Lecture 24: Other Parallel Applications

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Announcements

- Quiz 3 will be posted on Dec 2 midnight AoE and due on Dec 3 midnight AoE
- Check your presentation slot on the lectures page
  - All group members must be present
  - Be prepared to have your camera on when you are presenting
- Final project and report due on Dec 14

Presentation and Final report format

- Upload pdf slides on ELMS after your presentation
  - Introduce your project so that it is understandable by a CS audience
  - Present what you are implementing or evaluating (serial / parallel algorithms)
  - Progress so far
  - Results (performance / performance analysis)
- Final report
  - Upload code and pdf report to ELMS
  - E-mail Abhinav and Shoken how you are distributing your virtual dollars (100) among your teammates with justification

1.47 million people have died of COVID-19 this year alone

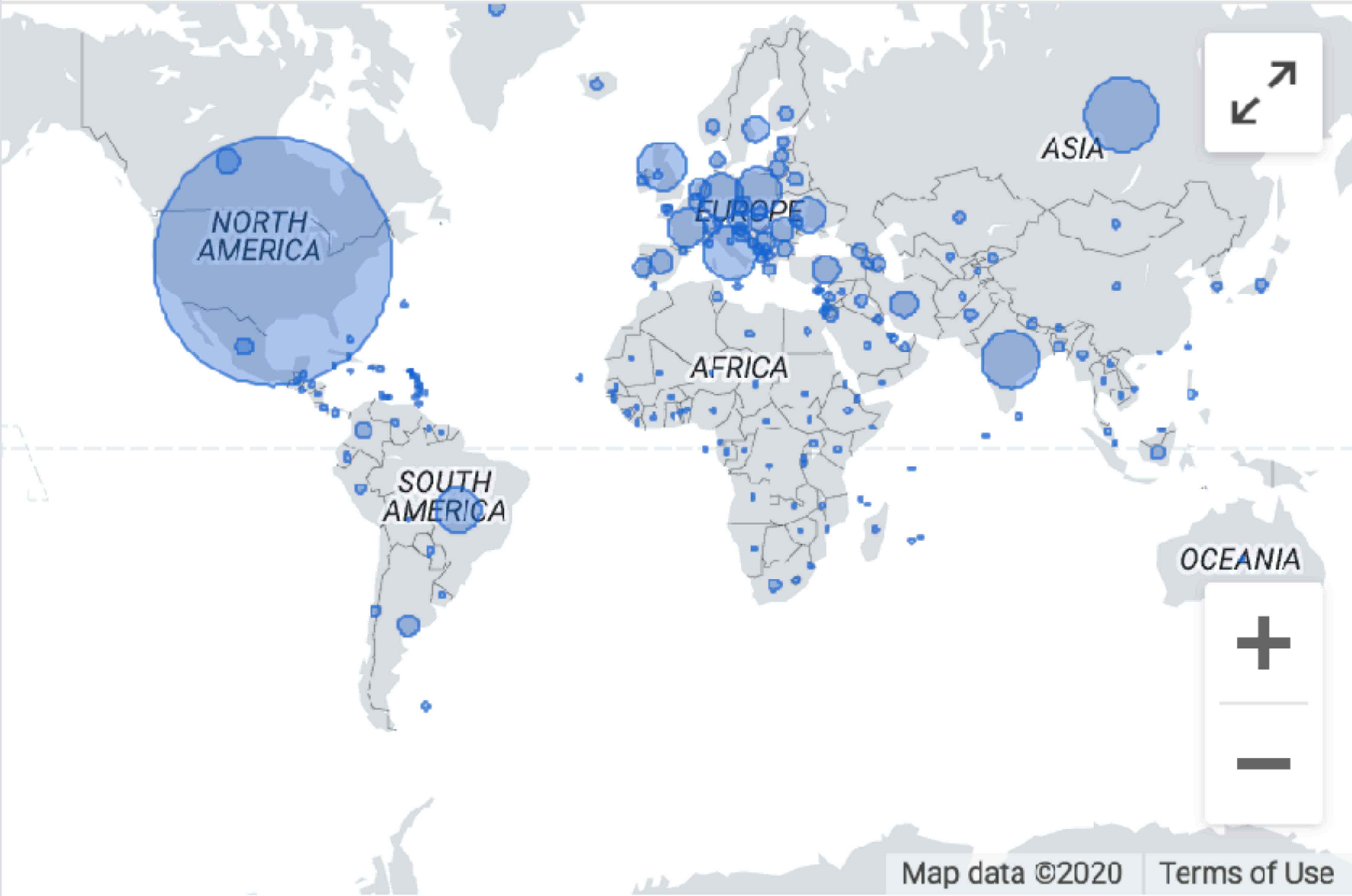
Cases

Total ▾ | Worldwide ▾

Cases	Recovered	Deaths
63.3M	40.6M	1.47M

Location	Cases ↓	Recovered	Deaths
United States	13.6M +168K	-	268K +1,265
India	9.46M +38,772	-	138K +443
Brazil	6.34M +21,138	5.6M	173K +287
Russia	2.32M +26,338	1.8M	40,464 +368
France	2.22M +4,005	162K	52,731 +406

Map of cases (last 14 days)



Sources: Wikipedia and others · About this data

Societal challenge

- Controlling the spread of infectious diseases is important
- Computational and mathematical modeling of epidemics important to assist governments in responding to outbreaks
- Made challenging due to:
  - increased and denser urbanization
  - increased local and global travel
  - increasingly immuno-comprised population

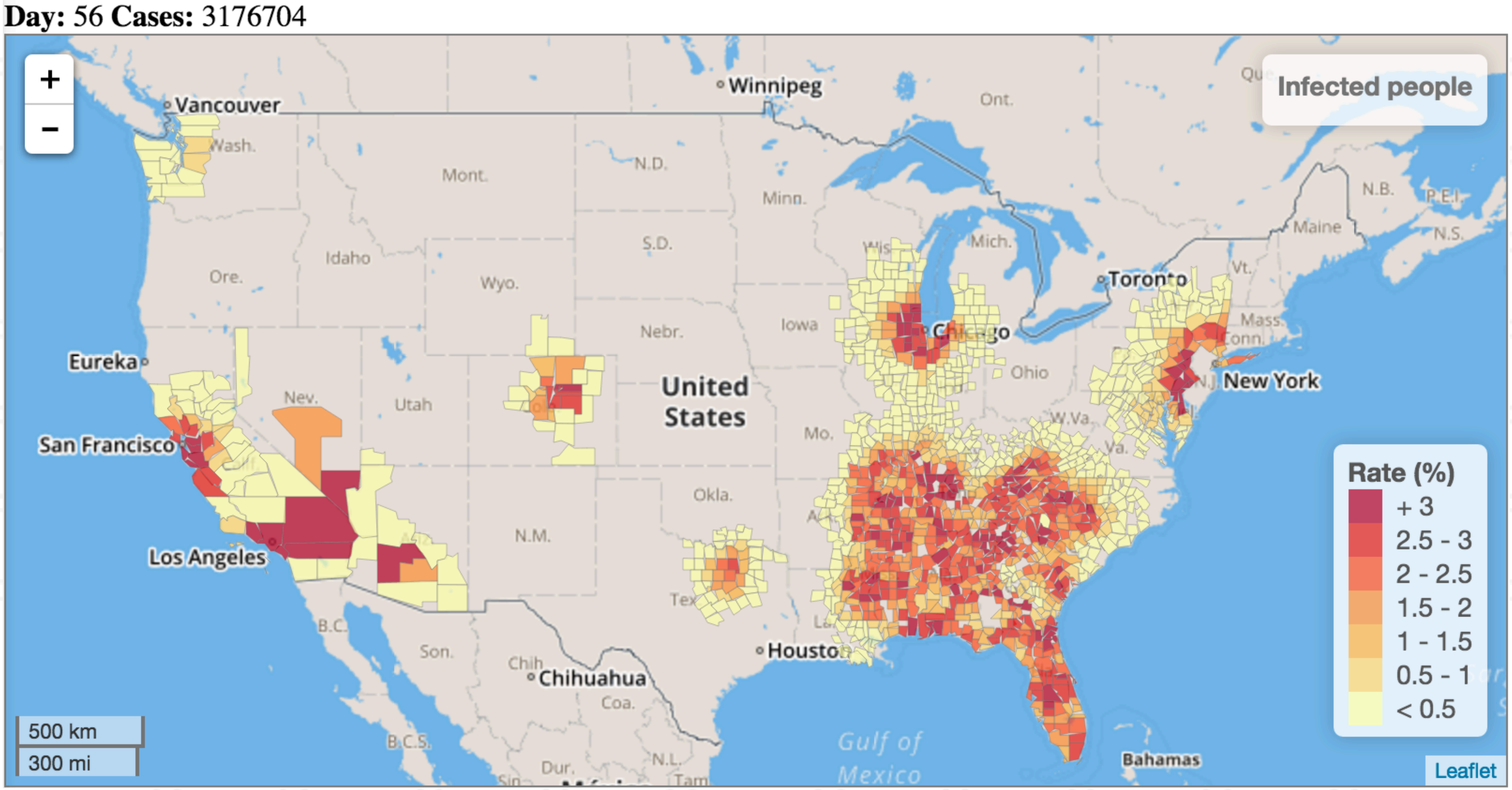
Approach: individual-based simulation

- Agent-based modeling to simulate epidemic diffusion
- Models agents (people) and interactions between them
- People interact when they visit the same location at the same time
- These "interactions" between pairs of people are represented as "visits" to locations
- Use a bi-partite graph of people and locations or a people-people interactivity graph

Serial algorithm

- At each timestep (typically a day):
  - Determine which people visit which locations
  - "Send" people to those locations
  - At each location "interactions" happen and transmission happens
  - Update people's states at the end of the day and continue
- Interventions (vaccinations, school closures) can be added on certain days to change people's susceptibility, movements etc.

Parallel simulation



Parallel simulation is challenging

- Size and scale of the social contact network (6 billion agents for a global simulation)
  - Unstructured networks and complicated dependencies lead to high communication cost
- Individuals and their behaviors are not identical
- Co-evolving epidemics, public policies and agent behaviors make it impossible to apply standard model reduction techniques

Deep learning

- Uses artificial neural networks (ANNs) to approximate a function

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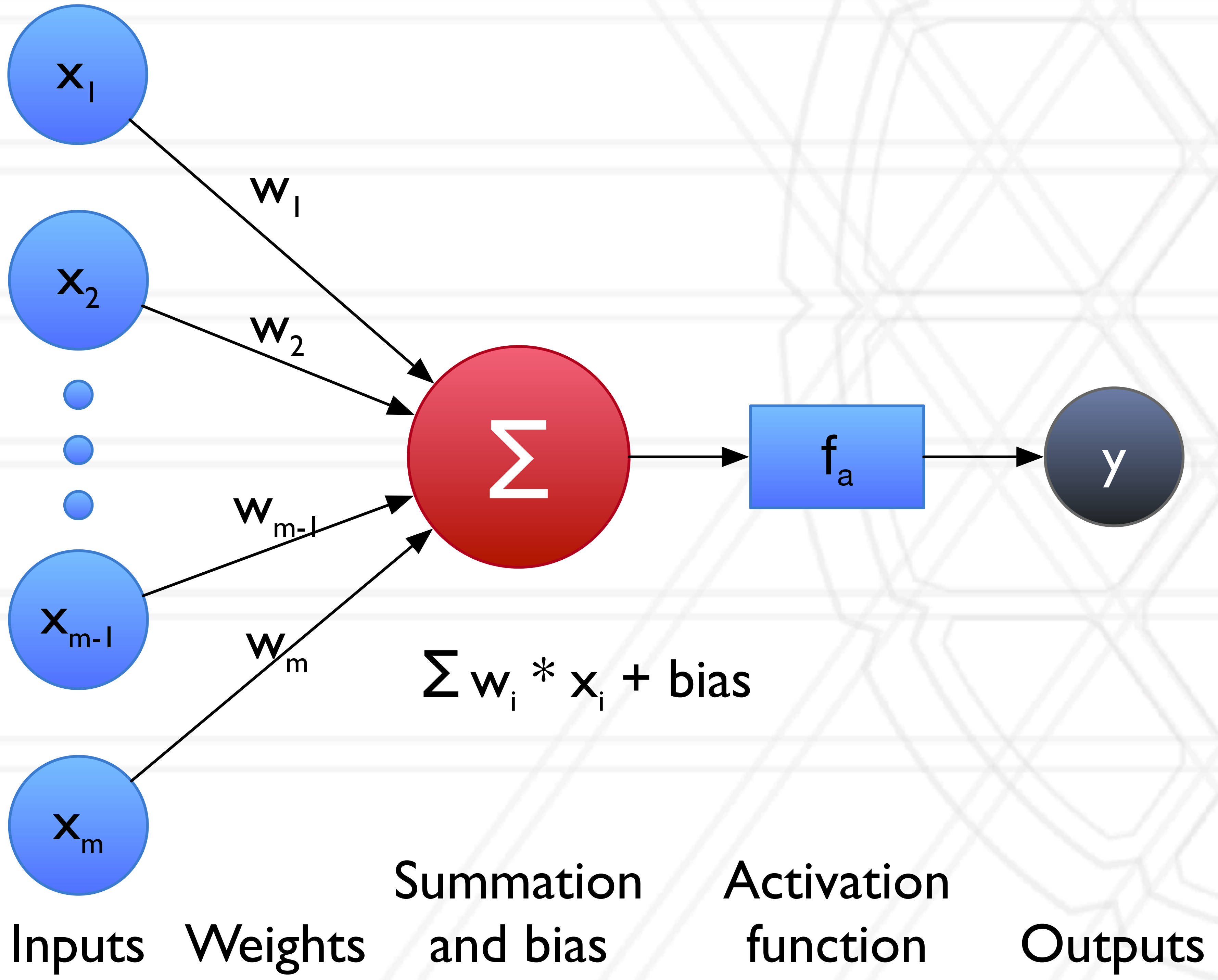

Deep learning

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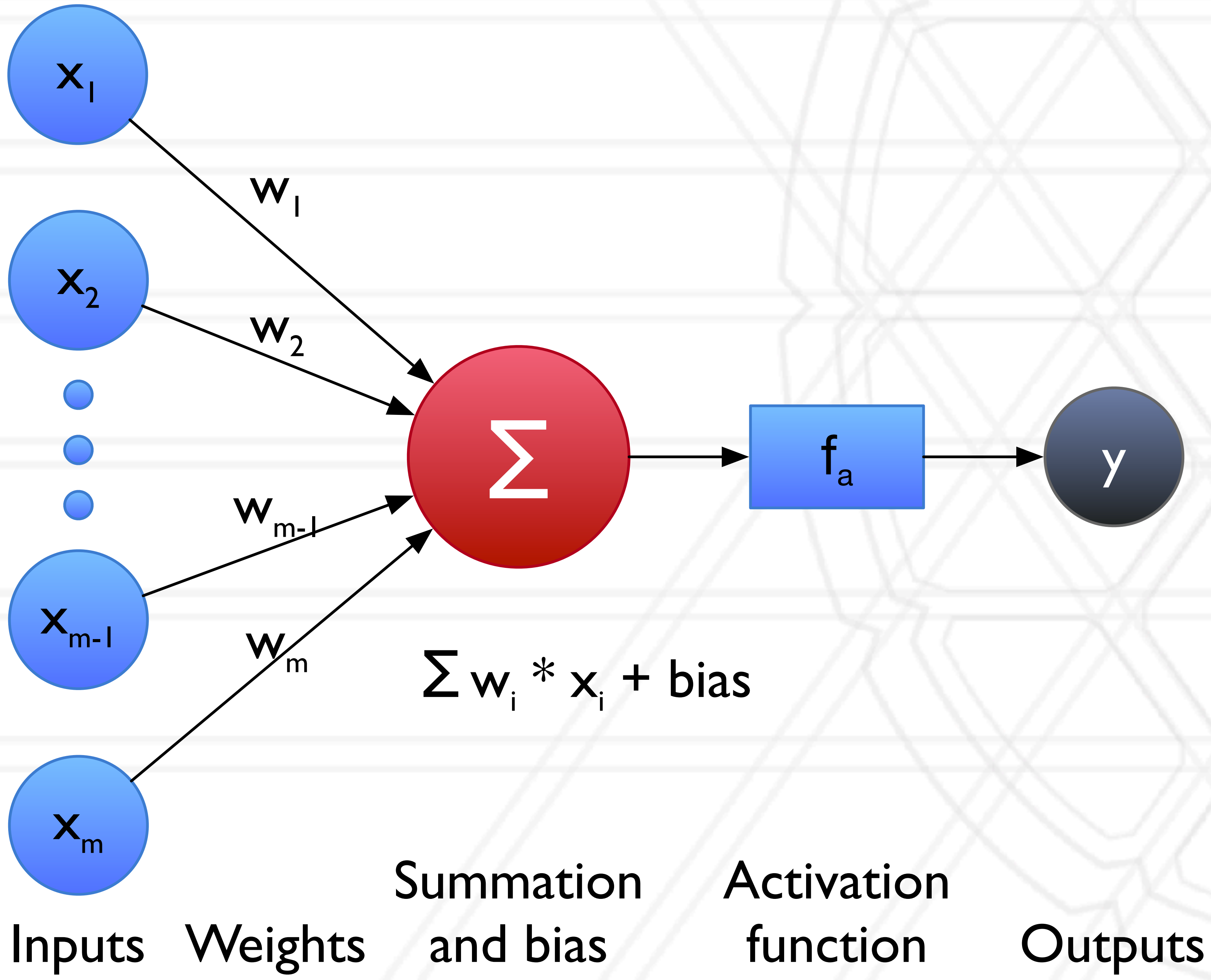
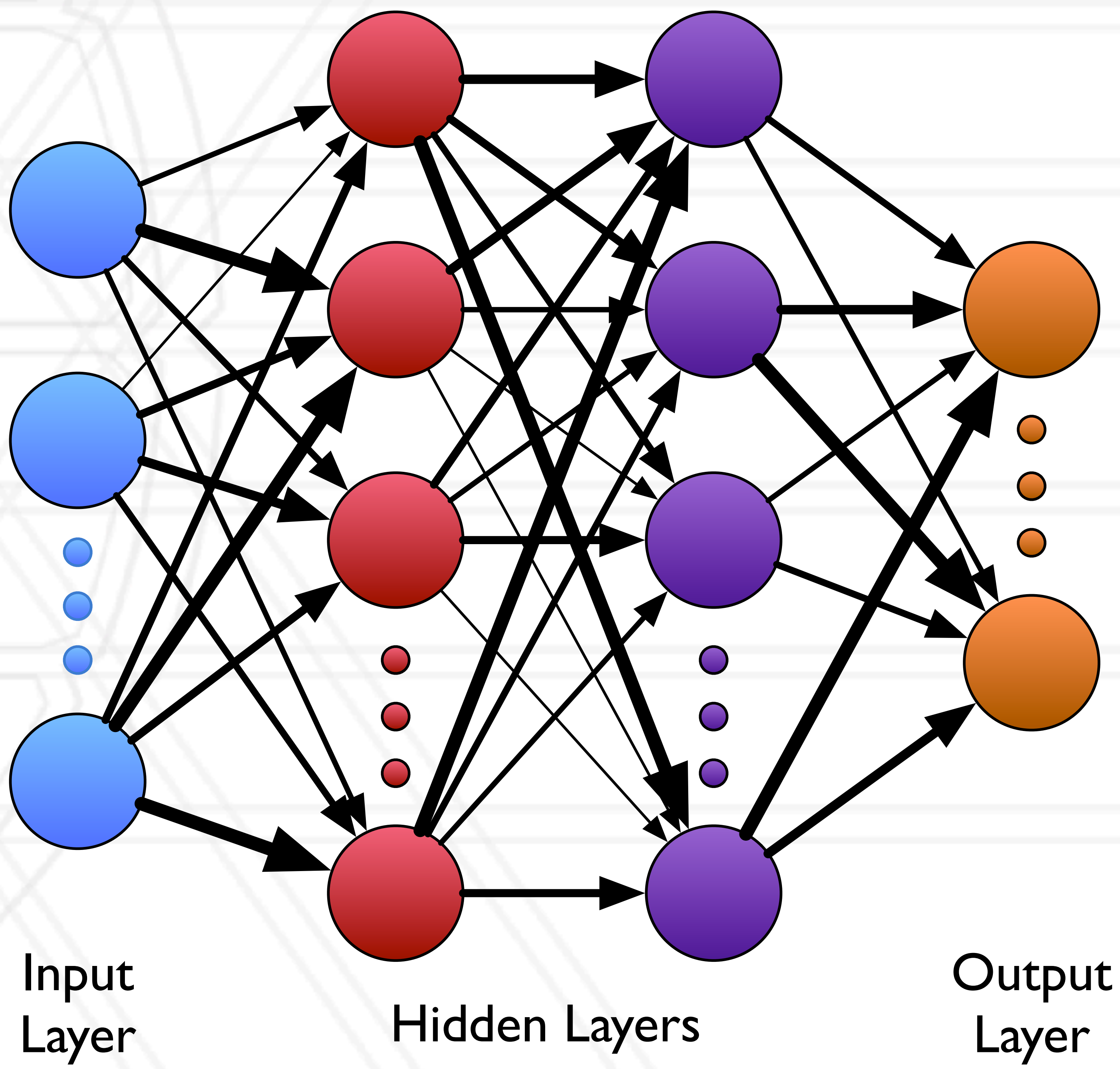




Additional terms

- Loss: A scalar whose minimization leads to more accurate function approximation
- Gradient: Derivative of the loss w.r.t. the gradient
- Forward pass: calculation of output activations
- Backward pass or backpropagation: calculation of and backward flow of weight gradients

Serial algorithm (SGD)

- Stochastic Gradient Descent
- Organize dataset into mini-batches and process one mini-batch at a time
- Going over all the mini-batches is referred to as an epoch
- At each epoch:
  - For all mini-batches
    - Calculate activations and do a forward pass through all the layers
    - Calculate the loss on the last layer
    - Compute gradients and do a backward pass through all the layers

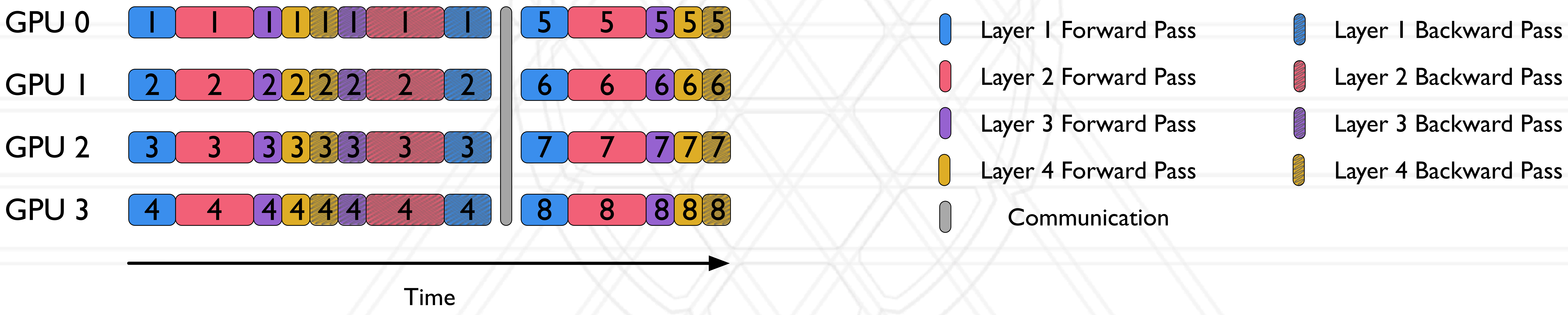
Parallelism approaches

Parallelism approaches

- Data Parallelism

Parallelism approaches

- Data Parallelism



Parallelism approaches

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- Model Parallelism

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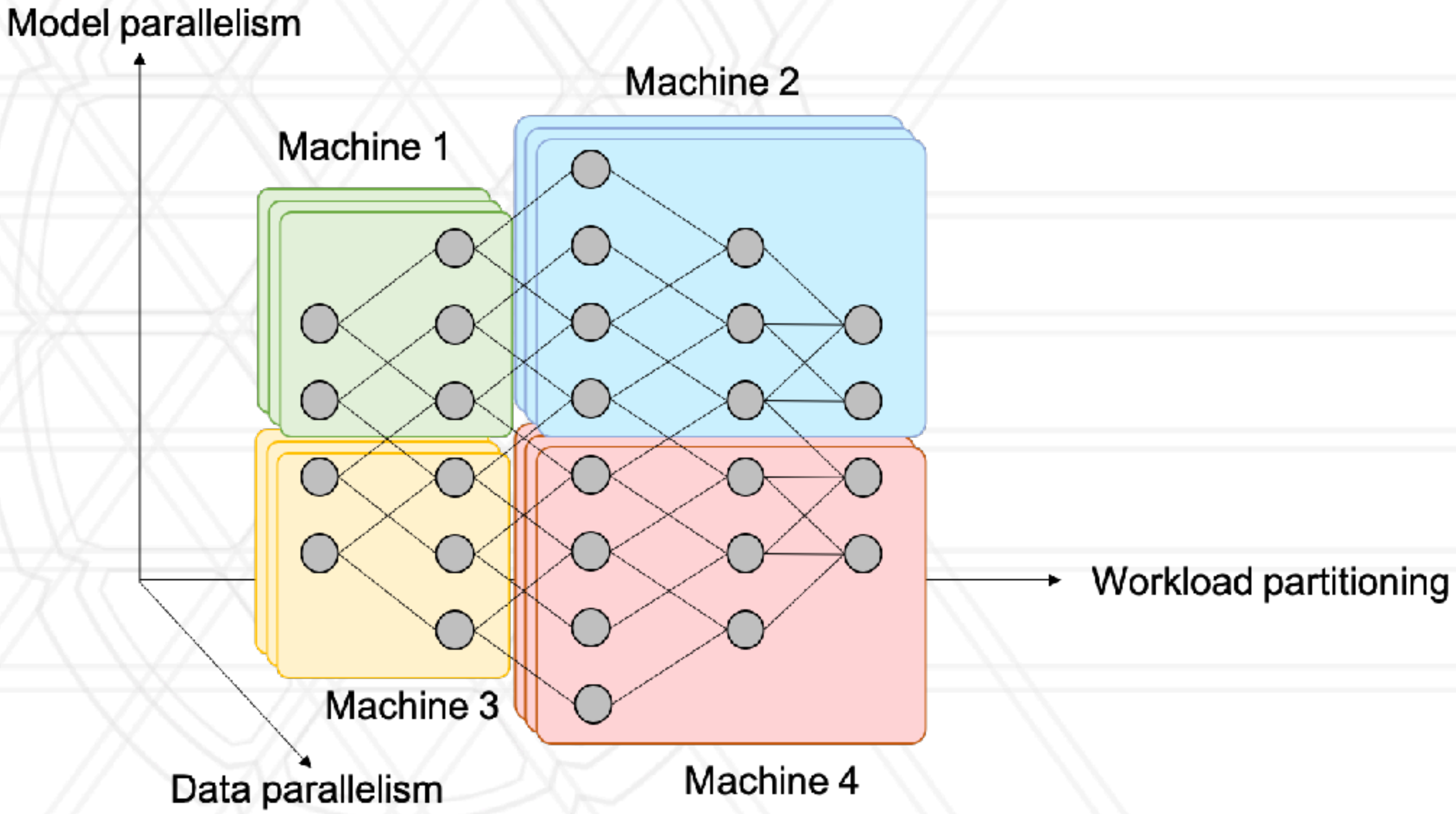

Parallelism approaches

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- Pipeline Parallelism

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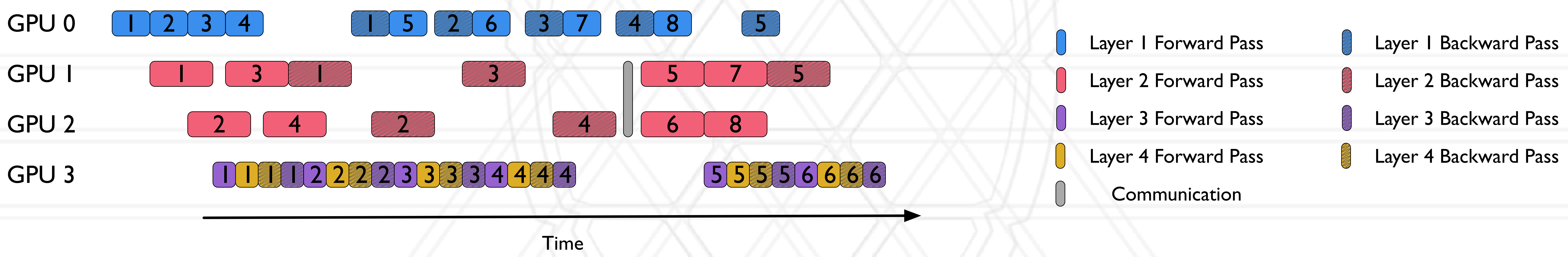
- Pipeline Parallelism



Course evaluation

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