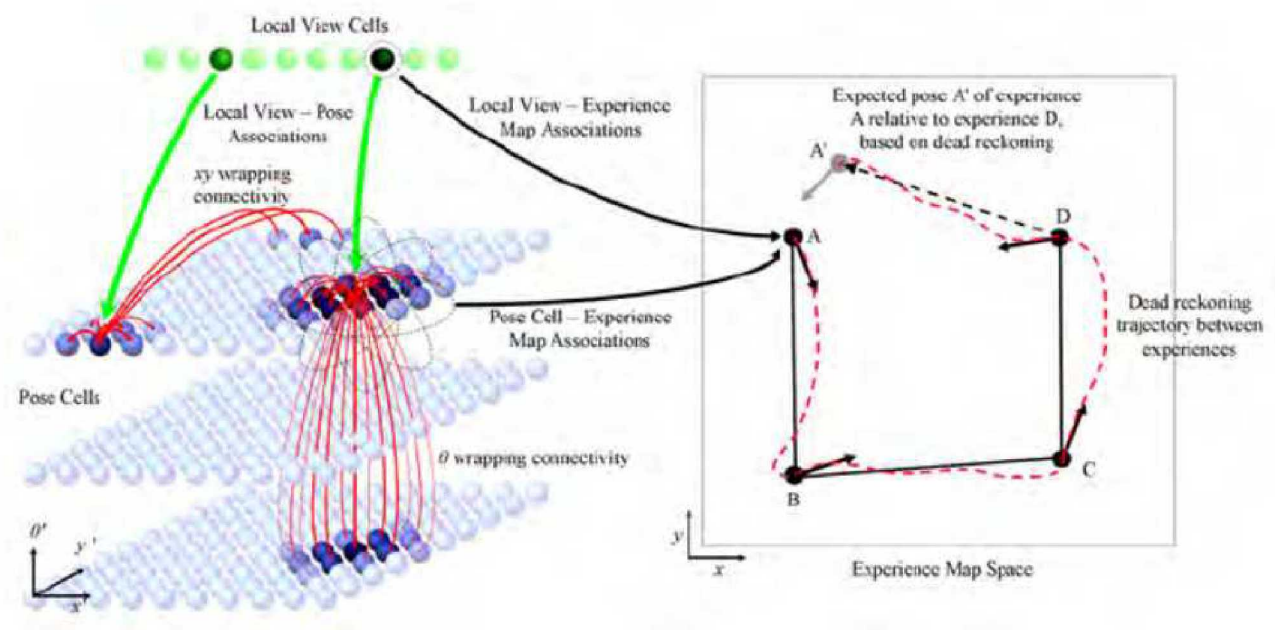
RatSLAM

Milford and team, University of Queensland

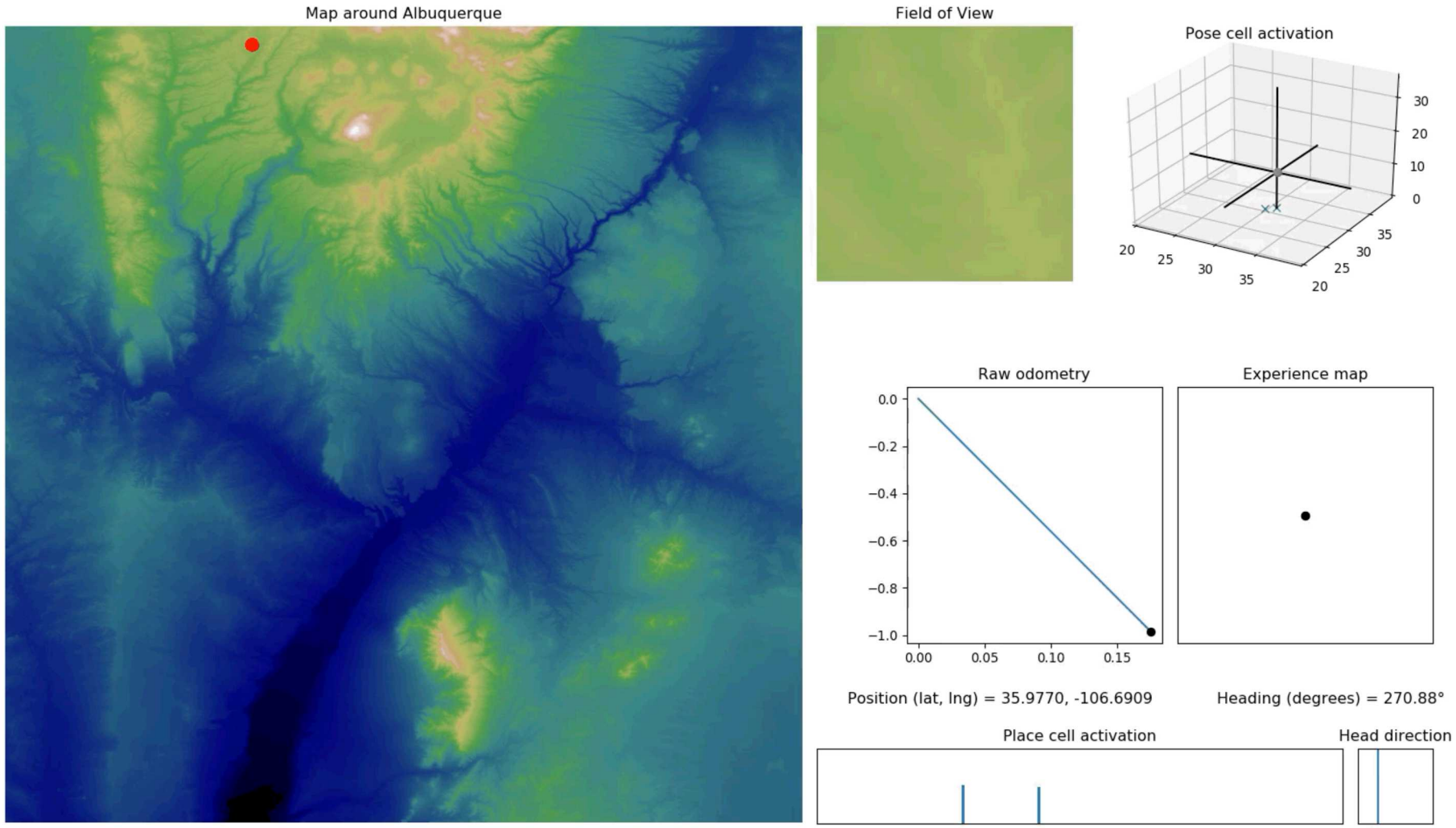
Hippocampus

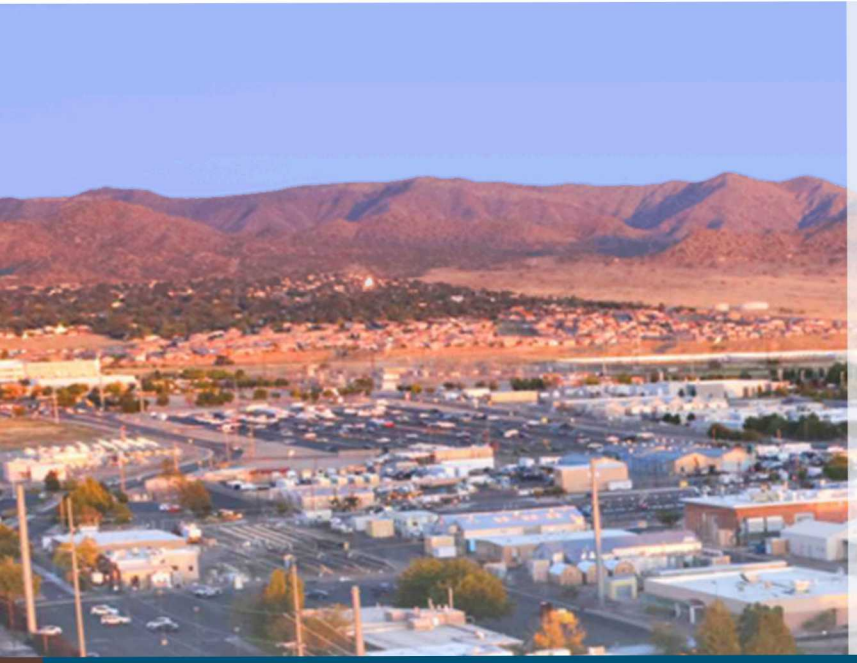


Santiago Ramón y Cajal (1852–1934)



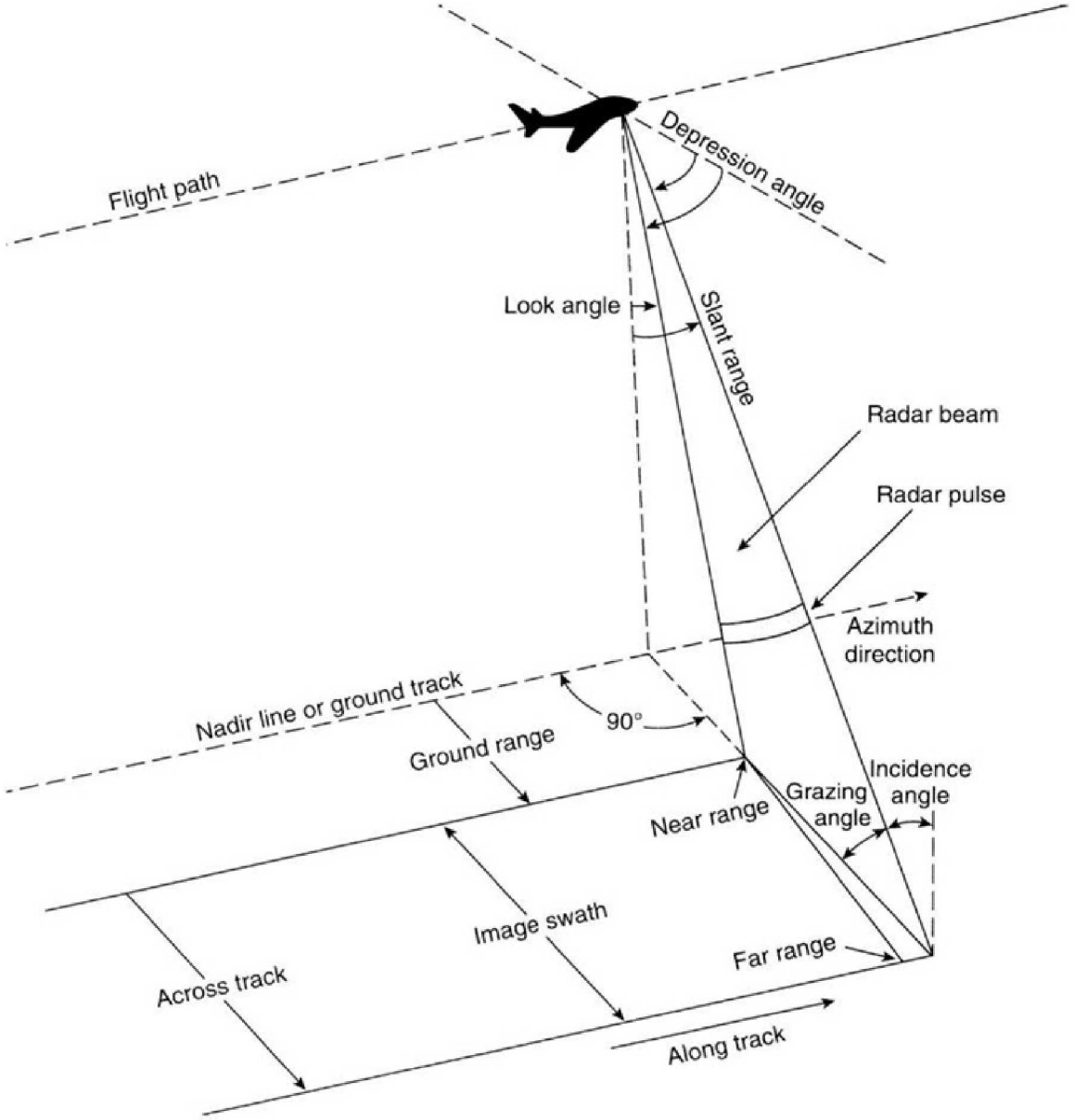
Milford and Weyth, IJRR 2010


Map around Albuquerque
Field of View
Pose cell activation
30
20
10
0
20
25
30
35
35
30
25
20
Raw odometry
Experience map
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0.00
0.05
0.10
0.15
Position (lat, lng) = 35.9770, -106.6909
Heading (degrees) = 270.88°
Place cell activation
Head direction

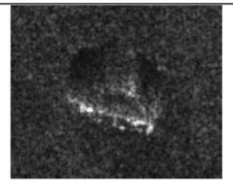
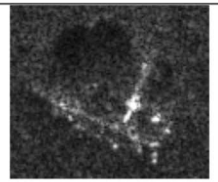
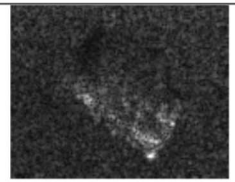
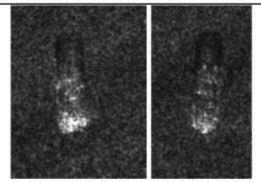
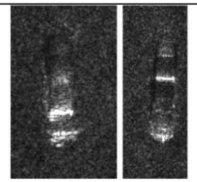
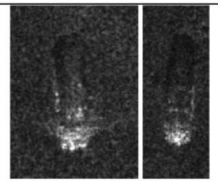
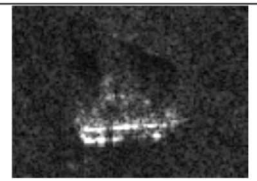
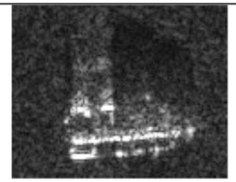
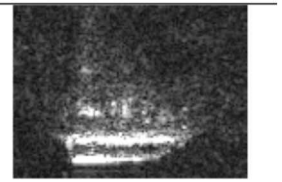


Object recognition in SAR data

Using Template Matching

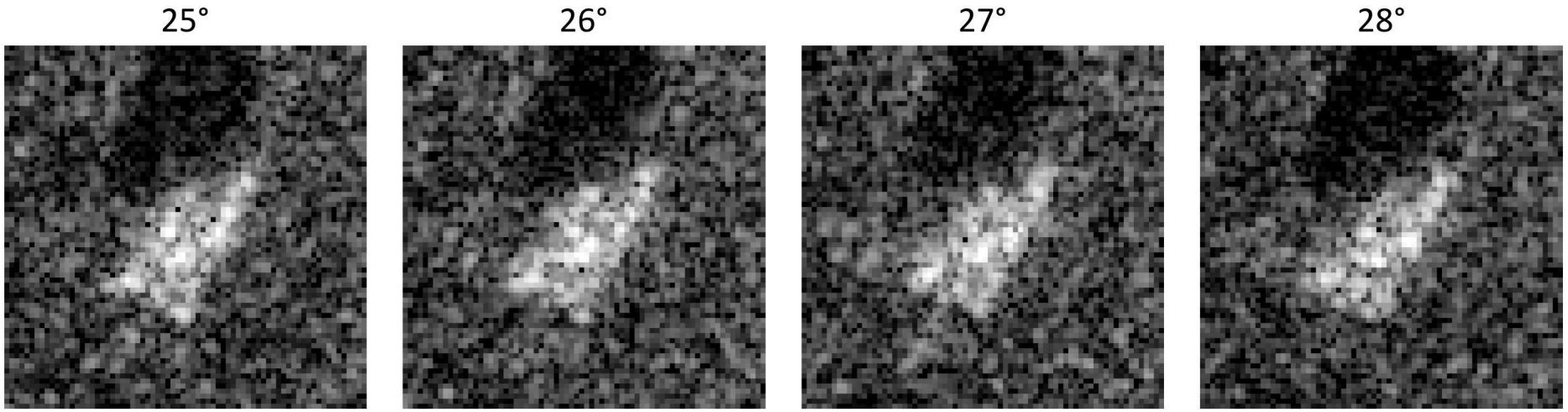

Flight path
Depression angle
Look angle
Slant range
Radar beam
Radar pulse
Azimuth direction
Nadir line or ground track
90°
Ground range
Near range
Grazing angle
Incidence angle
Image swath
Across track
Far range
Along track

Vehicle	Location 1	Location 2	Location 3	Location 4	Location 5
	Chevrolet Express	Ford F350	Pontiac Grand Am	Dodge Caravan	Dodge Ram
	Large Van	Large Truck	Mid-size Sedan	Mid-size Van	Mid-size Truck
					

	Sedan	Truck	Van
Side Oblique Angle			
Rear and Front Cardinal Angle			
Side Cardinal Angle			

Radar Cross Section Statistics of Ground Vehicles at Ku-band
Raynal et al., 2011

SAR chips (25°–28°)



Signal variability due to –

- Coherence: complex valued measurements encompassing magnitude and phase
- Specularity: radar energy is scattered directionally instead of diffusely as a consequence of the wavelength and size of objects
- Speckle: multiplicative noise process due to the coherent interaction between multiple scatters in individual cells

SAR Image

Deng et al., 2018
EURASIP Journal of Wireless Communication and Networking

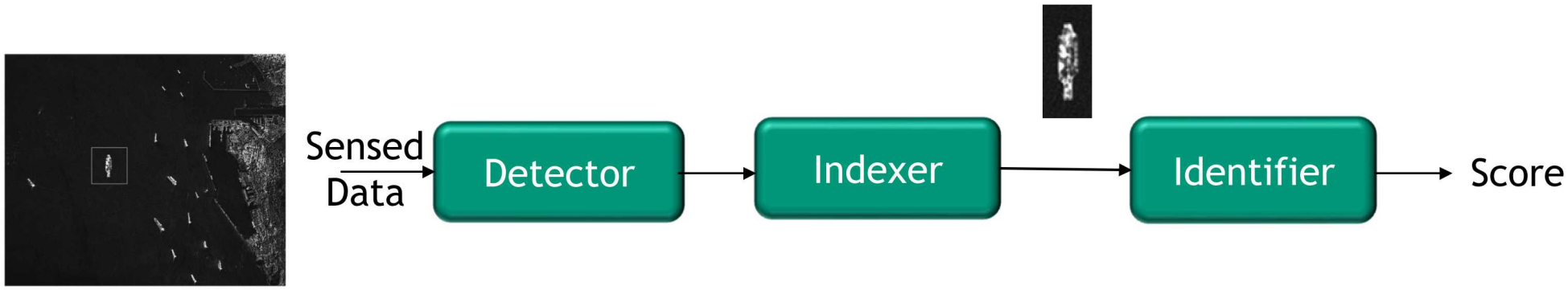
Object recognition

Not a brain inspired Approach!!

Koudelka et al., SPIE 2007

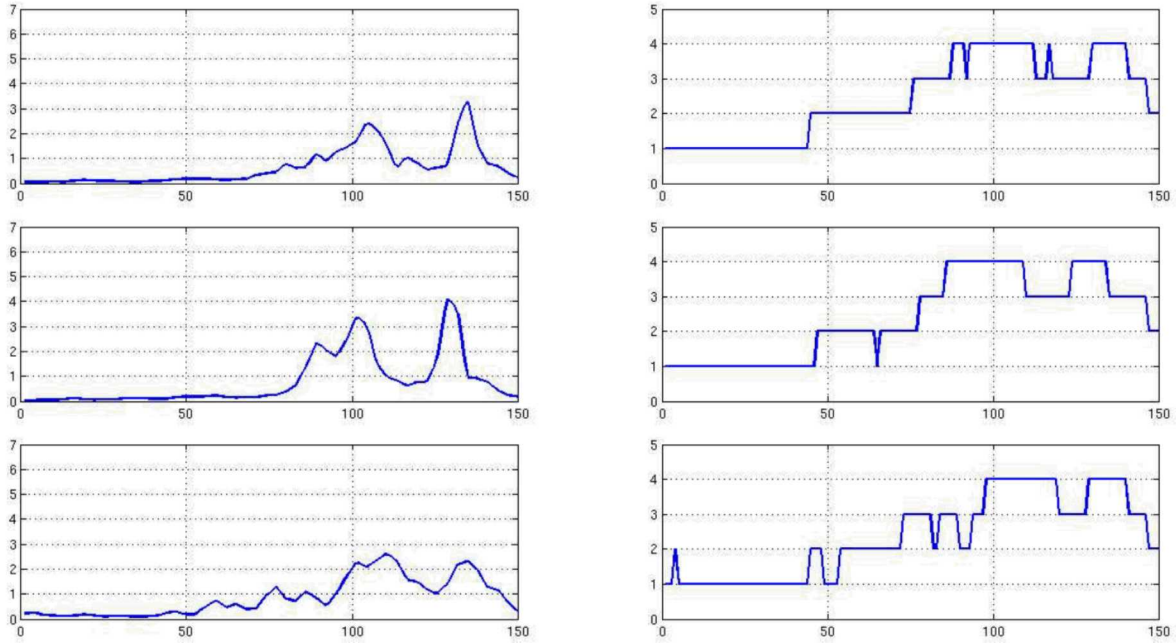
Object recognition

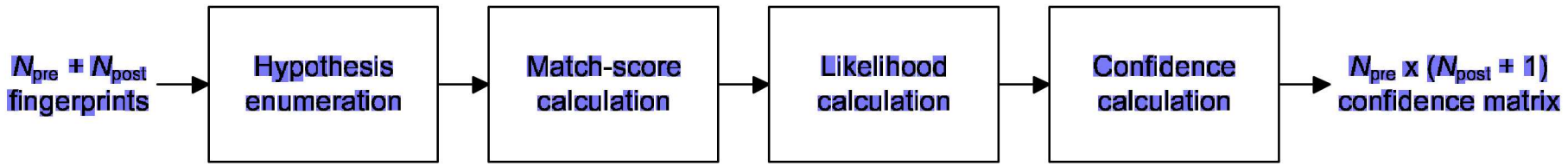
Object recognition



Multinomial Pattern Matching

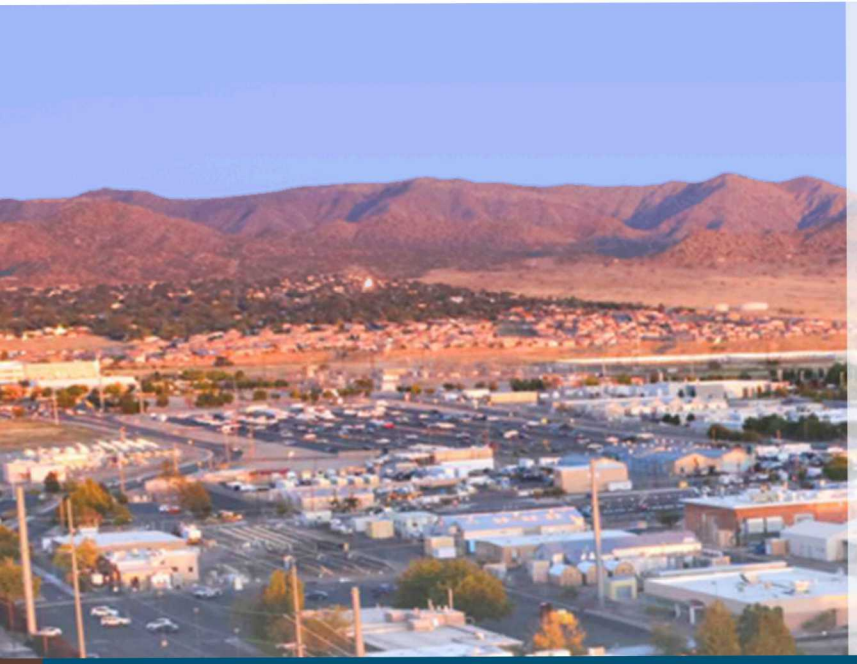
Koudelka et al., SPIE 2007





Algorithm composition

- Bitwise And
- Matrix Multiplications
- Shifts
- Rotations
- Sorting
- Thresholding
- Easily implemented in neuromorphic hardware!



Fugu

Neural Inspired Algorithm Development

Fugu aims to bring neuromorphic solutions to general computing world

Typical Computer Scientists

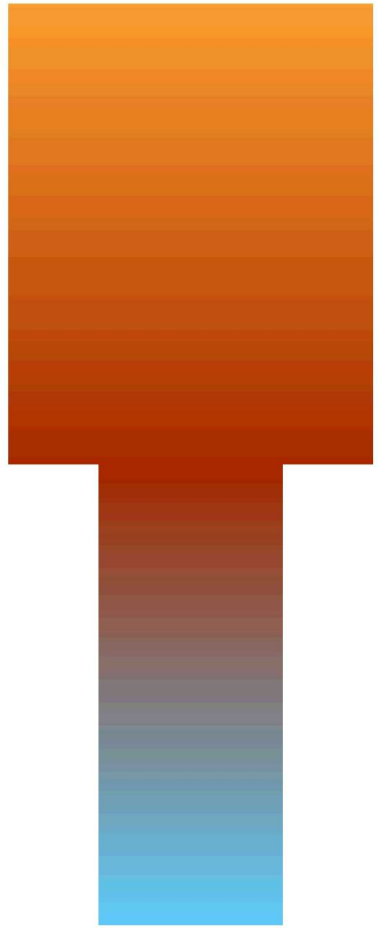
Wants to program with libraries

Neural Algorithm Researcher

Wants to program with neurons

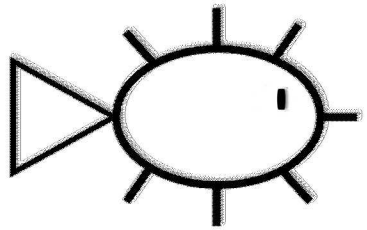
Neural Architecture Developer

Wants to program hardware directly

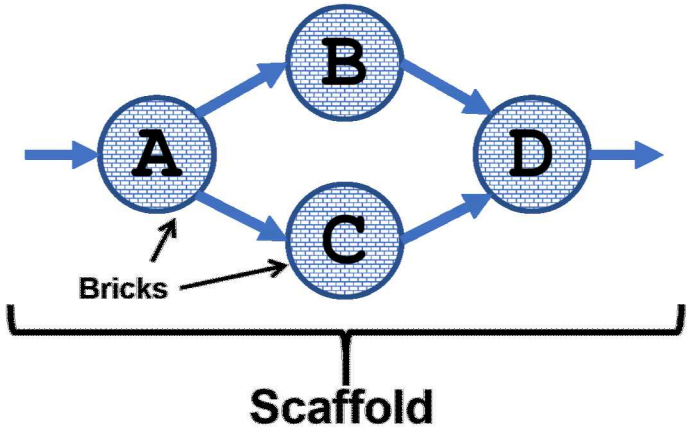


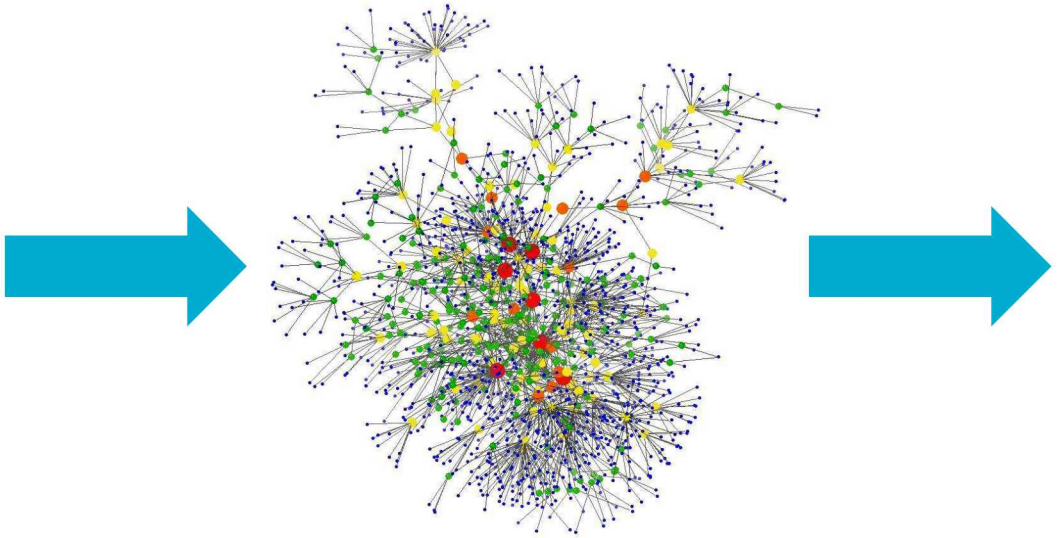
Challenges

- For spiking neural networks, it is (very) hard to
  - Implement someone else's network
  - Integrate multiple kernels into an algorithm
  - Port networks designed for one platform to another

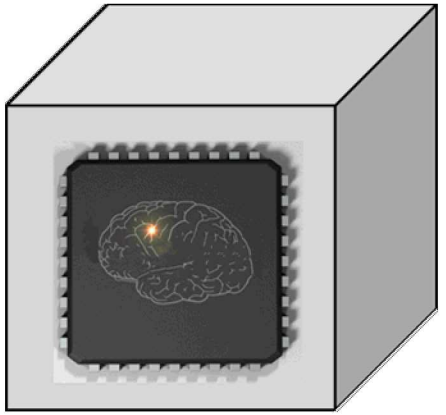


```
Algorithm
Insert Brick A, input IN     //A=f_A(in)
Insert Brick B, input A      //B=f_B(A)
Insert Brick C, input A      //C=f_C(A)
Insert Brick D, input B, C   //D=f_D(B, C)
```

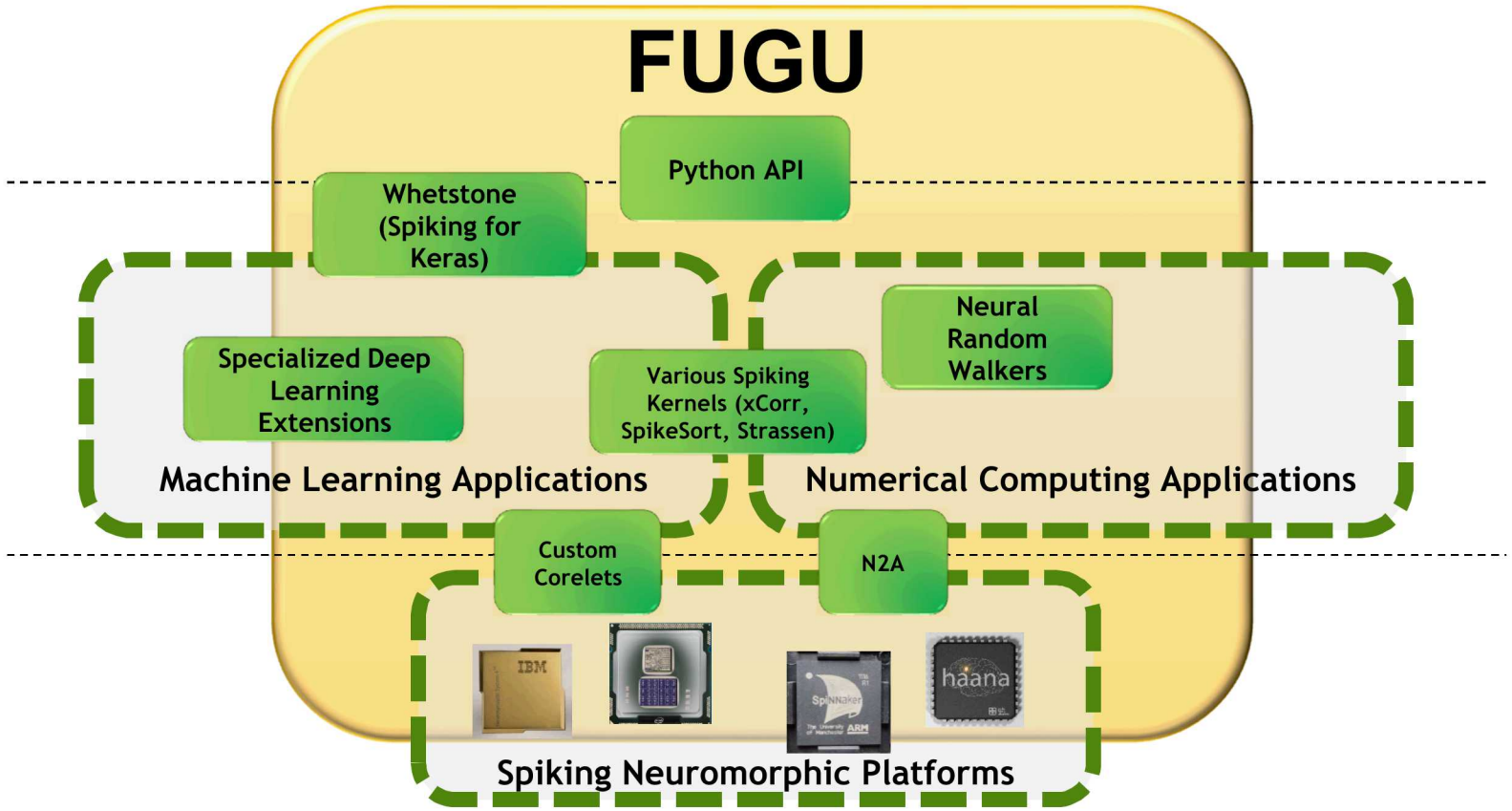




Not actual syntax or network



Fugu Overview



Under development
Collaborators welcome!

Fugu Overview - What Fugu *is*

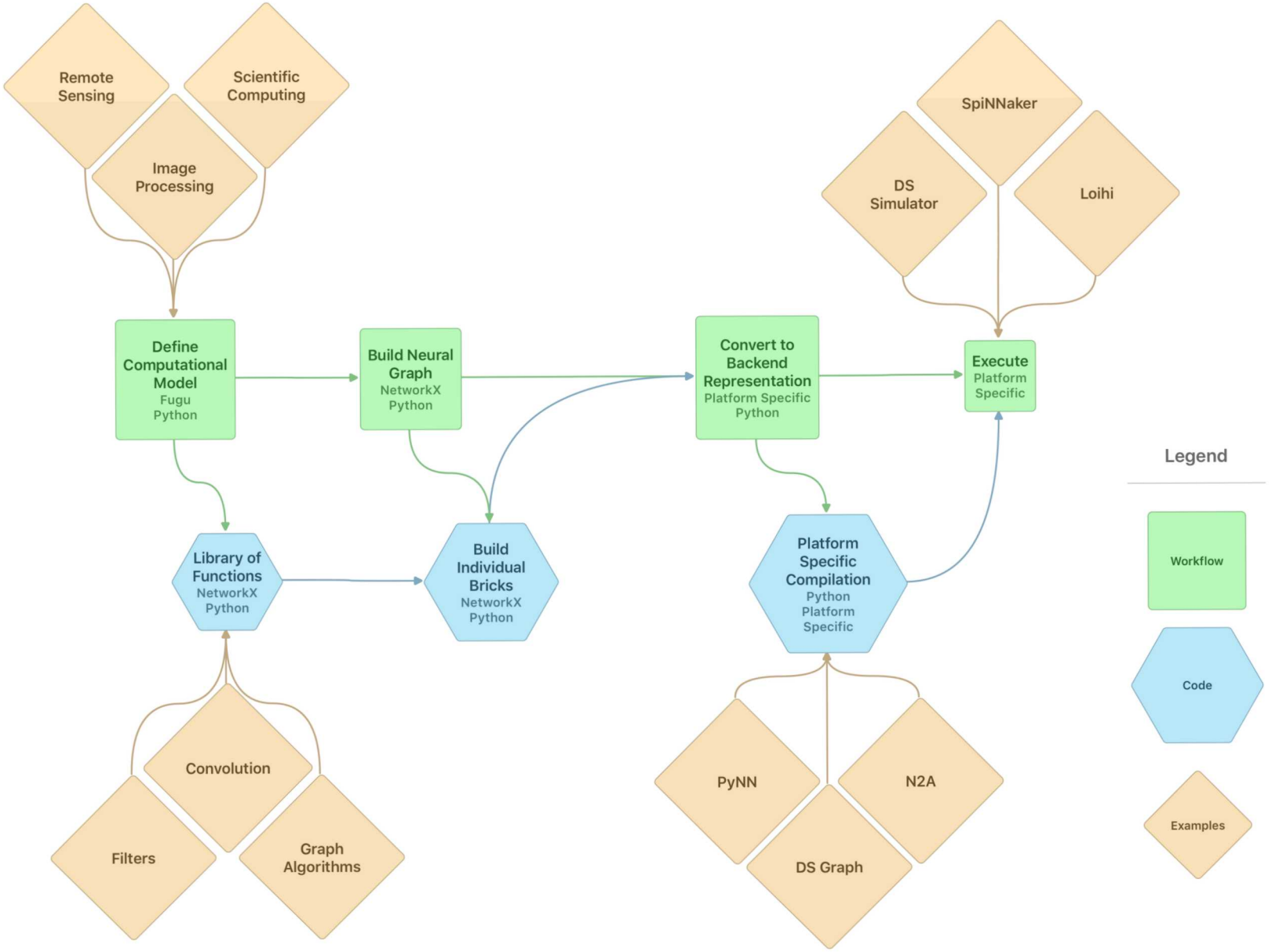
- Fugu is a linking framework
  - It's "easy" to build spiking circuits for a single computation
  - It's hard to do application-level computation on neuromorphic
  - We provide a mechanism to combine small computational kernels (Bricks) into large computational graphs
- Fugu is a spec
  - For the Bricks to transfer information, we need to agree on data formatting
  - For computation to be consistent, we need to agree on neuron behavior (lowest common denominator*)
  - For this to be useful, we need a hardware independent intermediate representation

*Usually, for most cases

Fugu Overview – What Fugu *is not*

- Fugu includes but is NOT a simulator
  - Uses reference simulators which can quickly run small-medium sized spiking networks
  - Simulators instantiates the fugu neuron model (discrete time, point synapses)
  - Fugu is designed to support a variety of backends including hardware platforms
- Fugu includes but is NOT a spiking algorithm
  - The goal of Fugu is to have a library of Fugu Bricks for many kernels
  - *We're hoping that the community will help contribute*
- Fugu includes but is NOT a graph utility
  - NetworkX provides (nearly) all of our graph functionality
  - Node and edge properties are inherent in NetworkX and only become meaningful when interpreted by a backend

Fugu Overview



Questions?