Enabling machines to perceive the world

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e-Lab

team

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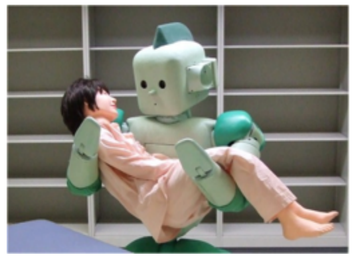


ROBOTICS

UAV

Our Goal: enable machines to perceive the world like we do!

FOOD INSPECTION

PARTS INSPECTION

Autonomous cars

HOME AUTOMATION

PARKING MANAGEMENT

BUILDING SECURITY

BIOMETRICS

enabling technology

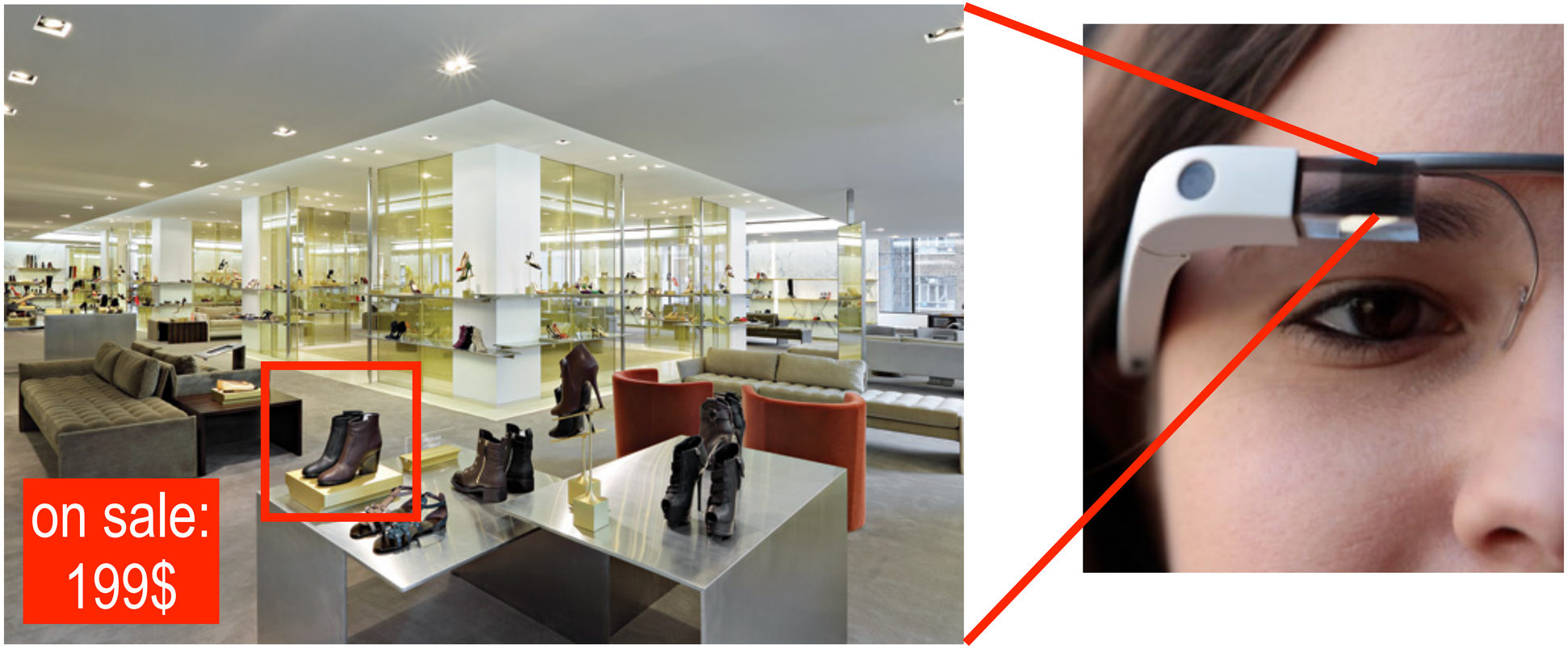
70k$

+TeraDeep HW

~100$

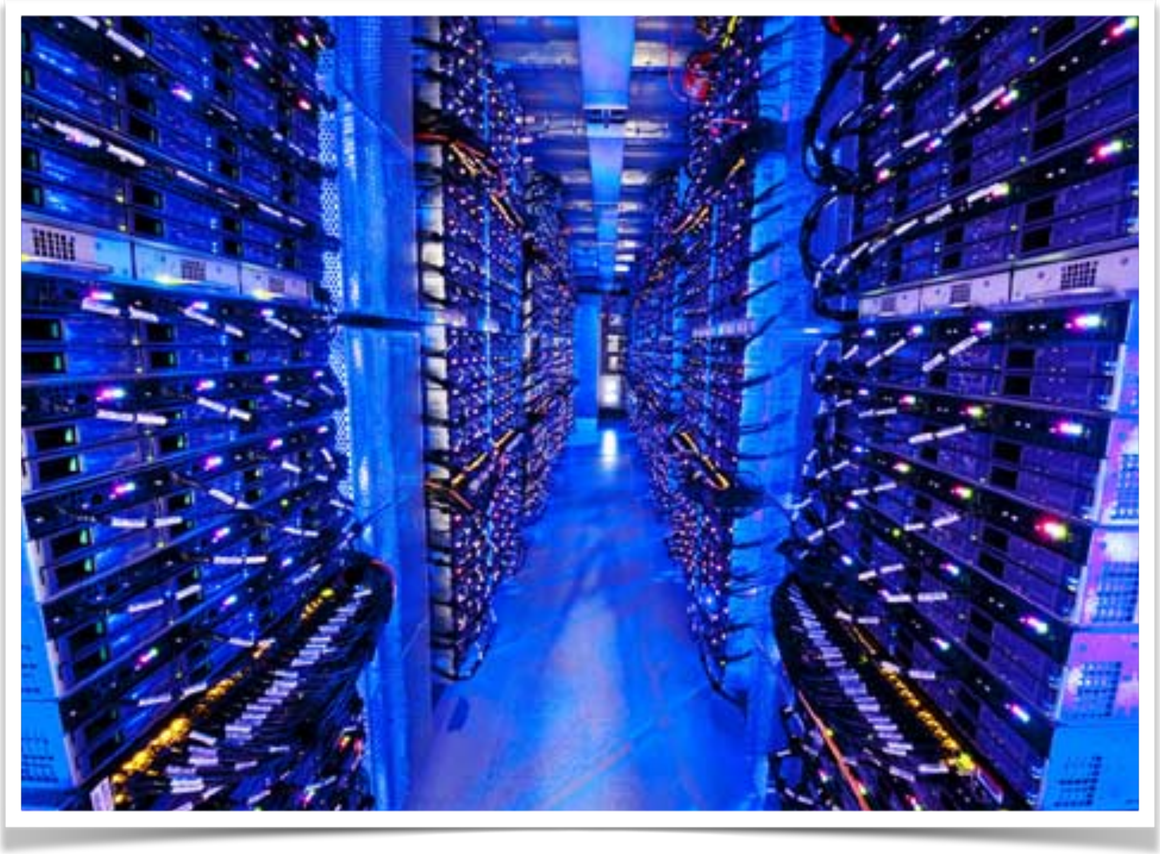
enabling low-cost autonomous driving!

enabling technology



enabling always-on real-time hardware
tagging videos on mobile devices!

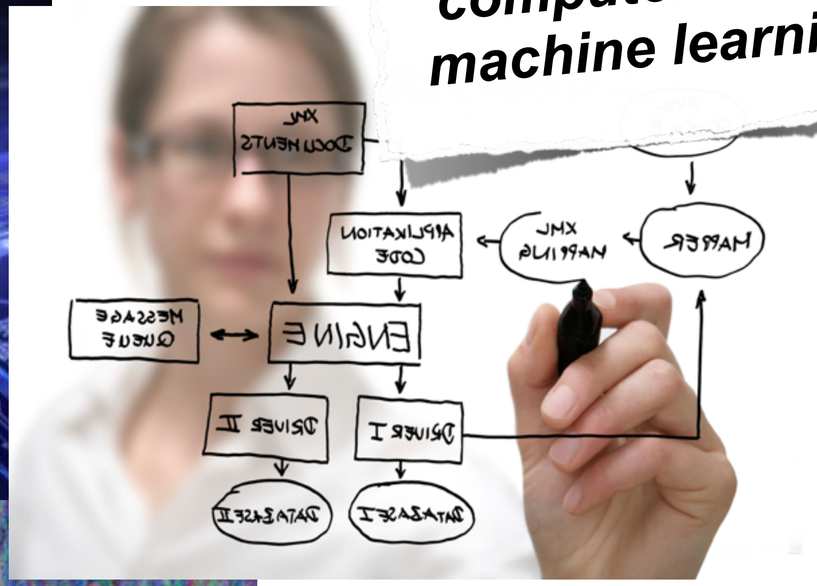
enabling technology



enabling low-power servers for parsing big data, images, videos!

Electrical Engineering
neuromorphic engineering
synthetic vision
computer architecture

Computer Science
computer vision
machine learning

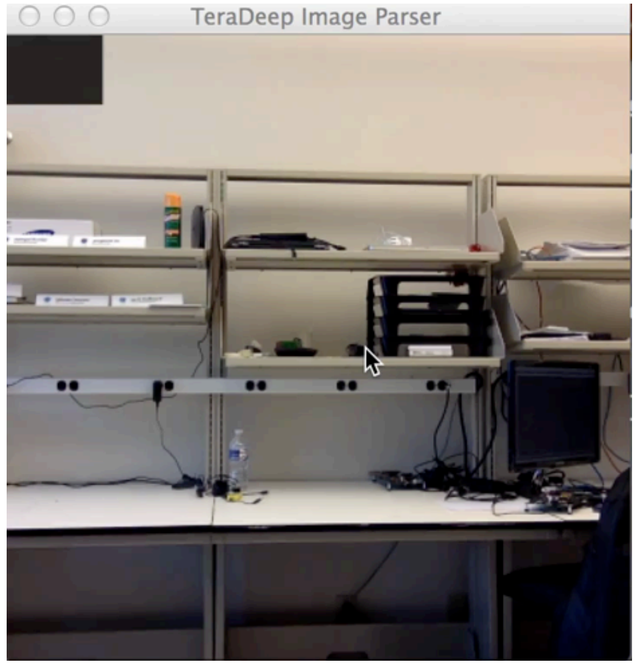


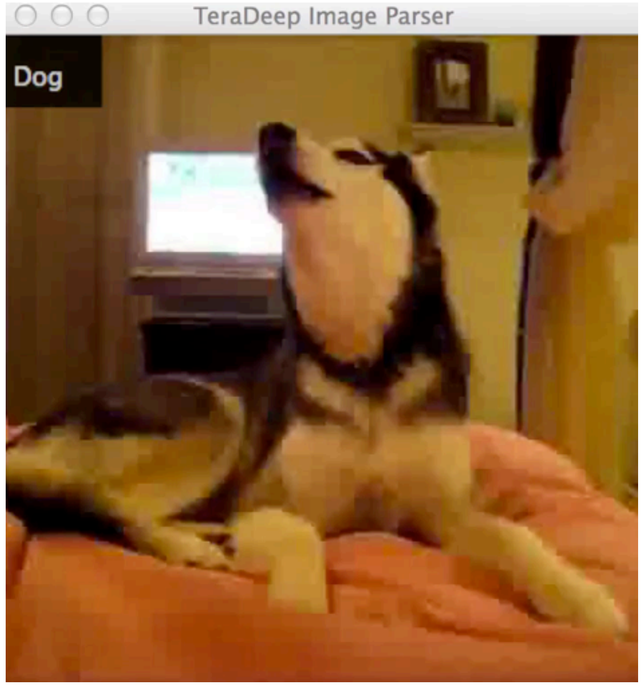
Neuroscience
vision
learning
neural networks

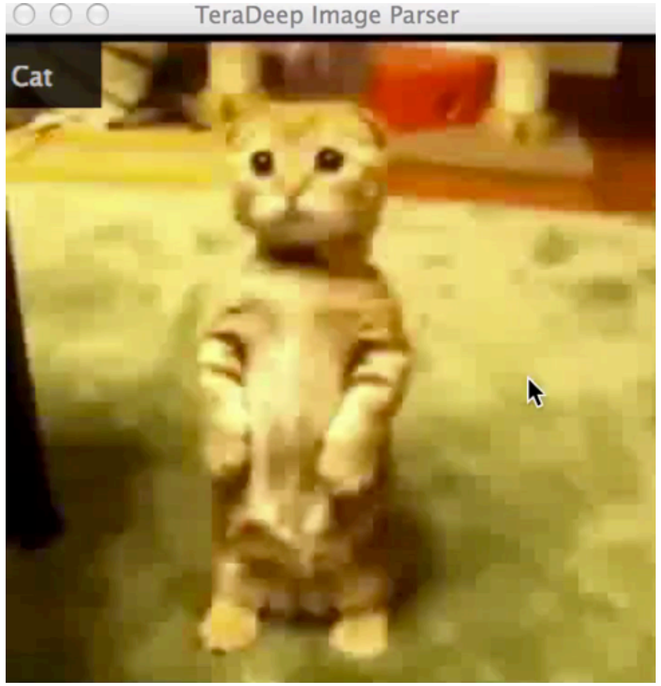
our vision system

palm sized!

demos

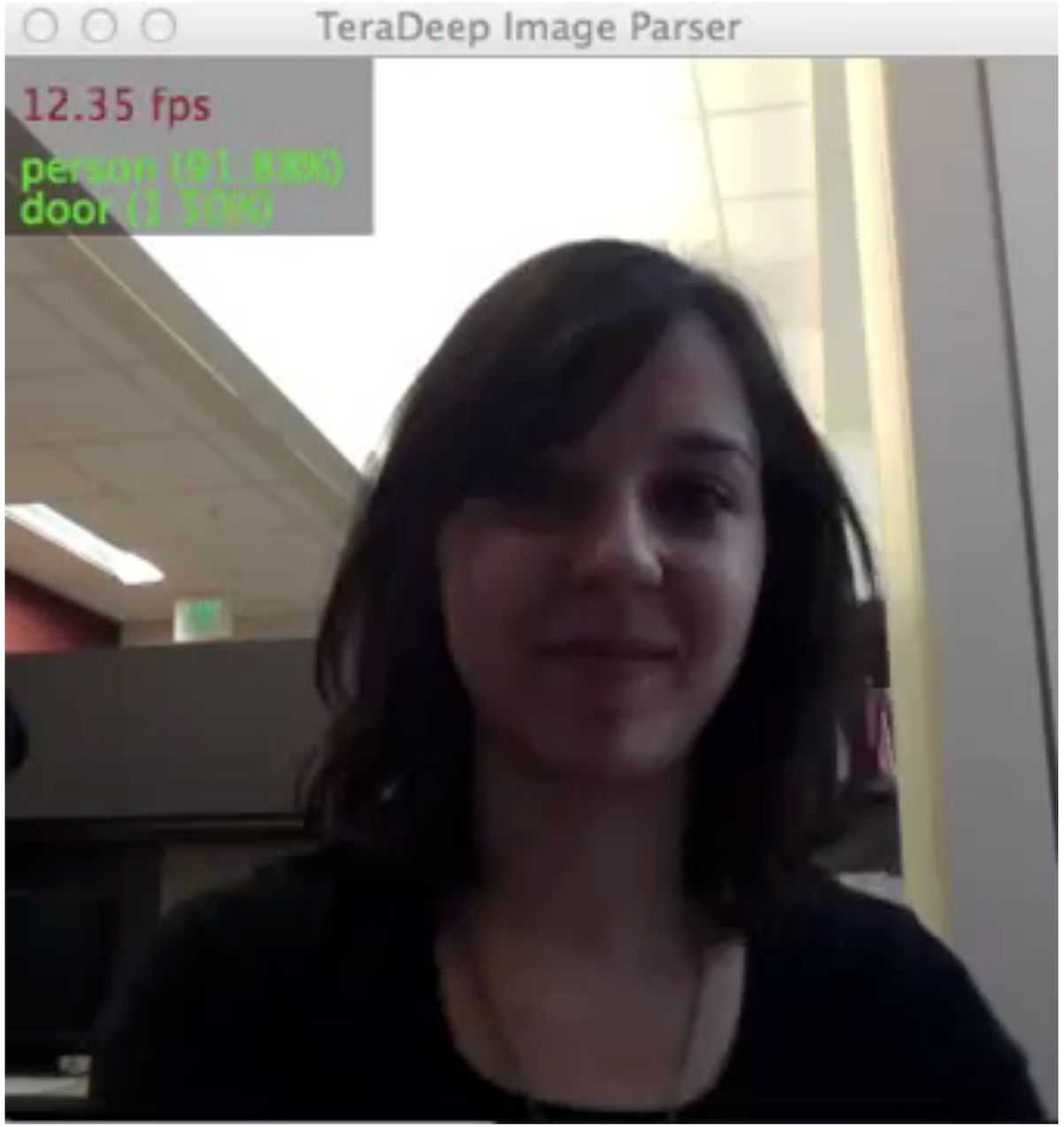






state-of-the-art

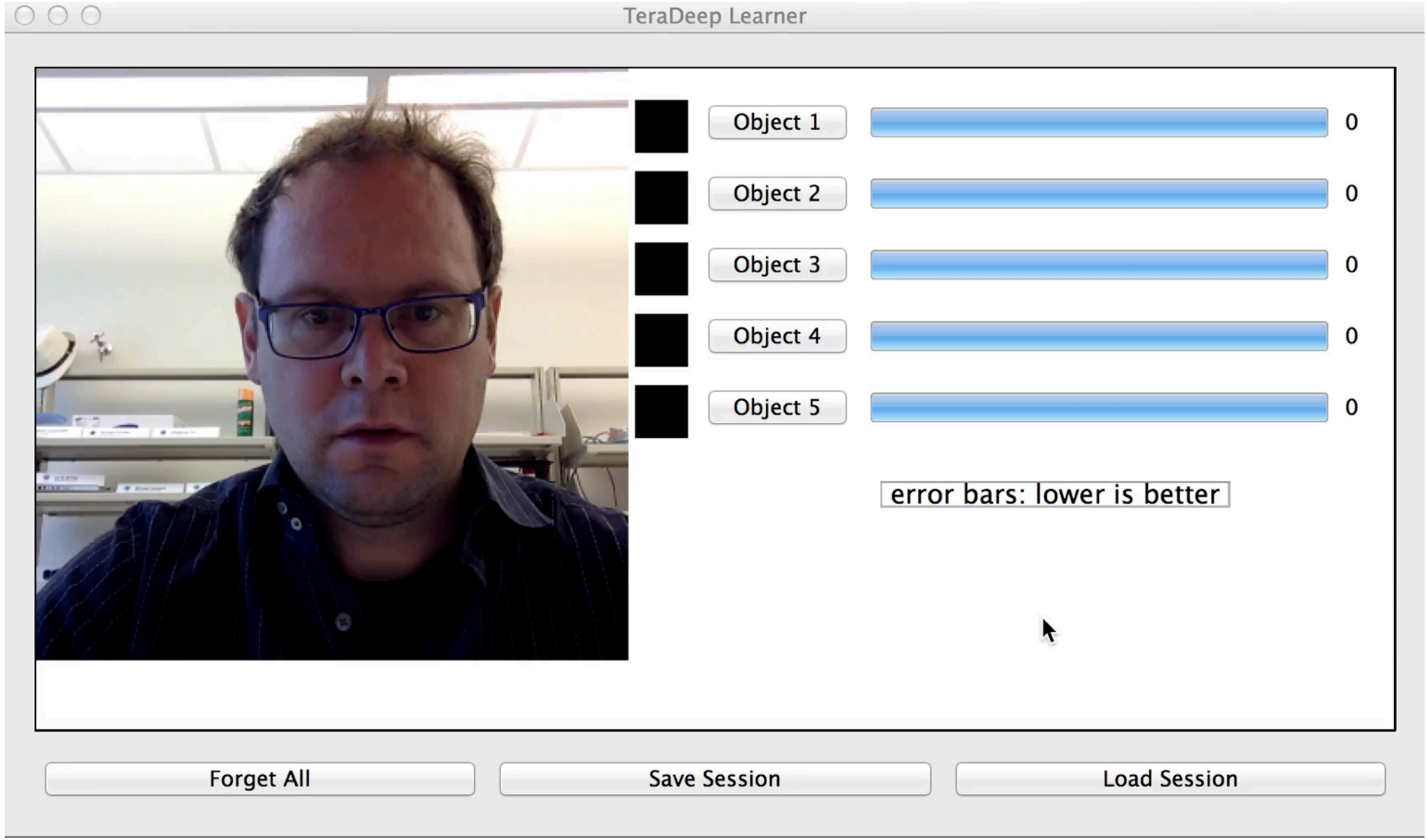
demos



state-of-the-art

Eugenio Culurciello

demos



state-of-the-art

how did we do this?

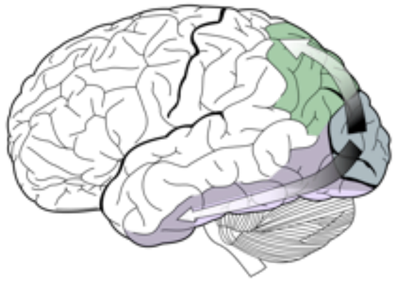
1: deep neural networks

2: streaming processor architecture

3: assemble vision systems

4: training deep networks

1: deep neural networks



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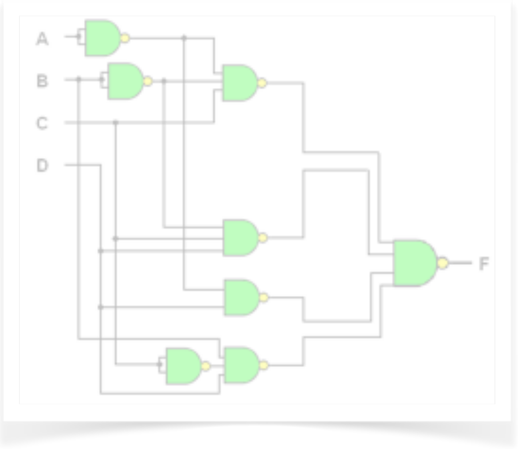
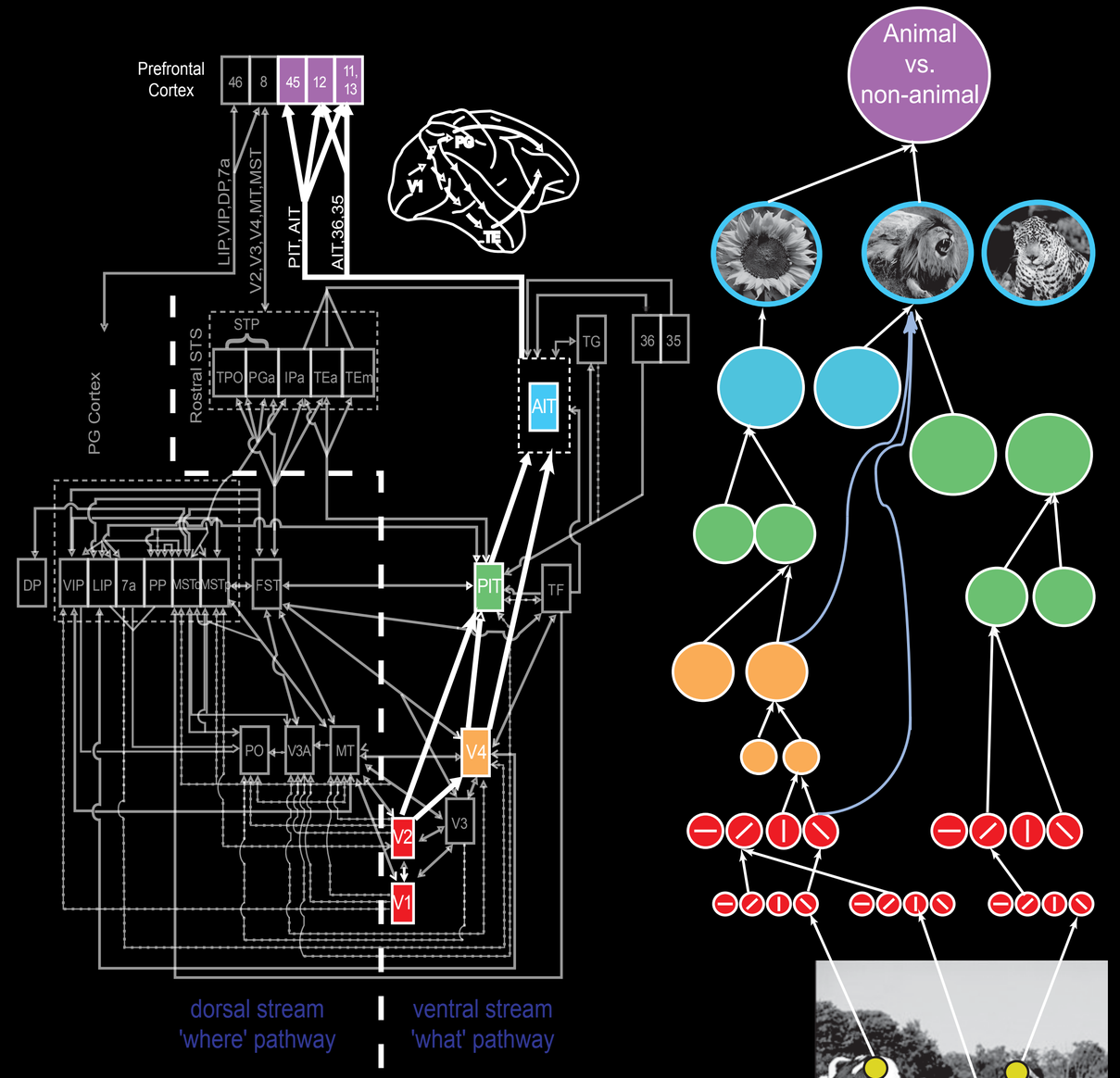
```





(Riesenhuber & Poggio 1999 2000;
Serre Kouh Cadieu Knoblich Kreiman & Poggio 2005;
Serre Oliva & Poggio 2007)

✦ V1:

- Simple and complex cells tuning properties (Schiller et al 1976; Hubel & Wiesel 1965; Devalois et al 1982)
- MAX operation in subset of complex cells (Lampl et al 2004)

✦ V4:

- Tuning for two-bar stimuli (Reynolds Chelazzi & Desimone 1999)
- MAX operation (Gawne et al 2002)
- Two-spot interaction (Freiwald et al 2005)
- Tuning for boundary conformation (Pasupathy & Connor 2001)
- Tuning for Cartesian and non-Cartesian gratings (Gallant et al 1996)

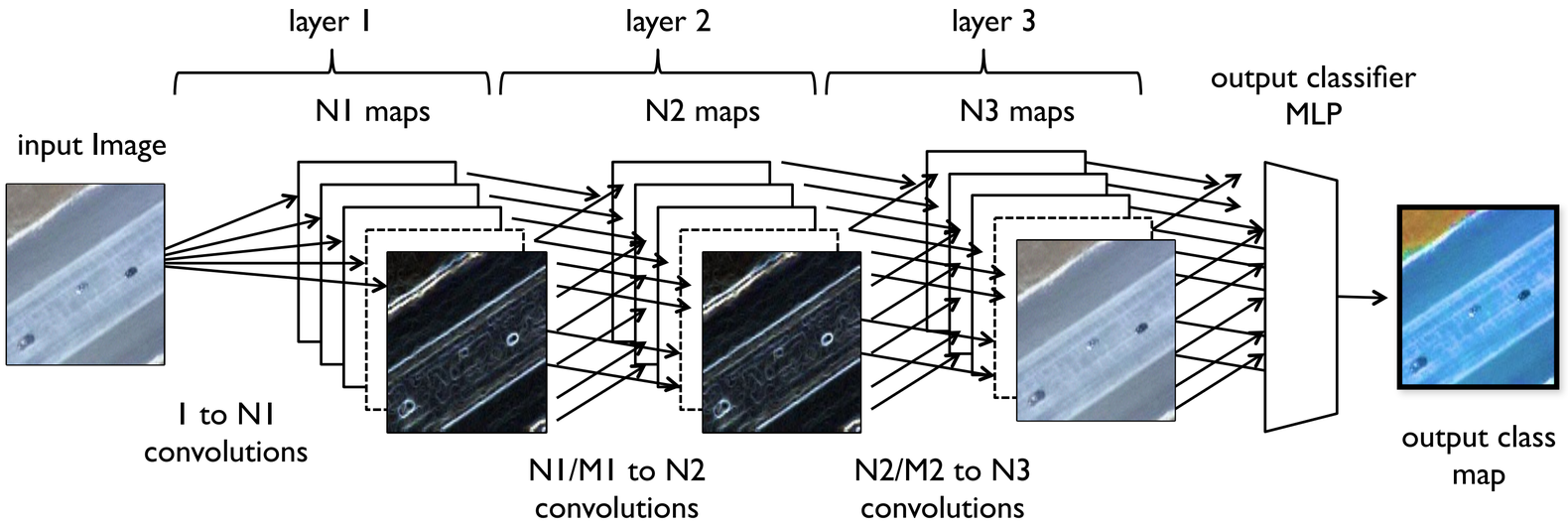
✦ IT:

- Tuning and invariance properties (Logothetis et al 1995)
- Differential role of IT and PFC in categorization (Freedman et al 2001 2002 2003)
- Read out data (Hung Kreiman Poggio & DiCarlo 2005)
- Average effect in IT (Zoccolan Cox & DiCarlo 2005; Zoccolan Kouh Poggio & DiCarlo in press)

✦ Human behavior:

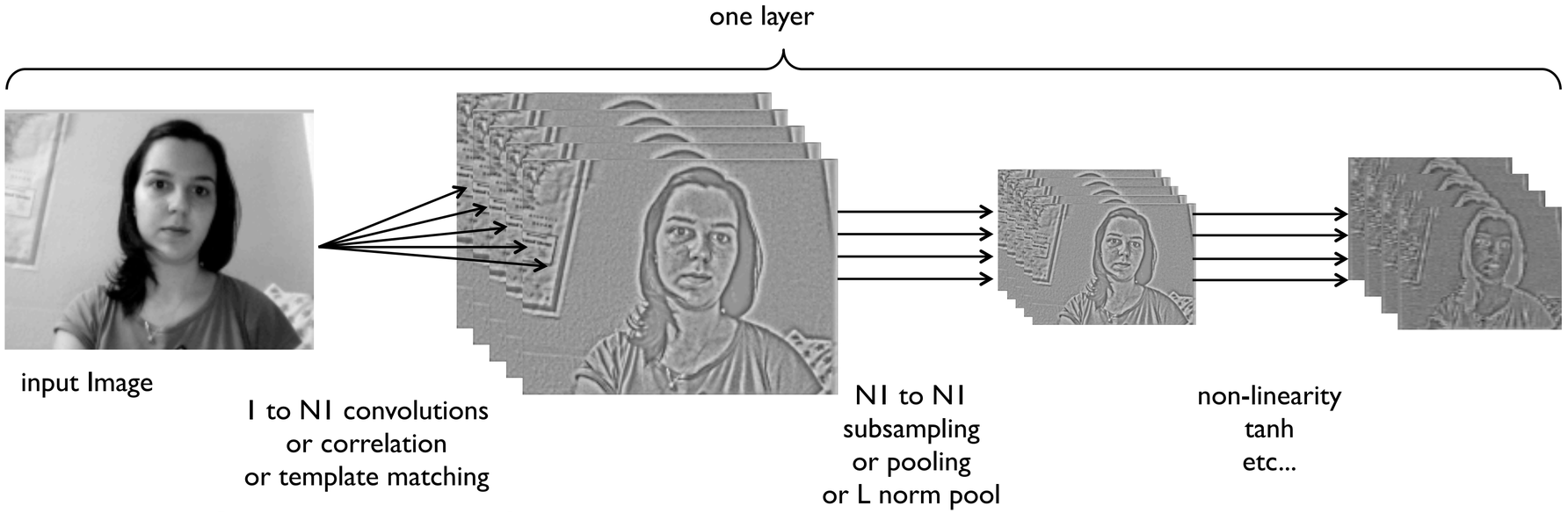
- Rapid animal categorization (Serre Oliva Poggio 2007)

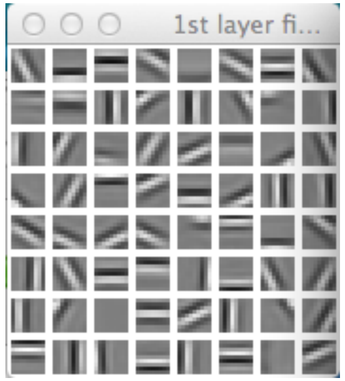
deep networks



deep, invariant,
trained on data,
model of visual system,
state-of-art

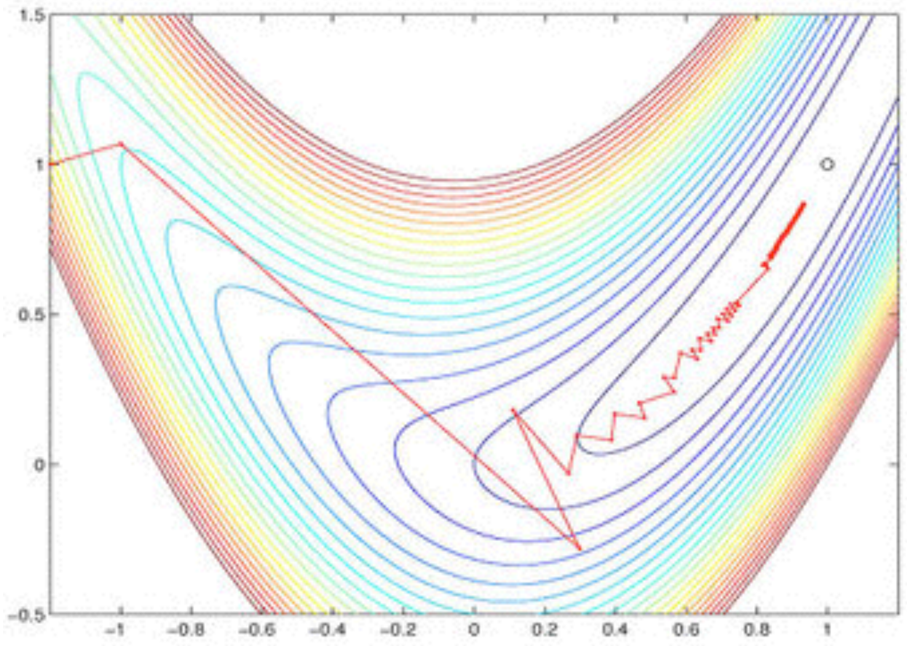
deep networks





deep network training

dataset



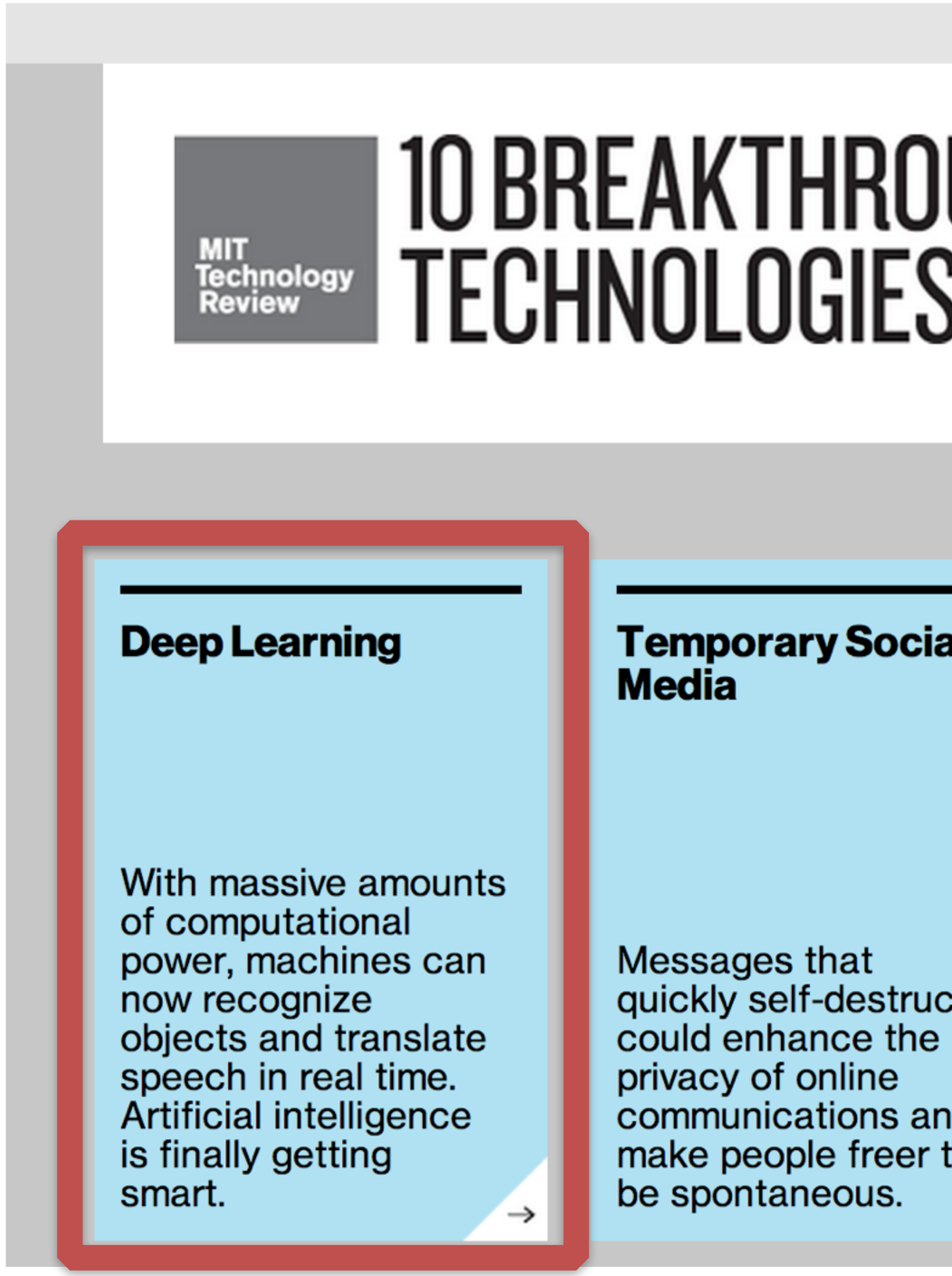
stochastic gradient descent

more on training later...

we use:

Deep Learning algorithms

multi-layer neural networks trained on large amounts of data



Our workhorse: deep learning algorithms

WIRED

Facebook's Quest to Build an Artificial Depends on This Guy

BY DANIELA HERNANDEZ 08.14.14 | 6:30 AM | PERMALINK

Yann LeCun, the new head of artificial intelligence at Facebook. Josh Valc

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Big Data

Why a deep-learning genius left Google & joined Chinese tech sh Baidu (interview)

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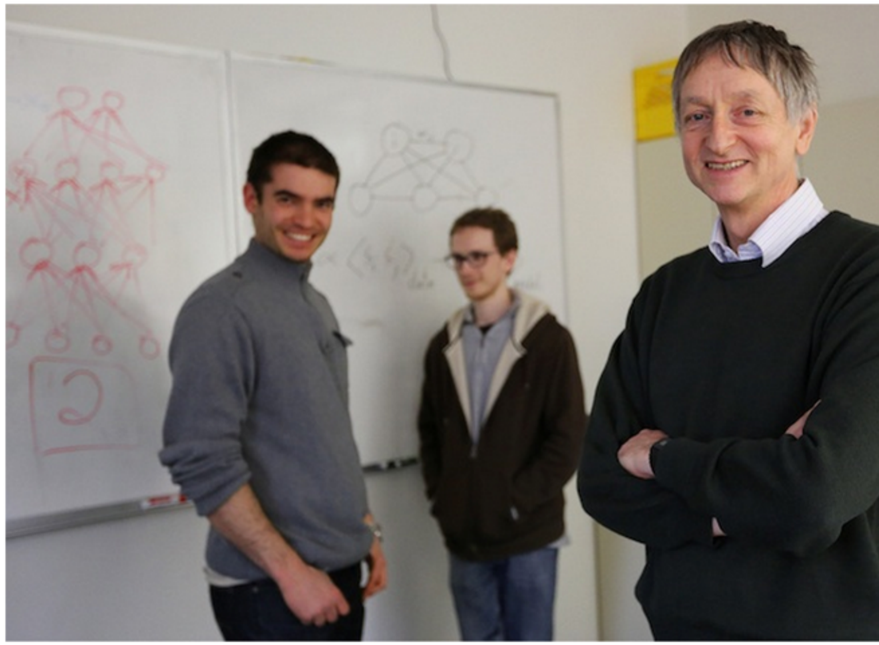
Google Hires Brains that Helped Supercharge Machine Learning

BY ROBERT MCMILLAN 03.13.13 | 6:30 AM | PERMALINK



Geoffrey Hinton (right) Alex Krizhevsky, and Ilya Sutskever (left) will do machine learning work

Our workhorse: deep learning algorithms

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Business on the cloud is made with IBM.

Tap into the IBM C

ENTERPRISE deep learning Deepminds google Madbits

Buying Madbits, Twitter Wants Image-Search Super Powers

BY CADE METZ 07.30.14 | 4:57 PM | PERMALINK

2: streaming processor architecture

```
begin
    make QUEUE empty;
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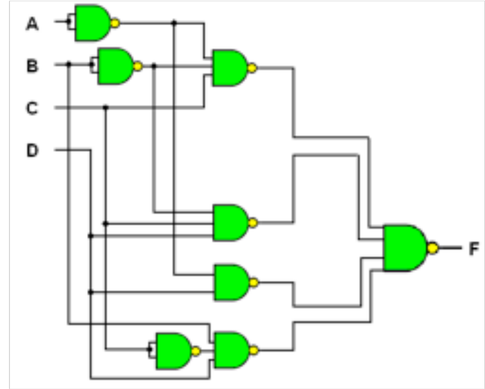
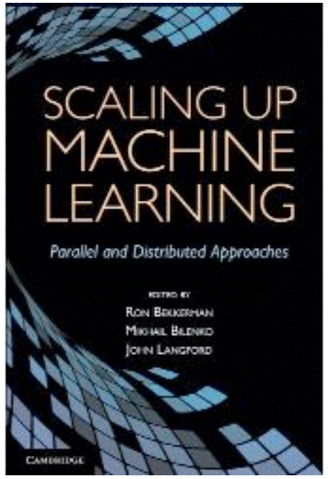
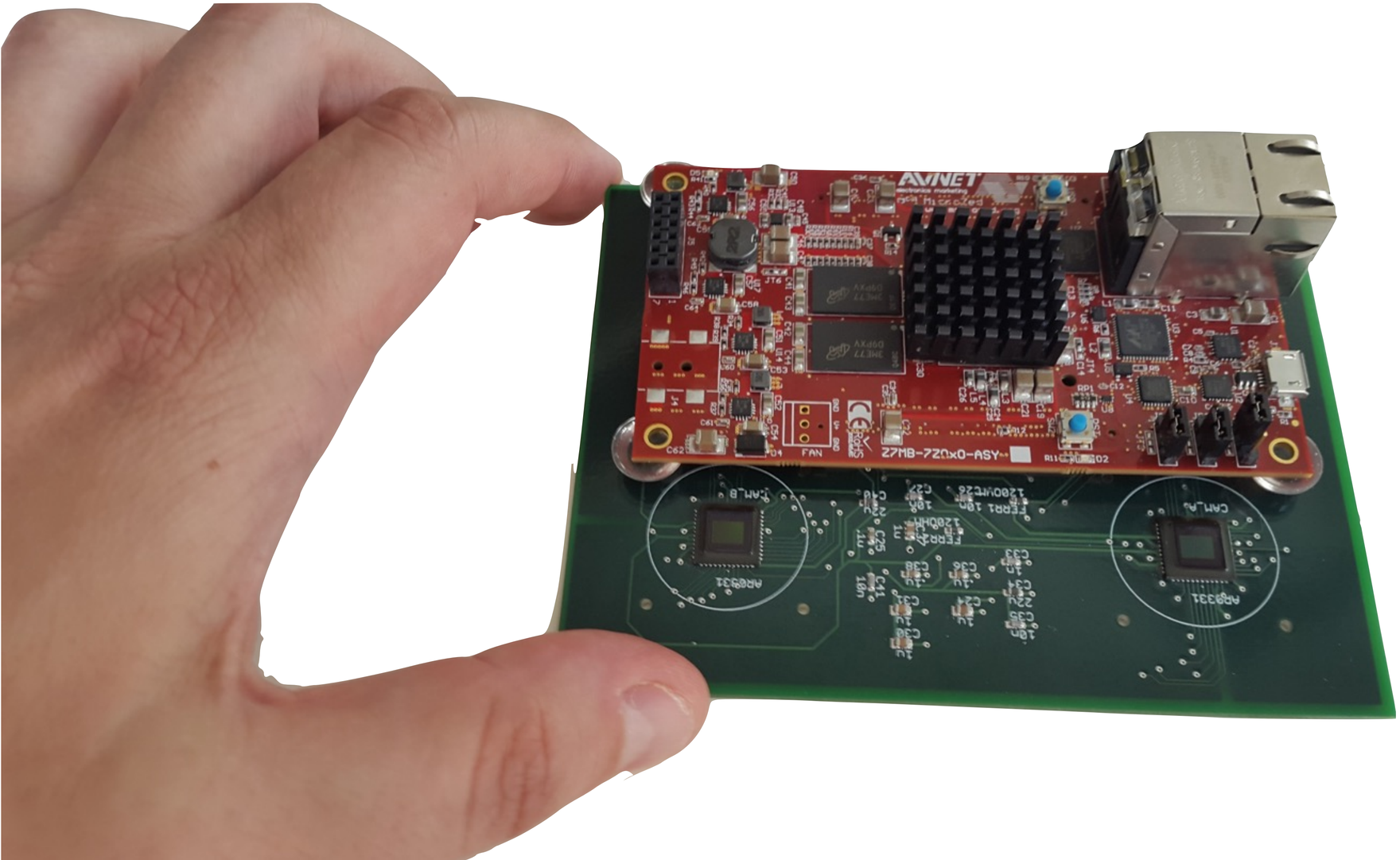


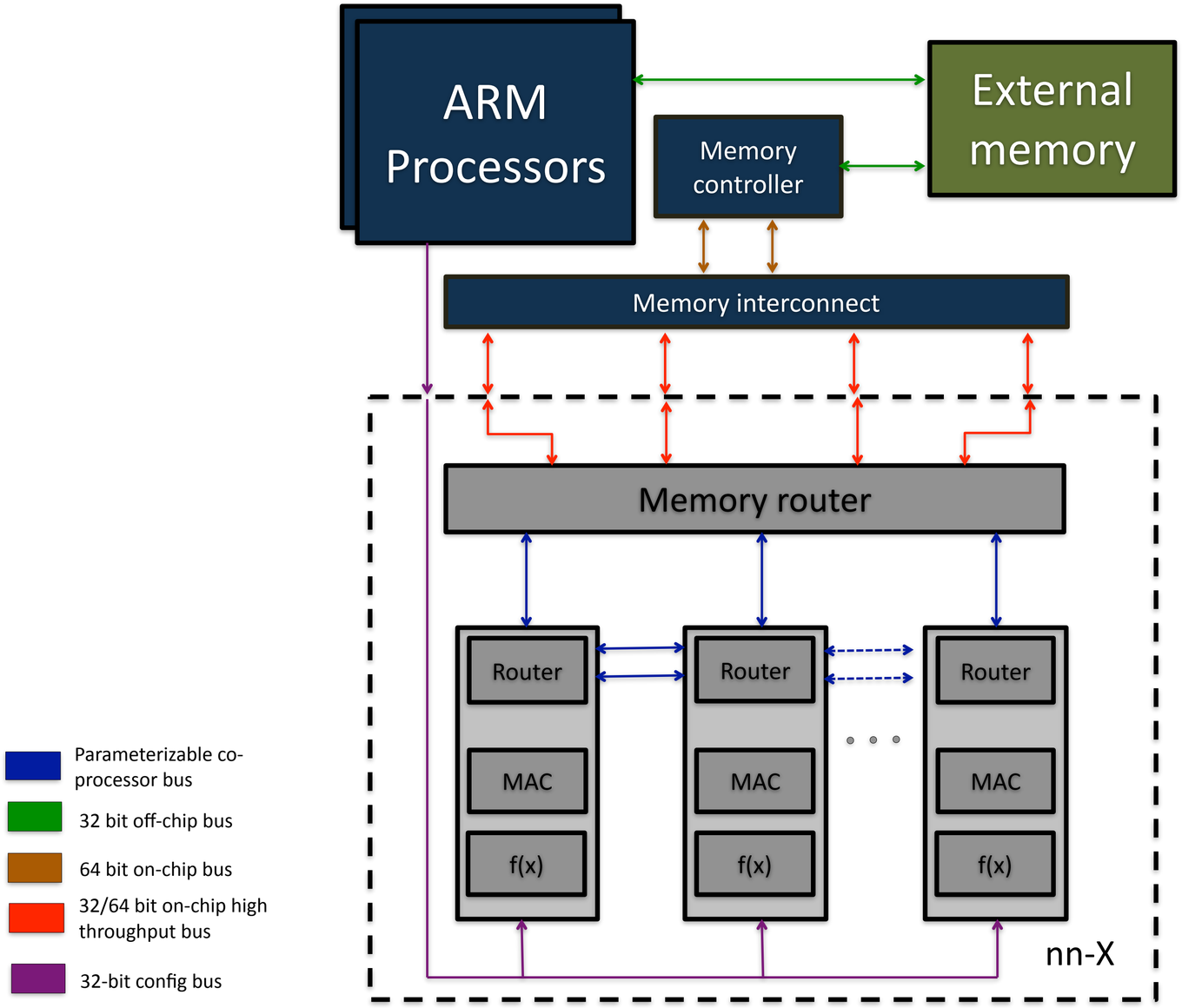
conventional hardware



our hardware: FPGA

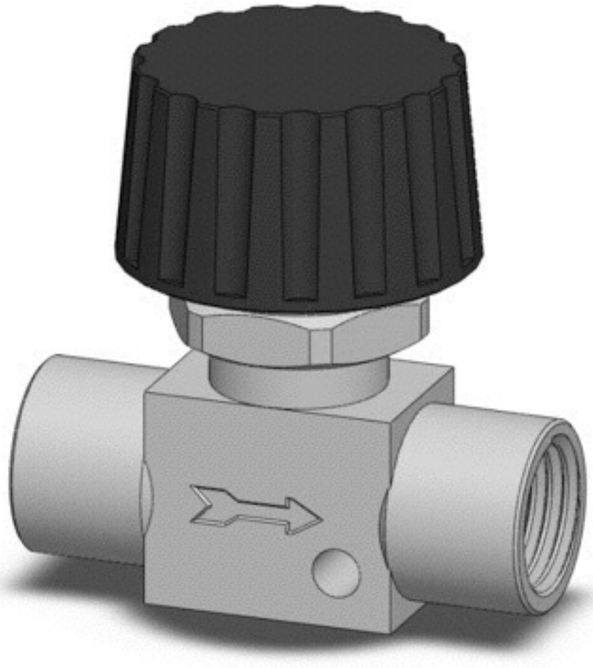


nn-X



streaming architecture

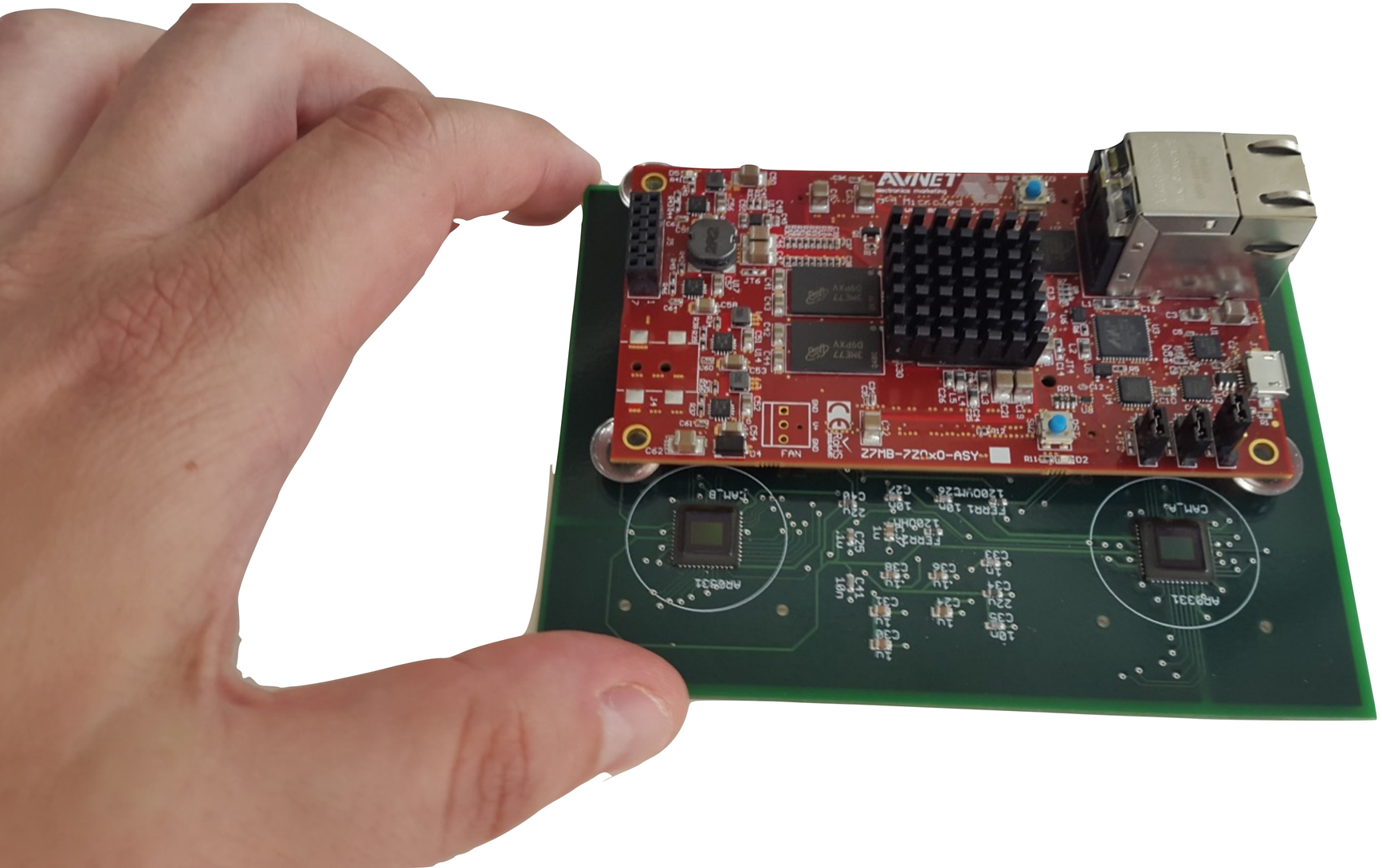
Parallel



no flow control

even with a slow clock

3: assemble vision systems

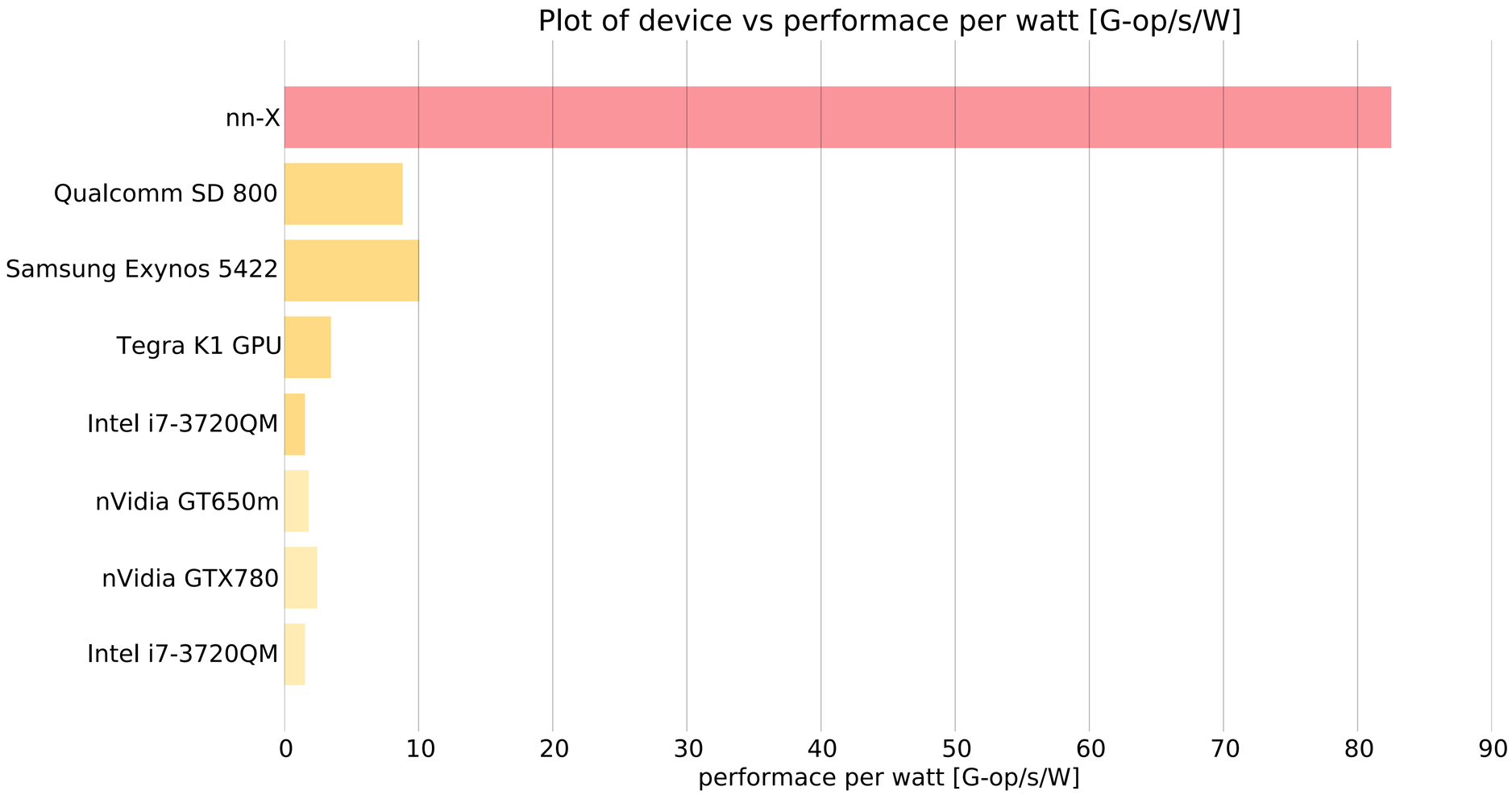


nn-X

> 360 G-ops/s on FPGA

parallel: 8x operators collections includes neural classifier

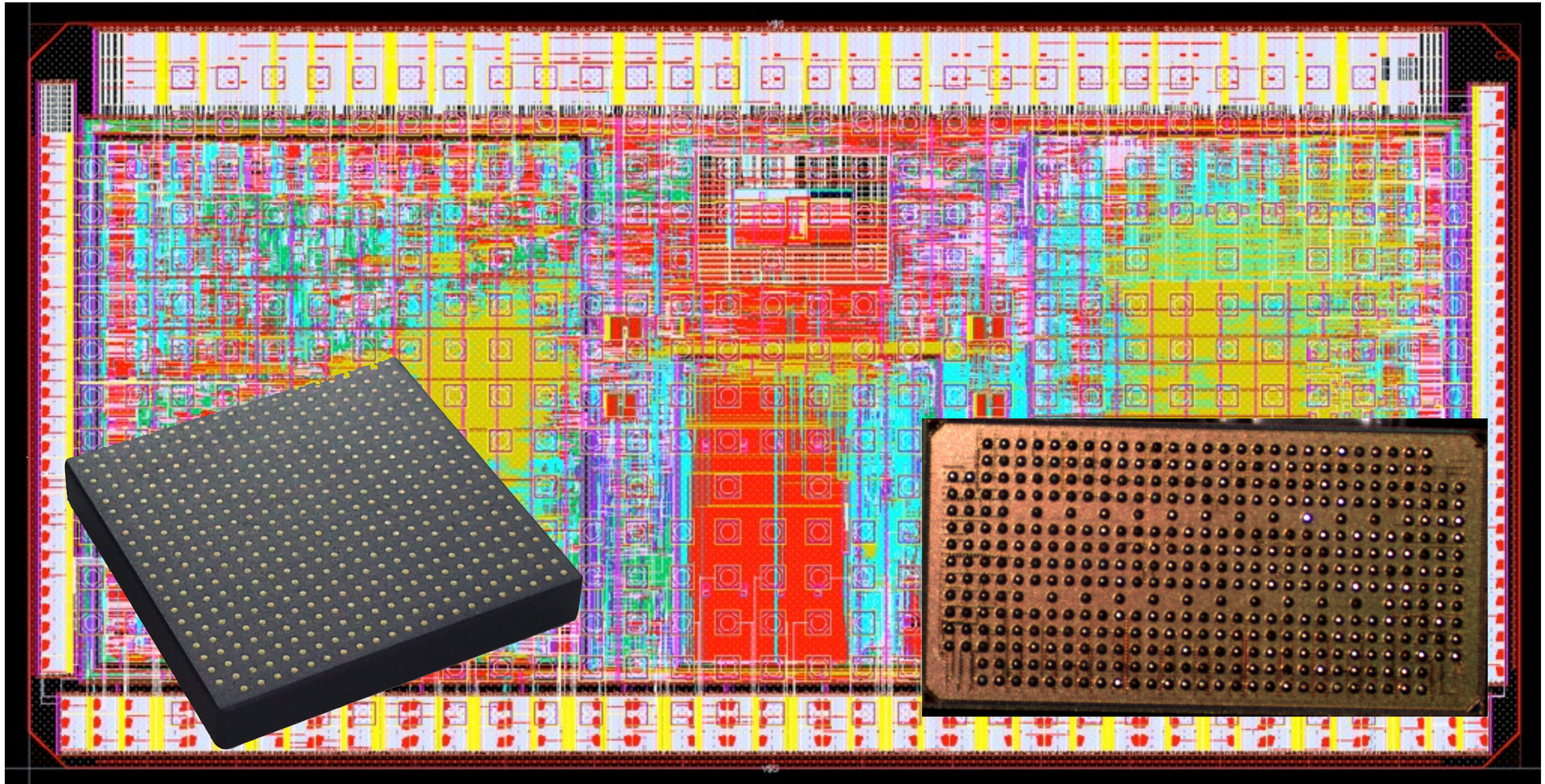
nn-X performance



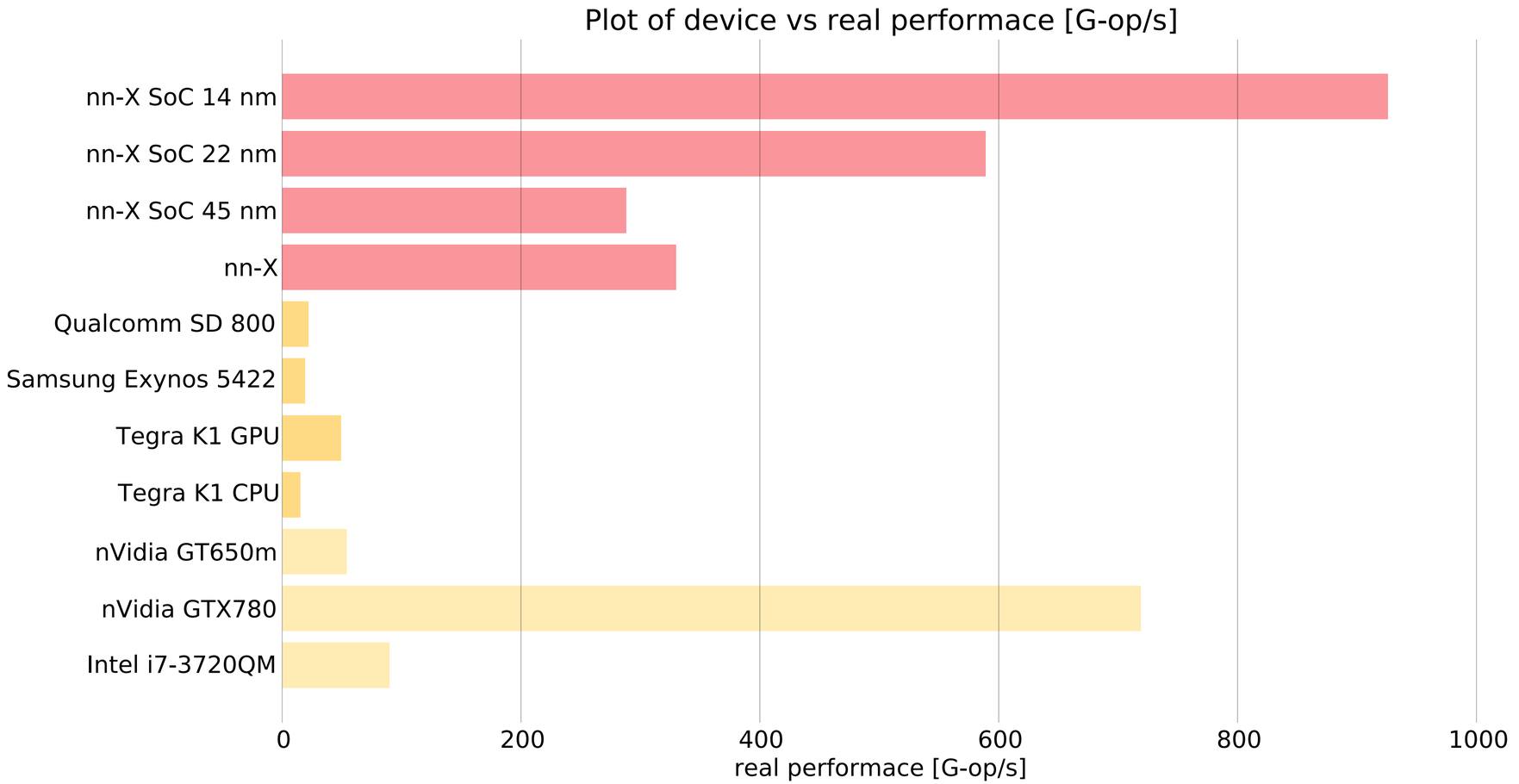
Performance and power consumption computed on a
16x10x10 filter-bank over a 500x500 input image

nn-X ASIC

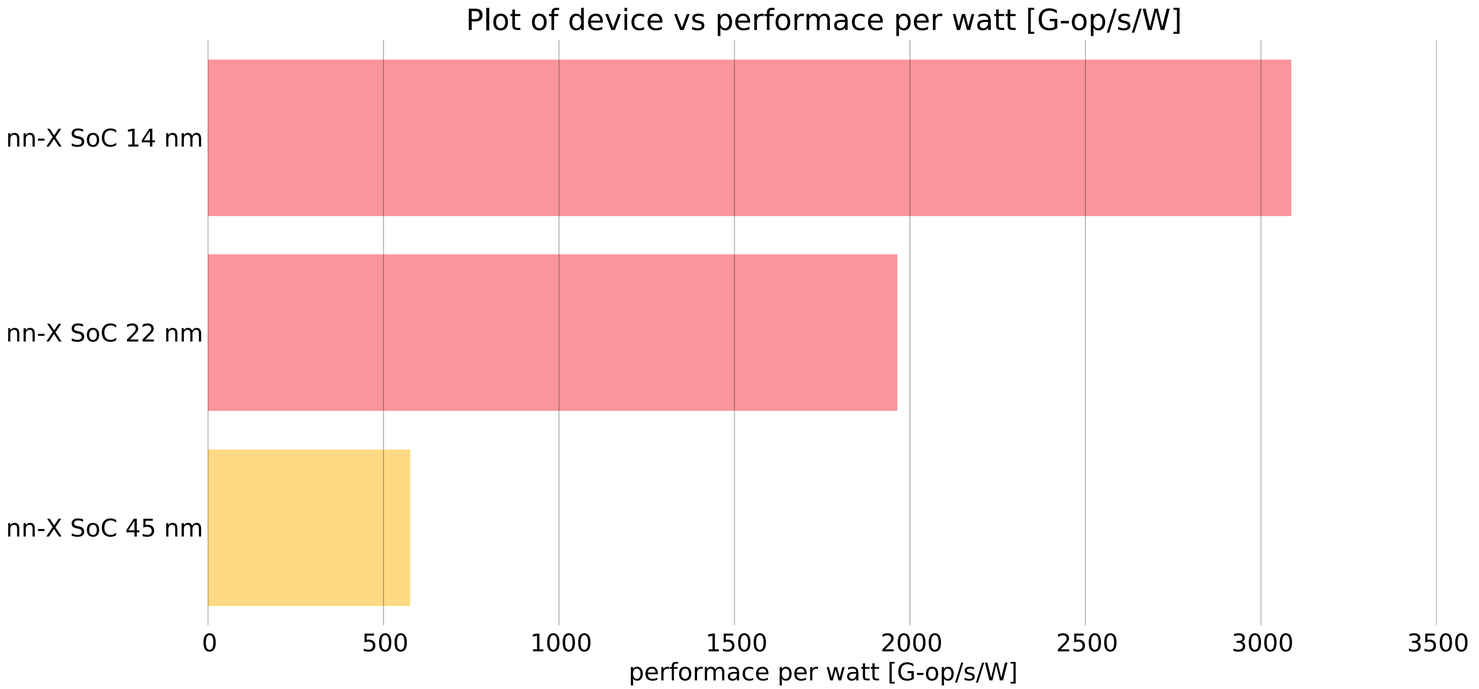
- IBM 45 nm high-density technology, 2.5x5mm
- 400MHz system clock, 200MHz CPU clock
- 4 convolvers, combiners, mappers
- Performance 12x better than FPGA (G-ops/Watt)



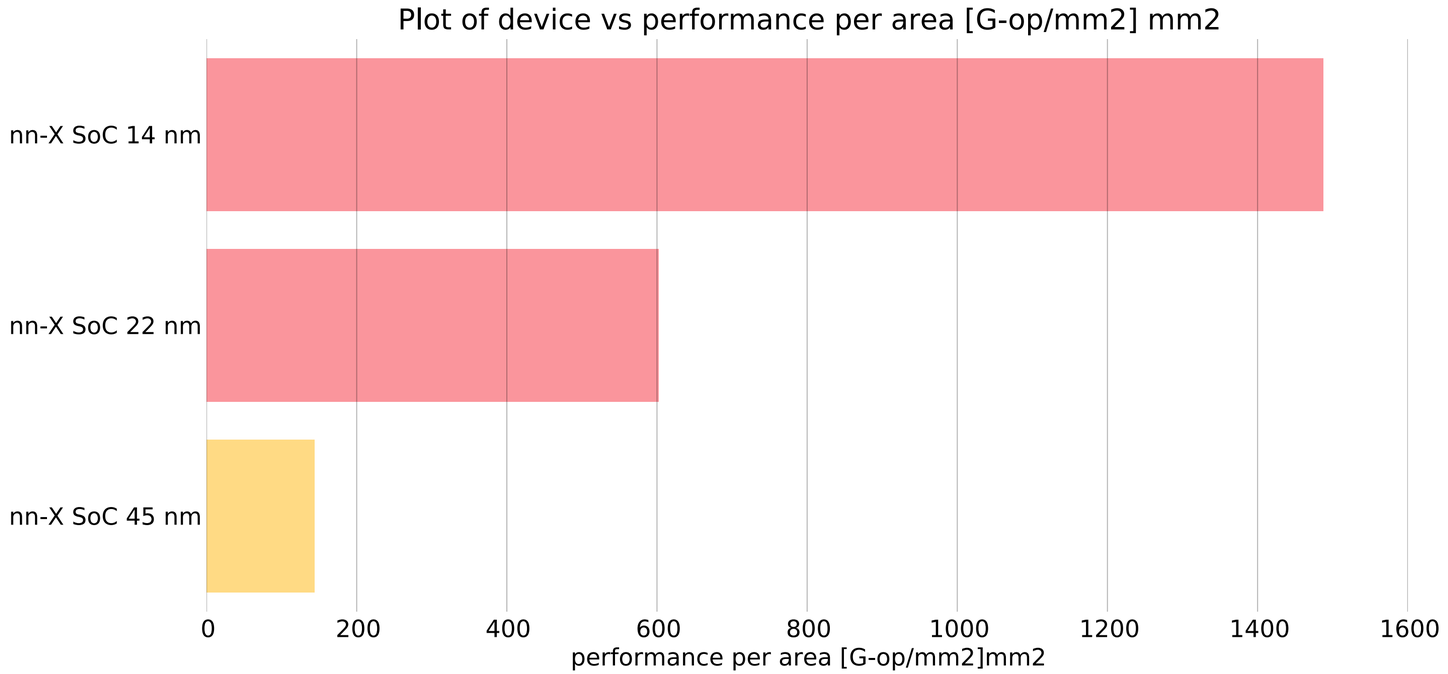
nn-X performance



nn-X performance

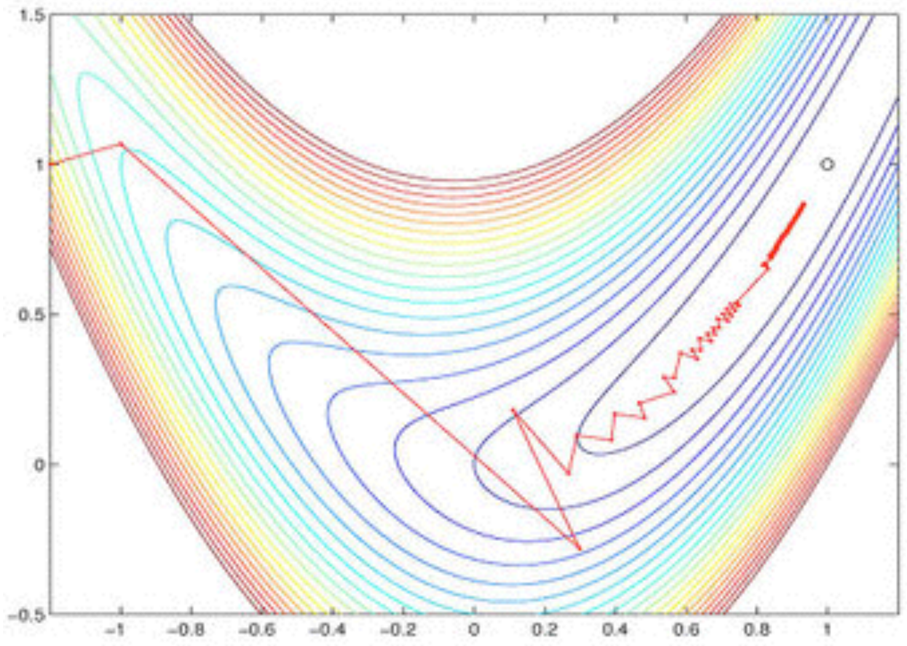


nn-X performance



4: training deep networks

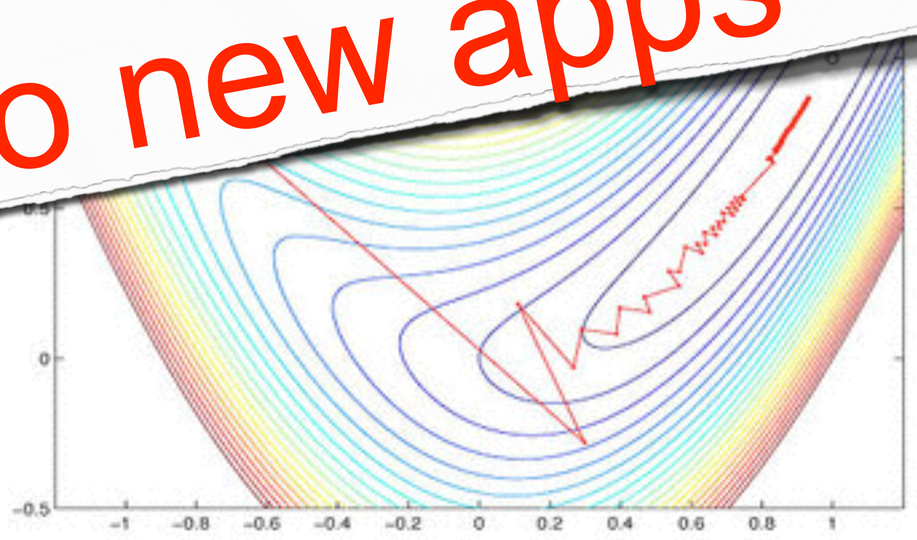
dataset



stochastic gradient descent

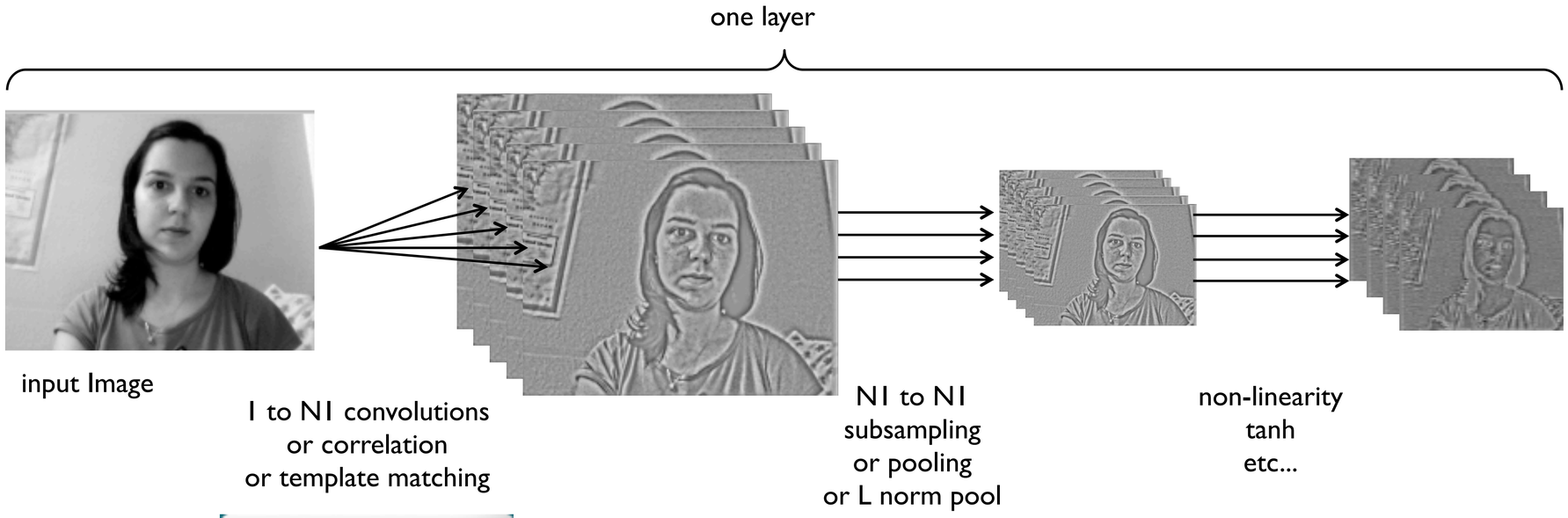
expensive, not scalable for videos, imprecise, not “portable” to new apps

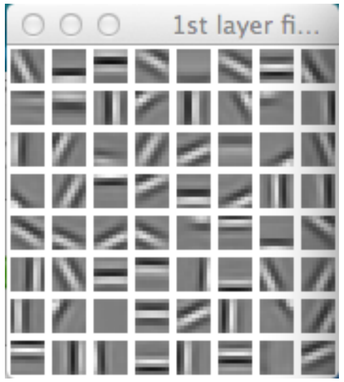
dataset



stochastic gradient descent

deep networks training





It is all about:
[filters], connections!!!

Hebbian Learning

Clustering Learning

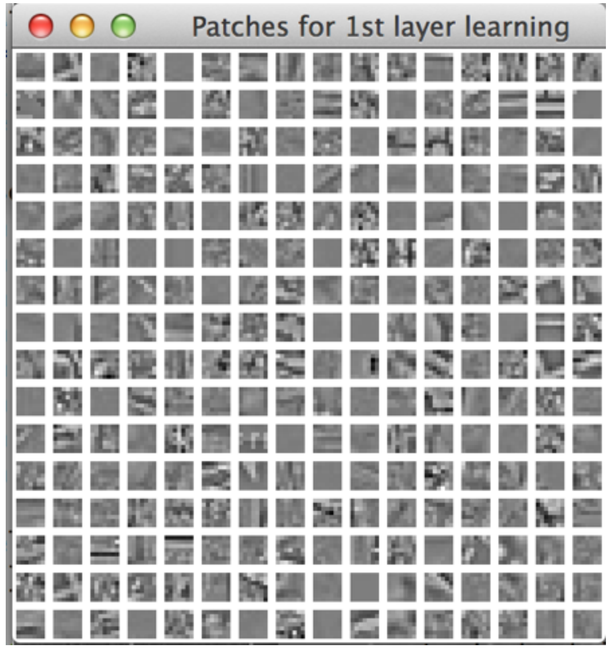
fire together
wire together

respond
together

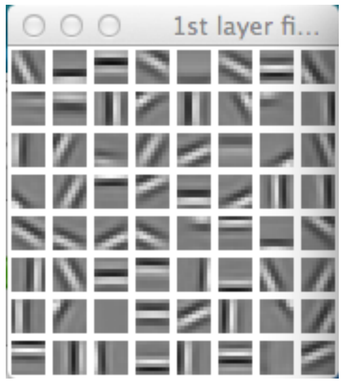
cluster together

compatible with STDP learning

clustering learning



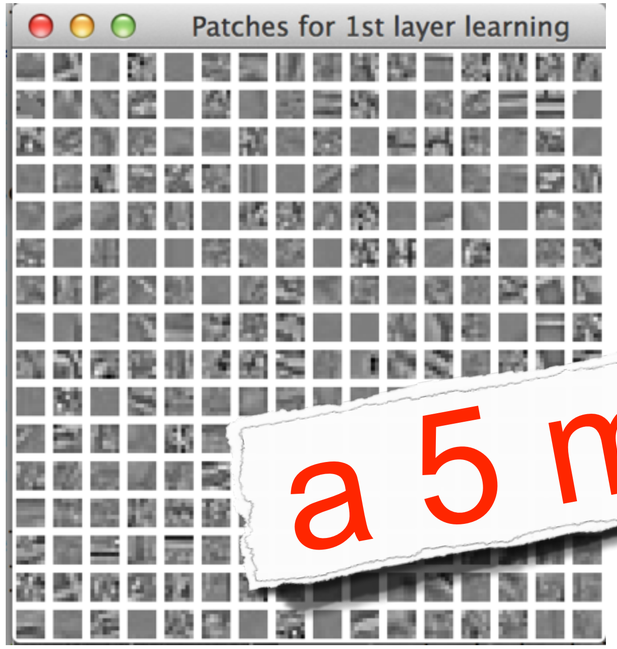
random patches of images



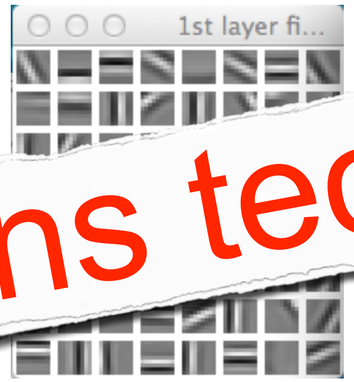
clustered means

use filters as parameters for this layer

clustering learning



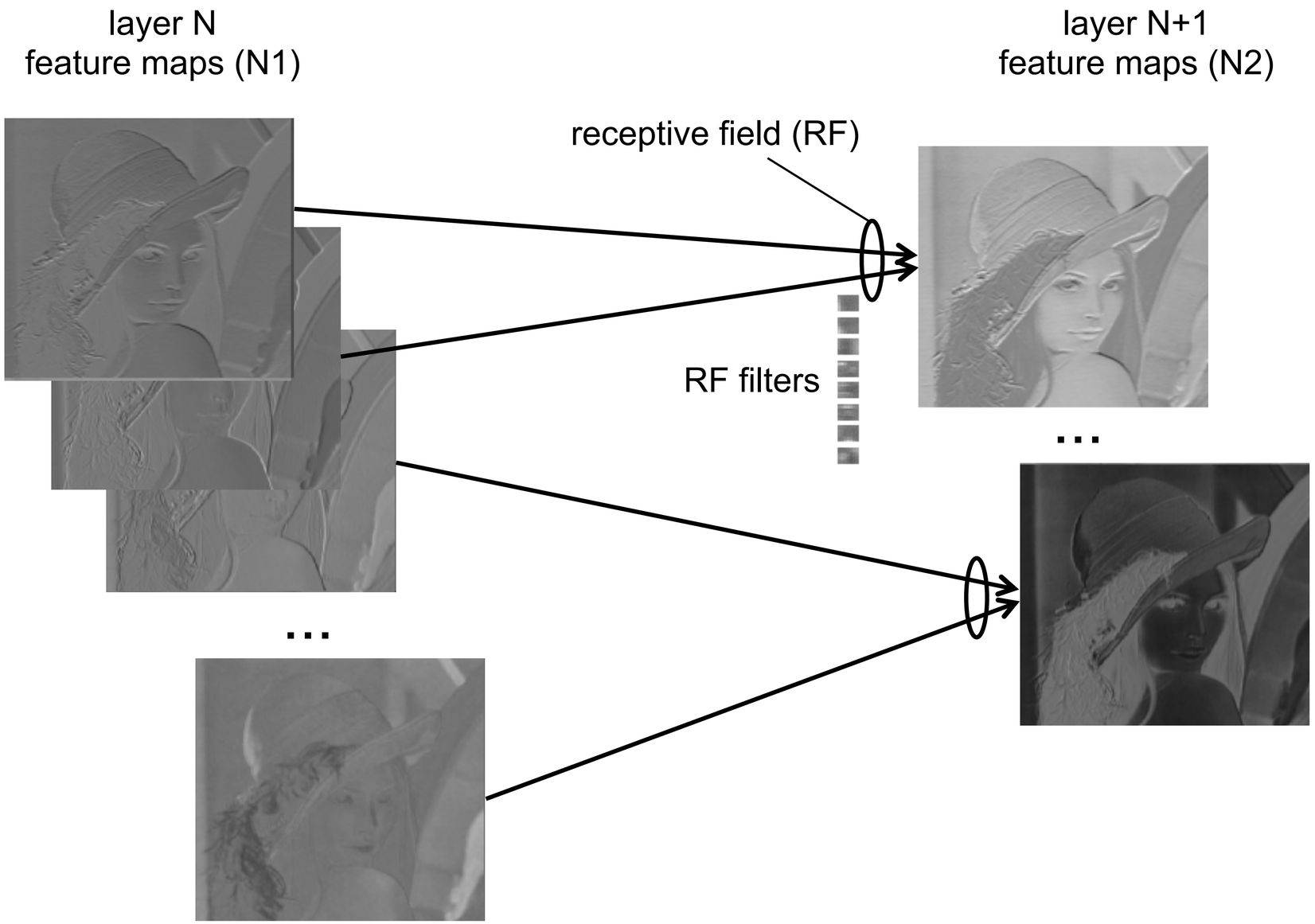
random patches of images



clustered means

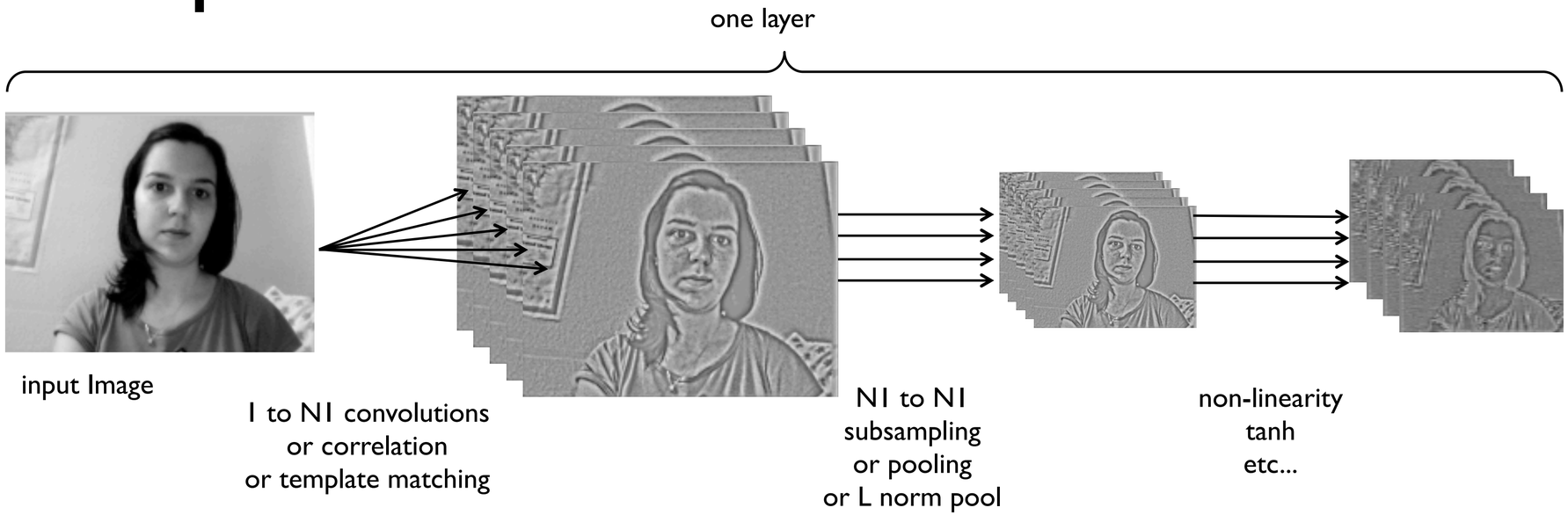
a 5 mins technique!

use filters as parameters for this layer



main idea: learn to CLUSTER inputs based on co-occurrence of features

deep networks



Multiple layers of deep network:

Repeat for each layer:

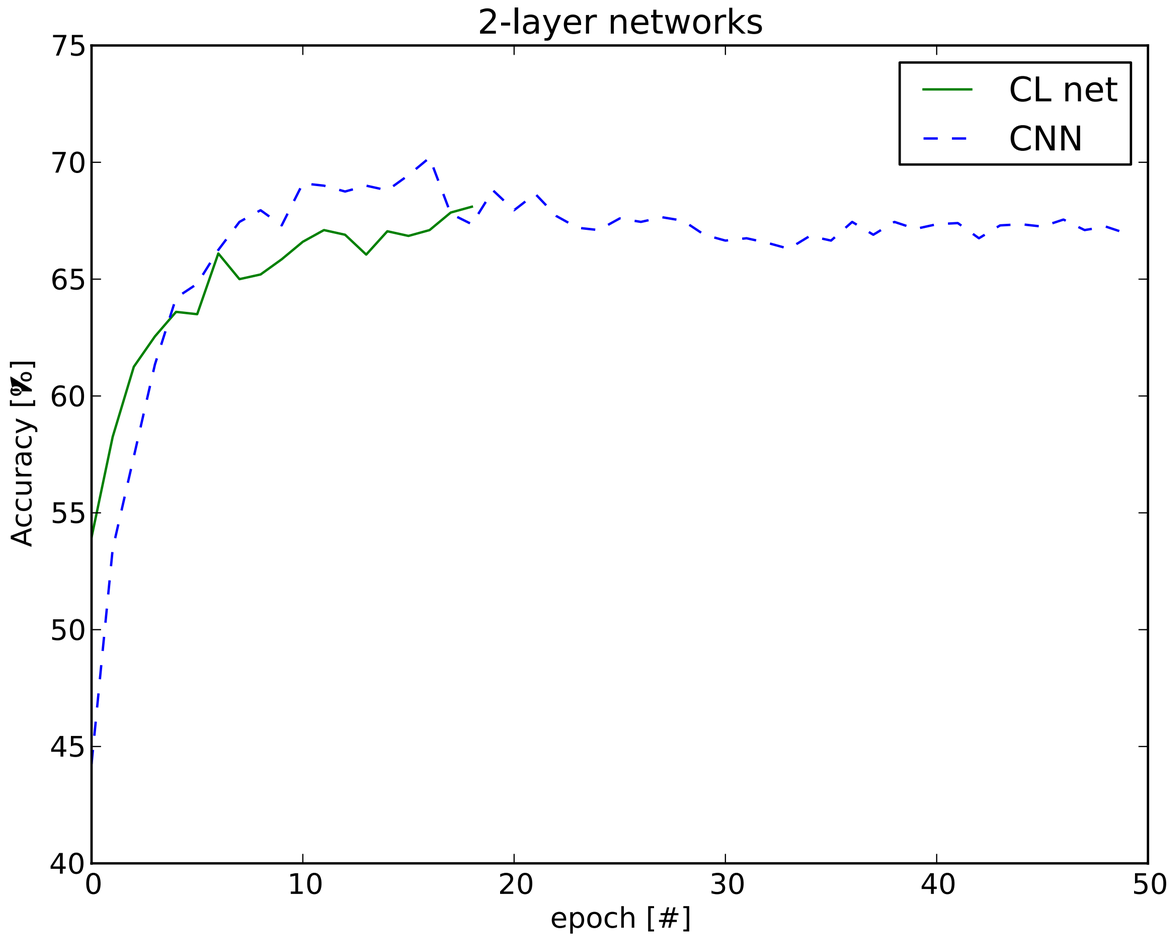
1- sample output of previous layer (new input)

2- cluster these inputs = filters

3- use filters to generate outputs

clustering learning

as well as standard convnet/CNN!!!

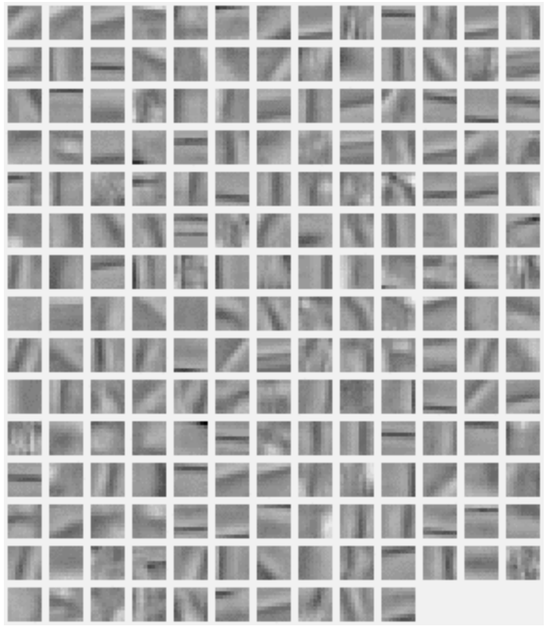


CIFAR10

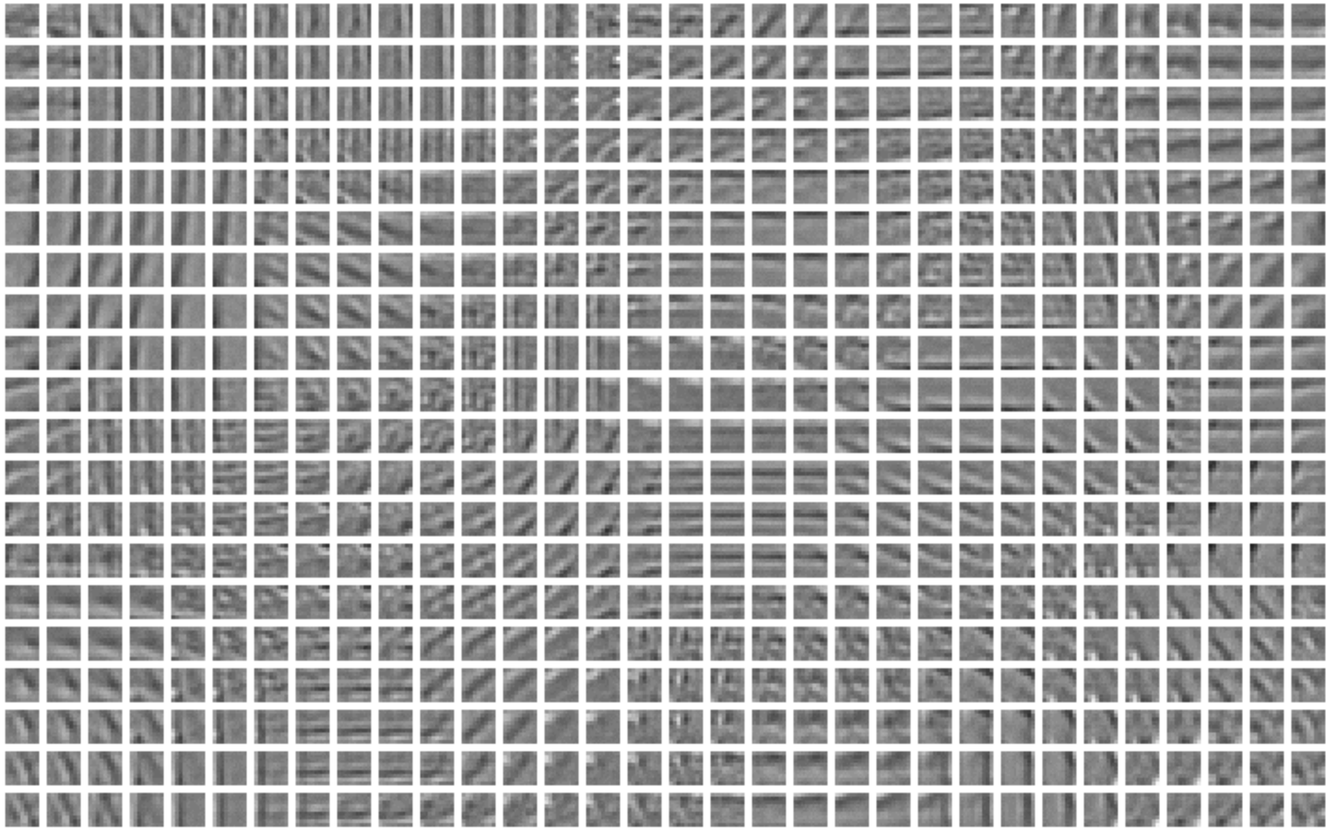
clustering learning: motion filters

same patch location for multiple frames

run k-means
on group of
patches



clustering learning: topographic filters



Eugenio Culurciello

Summary of results

- state-of-the-art architecture for complex understanding of the environment
- fully programmable
- customized for neural networks, is extendable to any state-of-the-art algorithms
- scalable to larger networks and applications
- To do: extend it to learning from videos, unsupervised multi-layer learning

e-Lab

Thanksgiving

E-Lab current members:
Aysegul Dundar
Vinayak Gokhale
Jonhoon Jin
Alfredo Canziani
Berin Martini

and with:
Clement Farabet

Visitors:
Jose Carrasco
Angelo Rottigni
Alejandro Linares-Barranco
Rafael Paz

Past members:
Zhengming Fu
Pujitha Weerakoon
Shoushun Chen
Farah Laiwalla
Huang Chenxi
Dongsoo Kim
Andrew Kunil Choe
Selcuk Talay
Polina Askelrod
Faye Zhao
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Hazael Montanaro
Darko Jelaca
Jonathan McMillan
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Phi-Hung Pham
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