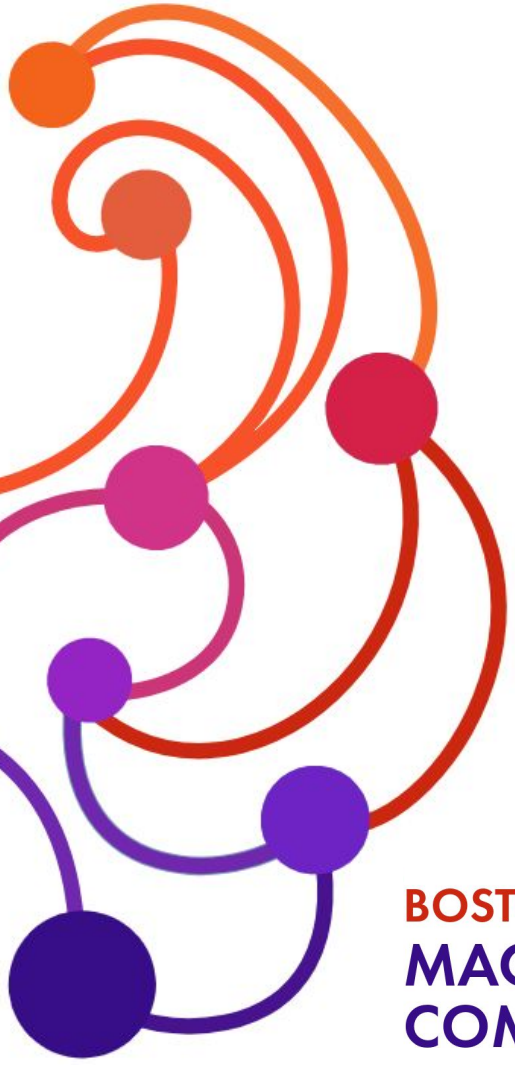

# Large Scale Distributed Deep Networks

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# Previous Limitations with Distributed Training

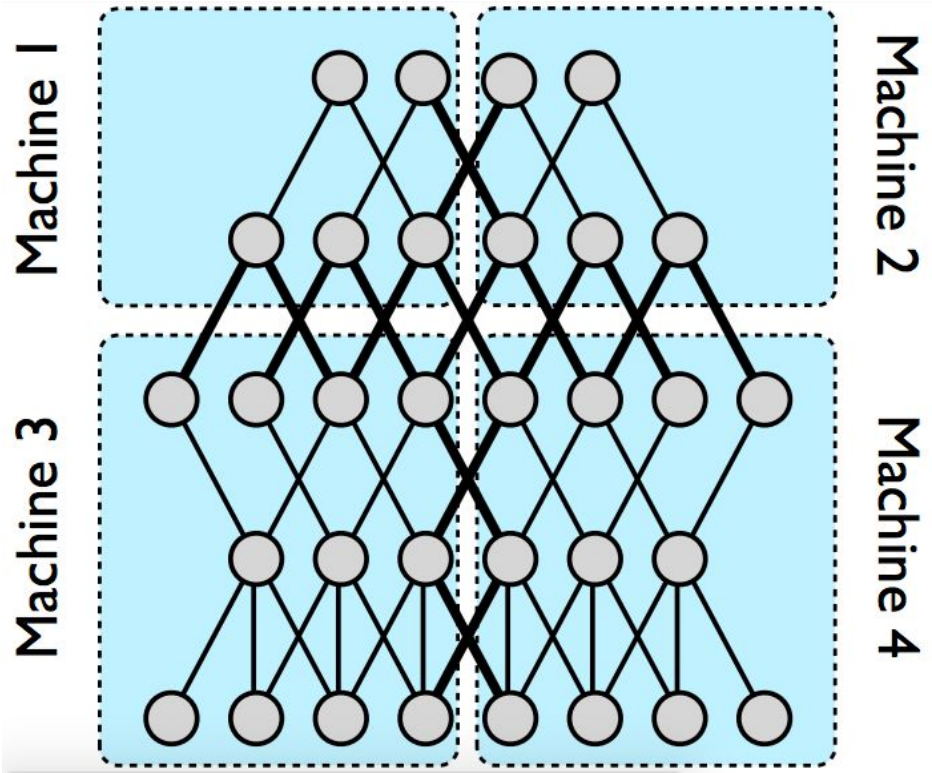
- Large models cannot fit onto a single GPU
- Previous distributed algorithms assumed convexity or sparsity
- MapReduce and GraphLab are not suitable
- Goal of this work:
  - Asynchronous
  - Distributed
  - No assumptions on architecture, sparsity, and convexity

# DistBelief Framework

- Eventually became TensorFlow
- Automatic parallelization, synchronization, and communication
- Model parallelism
  - Multithread on single machine
  - Message passing across machines
- Data parallelism
  - Multiple copies of model across cluster

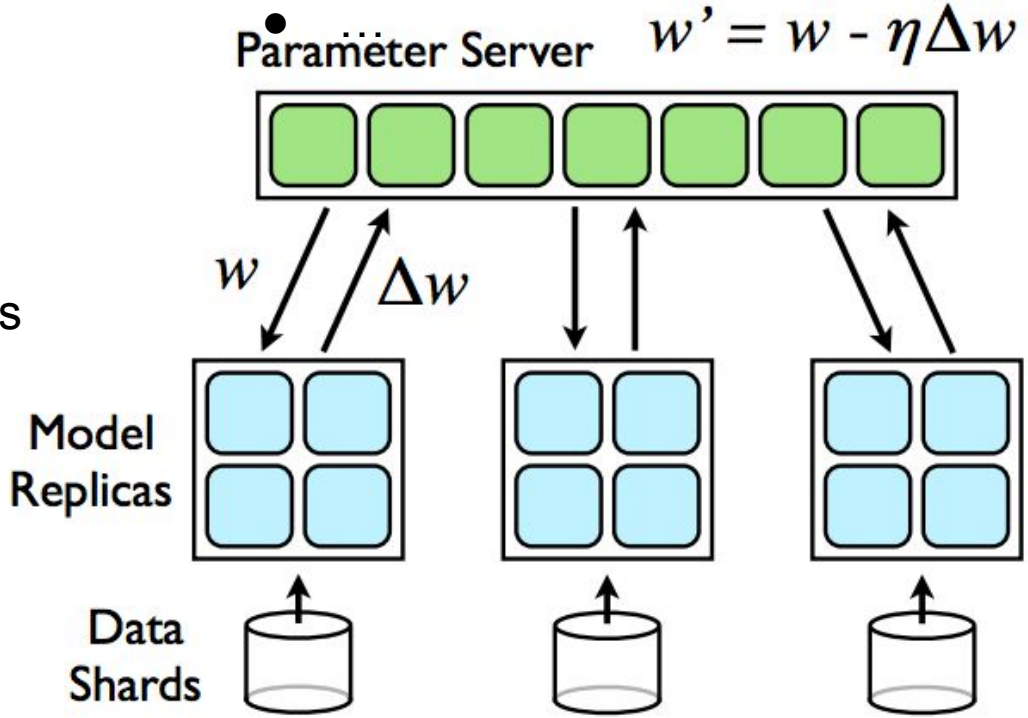
# Model Parallelism

- Image depicts a single replicated model across four machines
- Blue box/machine is a **partition**
- Parameters communicated once (thick black lines)
- Node parallelized within partition



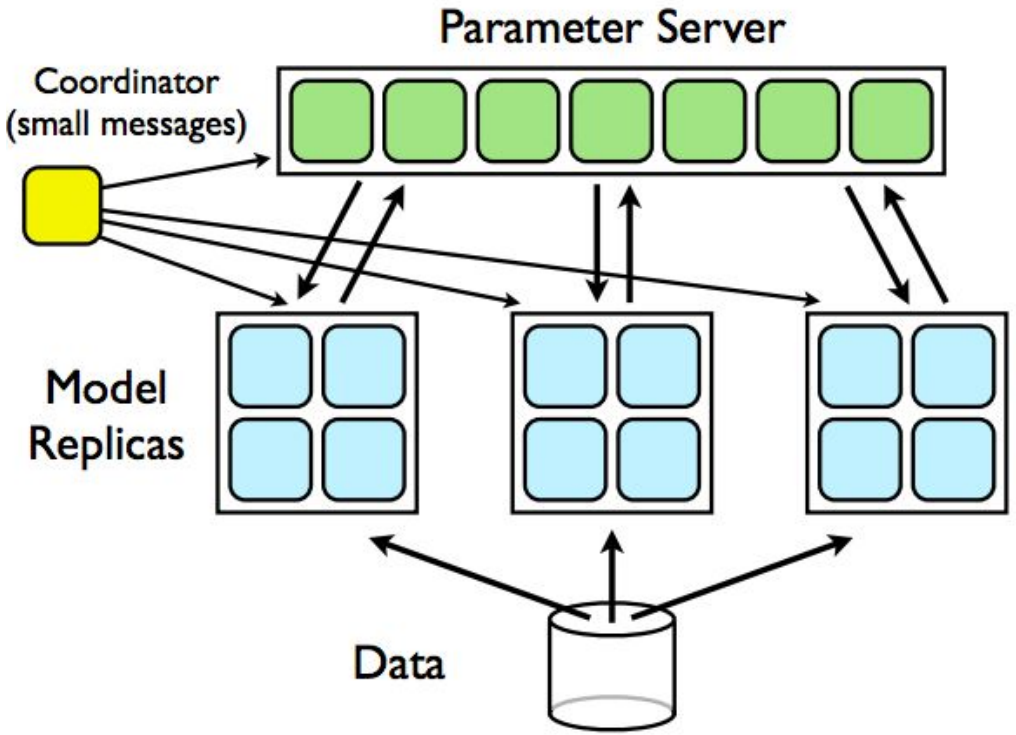
# Downpour Stochastic Gradient Descent (SGD)

- Asynchronous SGD
- Uses Adagrad adaptive learning rate
- Asynchronously push gradients and pull parameters
- Replicated models traverse parameters landscape together in parallel
- Dataset divided evenly into shards



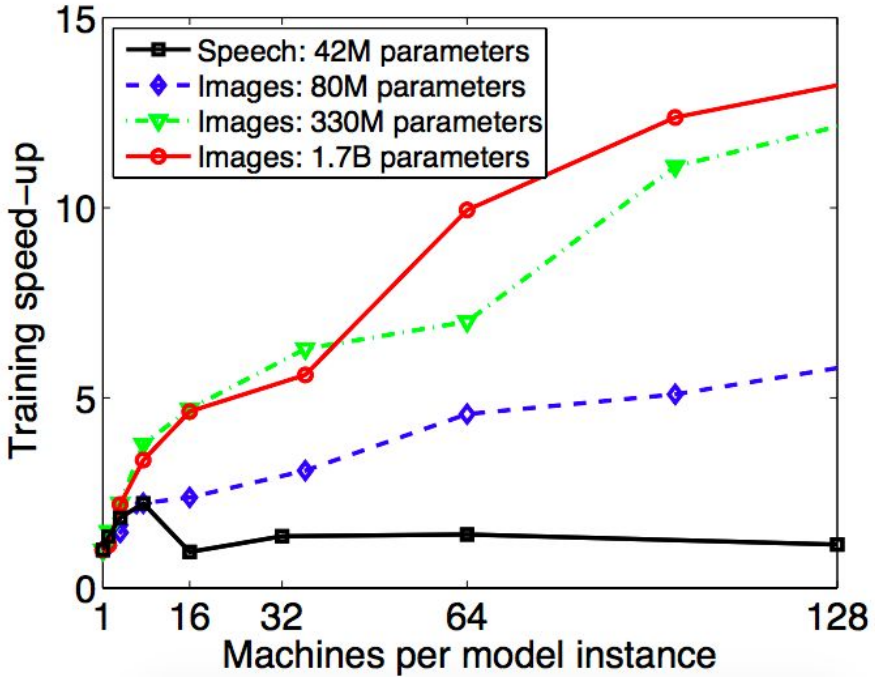
# Sandblaster L-BFGS

- Limited-memory Broyden–Fletcher–Goldfarb–Shanno (L-BFGS)
- Communicate operations instead of values
- **Load balancing** - assign model replicas < 1/N of batch
  - Data parallelism

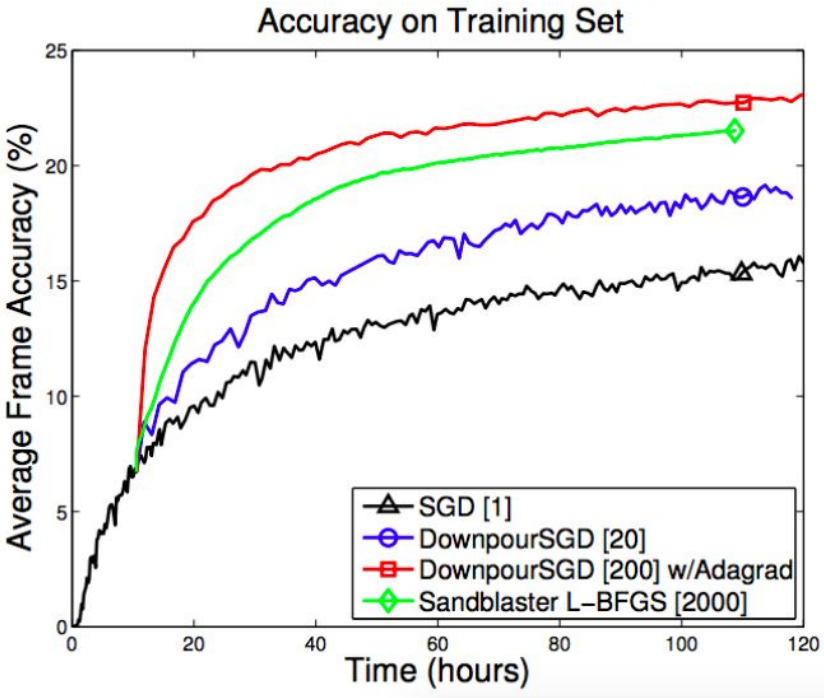


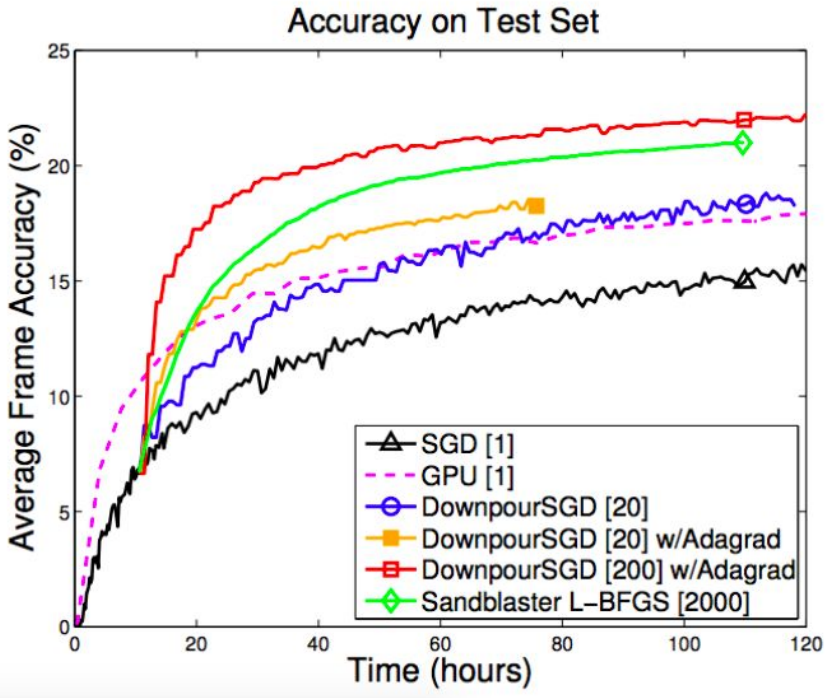
# Machines per Model Instance

- Convnet for ImageNet
- RNN for speech
- Local connectivity - models that are not densely connected are more amenable for distributed training

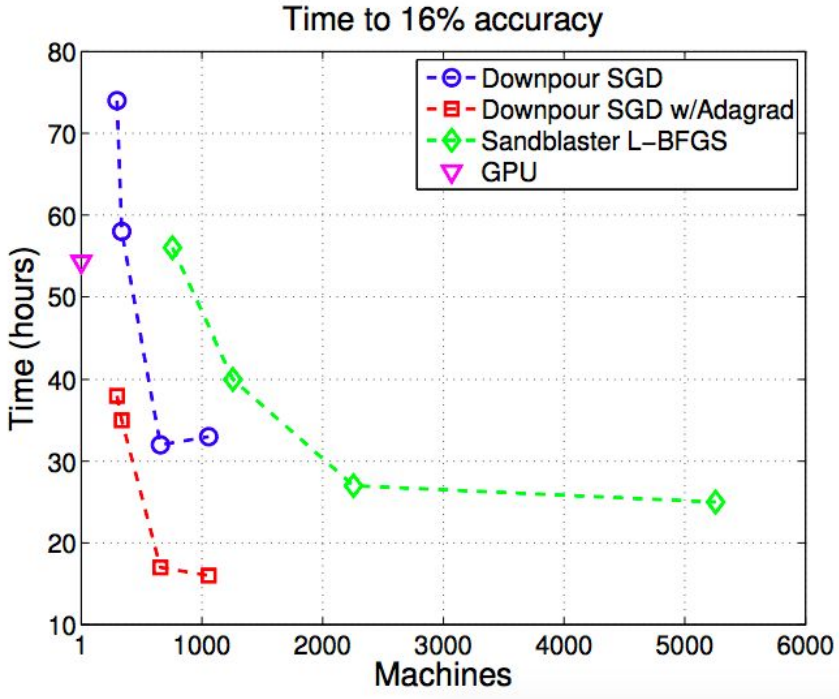


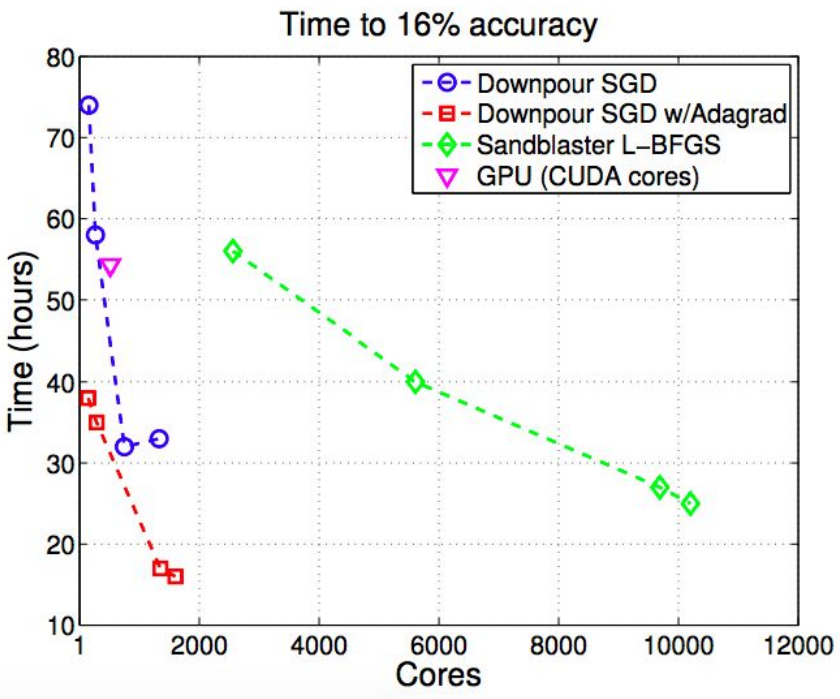
# Accuracy over Time



# Training Time per Machine



# References and Further Reading


1. Dean, Jeffrey, et al. "**Large scale distributed deep networks**." Advances in neural information processing systems. 2012.
2. Sergeev, Alex, et al. "**Meet Horovod: Uber's Open Source Distributed Deep Learning Framework for TensorFlow**." https://eng.uber.com/horovod/ (2017).
3. Black, Alex, et al. "**Distributed Deep Learning, Part 1: An Introduction to Distributed Training of Neural Networks**. "http://engineering.skymind.io/distributed-deep-learning-part-1-an-introduction-to-distributed-training-of-neural-networks (2017).
4. **Deep Gradient Compression: Reducing the  Communication Bandwidth for Distributed Training**
5. Micikevicius, Paulius, et al. "**Mixed Precision Training**." arXiv preprint arXiv:1710.03740 (2017).