

- Building Brains -

Parallel training strategies for large-scale deep learning

IBM Center for Open Source Data and AI Technologies (CODAIT)

IBM Disclaimer

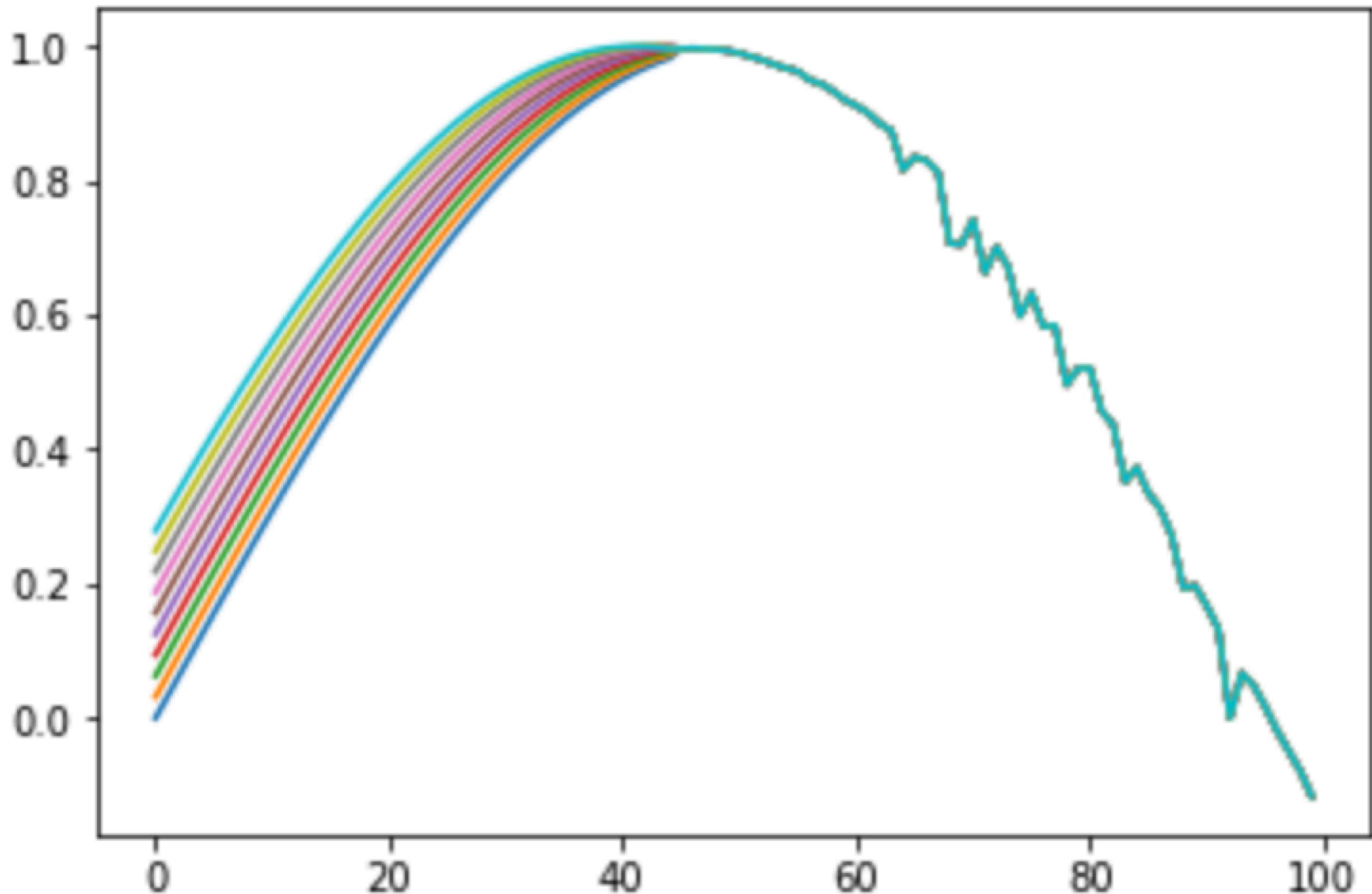
THE INFORMATION CONTAINED IN THIS PRESENTATION IS PROVIDED FOR INFORMATIONAL PURPOSES ONLY. WHILE EFFORTS WERE MADE TO VERIFY THE COMPLETENESS AND ACCURACY OF THE INFORMATION CONTAINED IN THIS PRESENTATION, IT IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED. IBM SHALL NOT BE RESPONSIBLE FOR ANY DAMAGES ARISING OUT OF THE USE OF, OR OTHERWISE RELATED TO, THIS PRESENTATION OR ANY OTHER DOCUMENTATION.

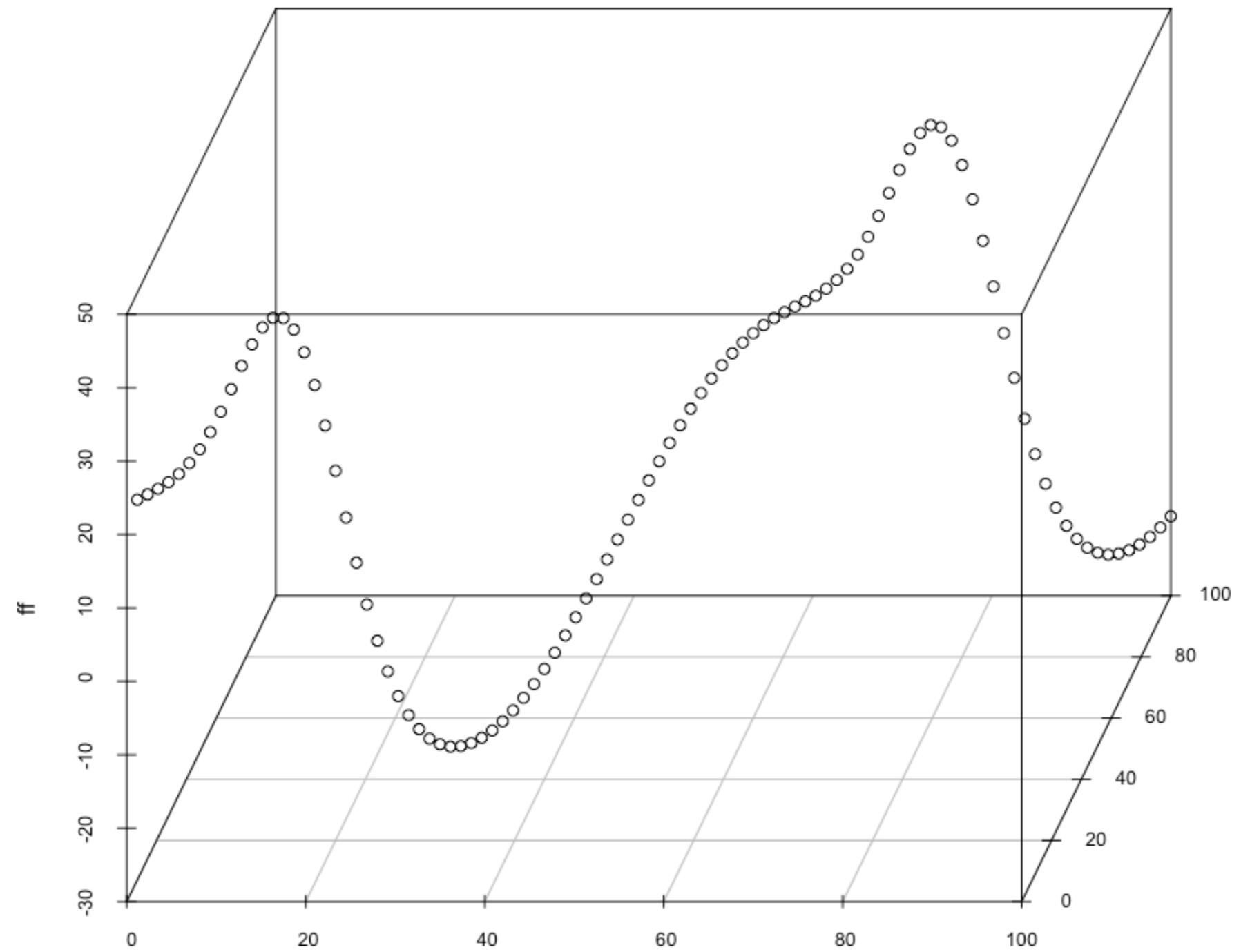
NOTHING CONTAINED IN THIS PRESENTATION IS INTENDED TO, OR SHALL HAVE THE EFFECT OF: CREATING ANY WARRANTY OR REPRESENTATION FROM IBM (OR ITS AFFILIATES OR ITS OR THEIR SUPPLIERS AND/OR LICENSORS); OR ALTERING THE TERMS AND CONDITIONS OF THE APPLICABLE LICENSE AGREEMENT GOVERNING THE USE OF IBM SOFTWARE.

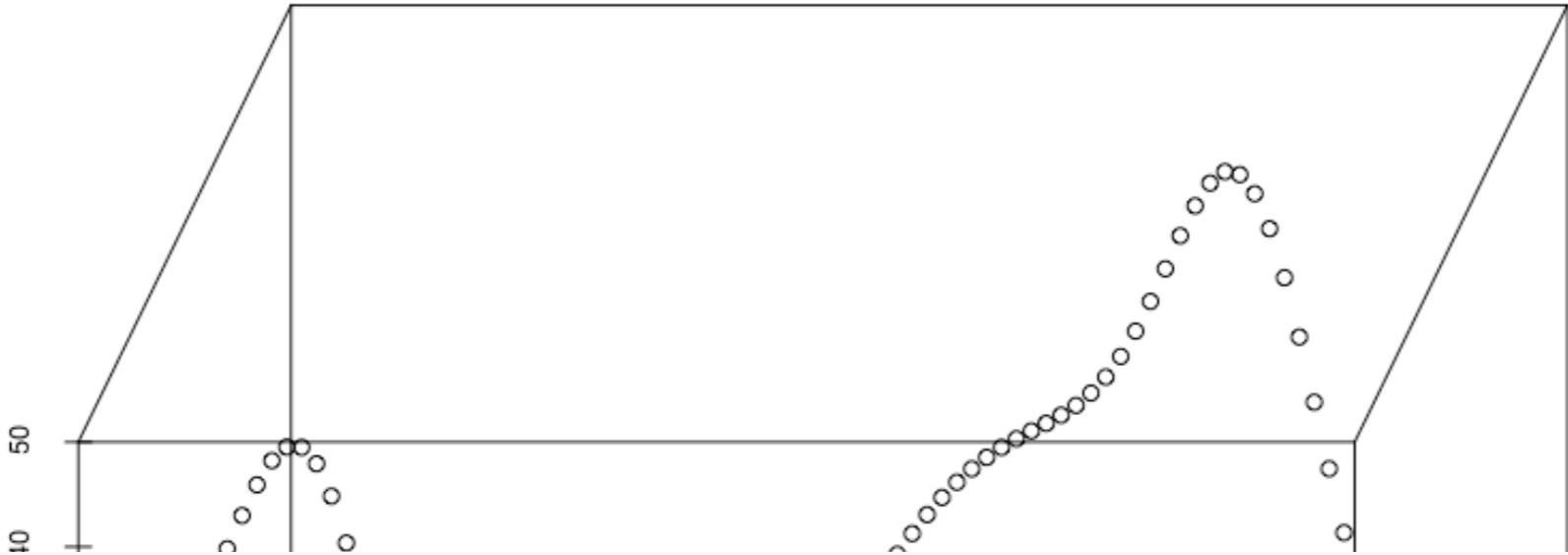
IBM's statements regarding its plans, directions, and intent are subject to change or withdrawal without notice at IBM's sole discretion. Information regarding potential future products is intended to outline our general product direction and it should not be relied on in making a purchasing decision. The information mentioned regarding potential future products is not a commitment, promise, or legal obligation to deliver any material, code or functionality. Information about potential future products may not be incorporated into any contract. The development, release, and timing of any future features or functionality described for our products remains at our sole discretion.

We are looking forward to hearing your suggestions and feedback so that we can improve our solutions and products.

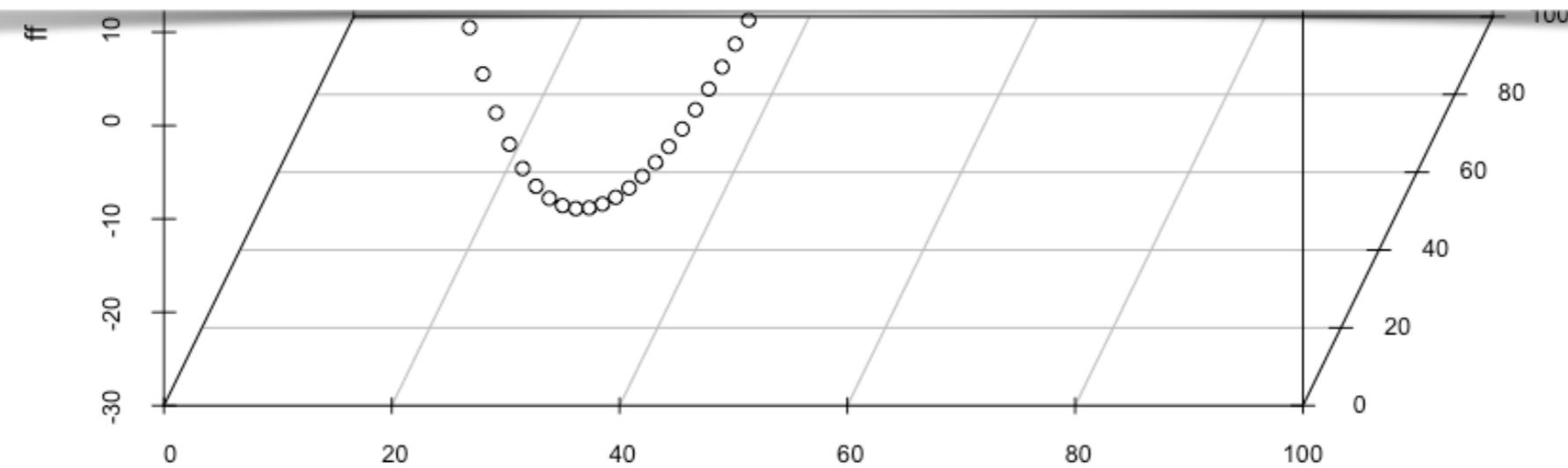
IBM shall be free to use for any purpose and without restriction any oral or written suggestions or feedback that you provide to IBM. By providing IBM with any information or material, you grant IBM an unrestricted, irrevocable license to copy, reproduce, publish, upload, post, transmit, distribute, publicly display, perform, modify, create derivative works from, and otherwise freely use, those materials or information. You also agree that IBM is free to use any ideas, concepts, know-how, or techniques that you provide us for any purpose.

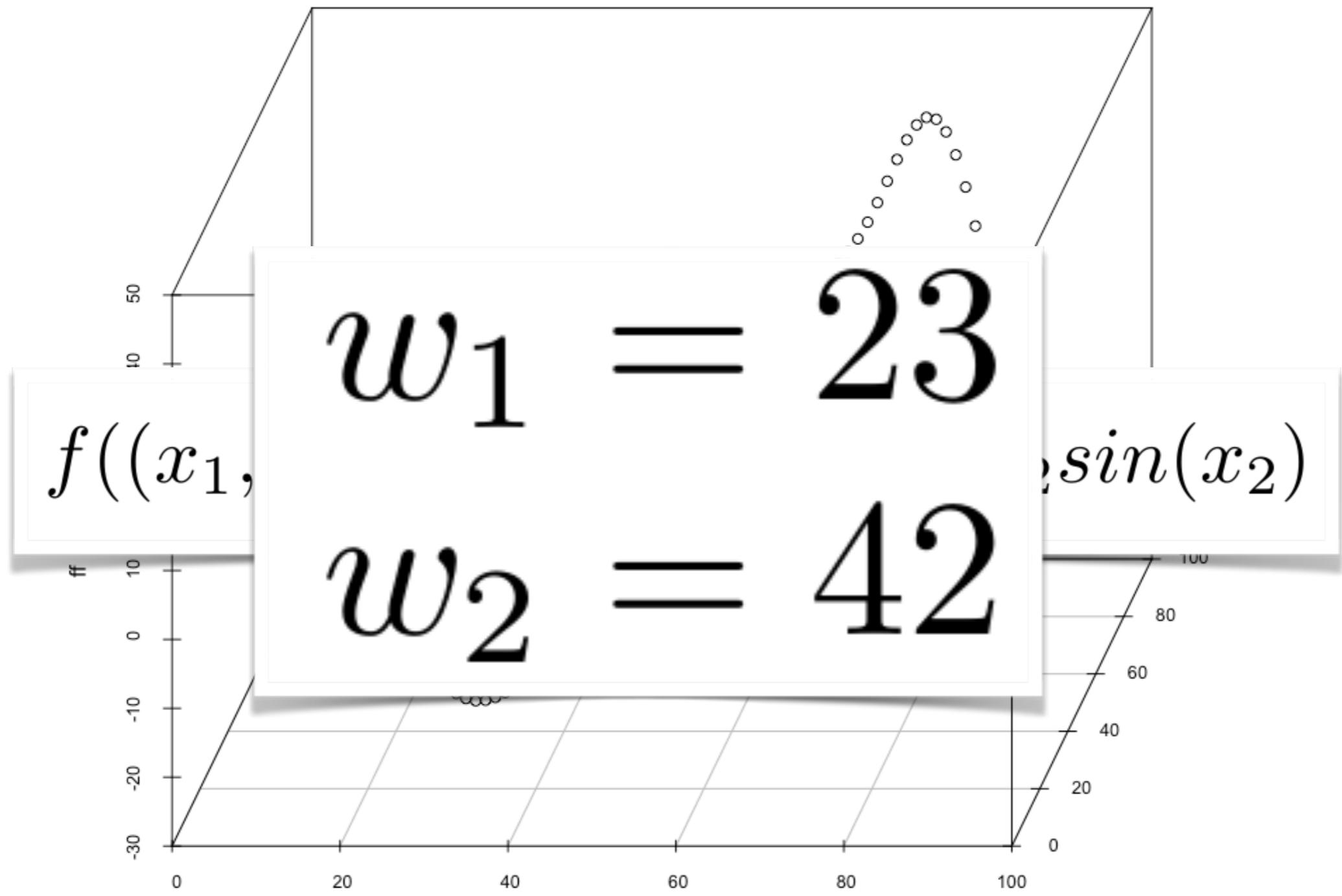




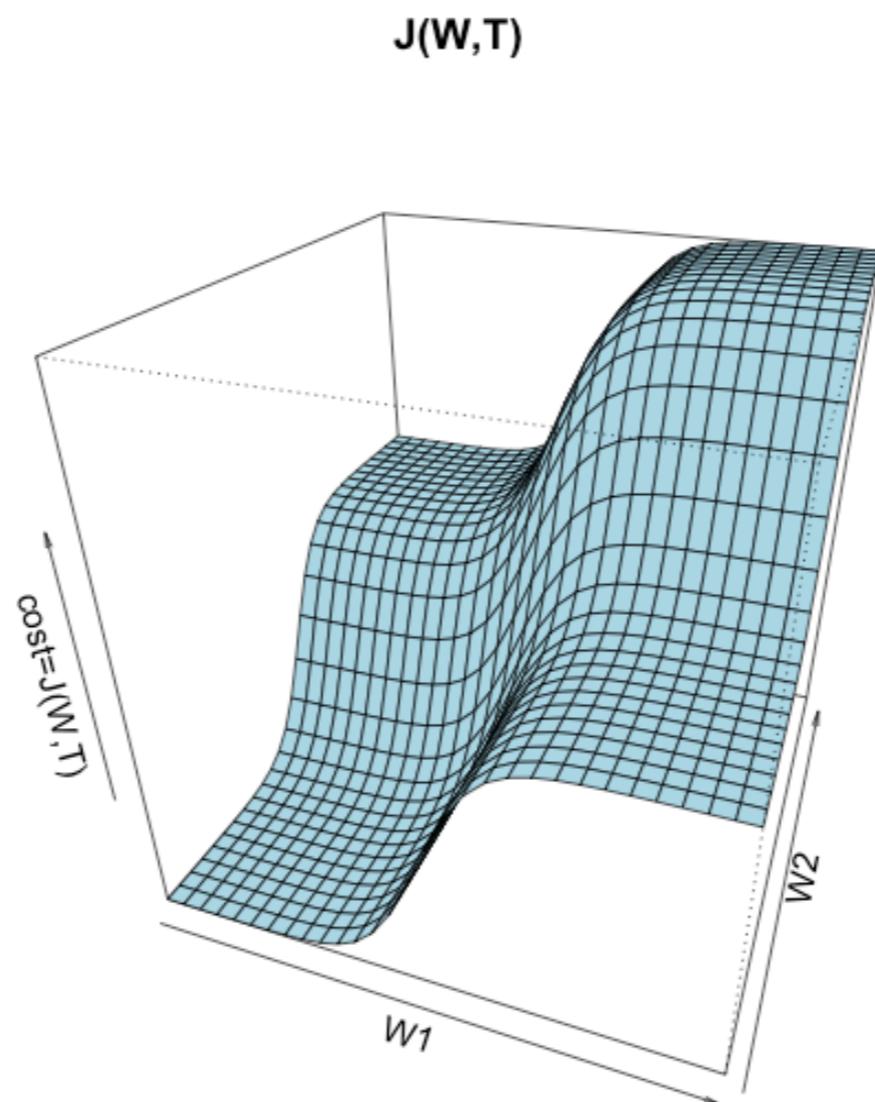


$$f((x_1, x_2)) = w_1 \cos(x_1) + w_2 \sin(x_2)$$

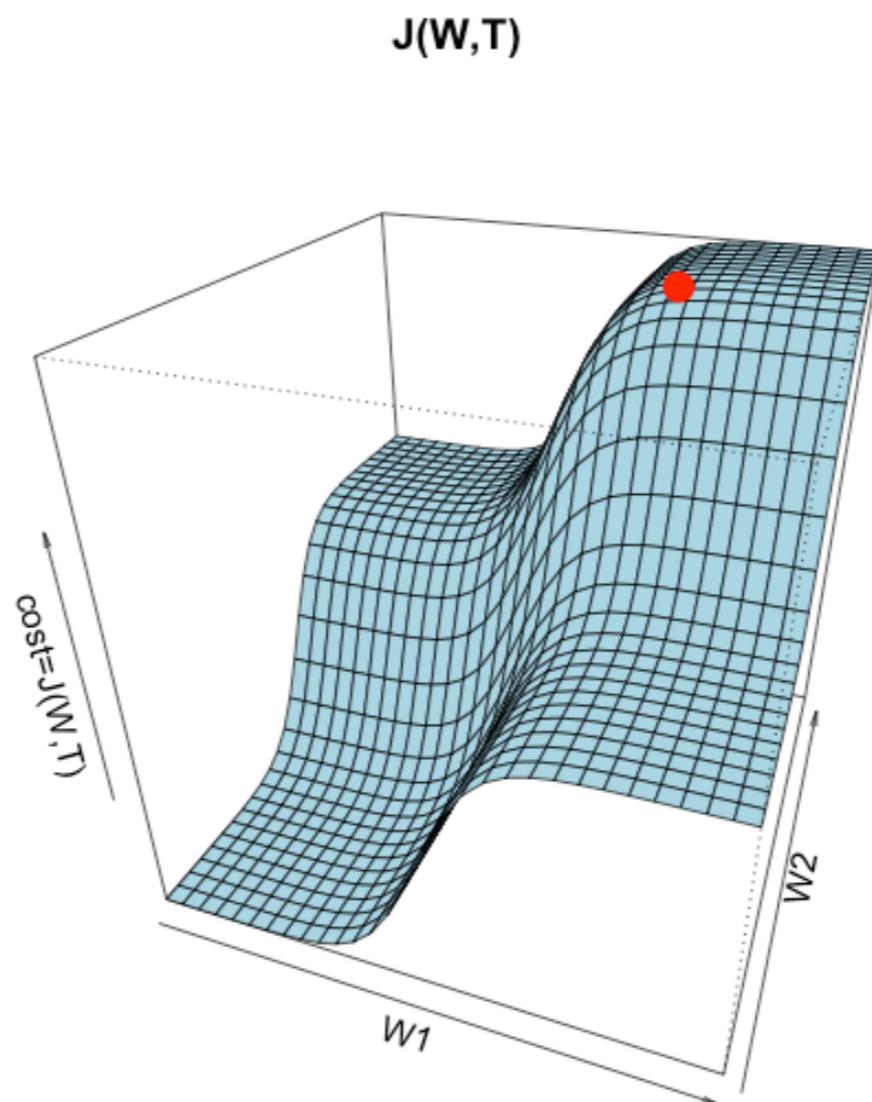




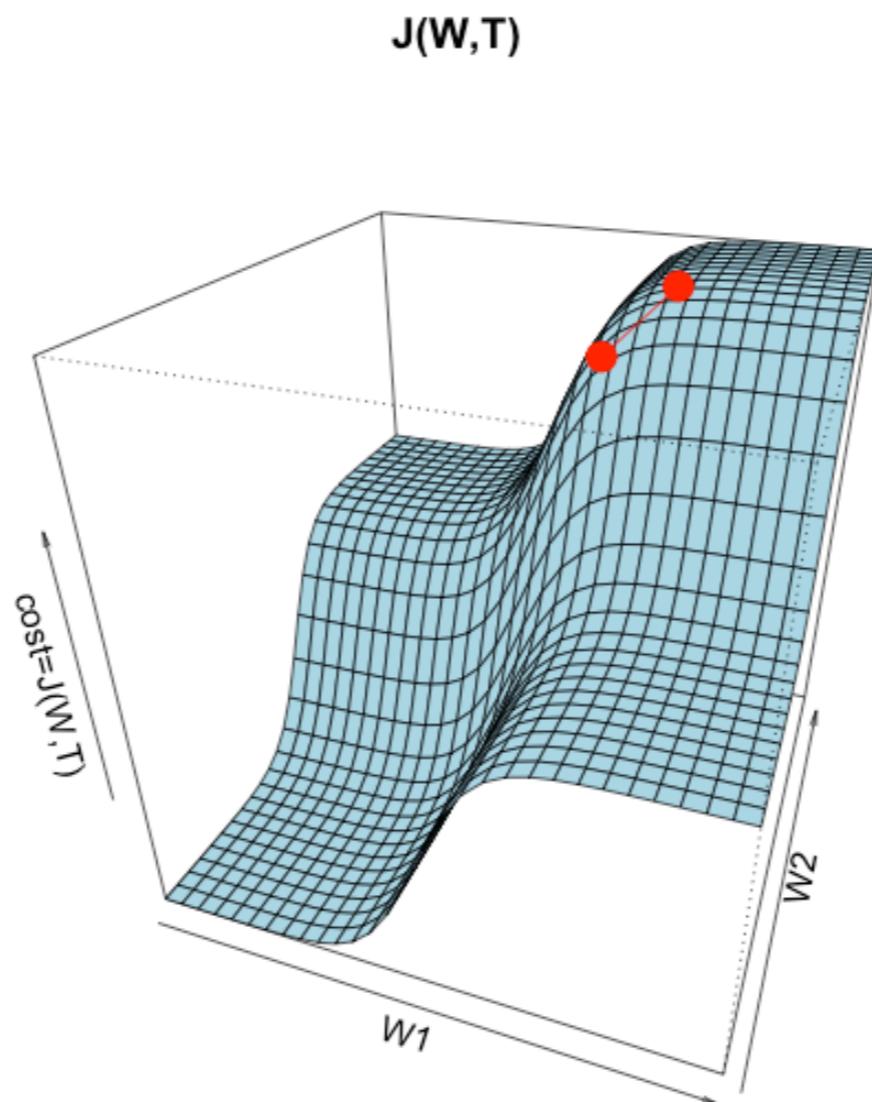
gradient descent



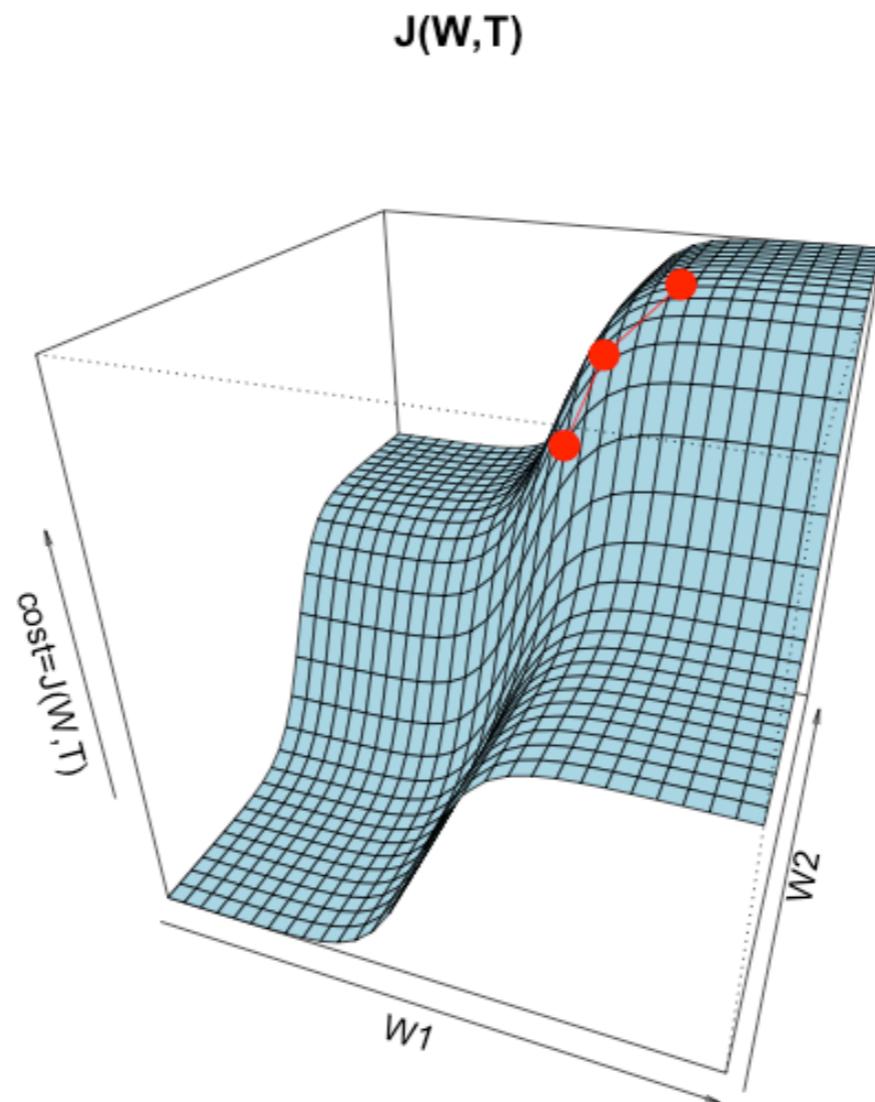
gradient descent



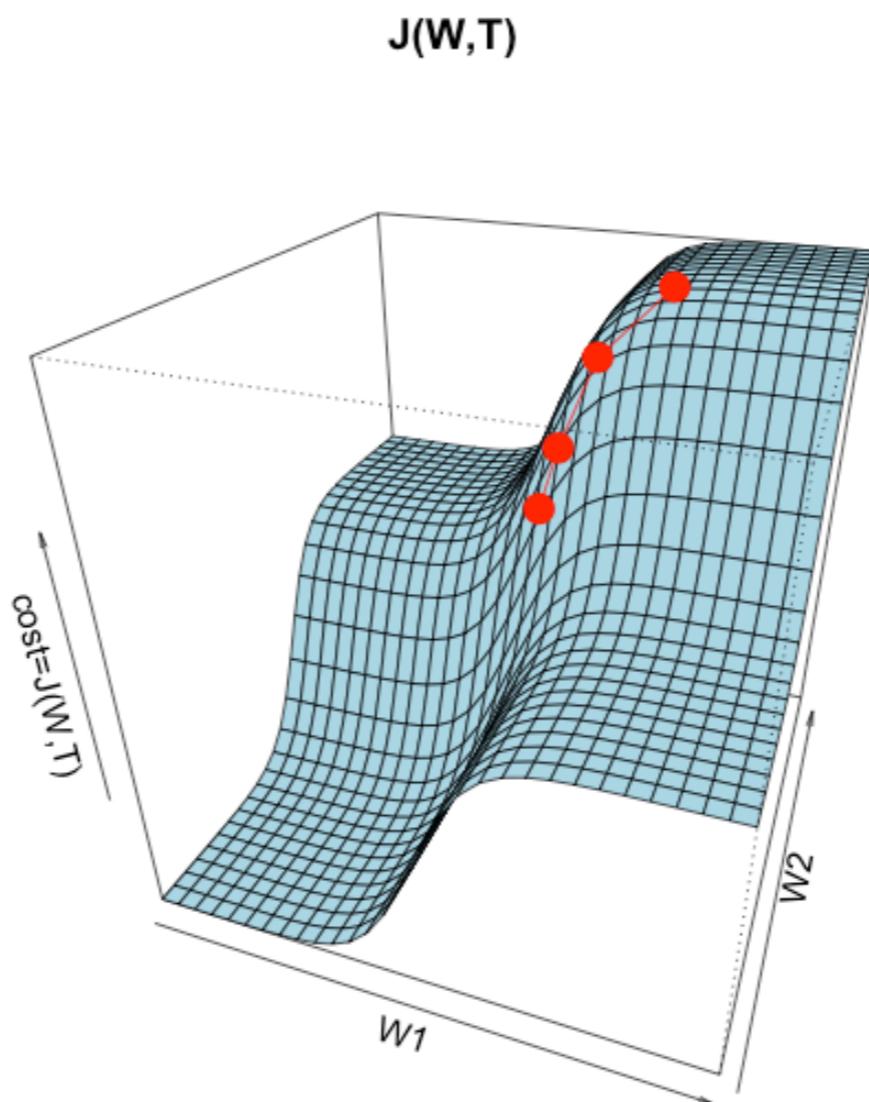
gradient descent



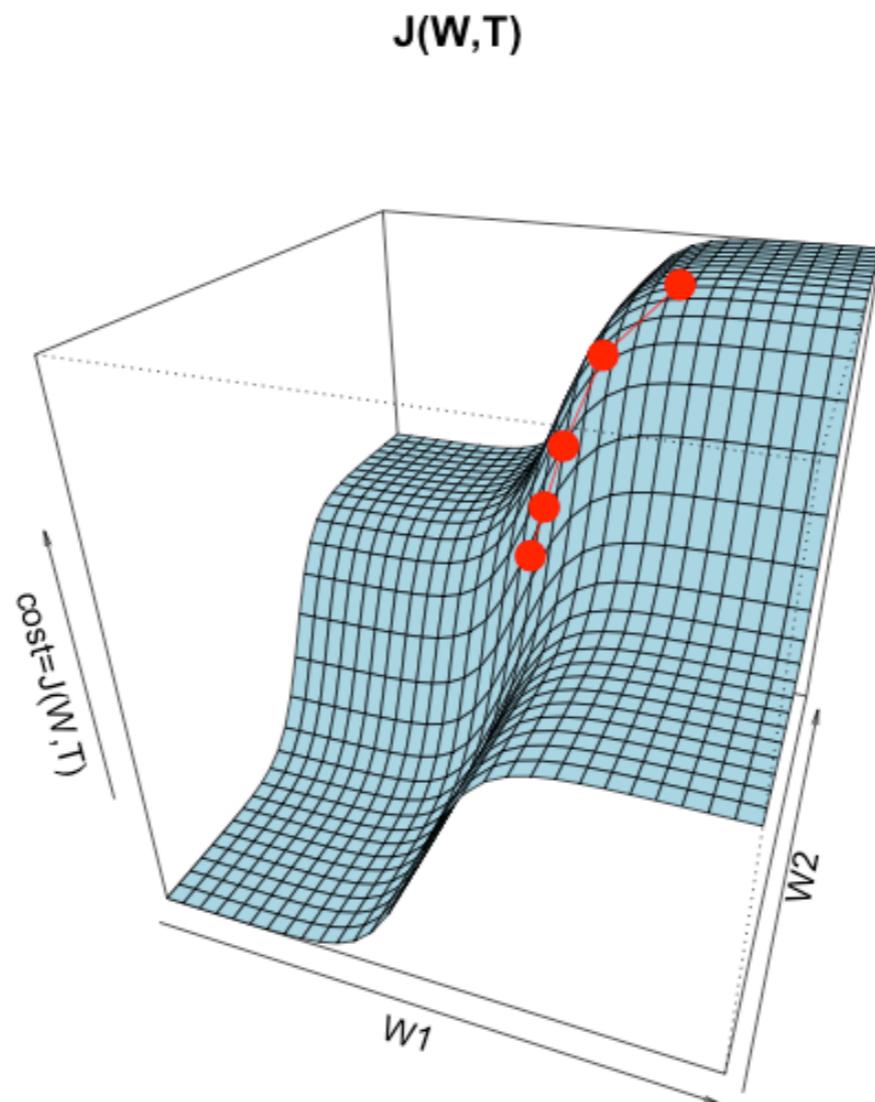
gradient descent



gradient descent



gradient descent



parallelisation

- ▶ inter-model parallelism
- ▶ data parallelism
- ▶ intra-model parallelism
- ▶ pipelined parallelism

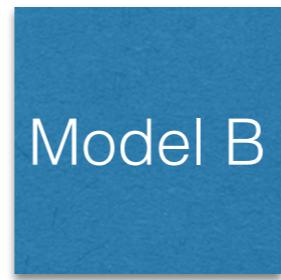
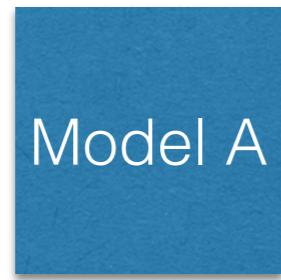
inter-model parallelism

aka. hyper parameter space exploration / tuning



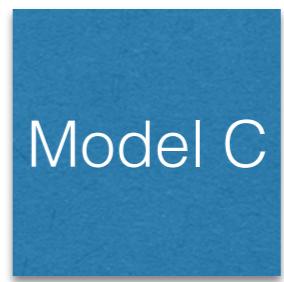
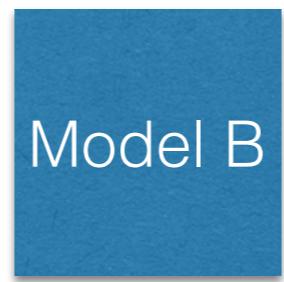
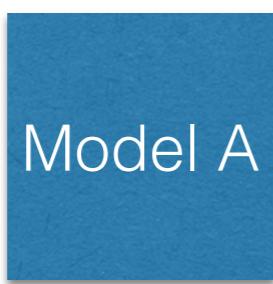
inter-model parallelism

aka. hyper parameter space exploration / tuning



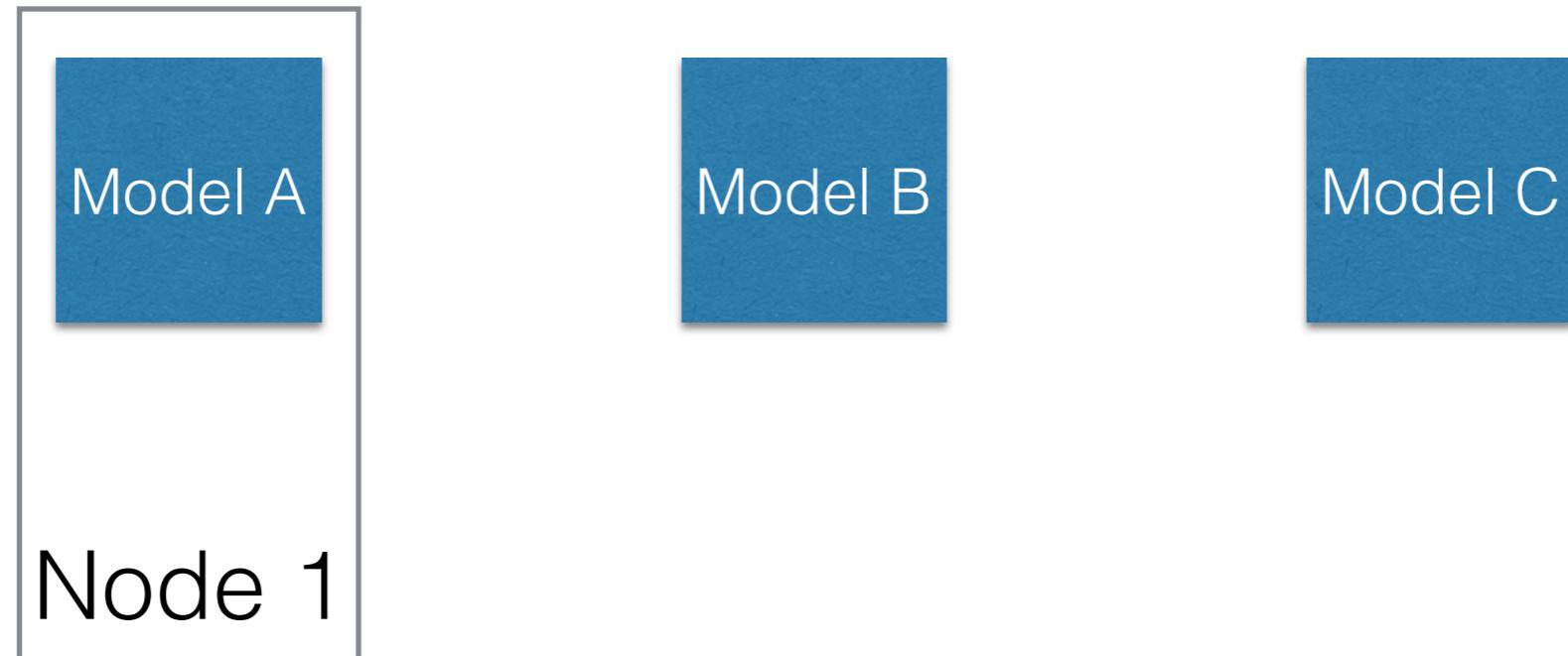
inter-model parallelism

aka. hyper parameter space exploration / tuning



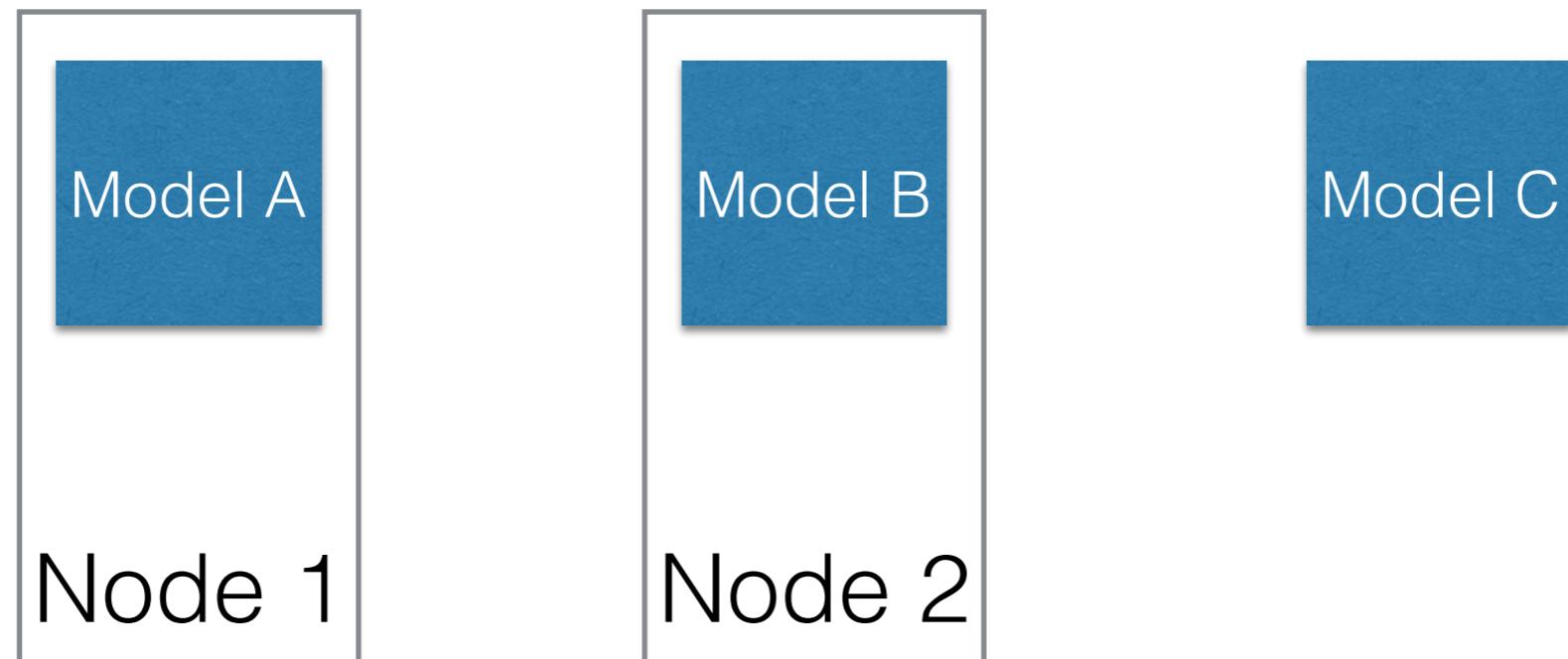
inter-model parallelism

aka. hyper parameter space exploration / tuning



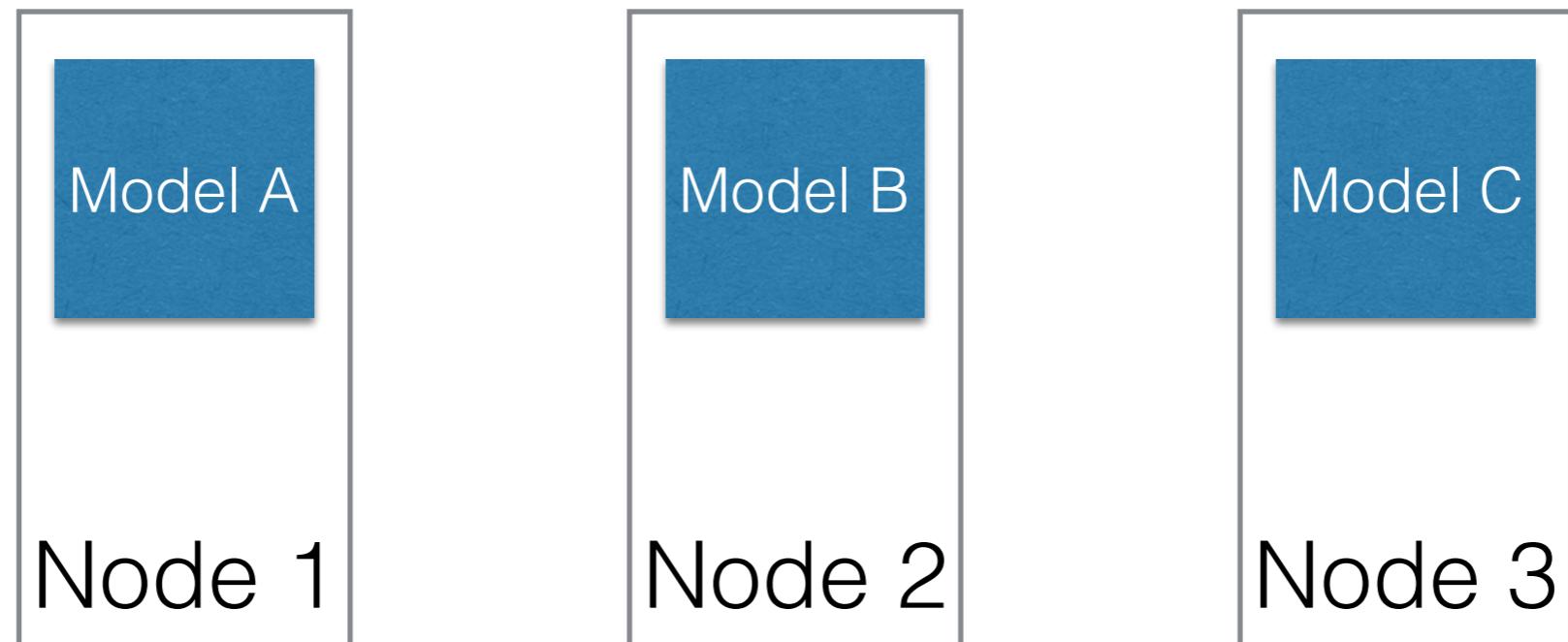
inter-model parallelism

aka. hyper parameter space exploration / tuning



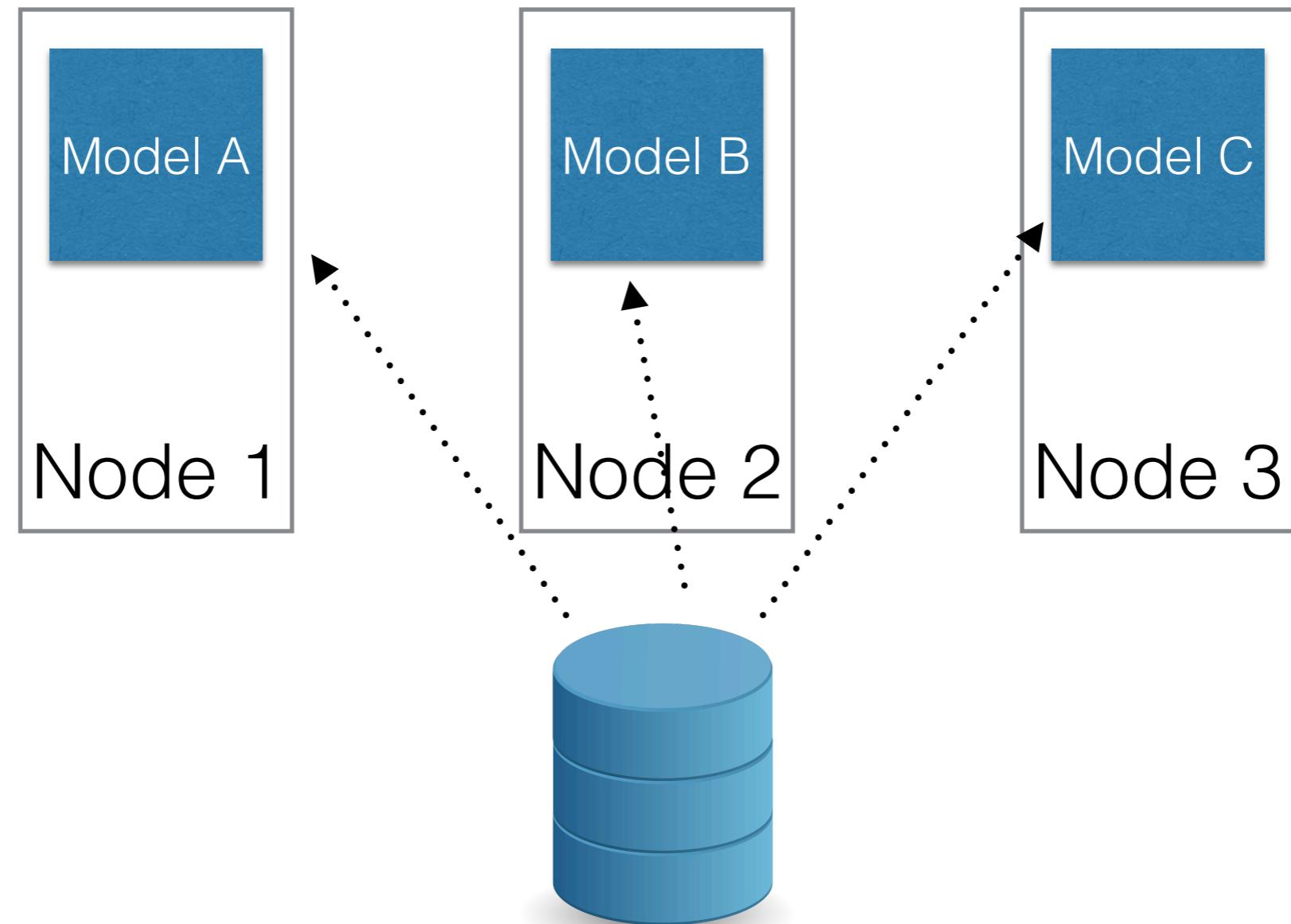
inter-model parallelism

aka. hyper parameter space exploration / tuning



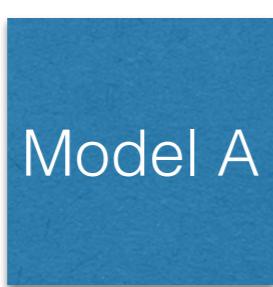
inter-model parallelism

aka. hyper parameter space exploration / tuning



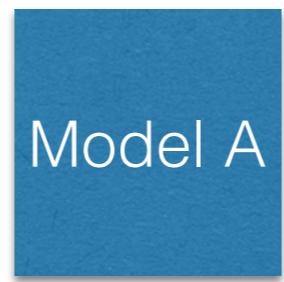
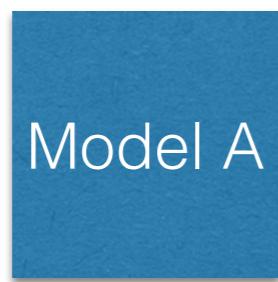
data parallelism

aka. “Jeff Dean style” parameter averaging



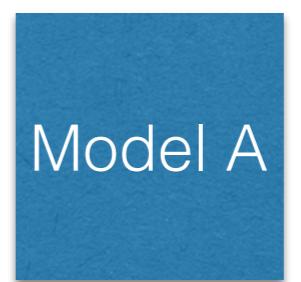
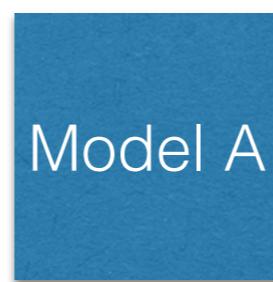
data parallelism

aka. “Jeff Dean style” parameter averaging



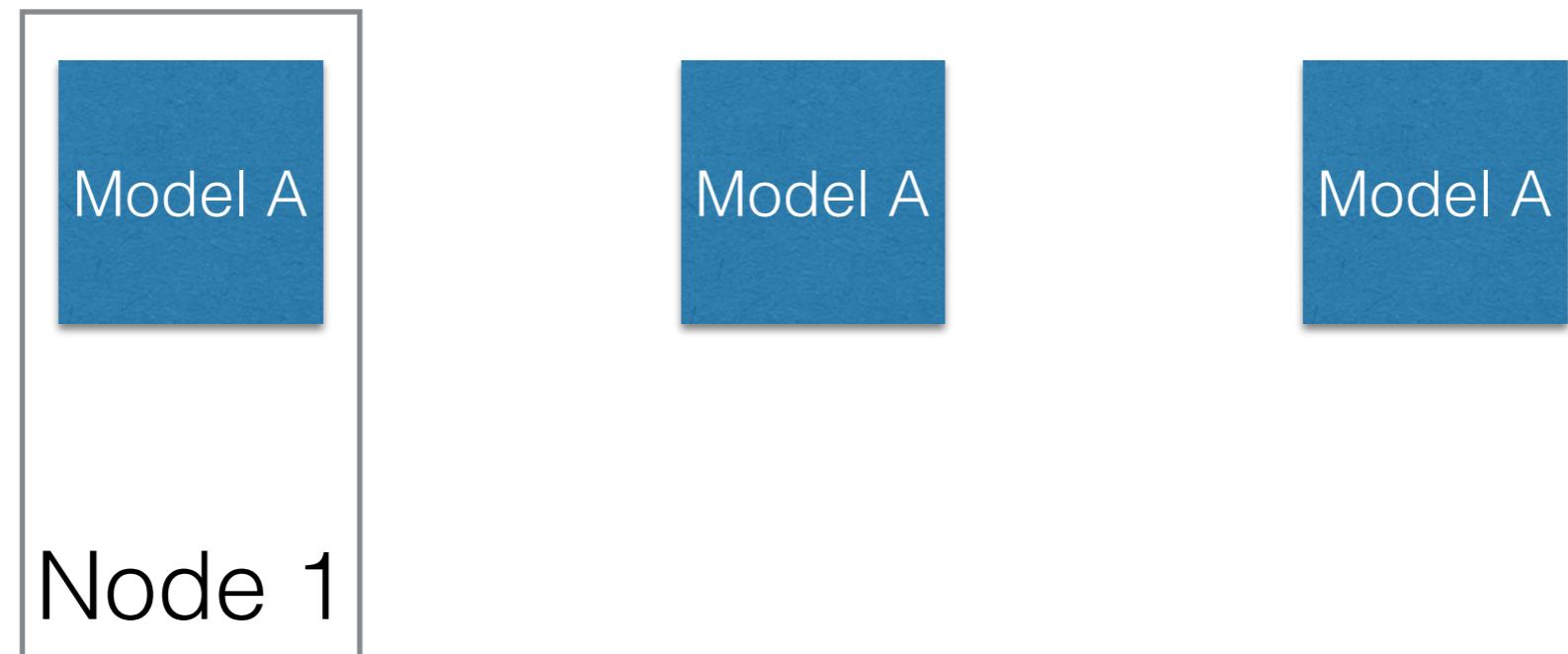
data parallelism

aka. “Jeff Dean style” parameter averaging



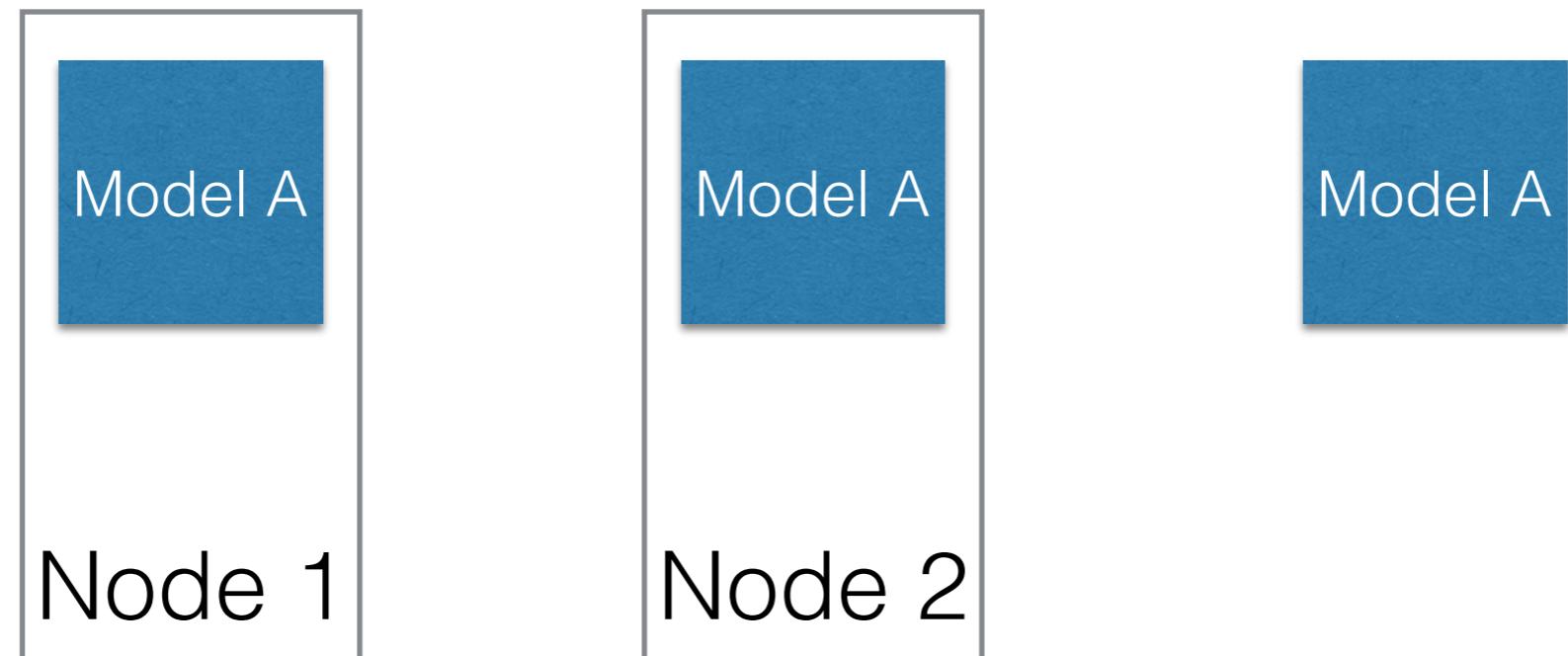
data parallelism

aka. “Jeff Dean style” parameter averaging



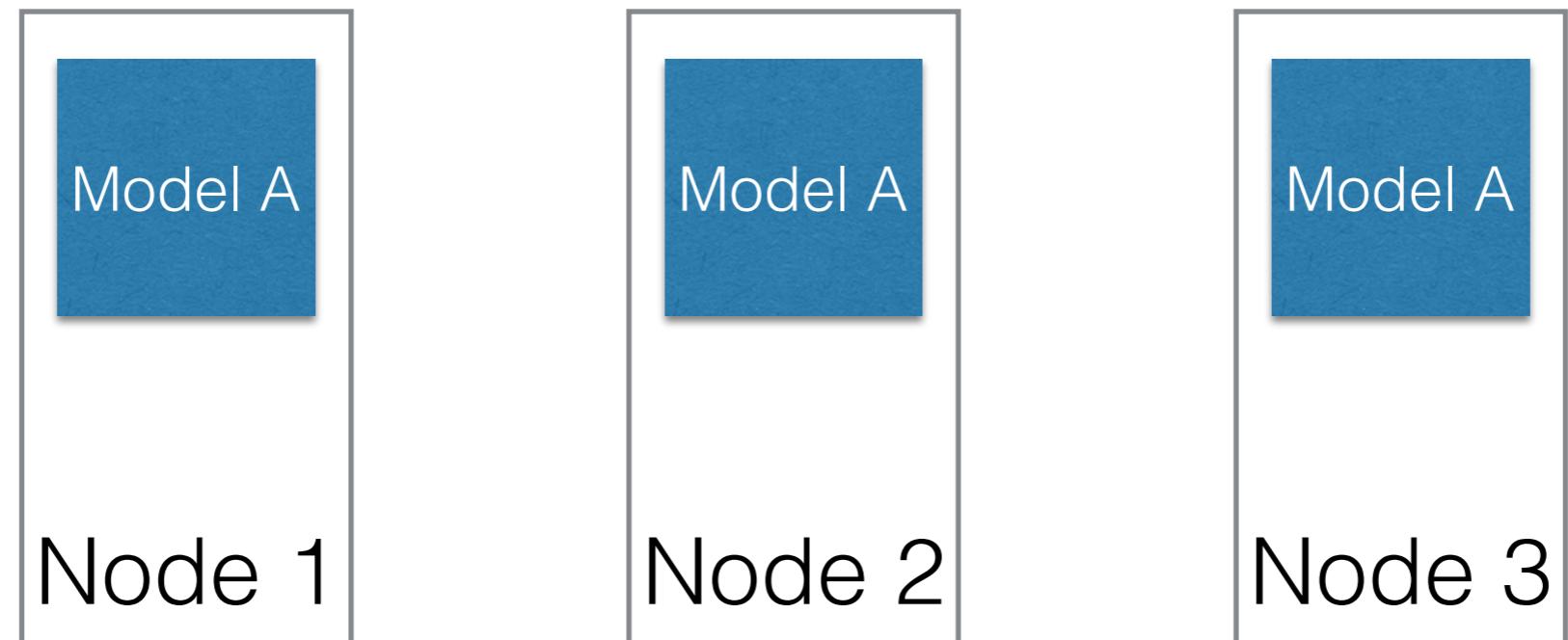
data parallelism

aka. “Jeff Dean style” parameter averaging



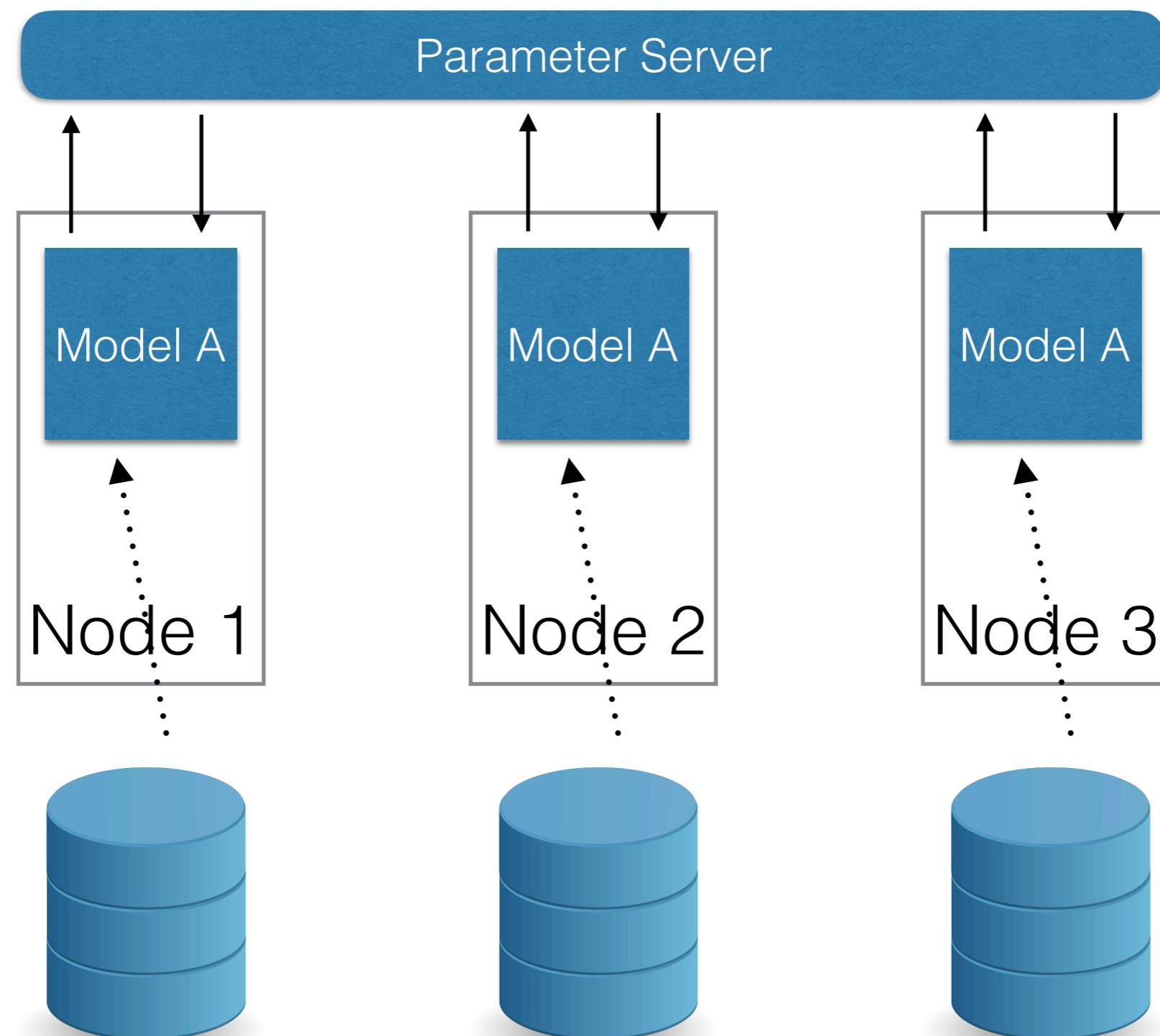
data parallelism

aka. “Jeff Dean style” parameter averaging



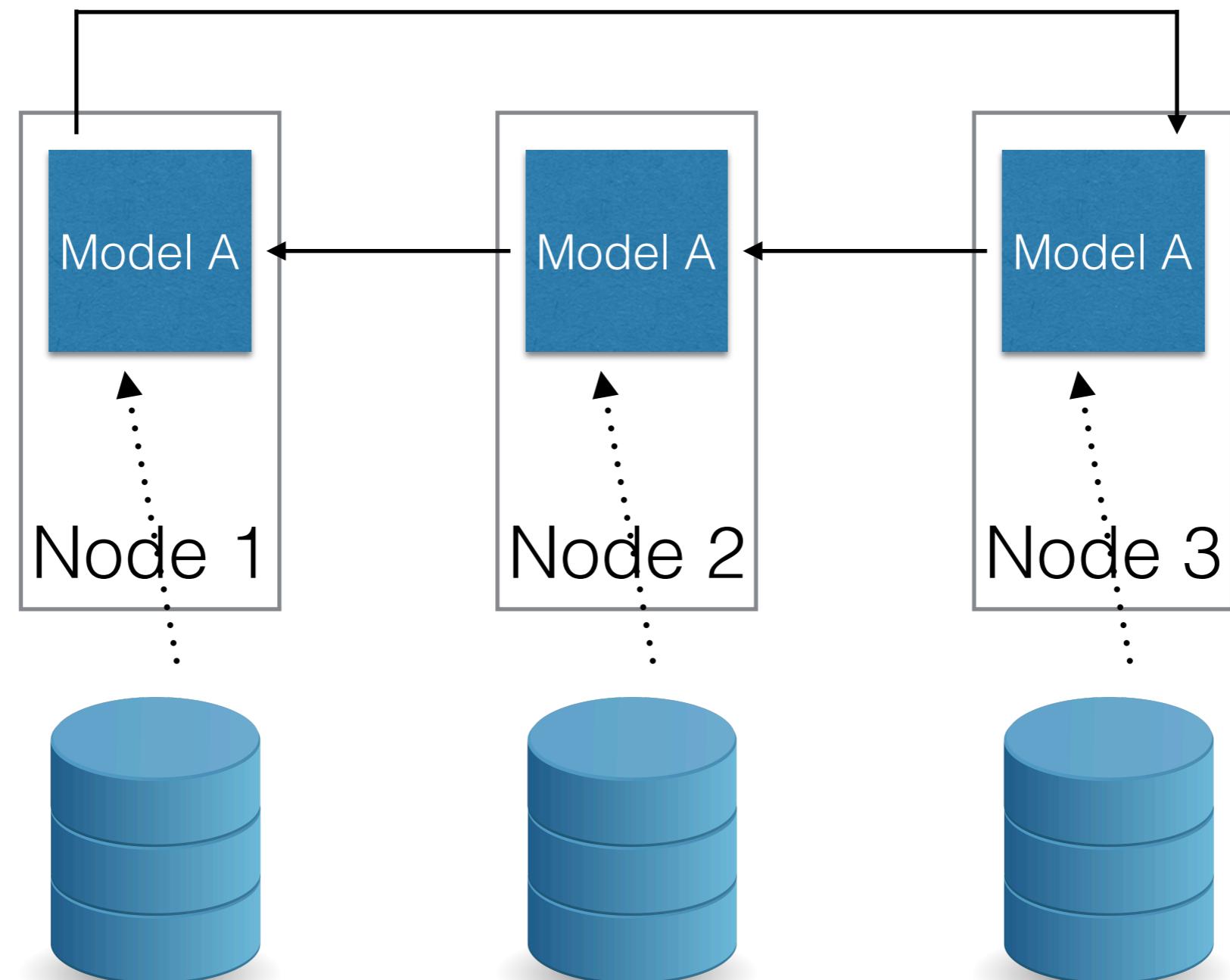
data parallelism

aka. “Jeff Dean style” parameter averaging

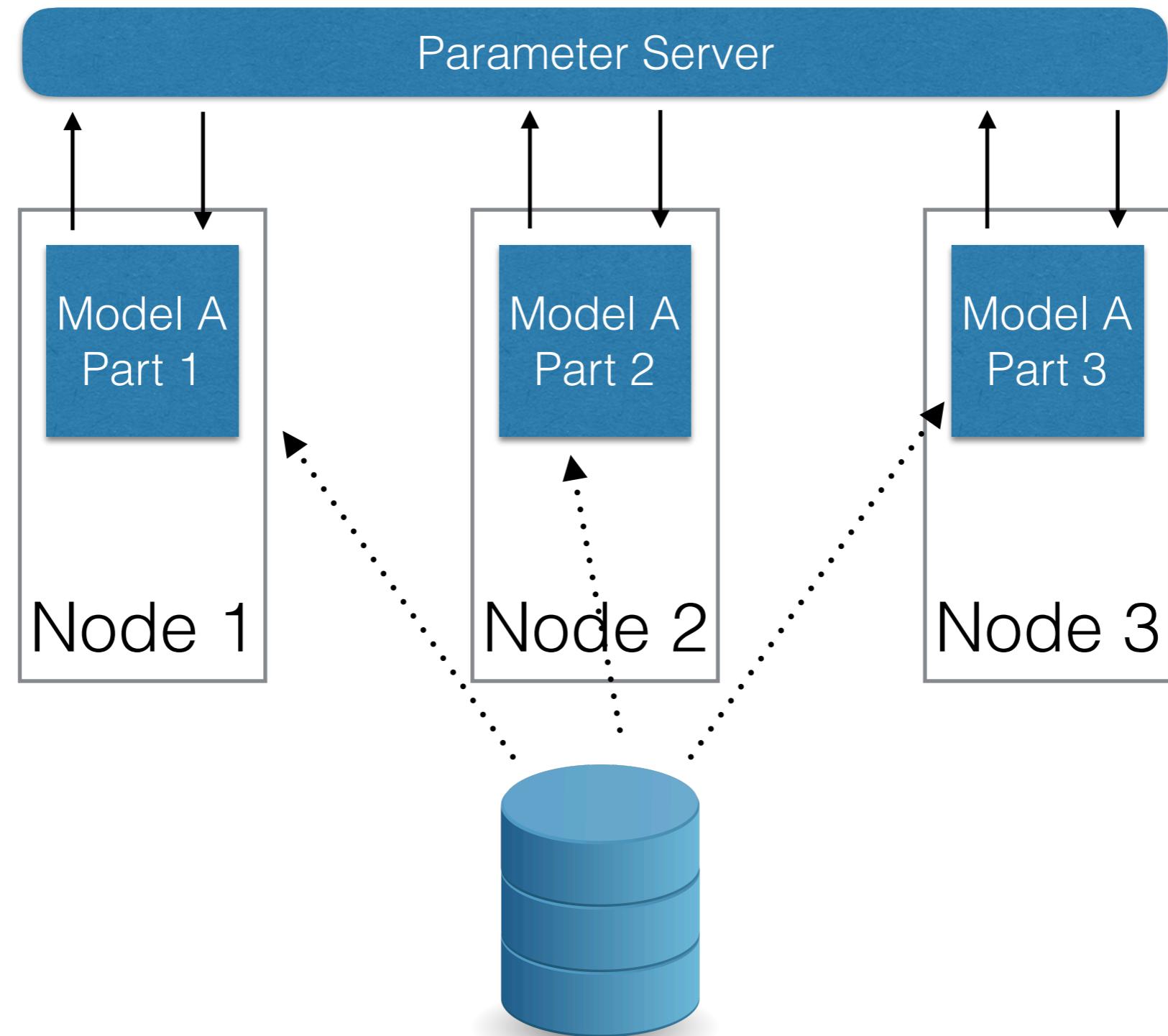


data parallelism

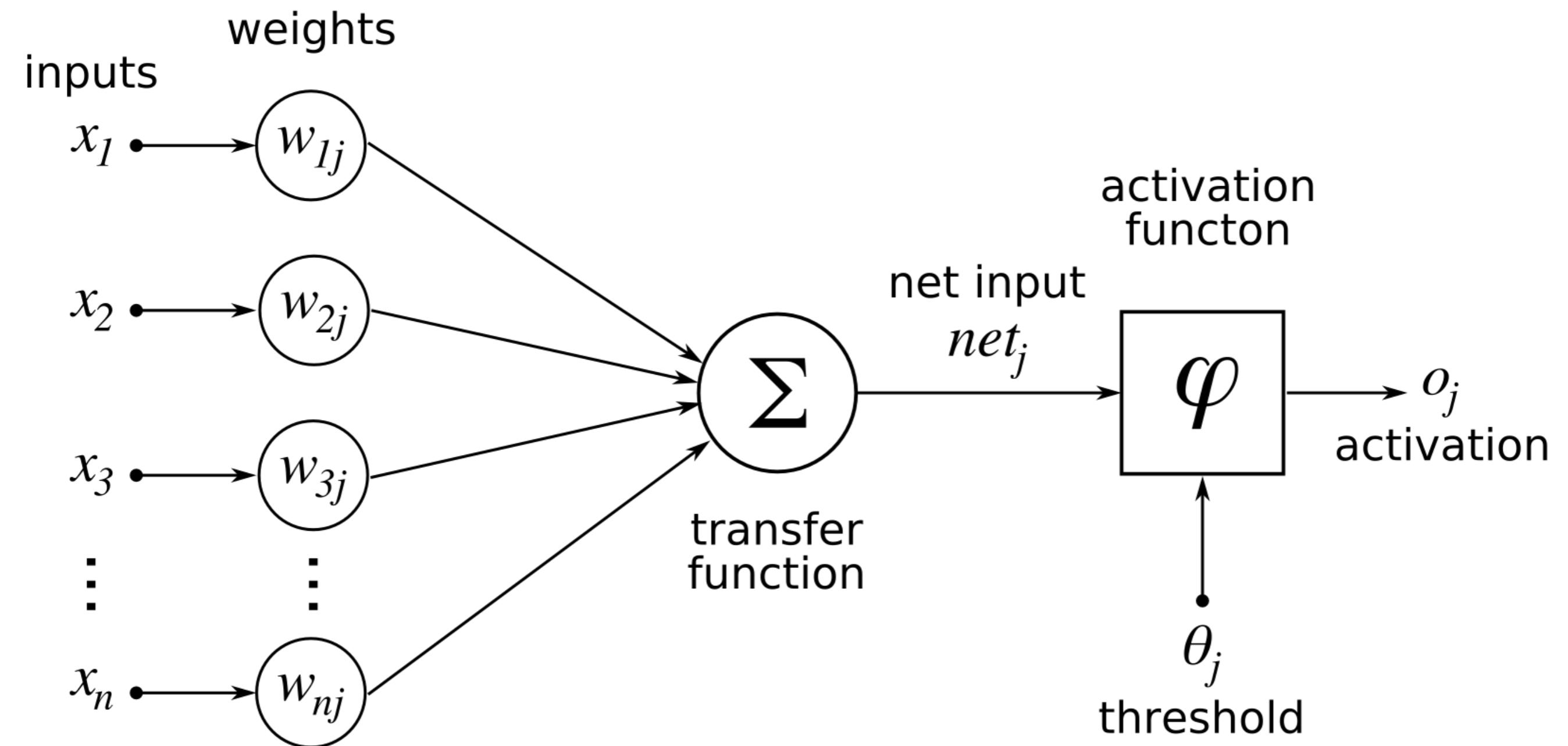
aka. “ReduceAll” parameter averaging



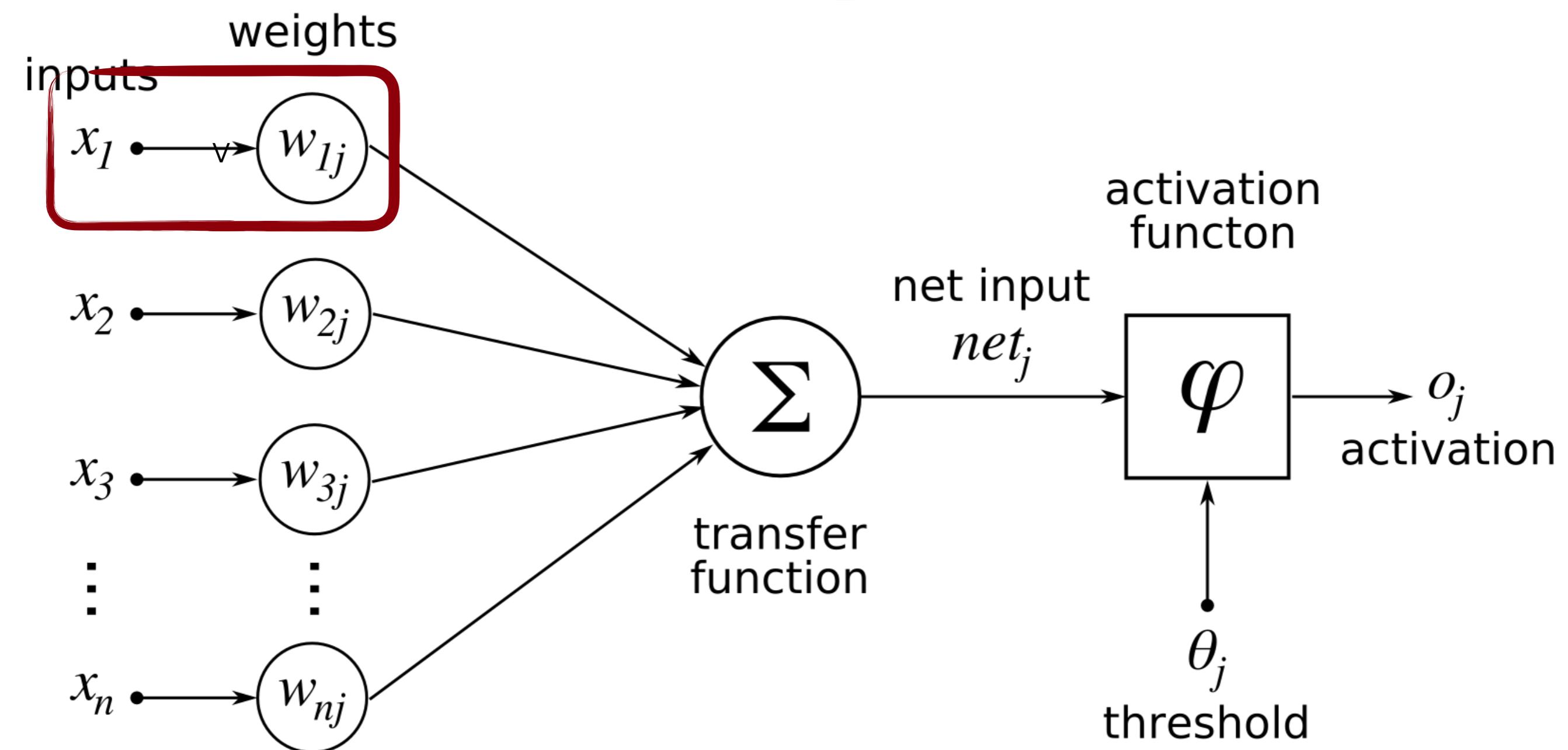
intra-model parallelism



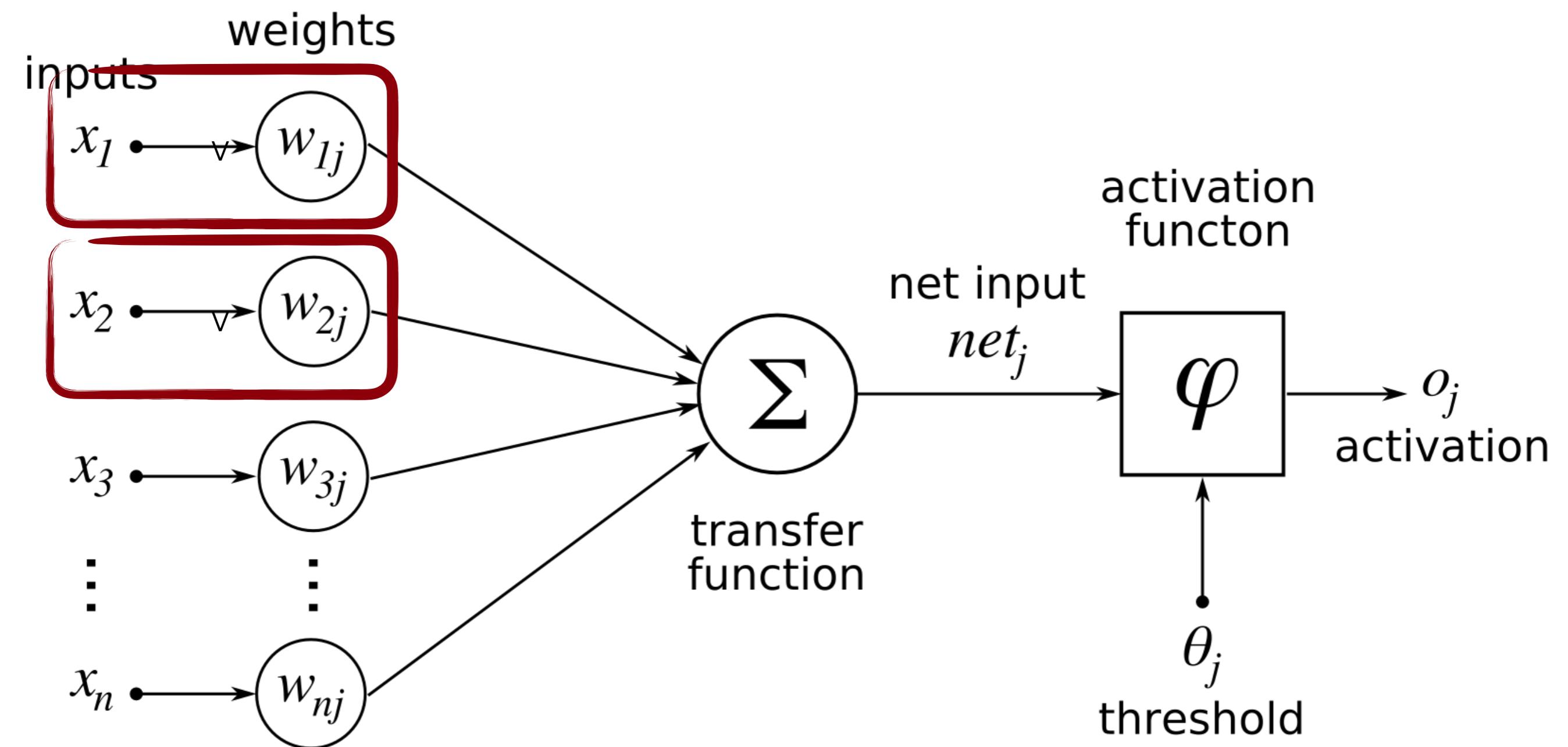
intra-model parallelism



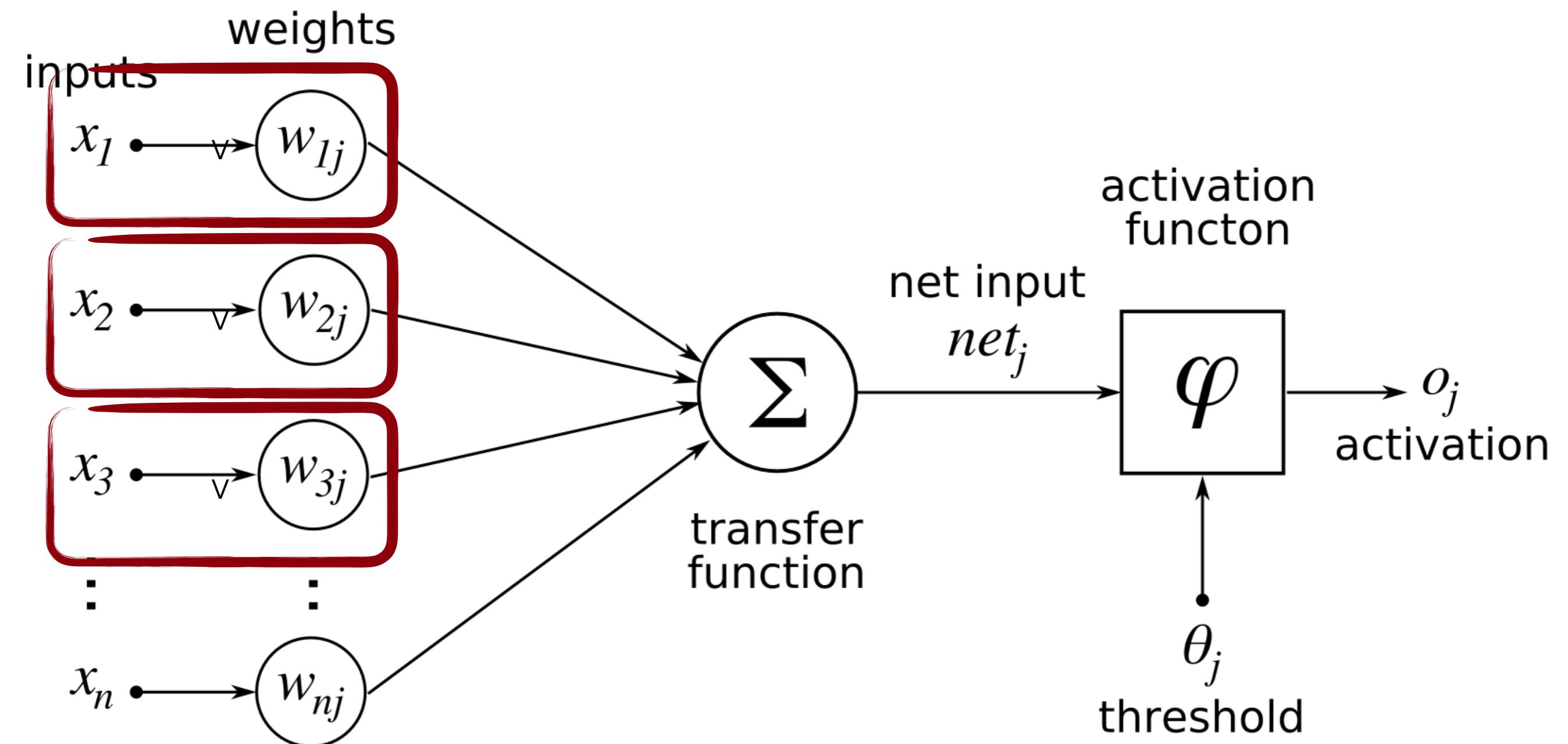
intra-model parallelism



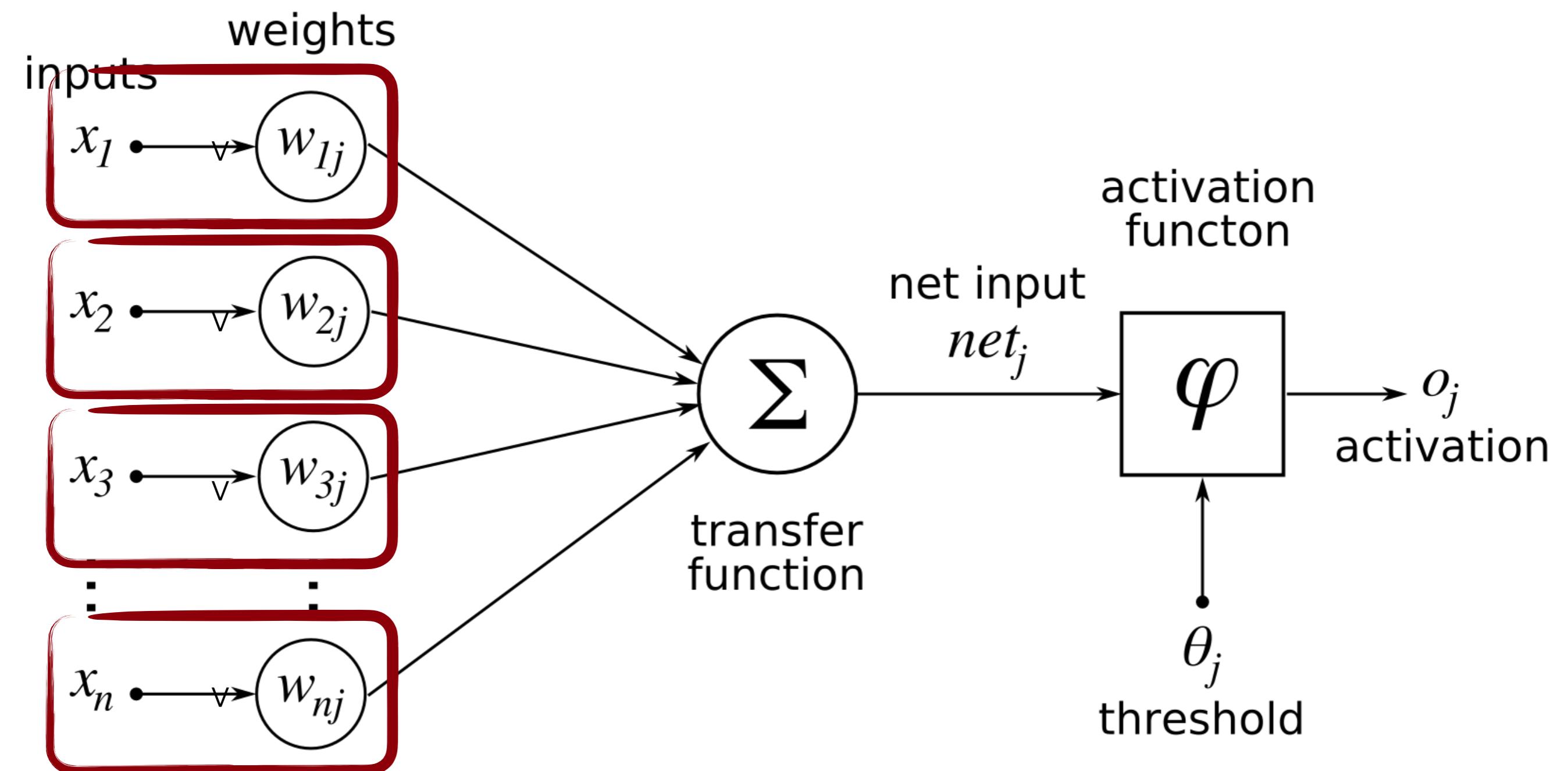
intra-model parallelism



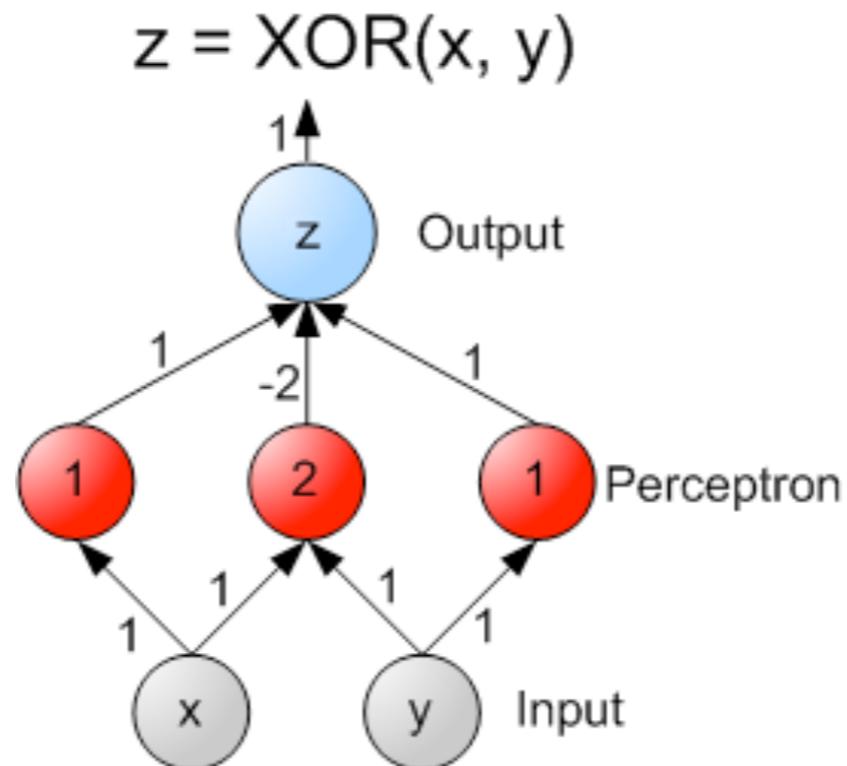
intra-model parallelism



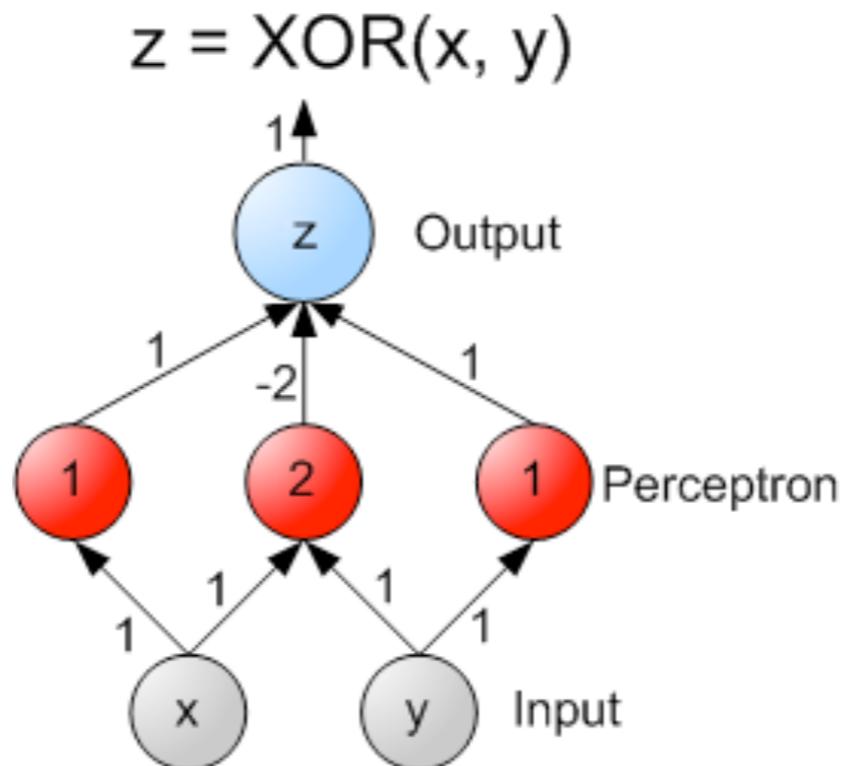
intra-model parallelism



pipelined parallelism

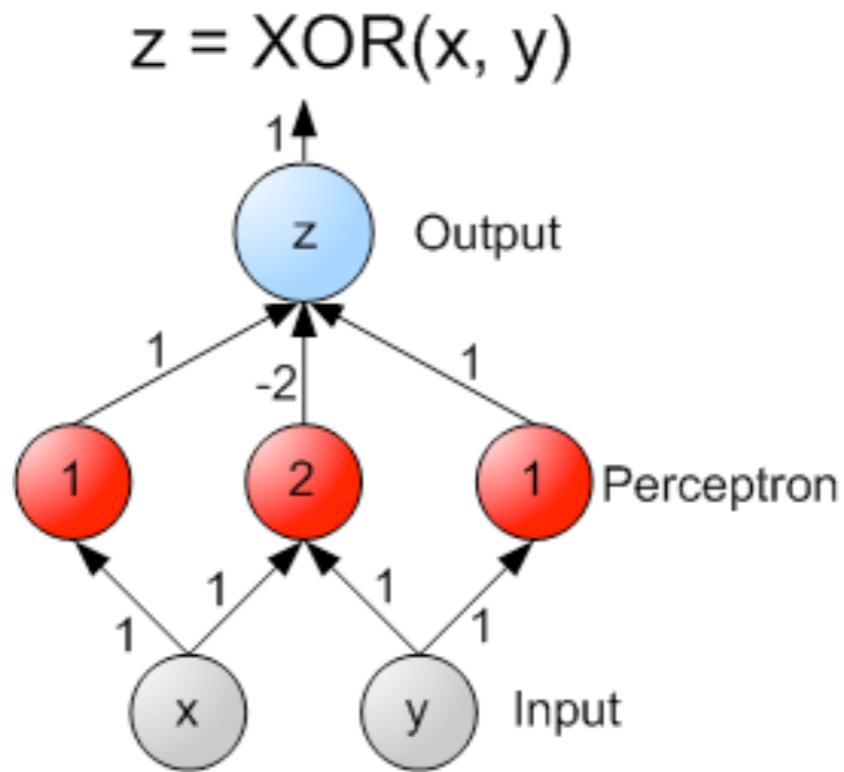


pipelined parallelism



0	0
0	1
1	0
1	1

pipelined parallelism



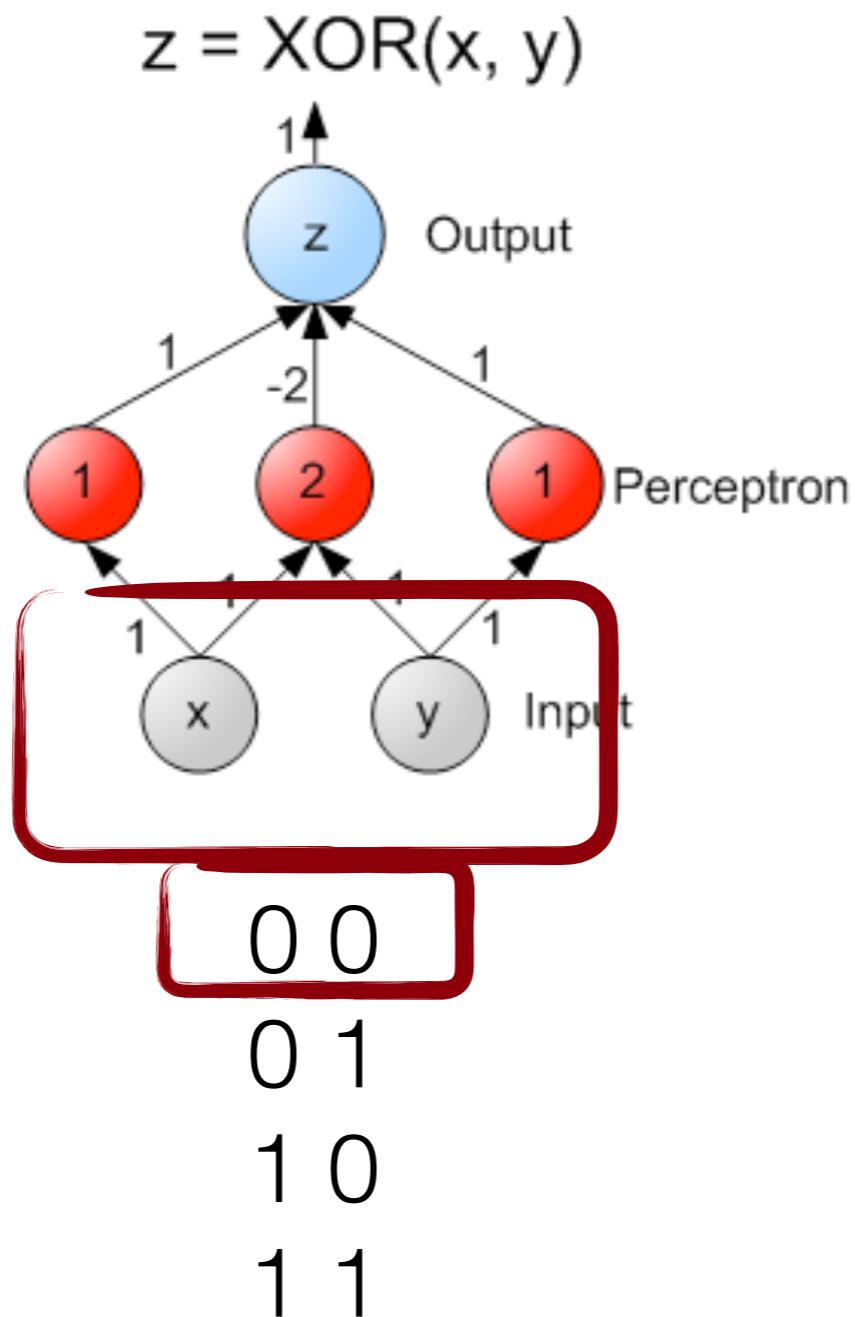
0 0

0 1

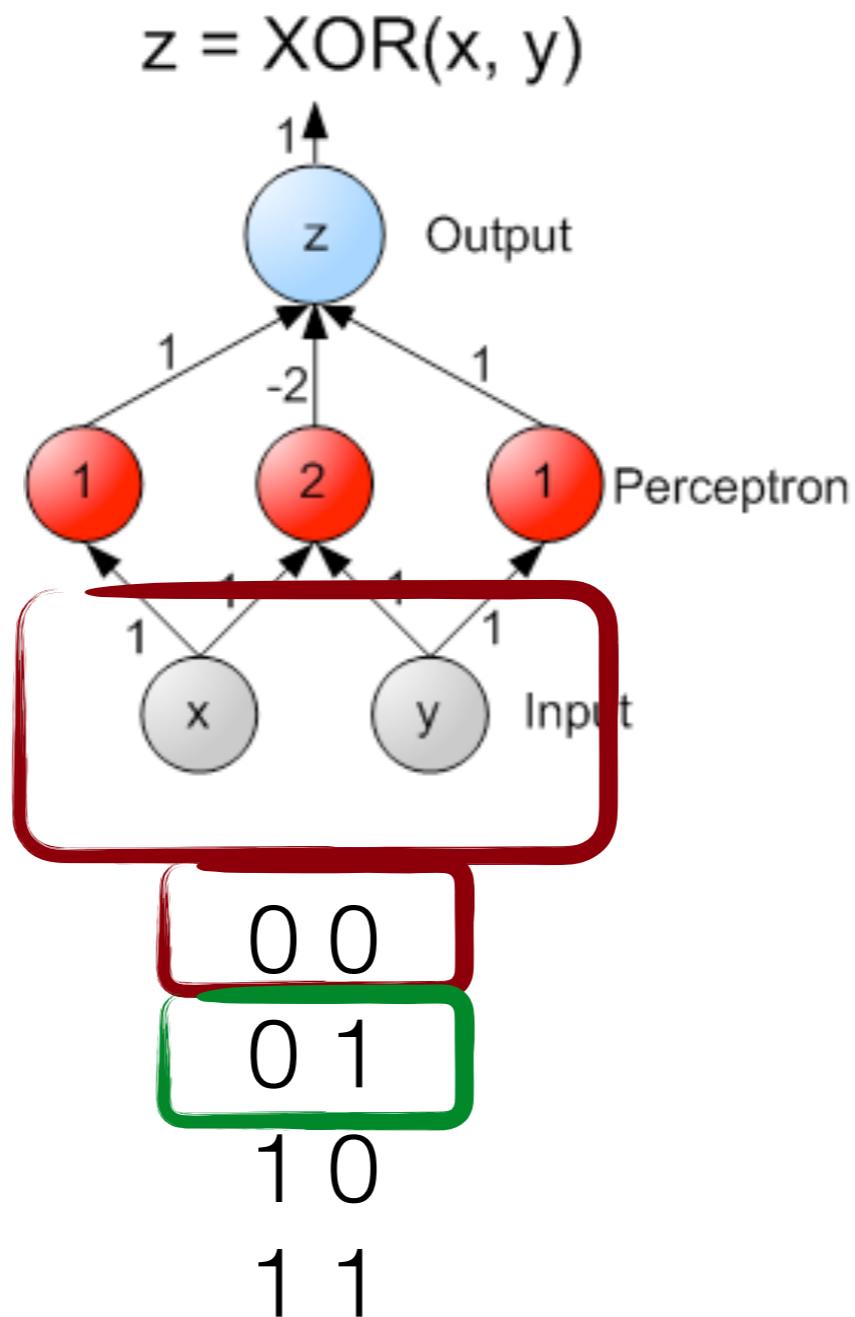
1 0

1 1

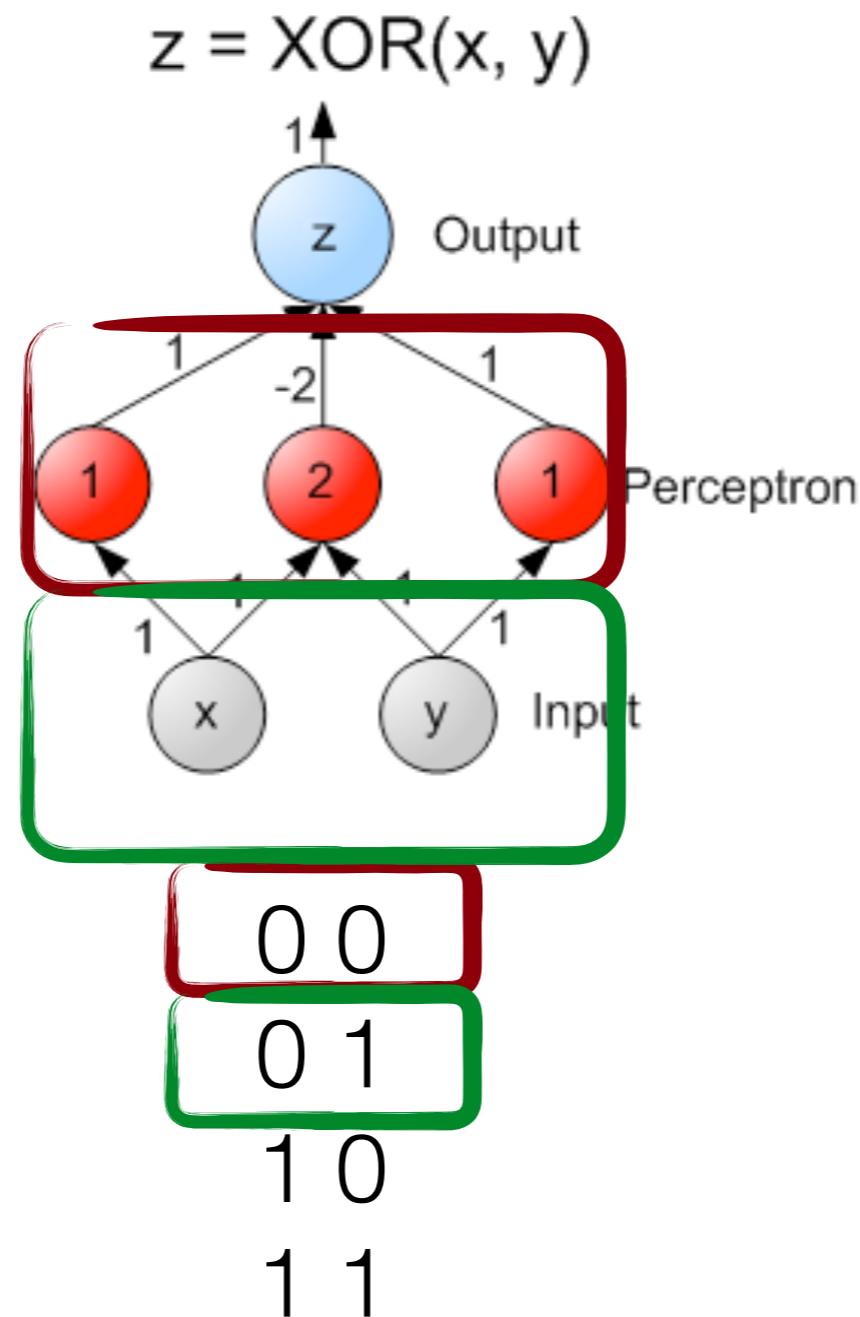
pipelined parallelism



pipelined parallelism



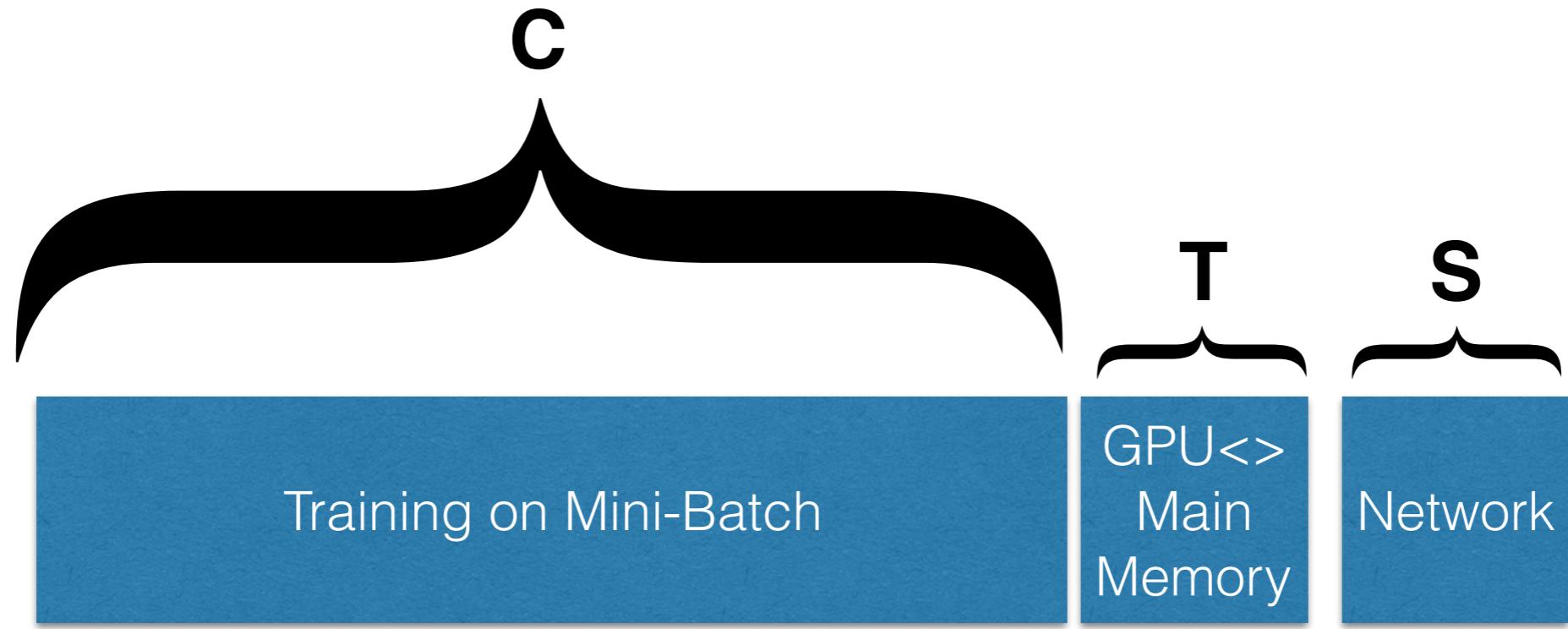
pipelined parallelism



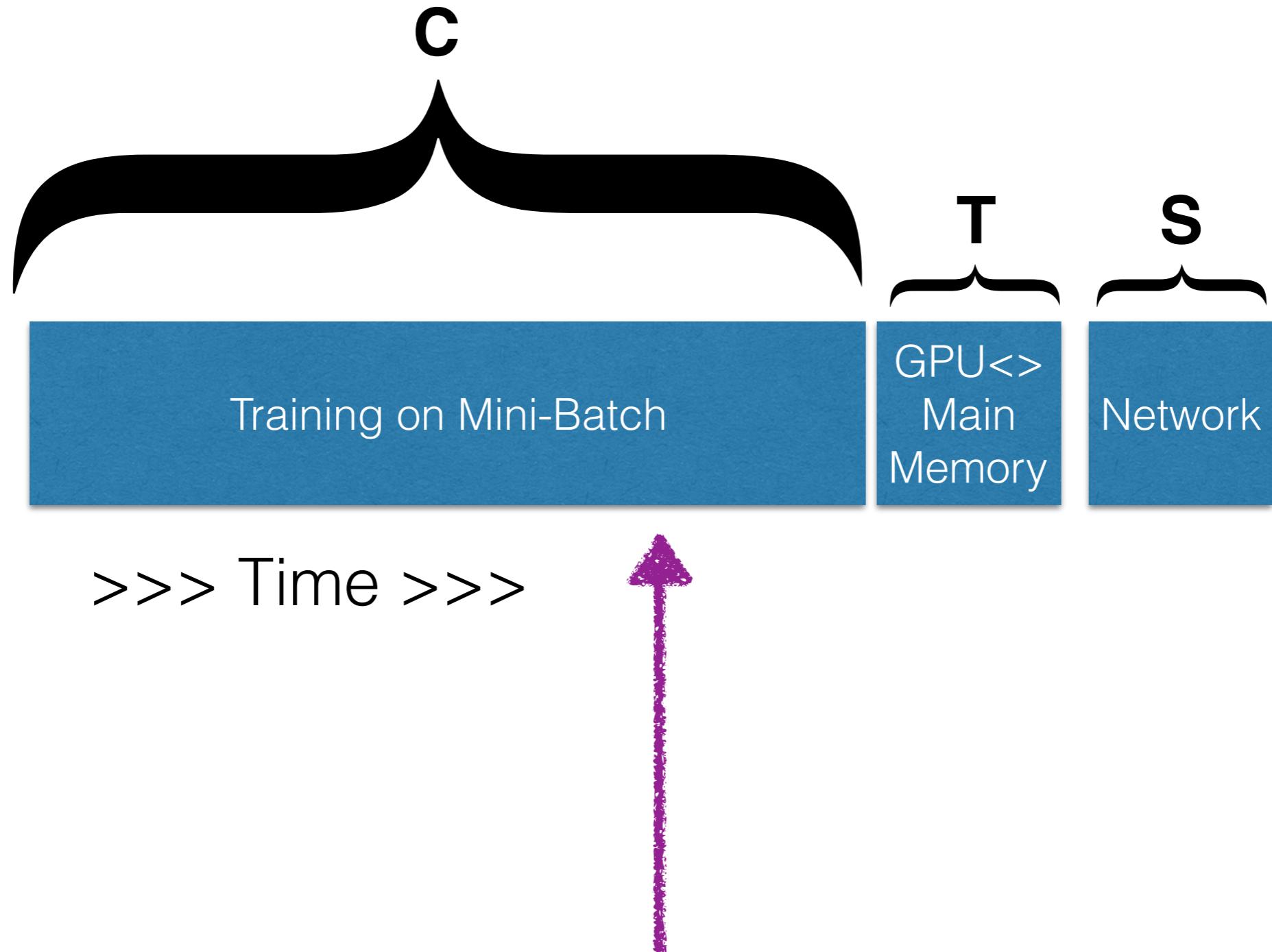
Interest over time ?

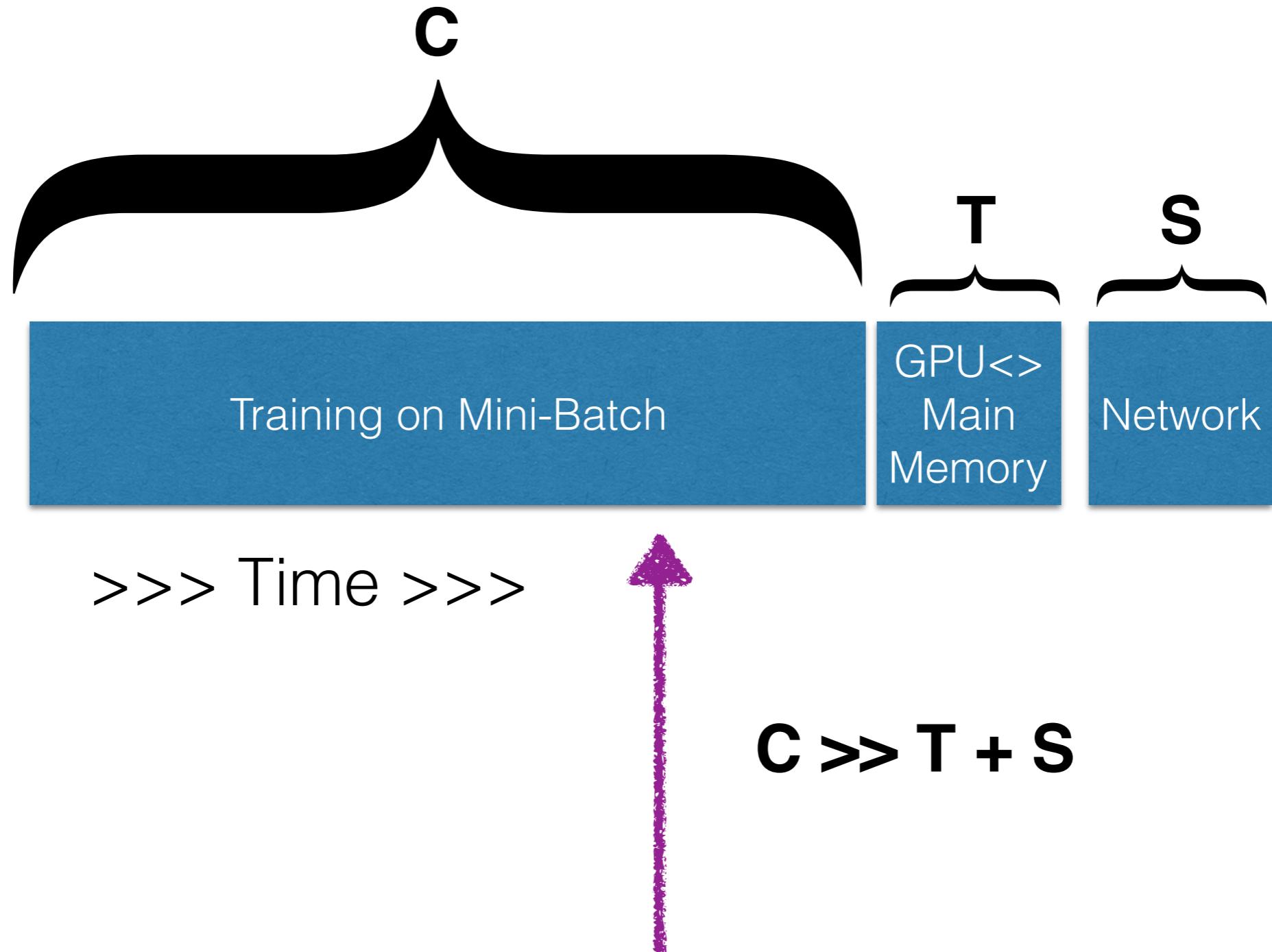
Download Share Embed

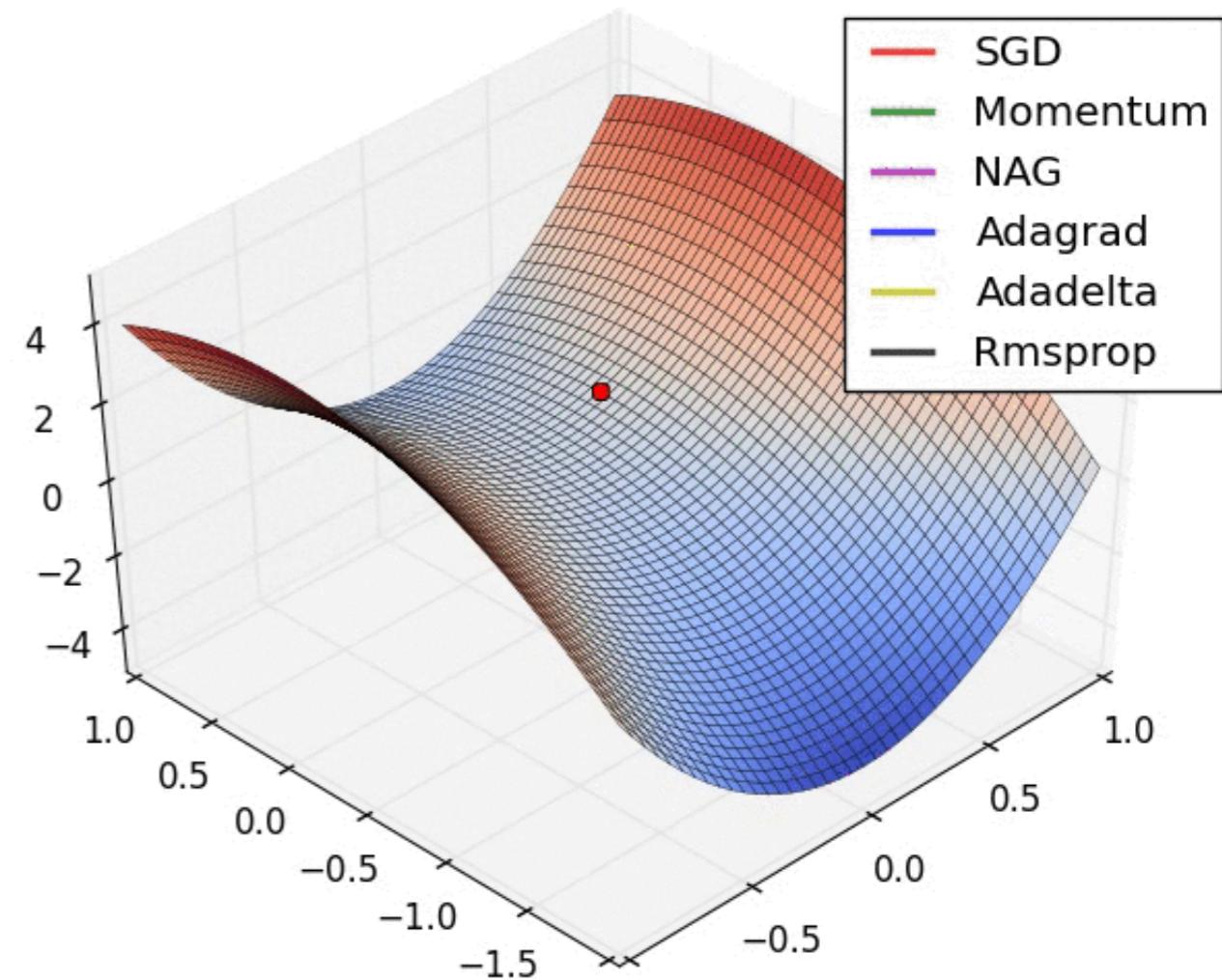
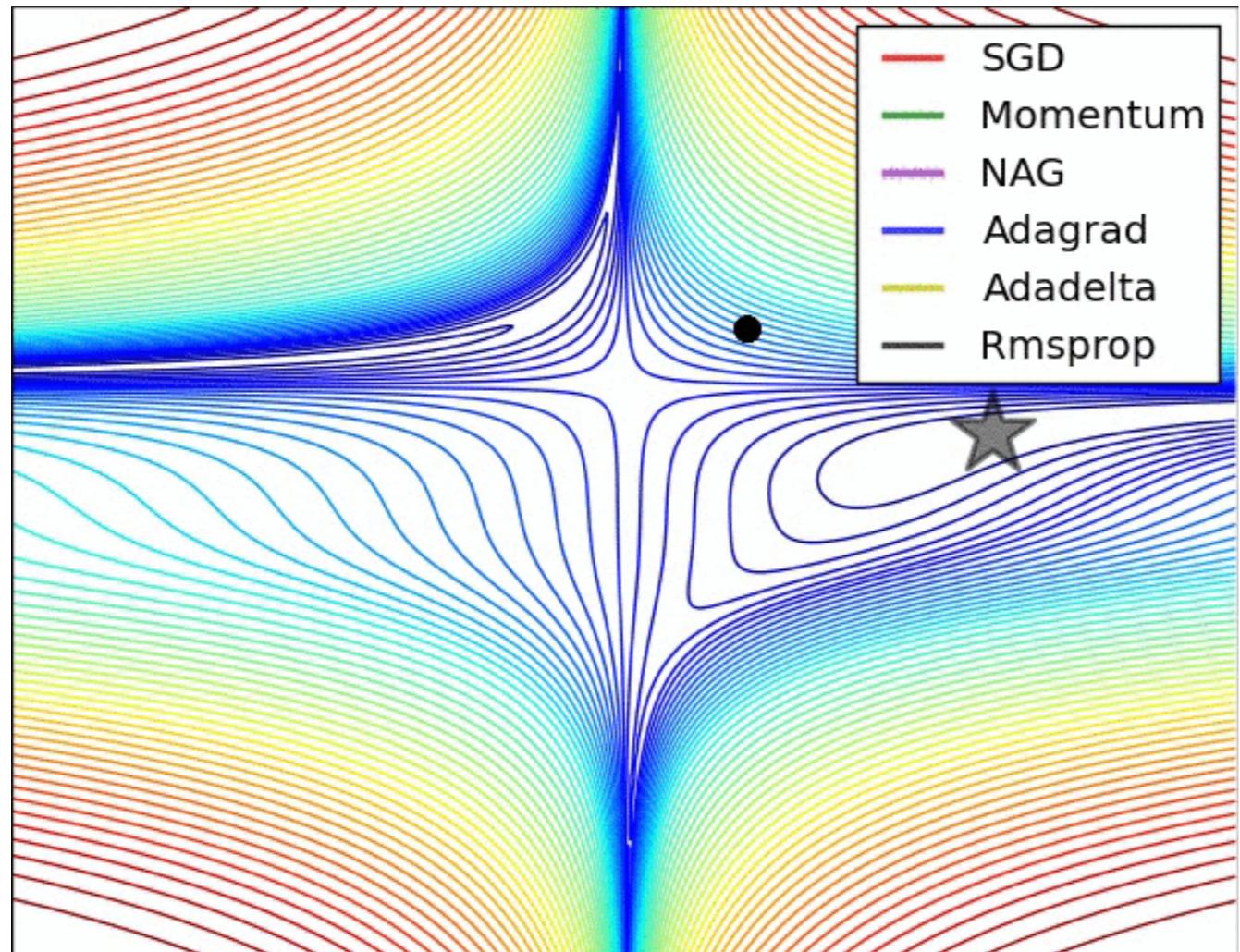




>>> Time >>>

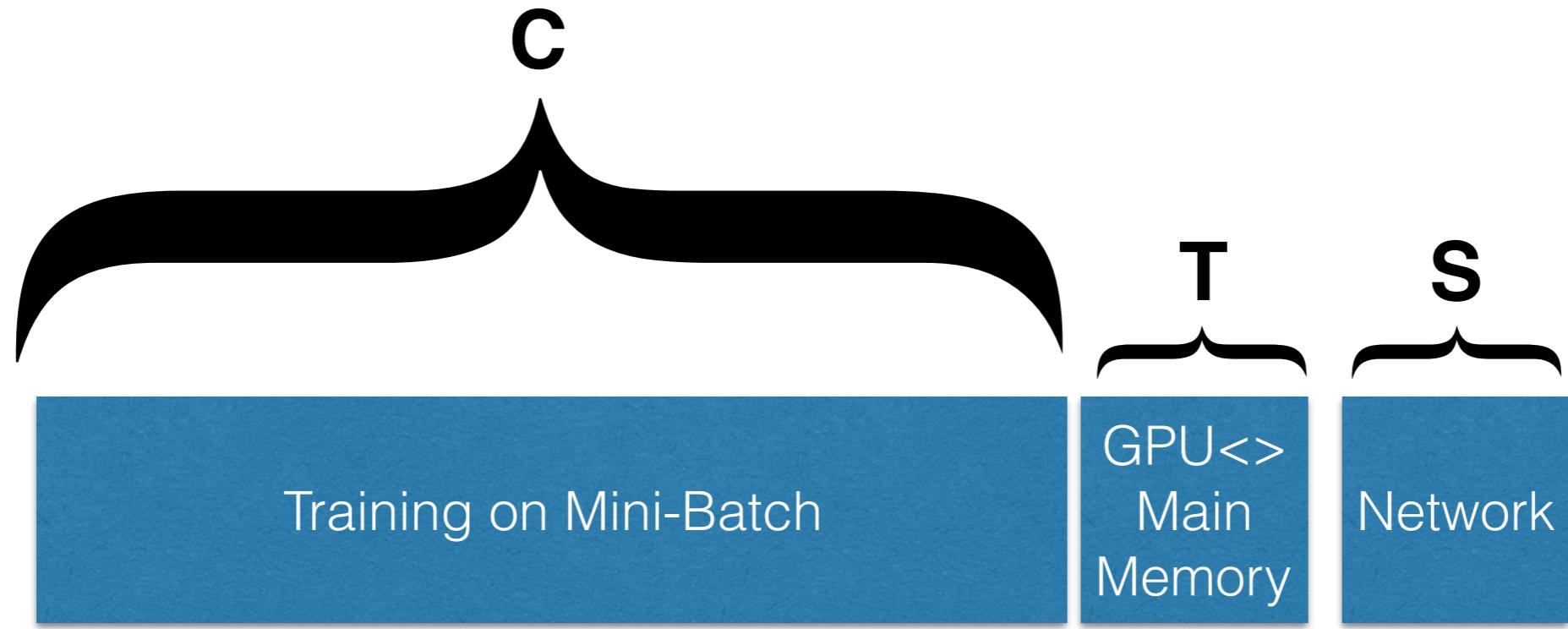






Credits:

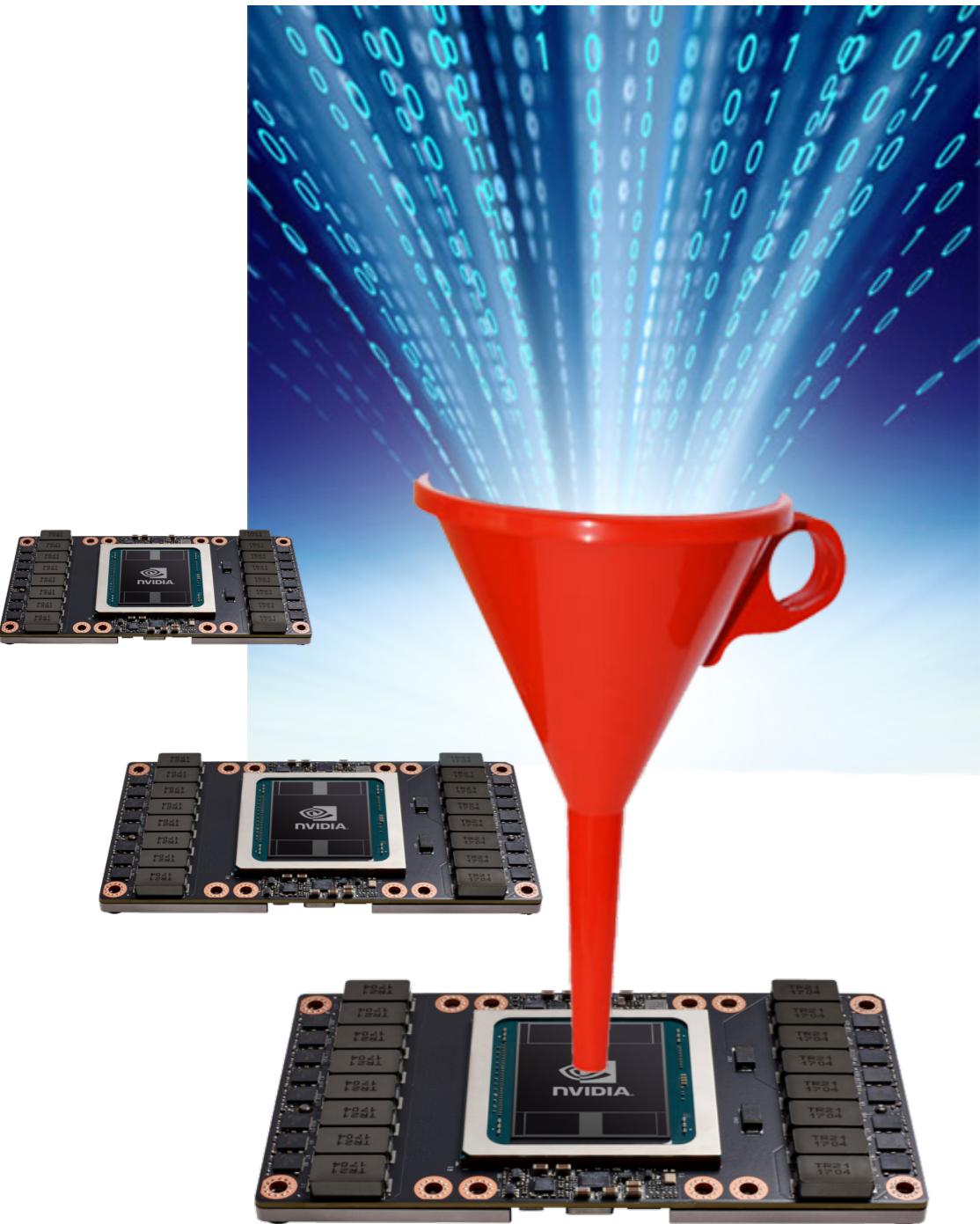
<http://www.denizyuret.com/2015/03/alec-radfords-animations-for.html>



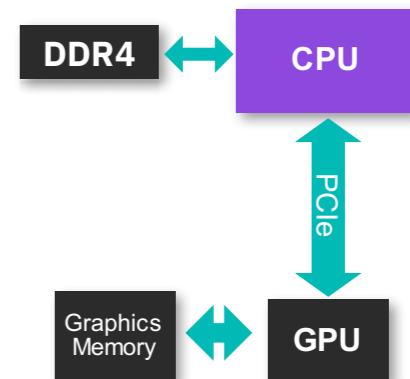
>>> Time >>>



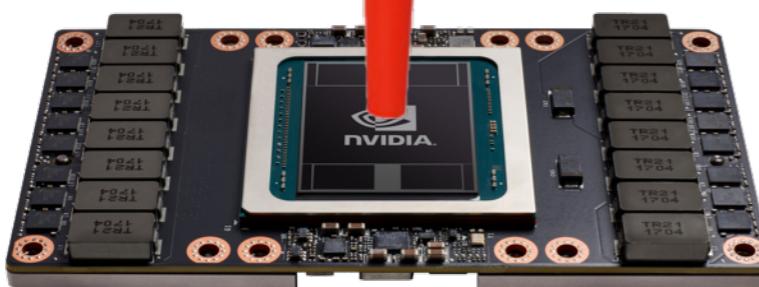
Time(%)	Time	Calls	Avg	Name
49.35%	29.581ms	1	29.581ms	[CUDA memcpy DtoH]
47.48%	28.462ms	1	28.462ms	[CUDA memcpy HtoD]
3.17%	1.9000ms	1	1.9000ms	naiveTransposeKernel



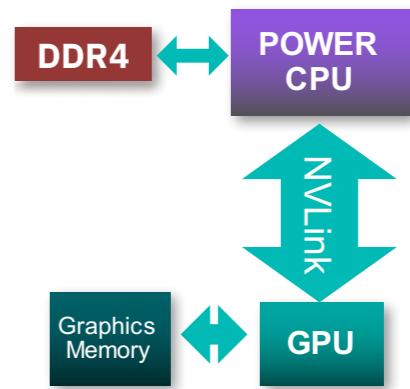
Time (%)	Time	Calls	Avg	Name
49.35%	29.581ms	1	29.581ms	[CUDA memcpy DtoH]
47.48%	28.462ms	1	28.462ms	[CUDA memcpy HtoD]
3.17%	1.9000ms	1	1.9000ms	naiveTransposeKernel



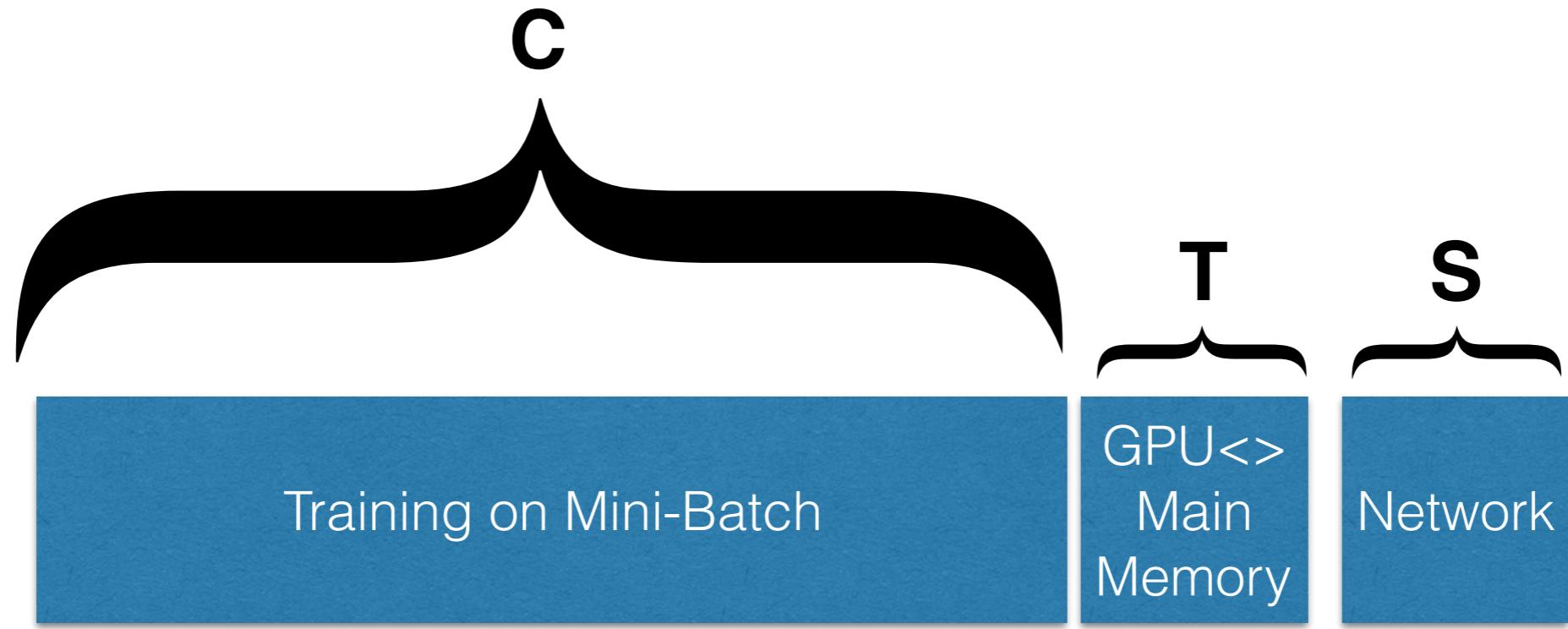
PCIe Gen3 – 32GB/sec



NVLink 1.0 – 80GB/sec



NVLink 2.0 – 150 GB/sec

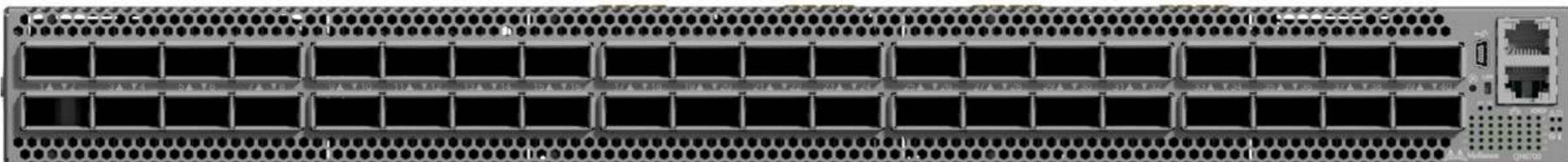


>>> Time >>>

QM8700 Series - Mellanox Quantum™ HDR 200Gb/s InfiniBand Smart Switches

40-port Non-blocking HDR 200Gb/s InfiniBand Smart Switch

Mellanox provides the world's smartest switches, enabling in-network computing through the Co-Design Scalable Hierarchical Aggregation and Reduction Protocol (SHARP)™ technology. The QM8700 series has the highest fabric performance available in the market with up to 16Tb/s of non-blocking bandwidth with sub 90ns port-to-port latency.





Open MPI: Open Source High Performance Computing

IBM Spectrum MPI

Accelerating high-performance application parallelization



 > Membership > Current Members

[Levels](#)

[Benefits](#)

[Current Members](#)

[How to Join](#)

Current Members

Platinum Level



PowerAI Vision

Auto-ML for Images & Video

Label

Train

Deploy

Watson Machine Learning

PowerAI: Open Source Frameworks



Large Model Support (LMS)

Watson Machine Learning Accelerator

Distributed Deep
Learning (DDL)

Elastic Distributed
Inference (Preview)

IBM Spectrum Conductor
Cluster Virtualization, Elastic Training
Auto Hyper-Parameter Optimization

Deep Learning Impact (DLI) Module

Data & Model
Management, ETL,
Visualize, Advise

Accelerated Infrastructure



Accelerated Servers AC922



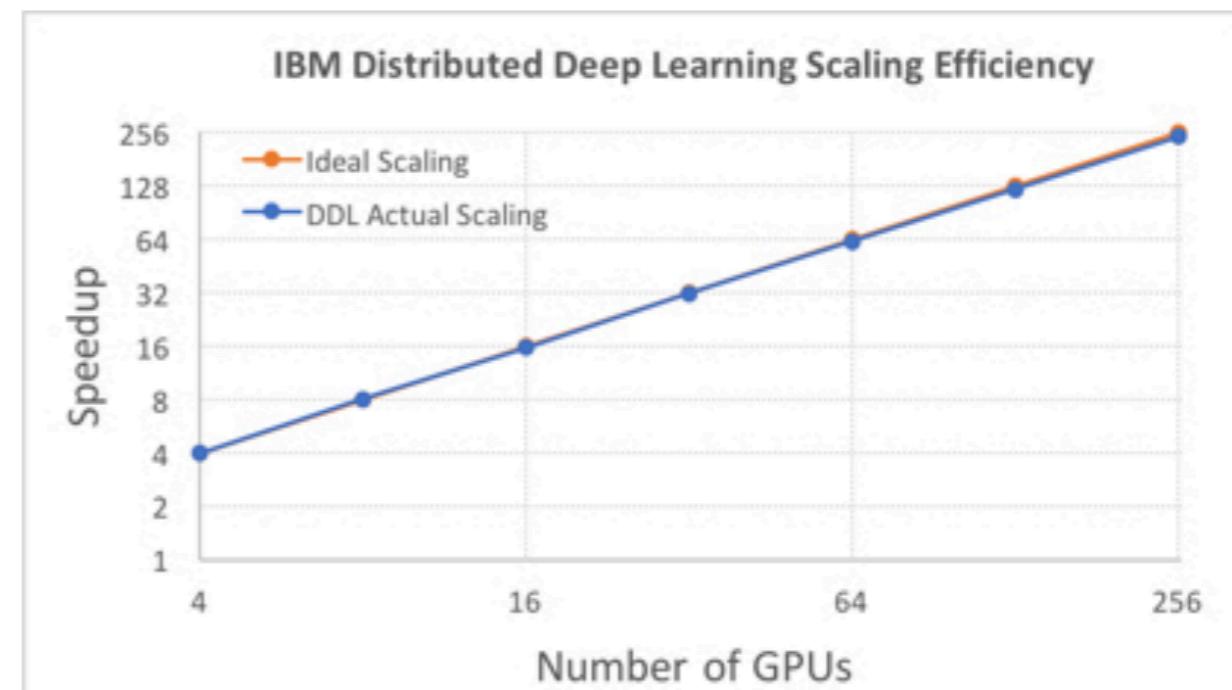
Storage (Spectrum Scale ESS)

August 8, 2017

Posted in: AI, Cognitive Computing

IBM Research achieves record deep learning performance with new software technology

Summary: IBM Research publishes in arXiv close to ideal scaling with new distributed deep learning software which achieved record communication overhead and 95% scaling efficiency on the Caffe deep learning framework over 256 NVIDIA GPUs in 64 IBM Power systems. Previous best scaling was demonstrated by Facebook AI Research of 89% for a training run on Caffe2, at higher communication overhead. IBM Research also beat Facebook's time by training the model in 50 minutes, versus the 1 hour Facebook took. Using this software, IBM Research achieved a new image recognition accuracy of 33.8% for a neural network trained on a very large data set (7.5M images). The previous record published by Microsoft demonstrated 29.8% accuracy.



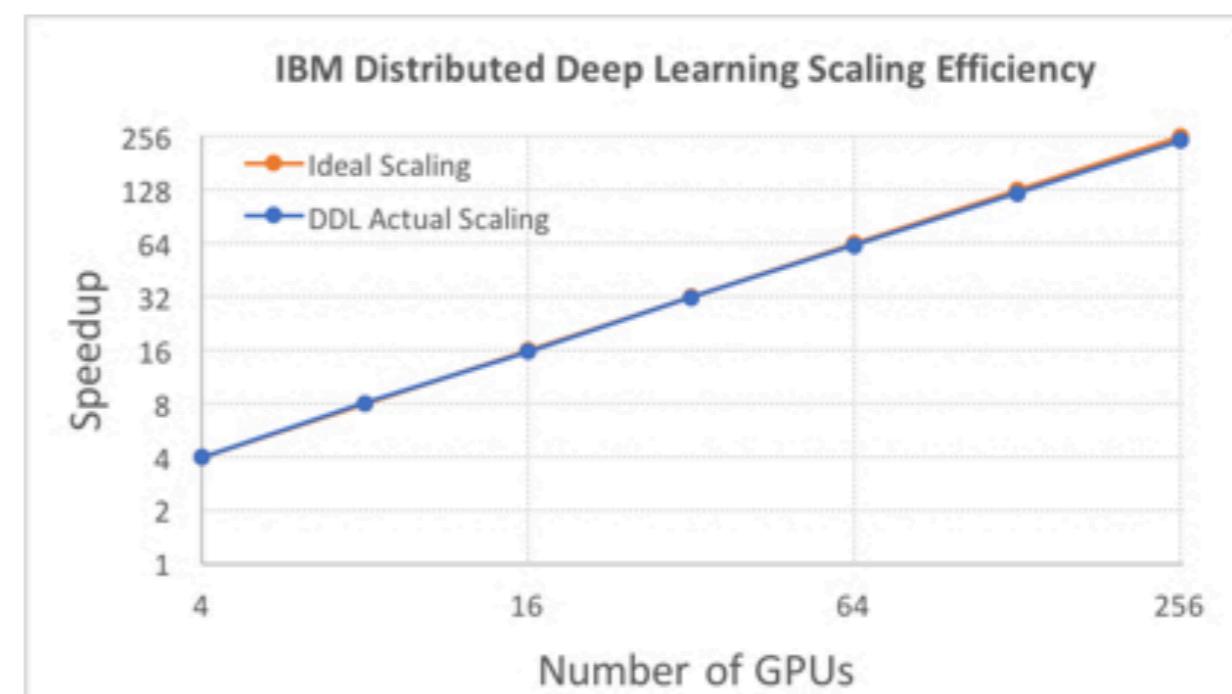
August 8, 2017

Posted in: AI, Cognitive Computing

IBM Research achieves record deep learning performance with new software technology

Summary: IBM Research publishes in arXiv close to ideal scaling with new distributed deep learning software which achieved record communication overhead and 95% scaling efficiency on the Caffe deep learning framework over 256 NVIDIA GPUs in 64 IBM Power systems. Previous best scaling was demonstrated by Facebook AI Research of 89% for a training run on Caffe2, at higher communication overhead. IBM Research also beat Facebook's time by training the model in 50 minutes, versus the 1 hour Facebook took. Using this software, IBM Research achieved a new image recognition accuracy of 33.8% for a neural network trained on a very large data set (7.5M images). The previous record published by Microsoft demonstrated 29.8% accuracy.

Scaling Efficiency
Facebook: 89%
IBM: 95%



August 8, 2017

Posted in: AI, Cognitive Computing

IBM Research achieves record deep learning performance with new software technology

Summary: IBM Research publishes in arXiv close to ideal scaling with new distributed deep learning software which achieved record communication overhead and 95% scaling efficiency on the Caffe deep learning framework over 256 NVIDIA GPUs in 64 IBM Power systems. Previous best scaling was demonstrated by Facebook AI Research of 89% for a training run on Caffe2, at higher communication overhead. IBM Research also beat Facebook's time by training the model in 50 minutes, versus the 1 hour Facebook took. Using this software, IBM Research achieved a new image recognition accuracy of 33.8% for a neural network trained on a very large data set (7.5M images). The previous record published by Microsoft demonstrated 29.8% accuracy.

Scaling Efficiency

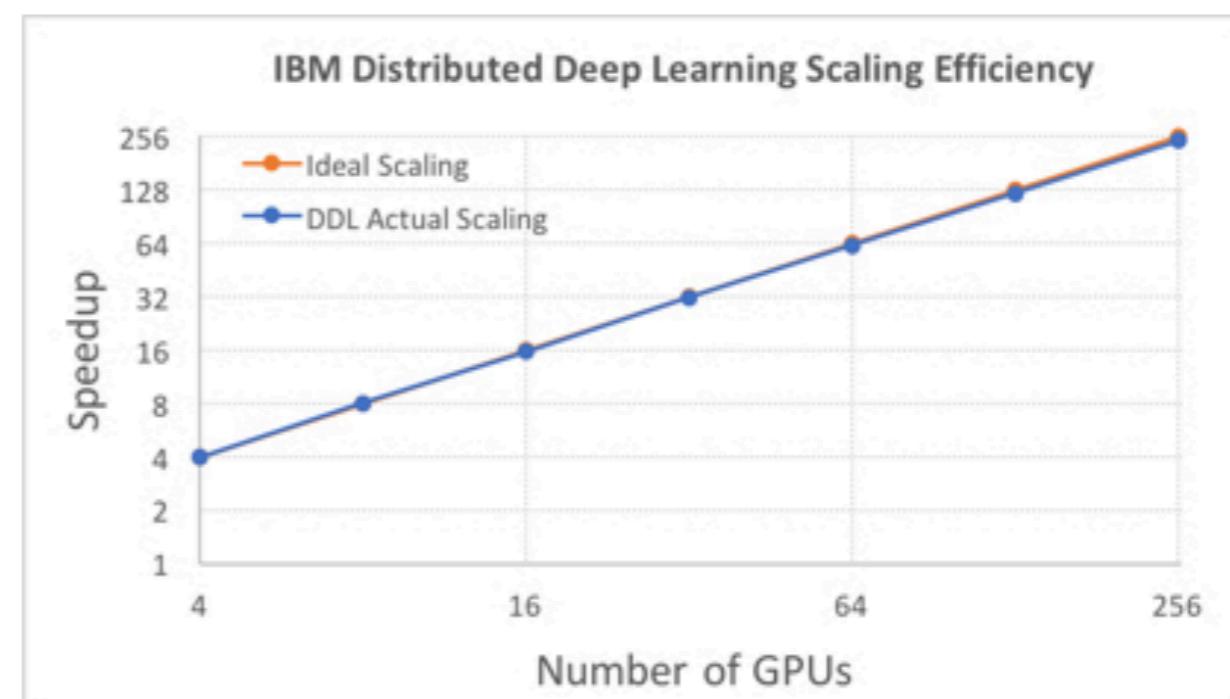
Facebook: 89%

IBM: 95%

Runtime

Facebook: 1h

IBM: 50 minutes



August 8, 2017

Posted in: AI, Cognitive Computing

IBM Research achieves record deep learning performance with new software technology

Summary: IBM Research publishes in arXiv close to ideal scaling with new distributed deep learning software which achieved record communication overhead and 95% scaling efficiency on the Caffe deep learning framework over 256 NVIDIA GPUs in 64 IBM Power systems. Previous best scaling was demonstrated by Facebook AI Research of 89% for a training run on Caffe2, at higher communication overhead. IBM Research also beat Facebook's time by training the model in 50 minutes, versus the 1 hour Facebook took. Using this software, IBM Research achieved a new image recognition accuracy of 33.8% for a neural network trained on a very large data set (7.5M images). The previous record published by Microsoft demonstrated 29.8% accuracy.

Accuracy

Microsoft: 29.8%

IBM: 33.8%

Scaling Efficiency

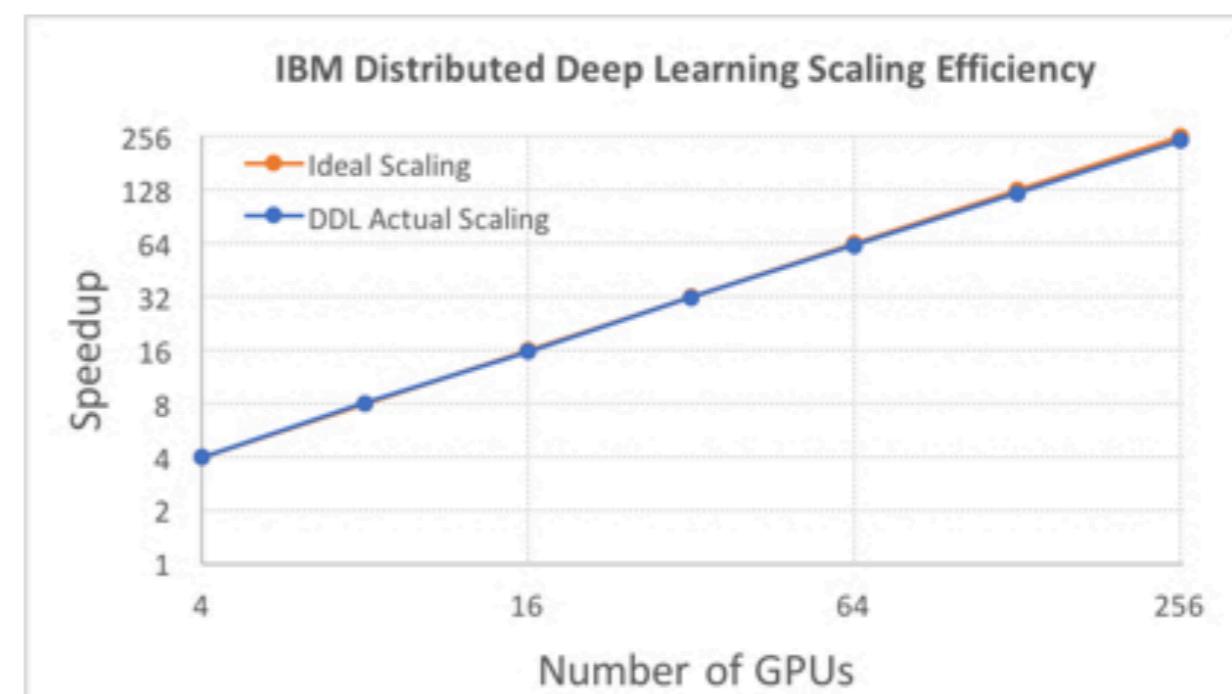
Facebook: 89%

IBM: 95%

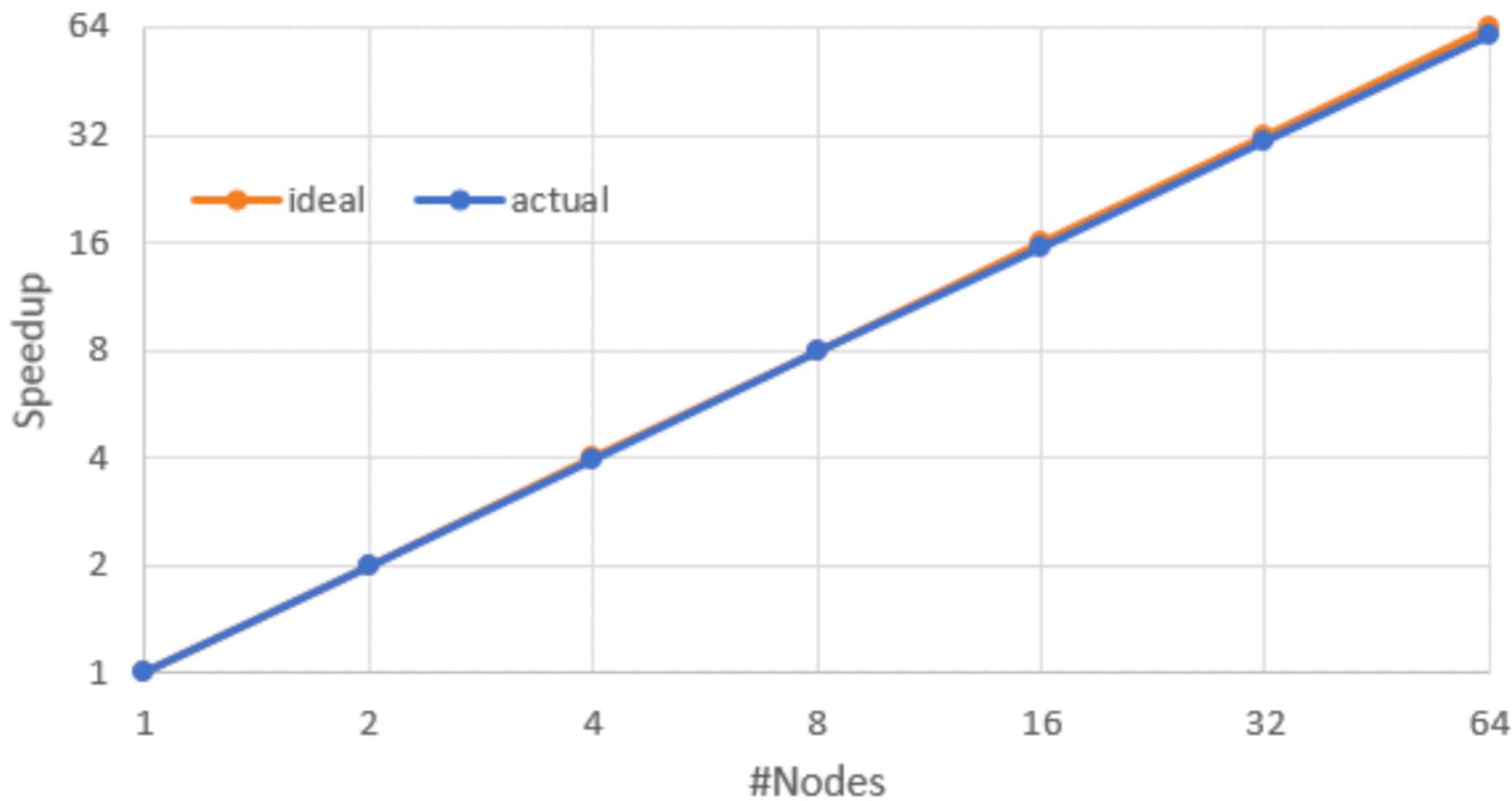
Runtime

Facebook: 1h

IBM: 50 minutes



PowerAI DDL



#GPUs	4	8	16	32	64	128	256
#Nodes	1	2	4	8	16	32	64
Speedup	1.0	2.0	3.9	7.9	15.5	30.5	60.6
Scaling efficiency	1.00	1.00	0.98	0.99	0.97	0.95	0.95

Figure 2: Resnet-50 for 1K classes using up to 256 GPUs with Caffe.



- **200 petaflops**
- **4600 nodes**
- **9200 Power9 CPU's**
- **220800 cores**
- **1766400 hyper threads**
- **27600 nVidia V100 GPUs**
- **10 PB memory**
- **Power 15 MW**
- **1% of Ethereum's hash rate**



Rank	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)
1	Summit - IBM Power System AC922, IBM POWER9 22C 3.07GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM DOE/SC/Oak Ridge National Laboratory United States	2,282,544	122,300.0	187,659.3	8,806
2	Sunway TaihuLight - Sunway MPP, Sunway SW26010 260C 1.45GHz, Sunway , NRCPC National Supercomputing Center in Wuxi China	10,649,600	93,014.6	125,435.9	15,371
3	Sierra - IBM Power System S922LC, IBM POWER9 22C 3.1GHz, NVIDIA Volta GV100, Dual-rail Mellanox EDR Infiniband , IBM DOE/NNSA/LLNL United States	1,572,480	71,610.0	119,193.6	

Romeo Kienzler

Mastering Apache Spark 2.x

Second Edition

Scale your machine learning and deep learning systems with SparkML, DeepLearning4j and H2O



Packt

Yu-Wei Chiu (David Chiu), Selva Prabhakaran, Tony Fischetti, Viswa Viswanathan, Shanthi Viswanathan, Romeo Kienzler

R Complete Data Analysis Solutions

Solve real-world data problems using the most popular R packages and techniques



Packt

Book Collection

Learning Path Apache Spark 2: Data Processing and Real-Time Analytics

Master complex big data processing, stream analytics, and machine learning with Apache Spark

Romeo Kienzler, Md. Rezaul Karim, Sridhar Alte, Stamak Amirogholu, Meenakshi Rajendran, Broderick Hall and Shuen Mei

Packt
www.packt.com

IBM Advanced Data Science Specialization Certificate on Coursera

Fundamentals of Scalable Data Science

www.coursera.org/learn/ds

Advanced Machine Learning and Signal Processing

www.coursera.org/learn/advanced-machine-learning-signal-processing

Applied AI with DeepLearning

www.coursera.ai/learn/ai

Advanced Data Science Capstone Project

<https://www.coursera.org/learn/advanced-data-science-capstone>

nopanic.ai/datascience

