http://synergy.ece.gatech.edu

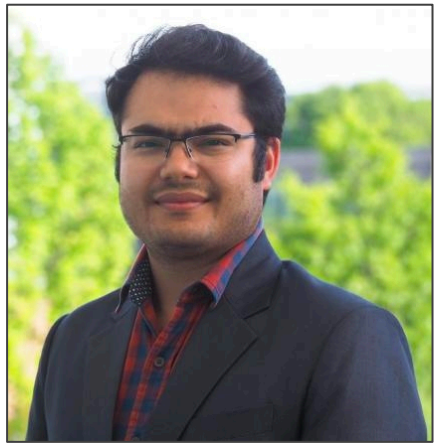
SCALE-Sim: Systolic CNN accelerator simulator

Tutorial @ ASPLOS 2021
April 16 2021

https://scalesim-project.github.io/
https://scalesim-project.github.io/tutorials-2021-asplos.html

Presenters

Tushar Krishna
Associate Professor
Georgia Tech



Ananda Samakdar
PhD Student
Georgia Tech

Jan Moritz Joseph
Post Doc Researcher
RWTH Aachen University

Paul Whatmough
Principal Research Engineer
ARM Research, Boston

Yuhao Zhu
Assistant Professor
Univ. of Rochester

Schedule (EST)

Time slot	Topic	
10:05 – 10:10	Welcome and Overview	Tushar
10:10 to 10:45	Introduction to DNNs and Accelerator Design	Paul & Tushar
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Brief Q/A at the end of each talk.

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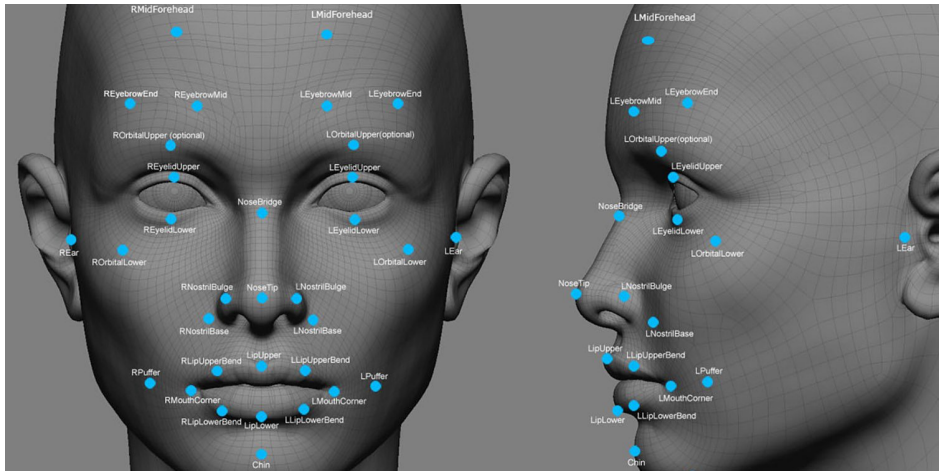
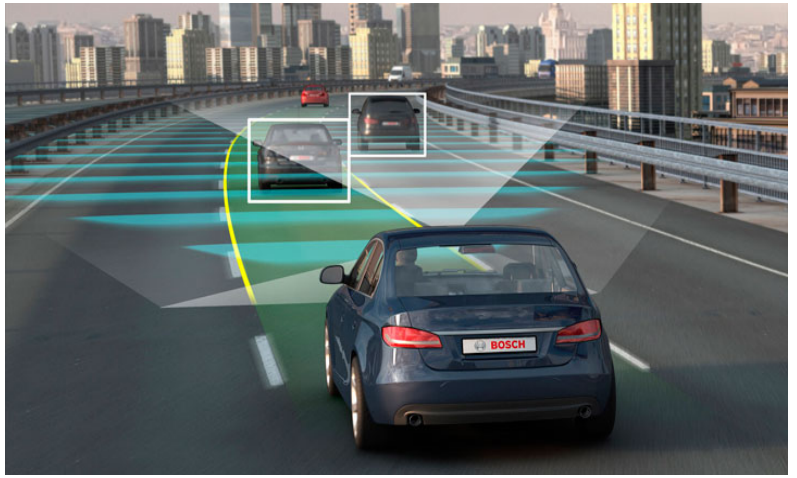
Outline

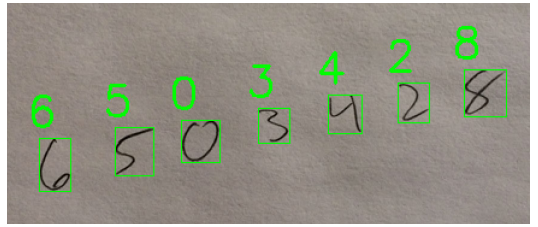
- **What this tutorial is about**
  - Role within the Deep Learning landscape
- **Resources**
  - SCALE-sim
  - Synthesis Lectures
- **Relevant Background**
  - Deep Learning Landscape
  - DNN Accelerators

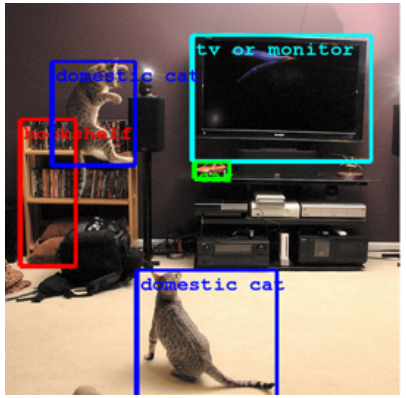
What this tutorial is about

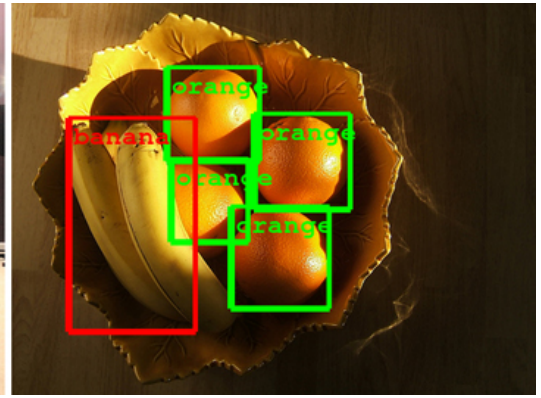
Deep Learning Applications

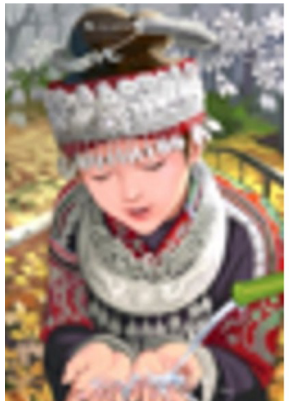


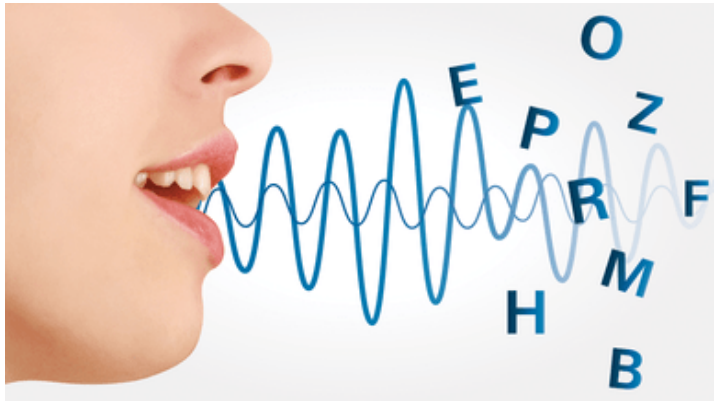




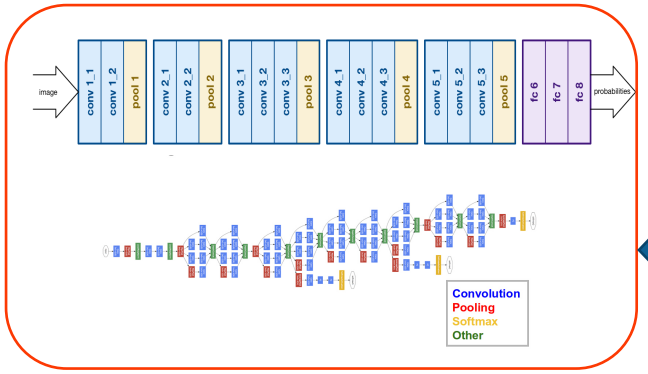








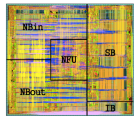
Deep Learning Landscape



Model Creation

Training

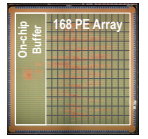
Inference



Apple Neural Engine

ShiDIanNao

NVDLA



ARM Trillum

CambriconX

Eyeriss

TensorFlow

Caffe

cuDNN

intel Software

MLSL

NVIDIA

TensorRT

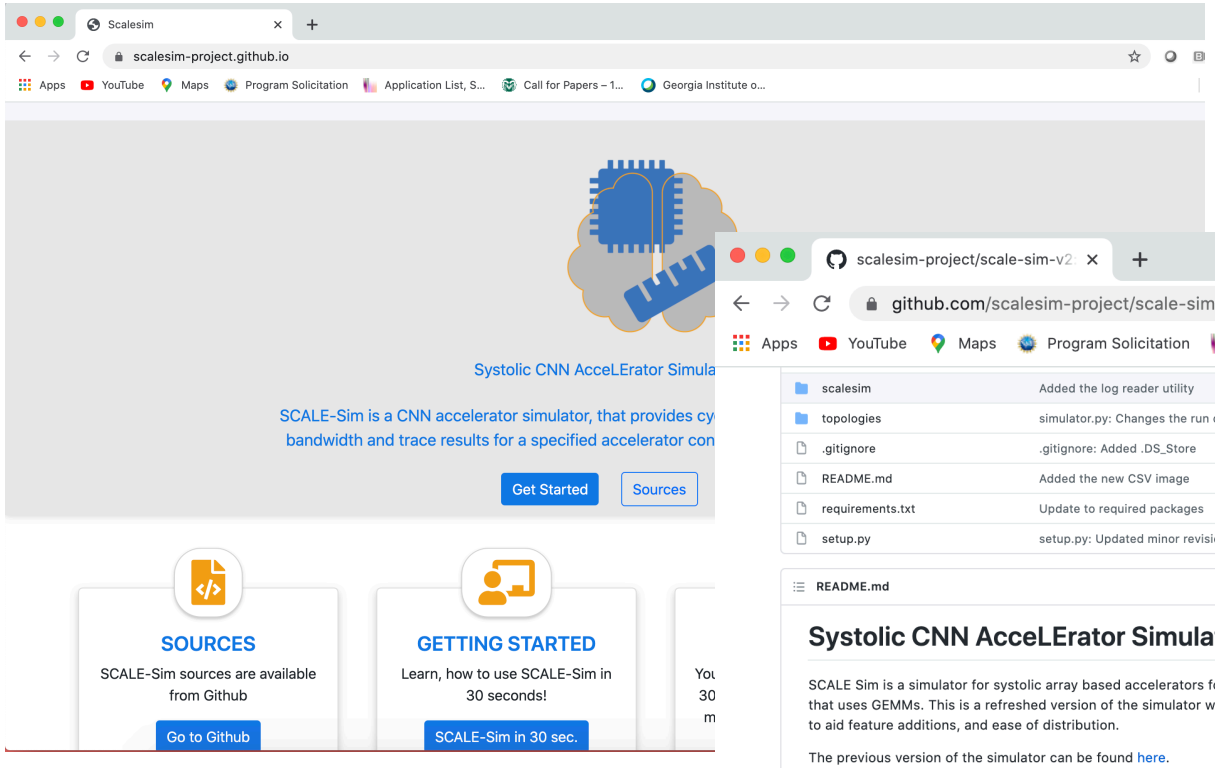
SCALE-sim

This Tutorial

Design Tools

Resources

SCALE-sim Webpage, Github and Tutorial



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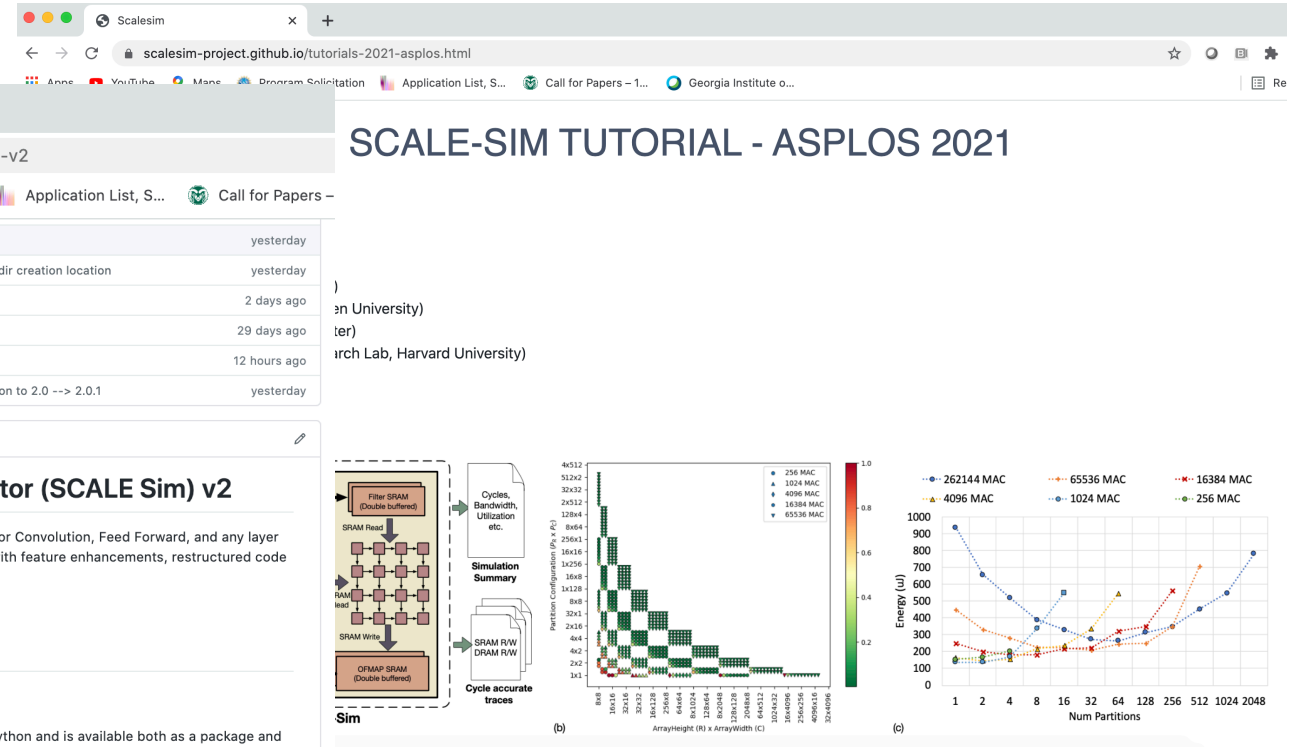
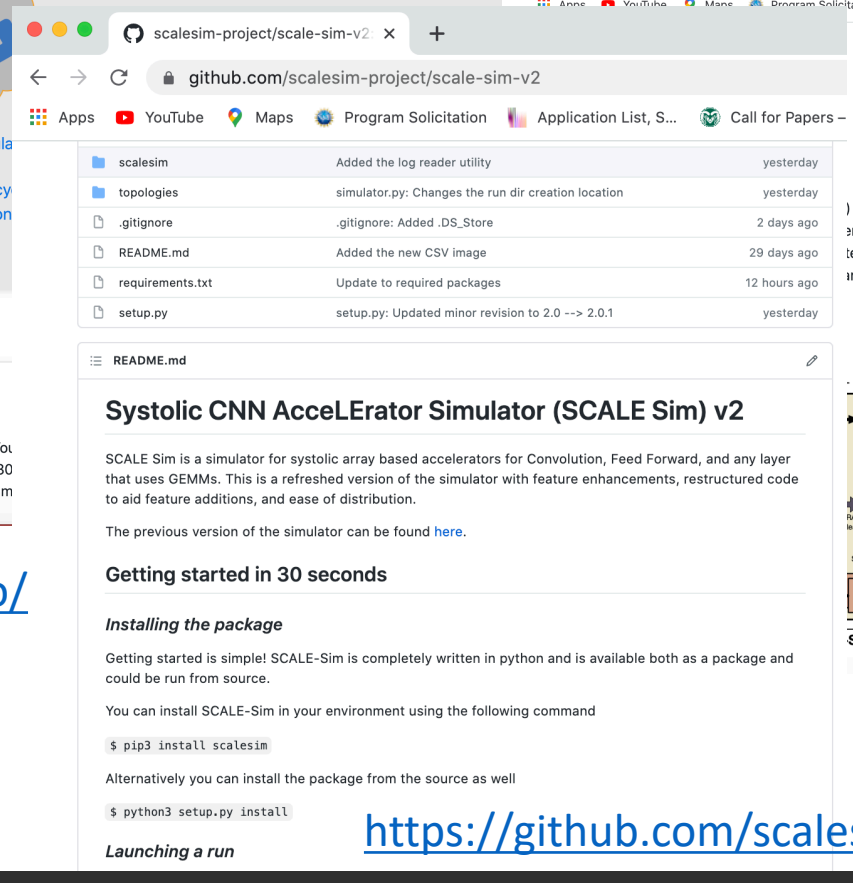
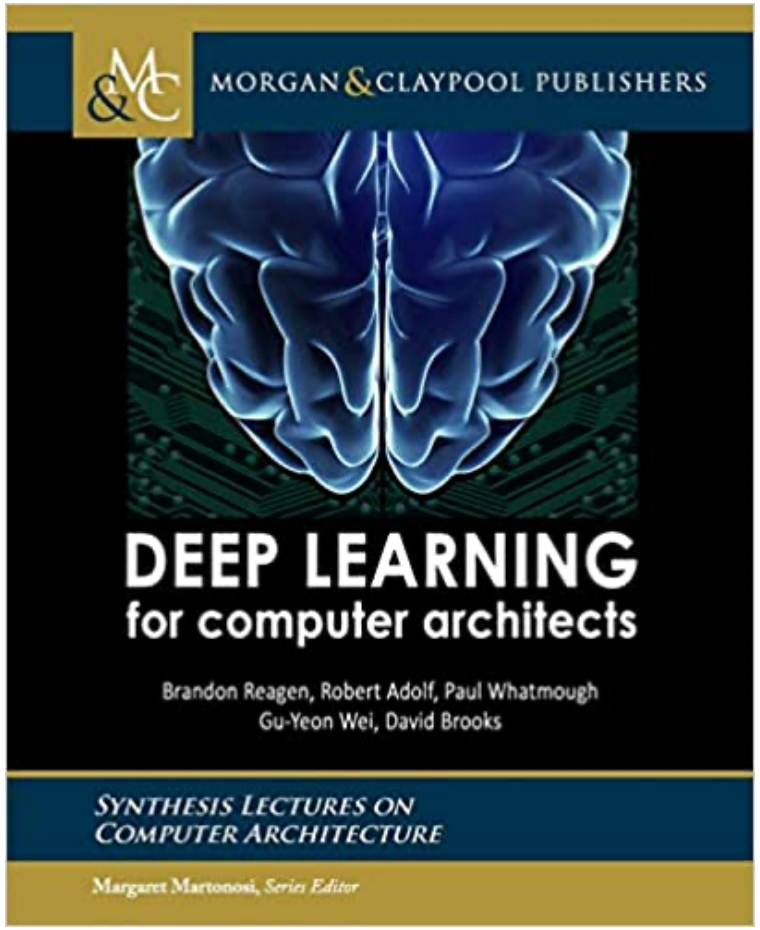
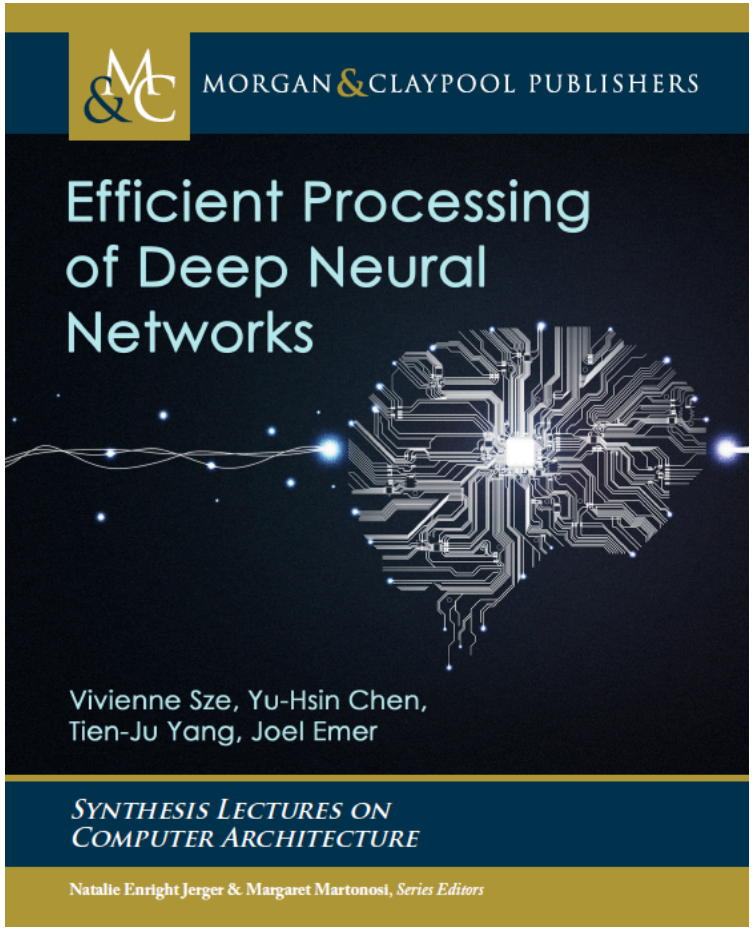


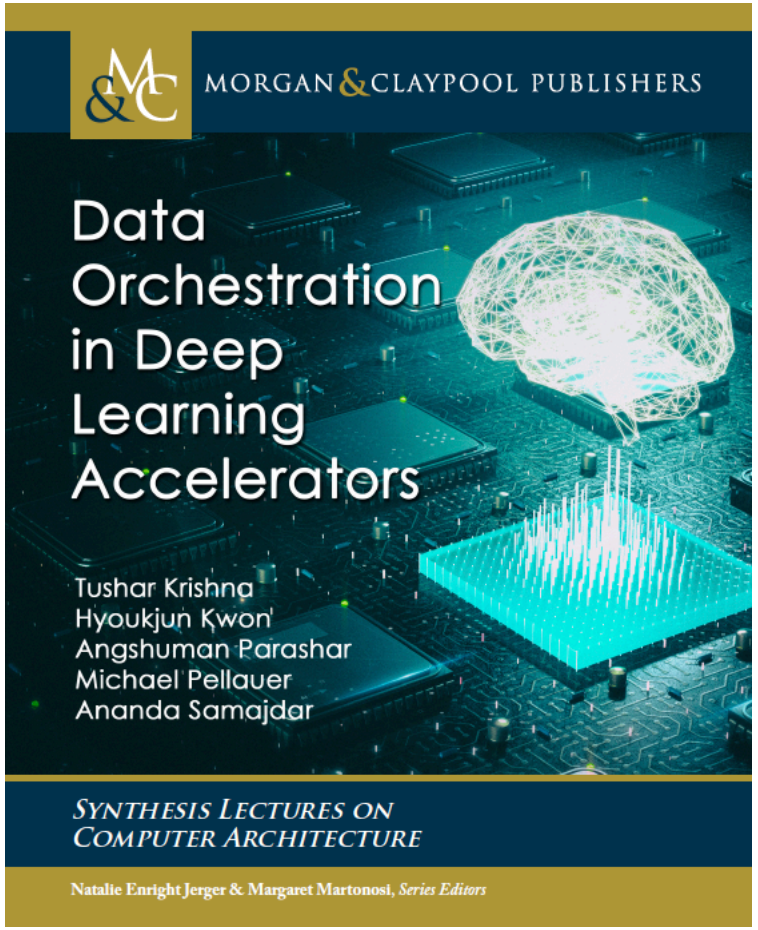


https://github.com/scalesim-project/scale-sim-v2

Synthesis Lectures







Welcome to the Tutorial!

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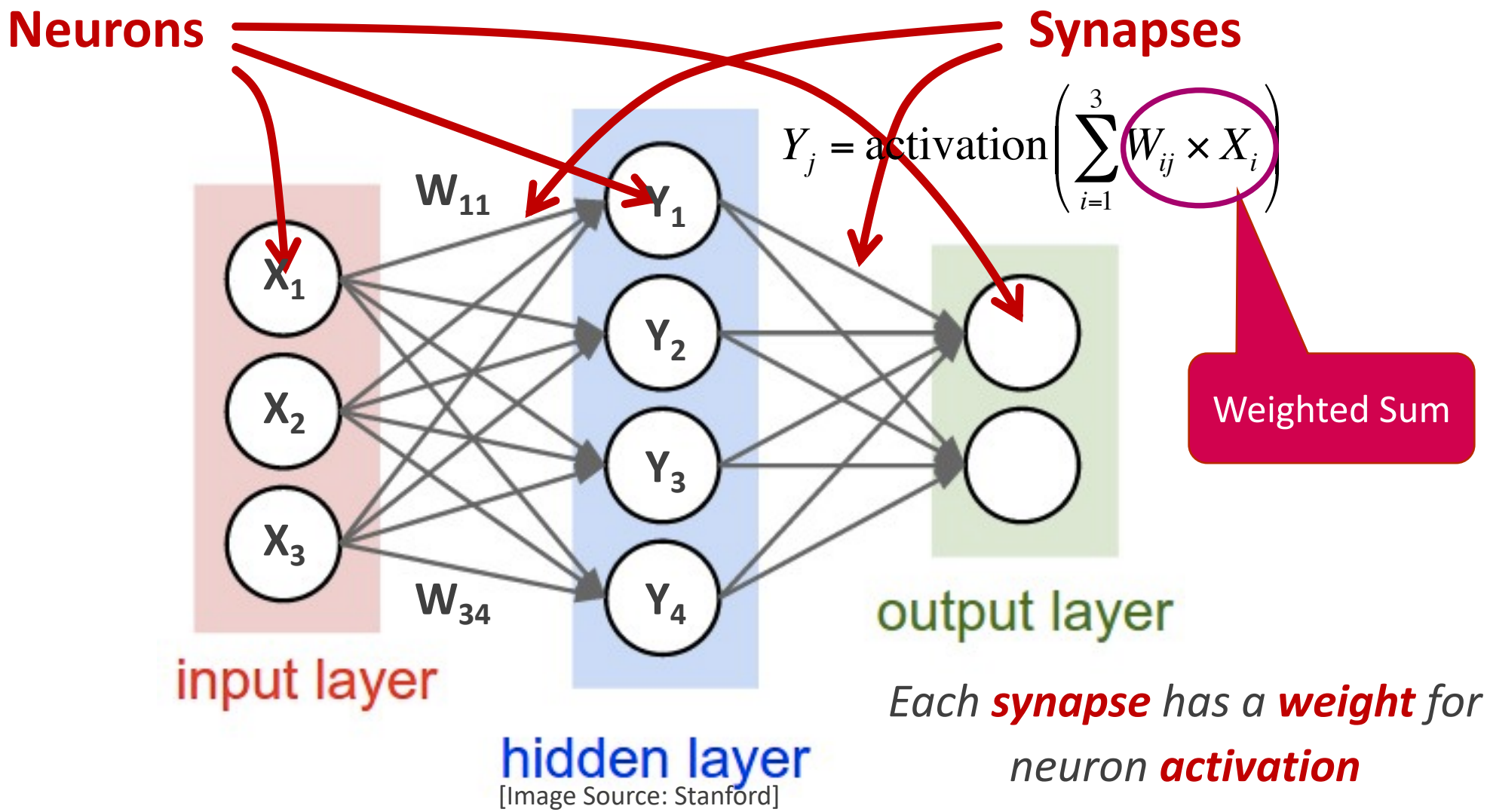
Relevant Background

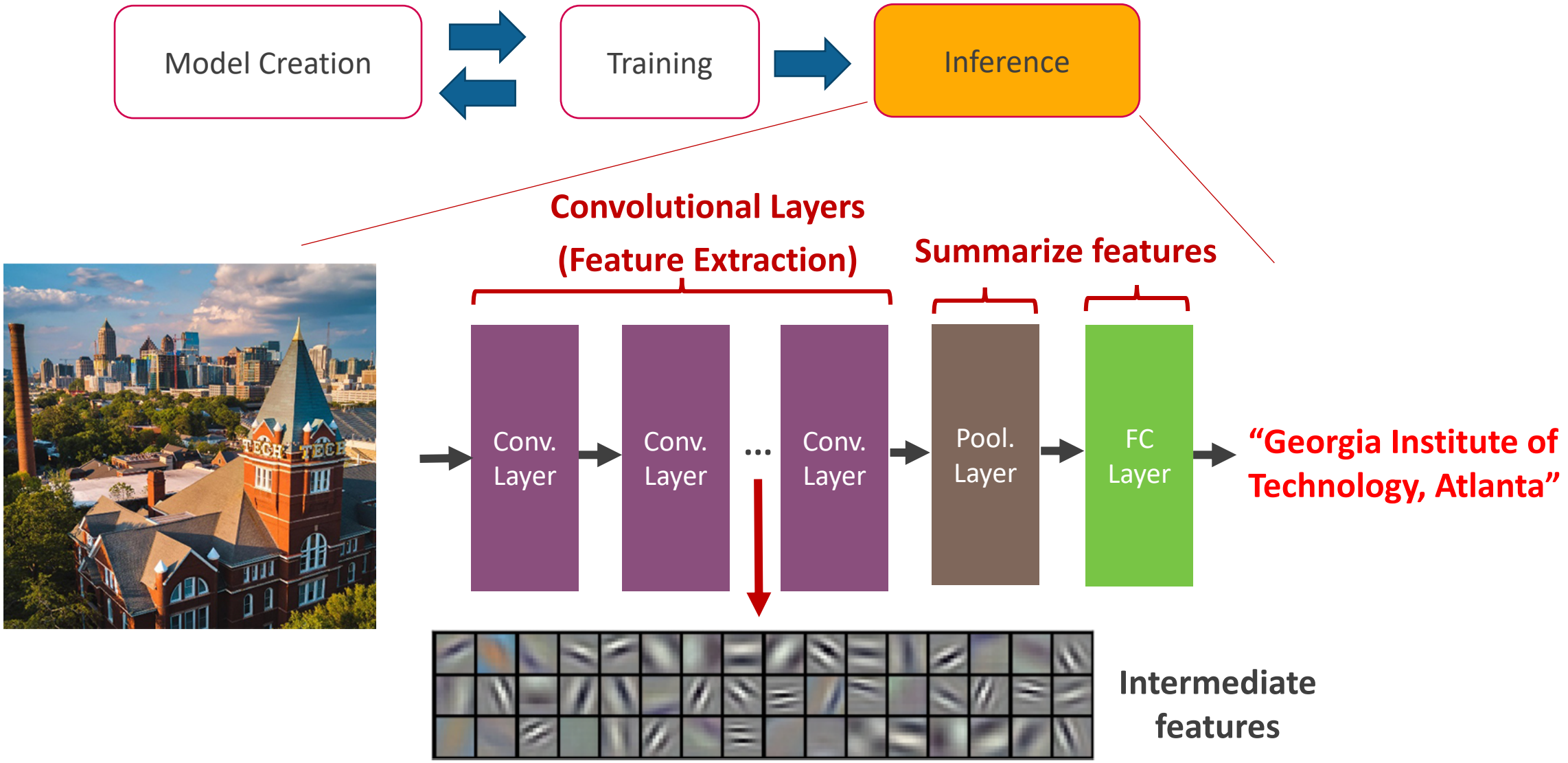
What is a Deep Neural Network?



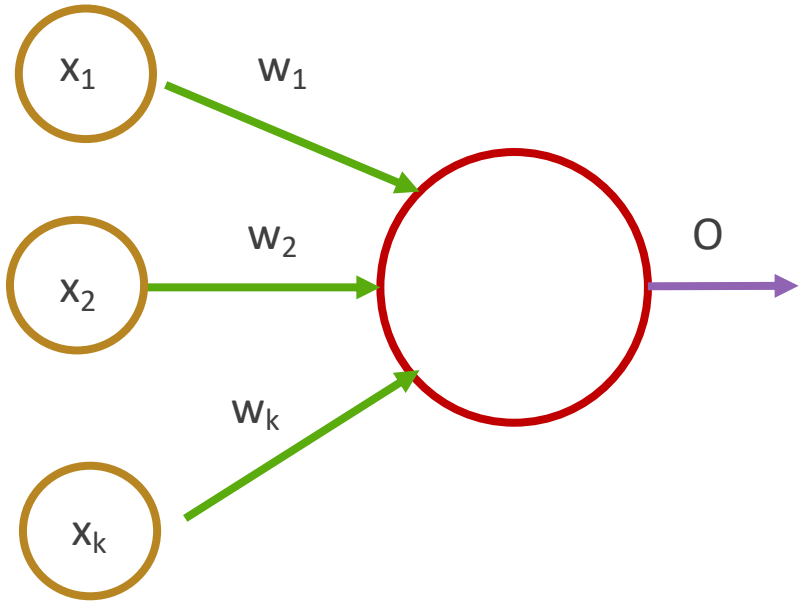
[Image Source: Stanford]

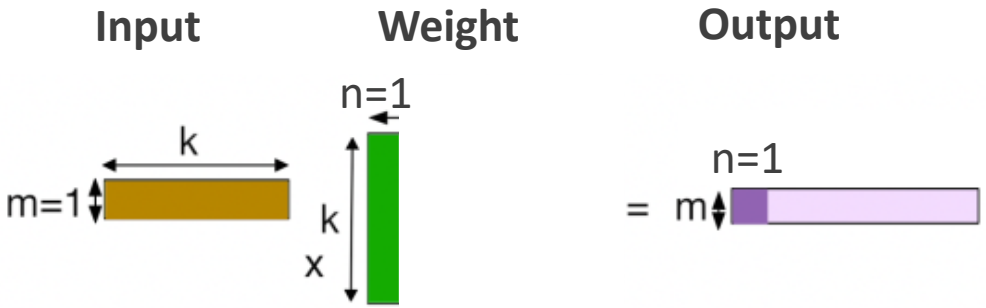
*Each **synapse** has a **weight** for neuron **activation***

Modern Deep Learning Landscape



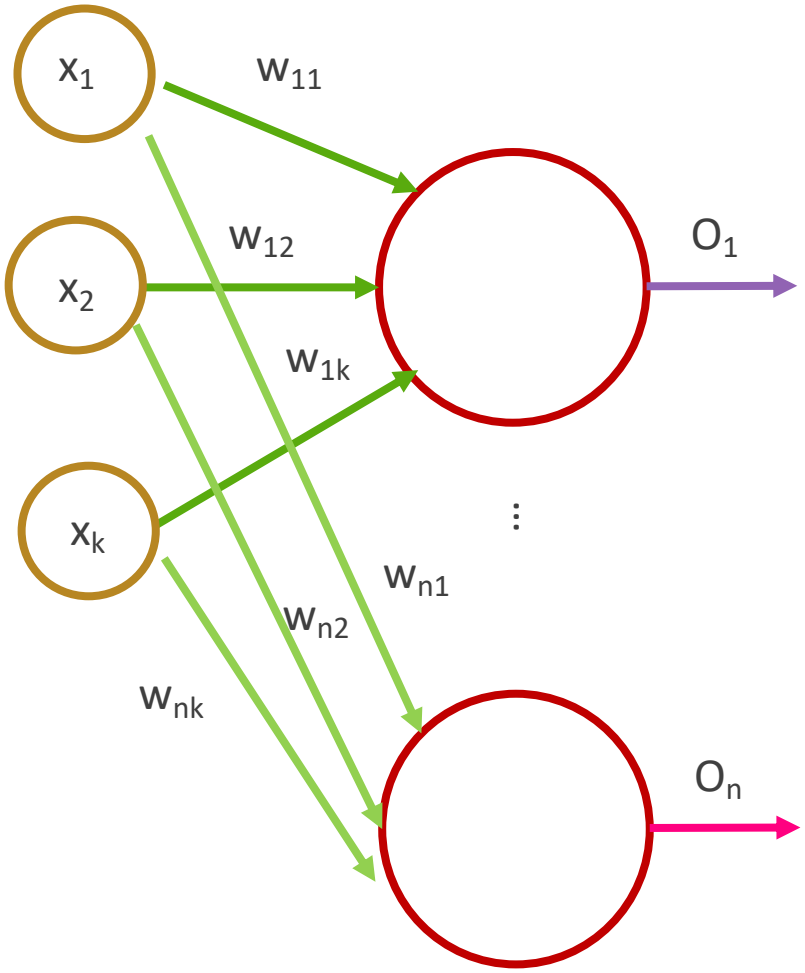
Computations in a DNN → Linear Algebra

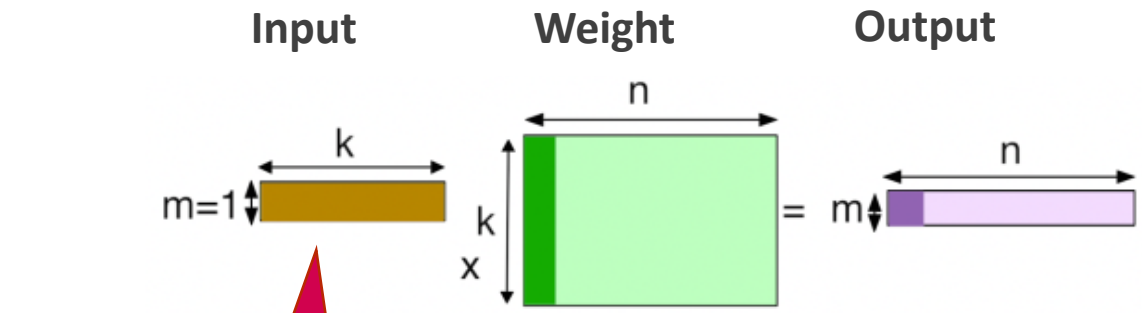




Neuron => Vector x Vector

Computations in a DNN → Linear Algebra

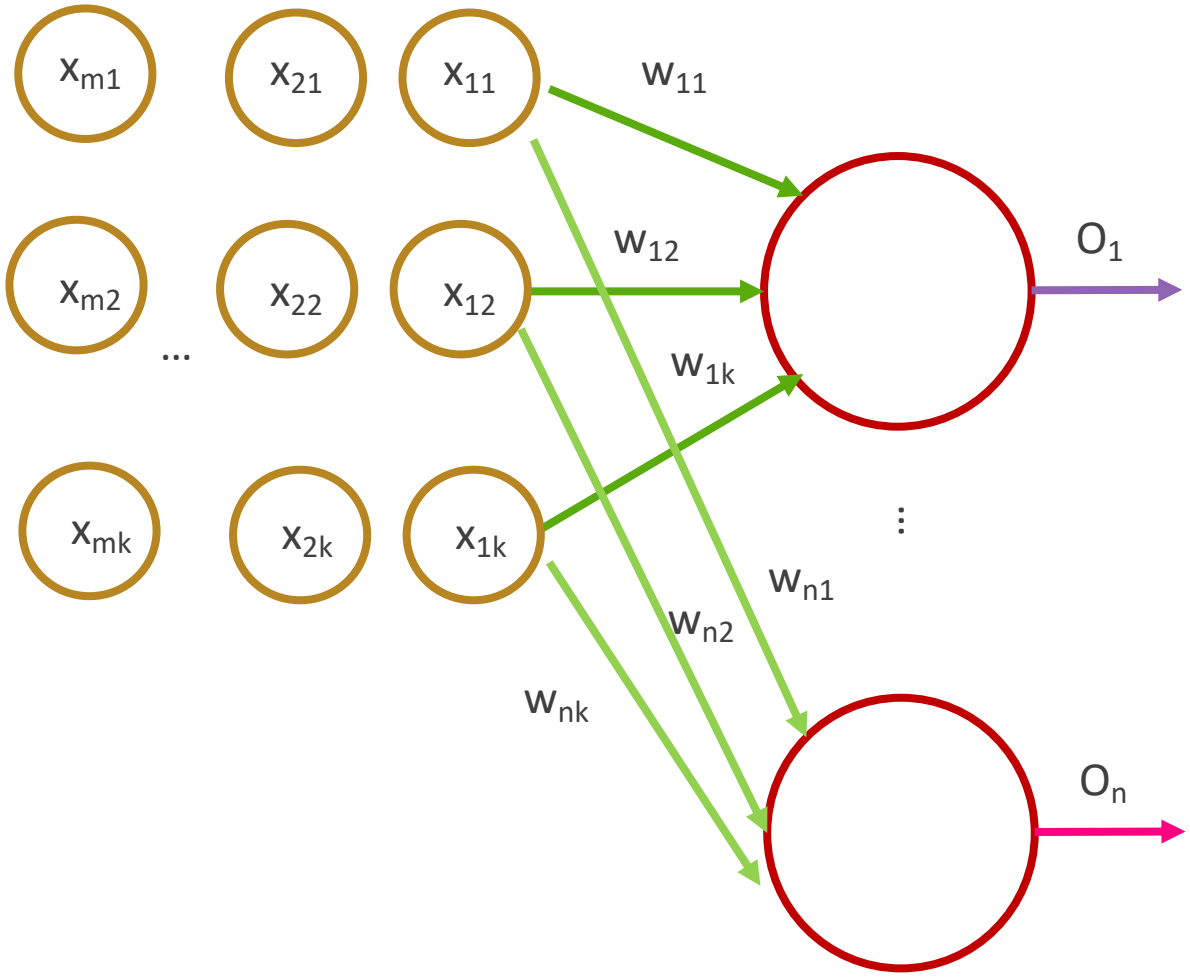


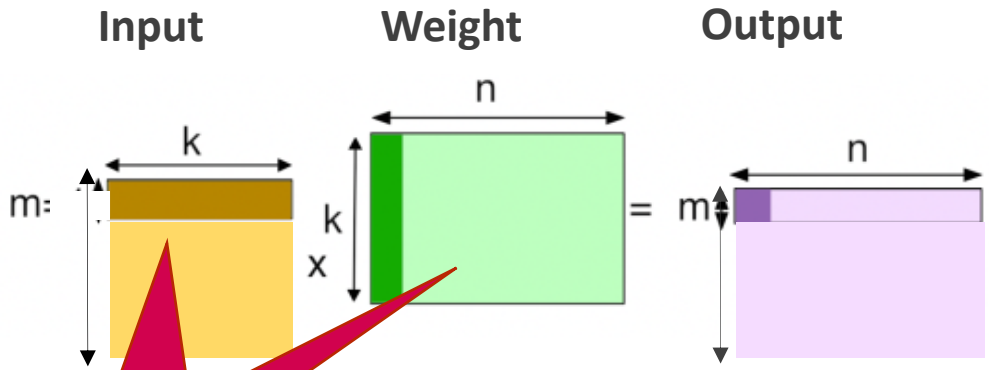


DNN Layer => Vector x Matrix

Data "Reuse"

Computations in a DNN → Linear Algebra



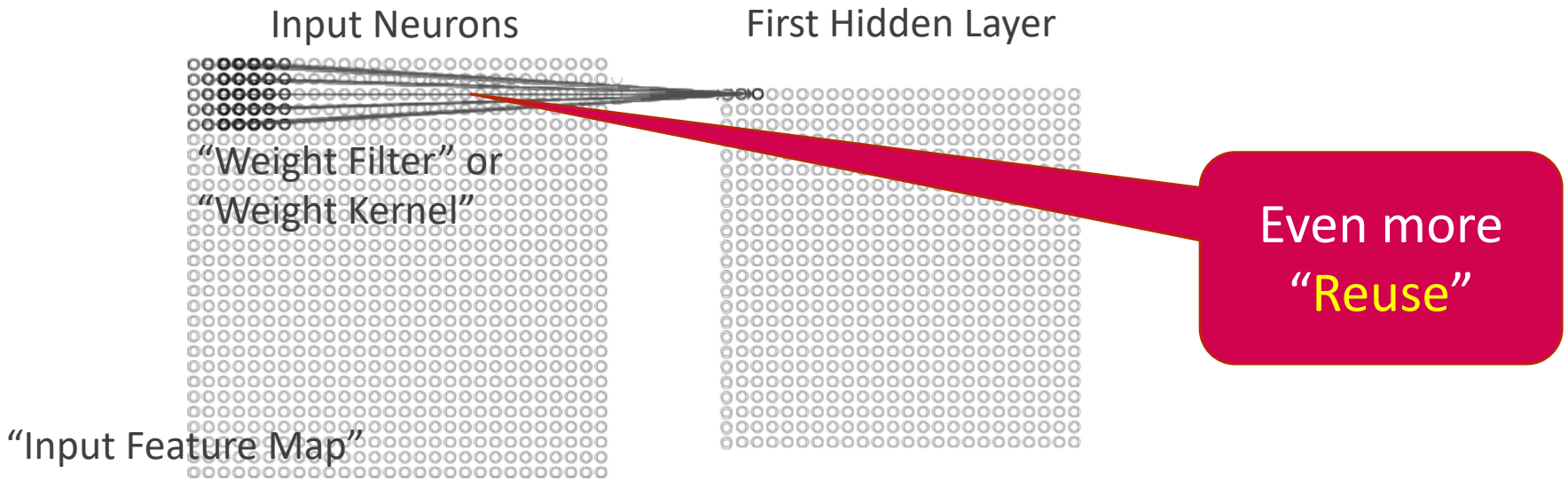


Batching => Matrix x Matrix

Data "Reuse"

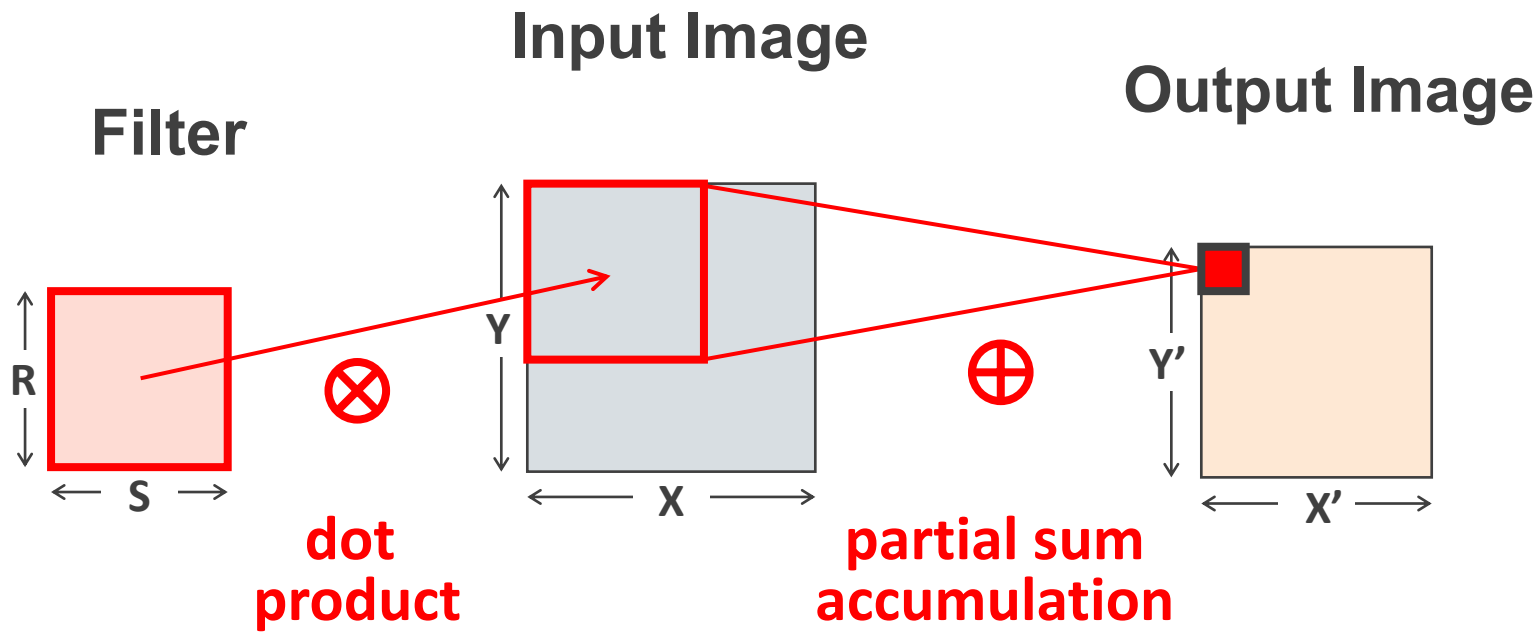
GEMM

Convolutional Neural Networks

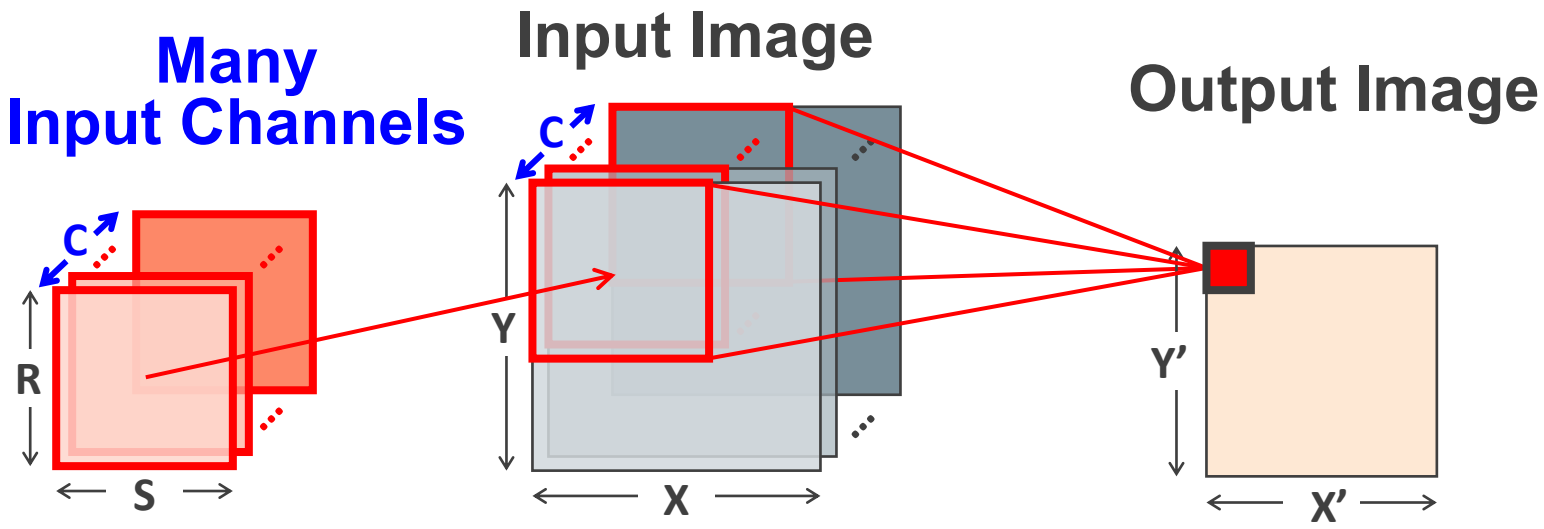


Shared Weights:
All neurons use the *same* filter weights

Convolution in CNN



Convolution in CNN



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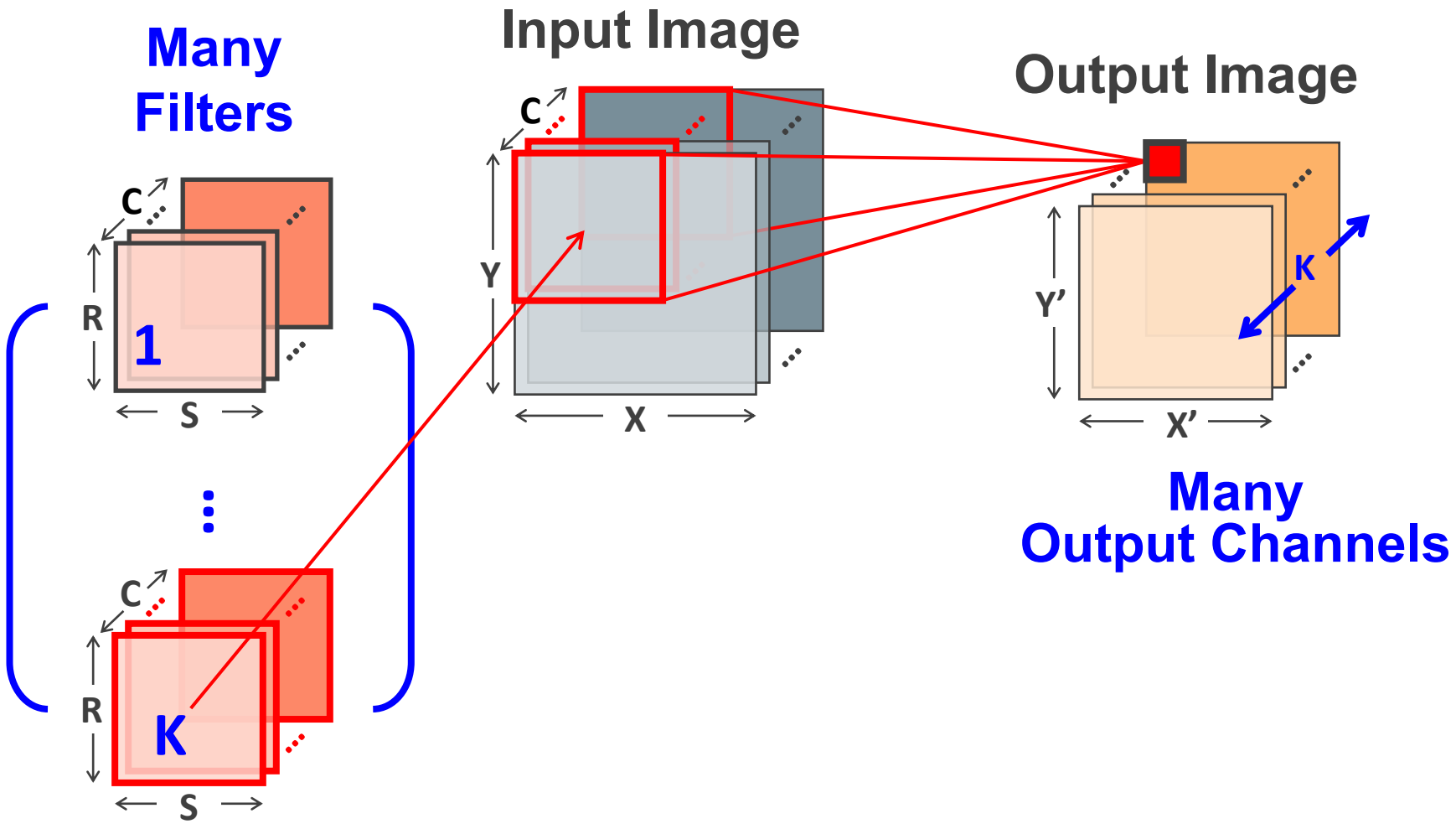

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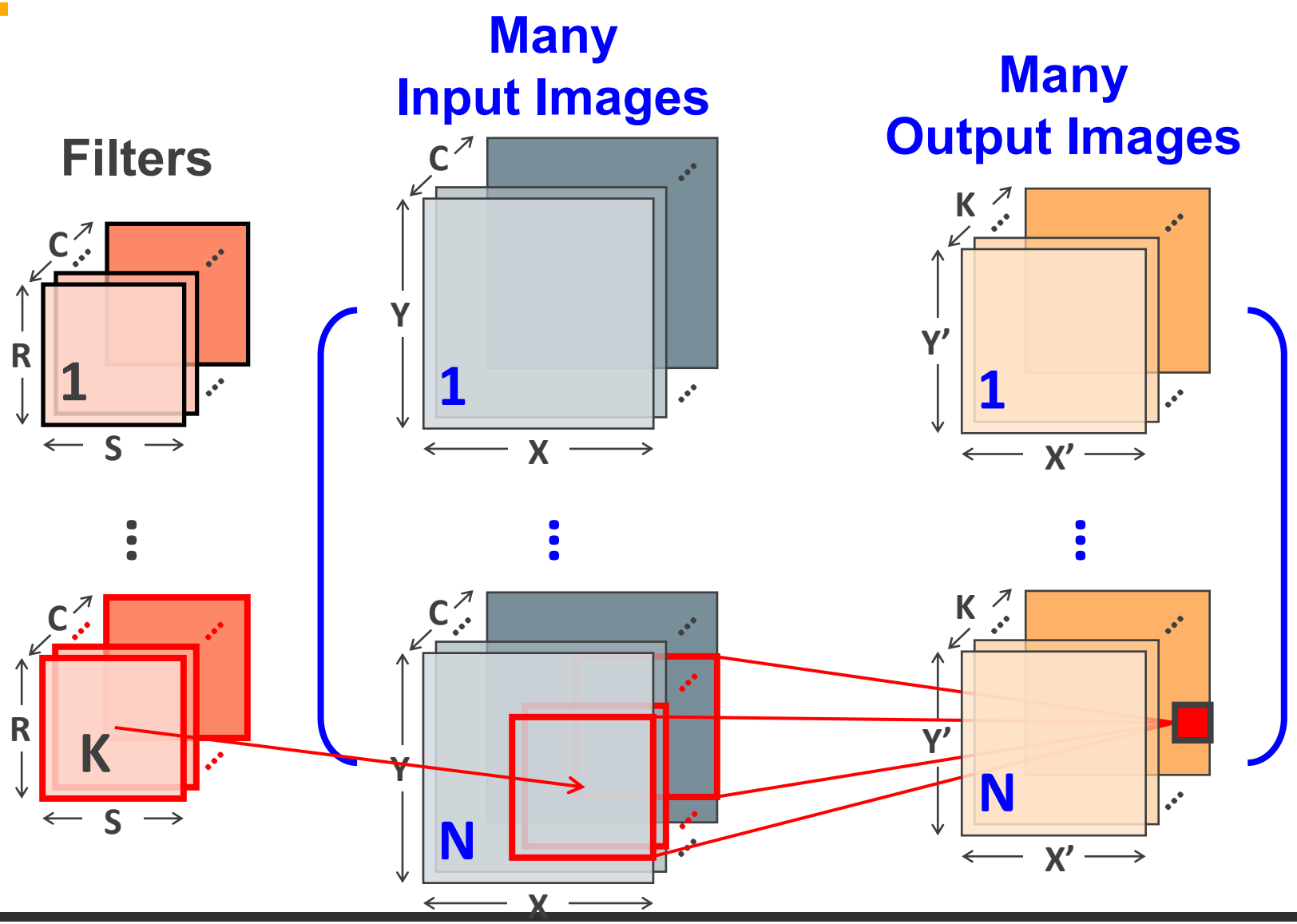


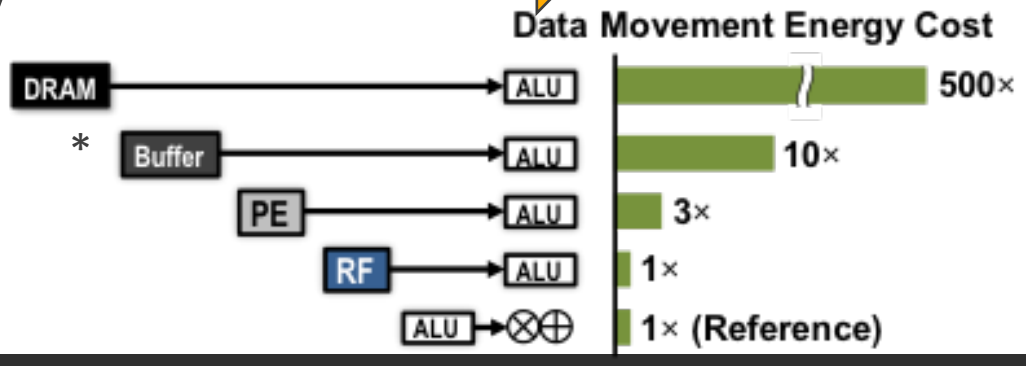
Challenges with DNN Computations

- **Millions of Parameters (i.e., weights)**
  - Billions of computations → **Need lots of parallel computations**

DNN Topology	Number of Weights
AlexNet (2012)	3.98M
VGGnet-16 (2014)	28.25M
GoogleNet (2015)	6.77M
Resnet-50 (2016)	23M
DLRM (2019)	540M
Megatron (2019)	8.3B

This makes CPUs inefficient

  - Heavy data movement → **Need to reduce energy**



This makes GPUs inefficient

*Y. Chen et. al., "Eyeriss: A Spatial Architecture for Energy-Efficient Dataflow for Convolutional Neural Networks," ISCA, 2016.

Spatial (or Dataflow) Accelerators

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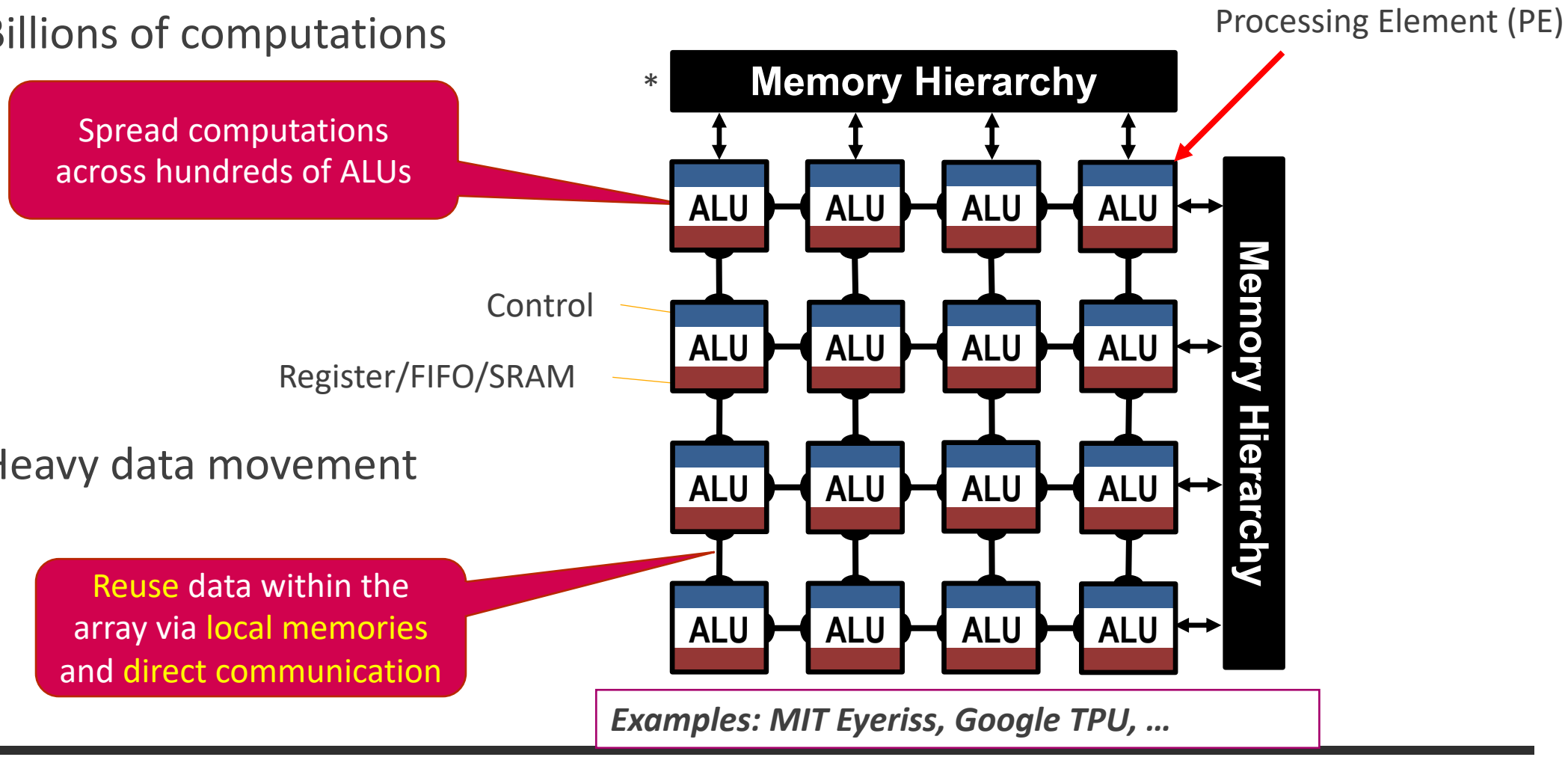
  - Billions of computations
  - Heavy data movement



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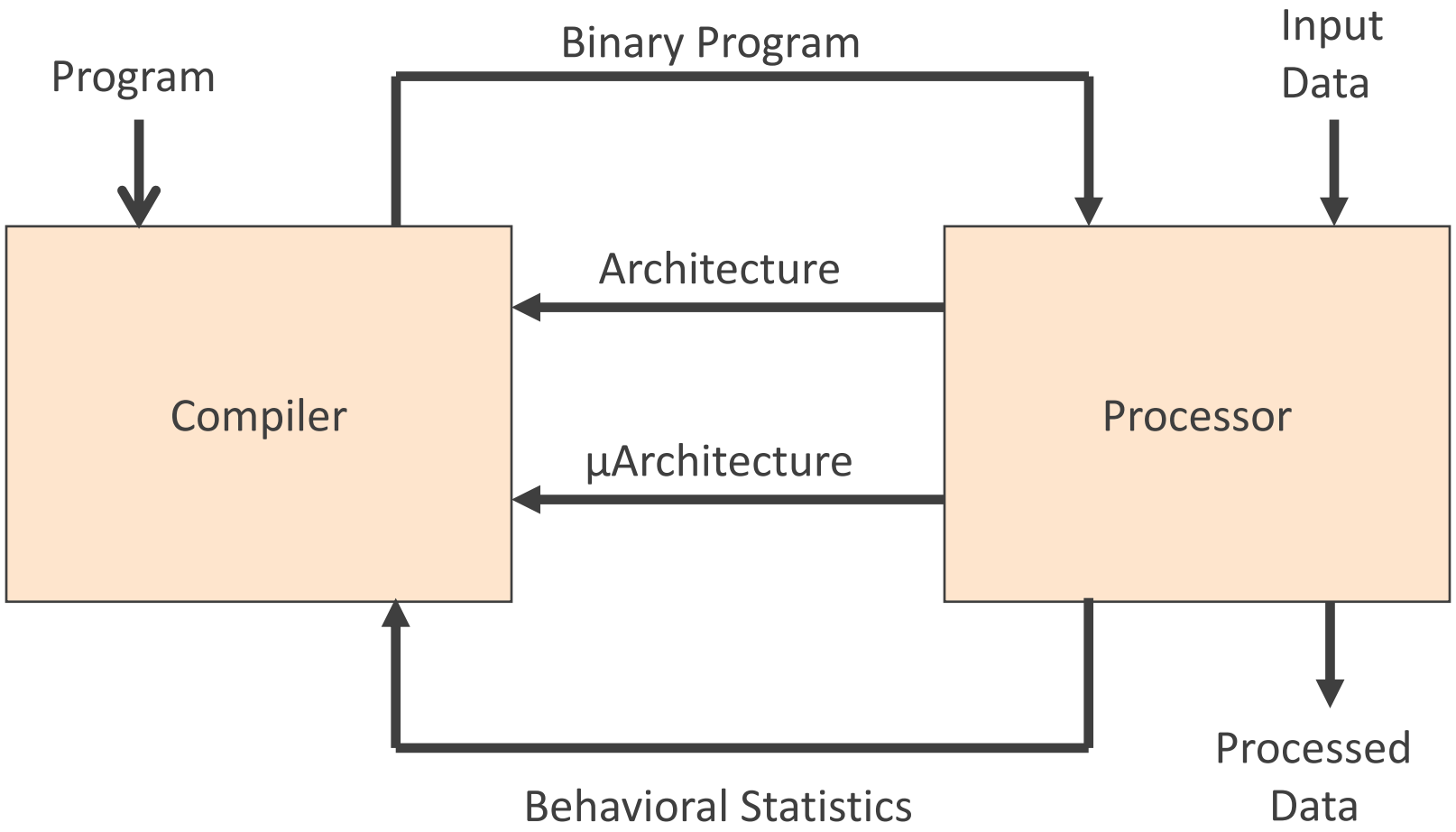
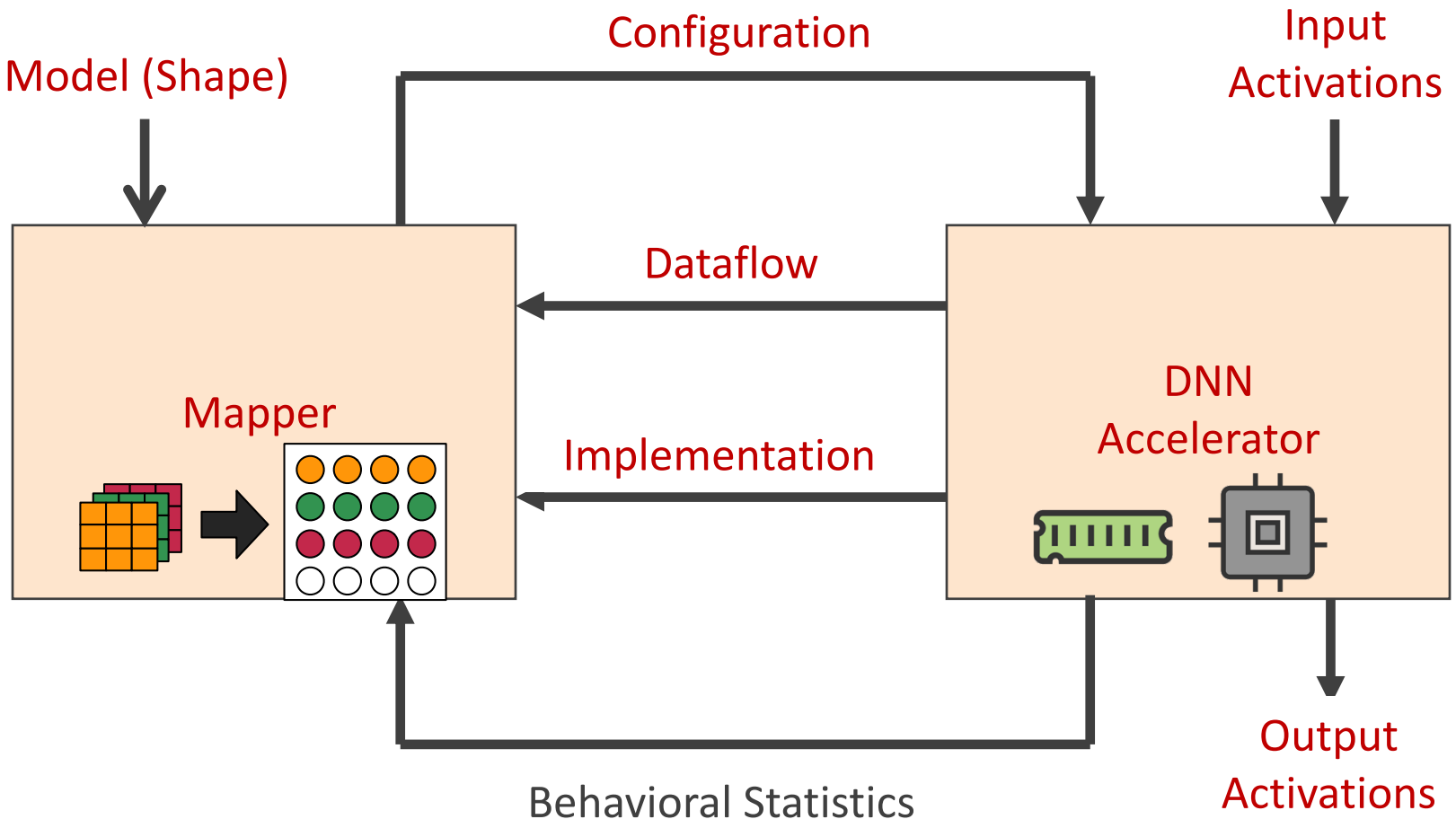
CPU Compute Model



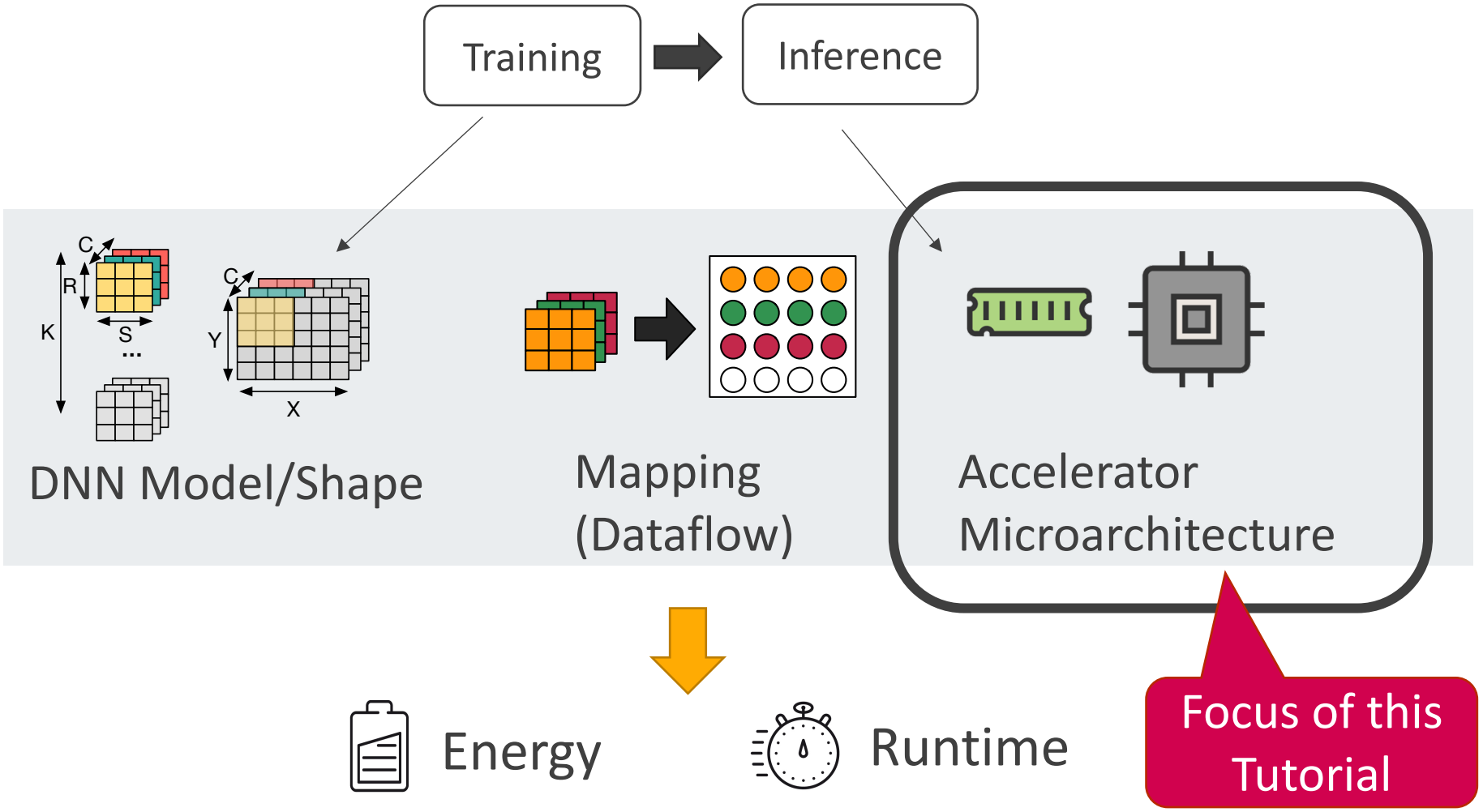
Slide Courtesy: Joel Emer and Vivienne Sze

DNN Compute Model

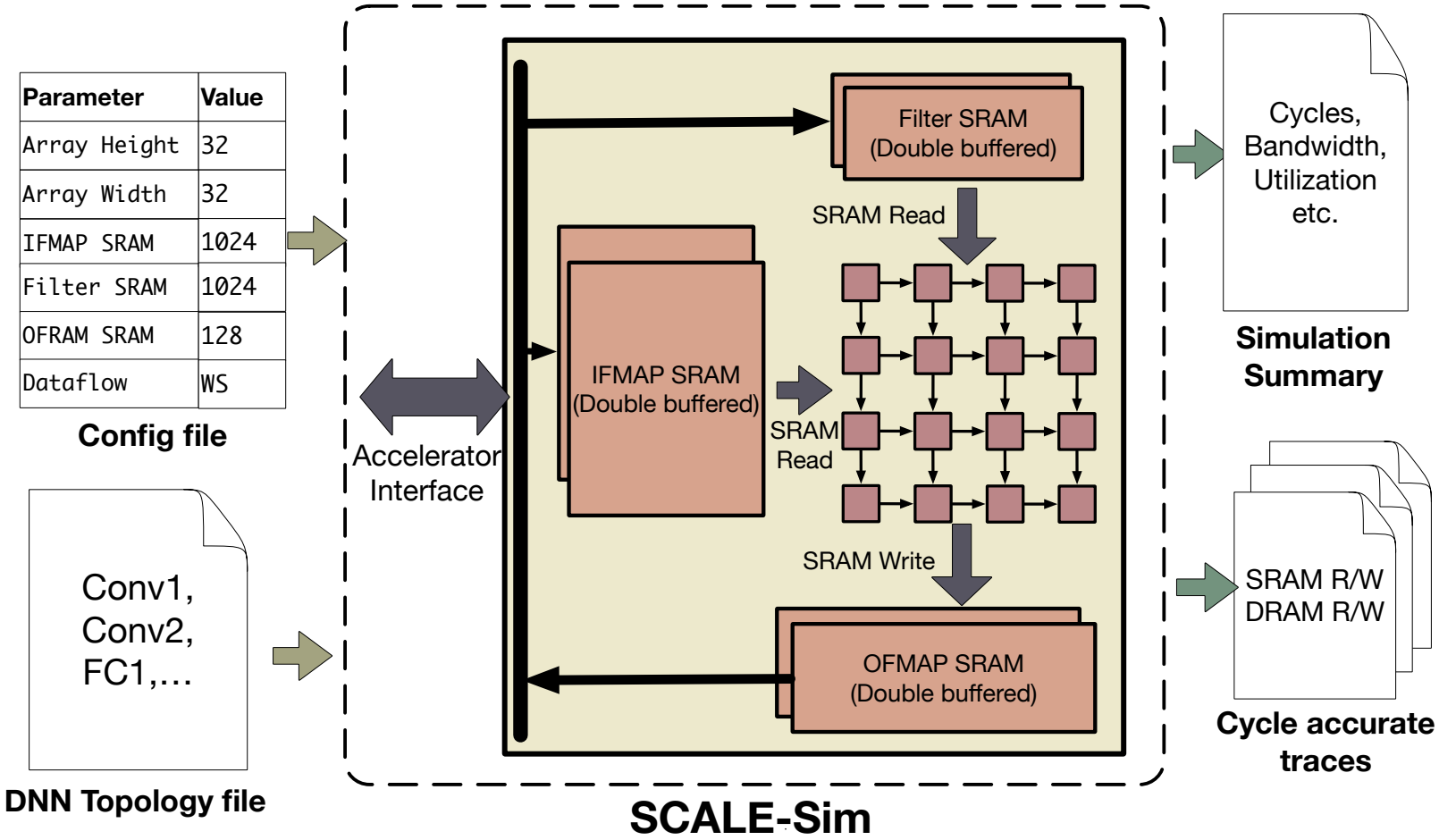


Slide Courtesy: Joel Emer and Vivienne Sze

Challenges in Design and Deployment



SCALE-sim



A Systematic Methodology for Characterizing Scalability of DNN Accelerators using SCALE-sim
Ananda Samajdar, Jan Moritz Joseph, Yuhao Zhu, Paul Whatmough, Matthew Mattina, and Tushar Krishna, ISPASS 2020

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