Georgia Tech School of Electrical and Computer Engineering
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STRA SIM

Exercise 4: Implementing a New Training Loop

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Agenda

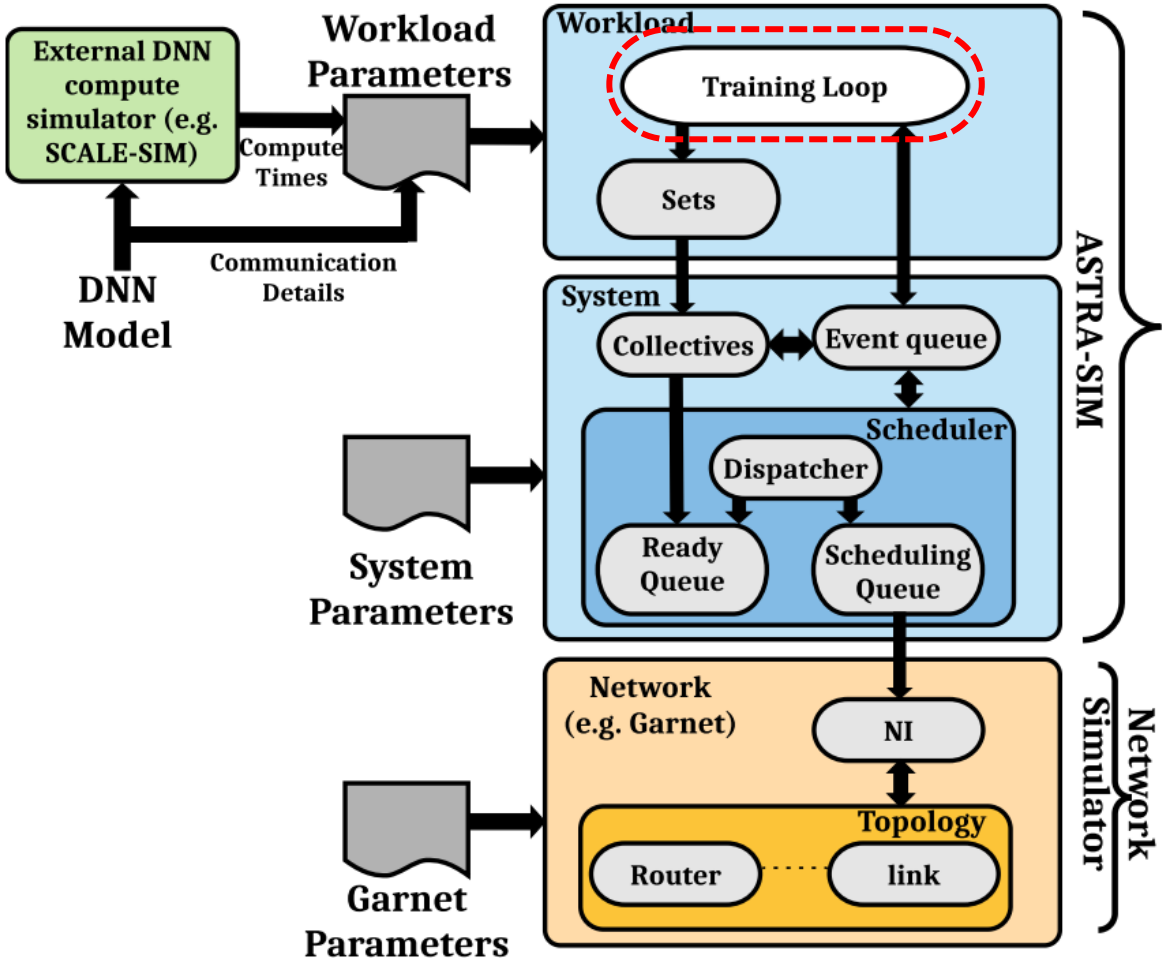
Time (CET)	Time (ET)	Topic	Presenter
15:00 – 16:00	9:00 – 10:00	**Introduction to Distributed Deep Learning Training Platforms**	Tushar Krishna
16:00 – 17:00	10:00 – 11:00	**ASTRA-sim**	Saeed Rashidi
17:00 – 17:10	11:00 – 11:10	**Break**	
17:10 – 17:50	11:10 – 11:50	**Demo and Exercises**	William Won and Taekyung Heo
17:50 – 18:00	11:50 – 12:00	**Extensions and Future Development**	Tushar Krishna and Saeed Rashidi

Tutorial Website

includes agenda, slides, ASTRA-sim installation instructions (via source + docker image)
https://astra-sim.github.io/tutorials/asplos-2022

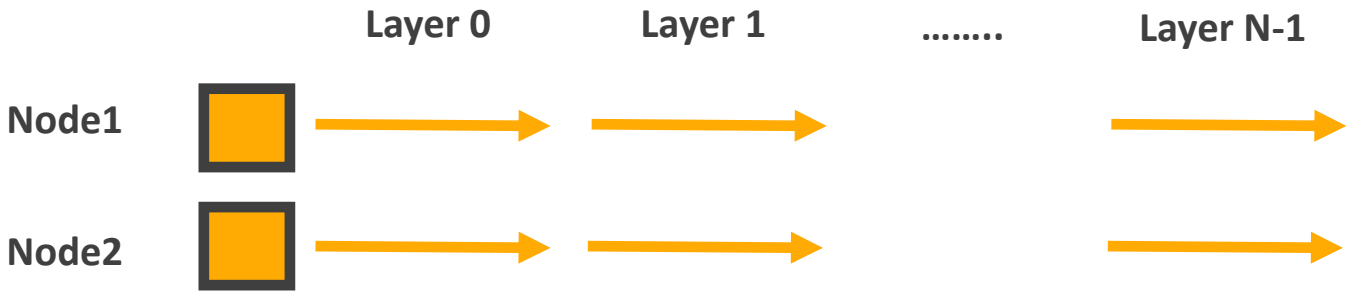
Attention: Tutorial is being recorded

Training Loops



- Training loop determines the behavior of a workload
  - Parallelization strategy
  - Computation order
  - Communication order
- Supported training loops
  - Data parallel ← Goal: tweak this loop
  - Model parallel
  - DLRM
  - Transformer
- You can implement a new training loop to support other models

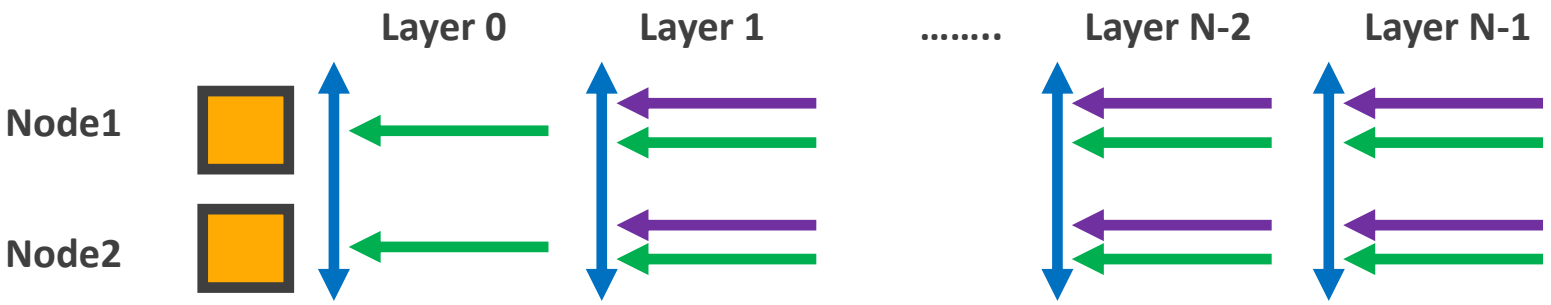
Vanilla Data-parallel Training Loop (FWD)



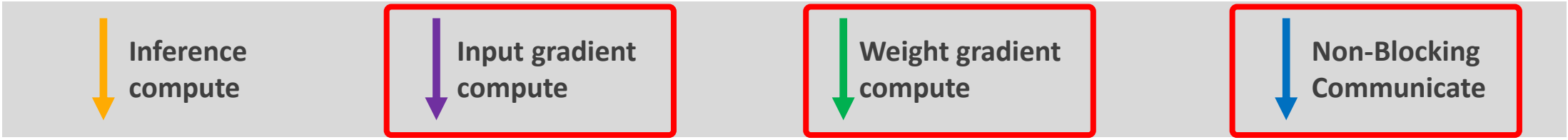
Flow-per-layer: 1.Compute output -> 2. go to the next layer

Vanilla Data-parallel Training Schedule

Vanilla Data-parallel Training Loop (BWD)



Flow-per-layer: 1.Compute weight gradient-> 2.issue weight gradient comm -> 3.compute input gradient -> 4. go to previous layer

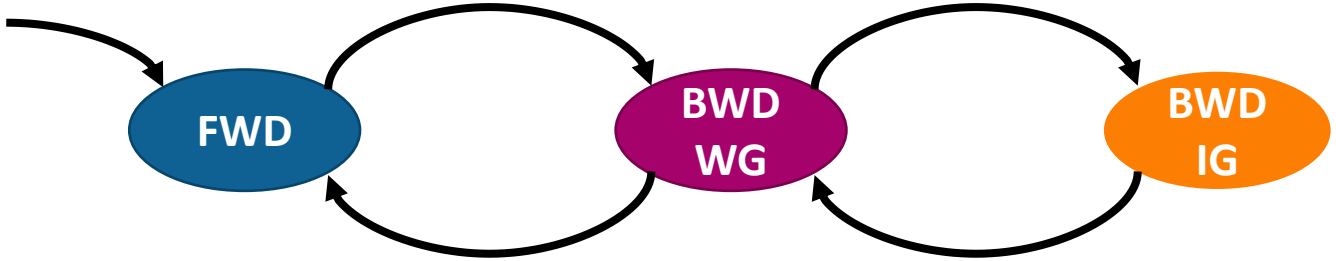


Vanilla Data-parallel Training Schedule

Vanilla Data-parallel Training Loop

Vanilla Data-parallel Training Schedule

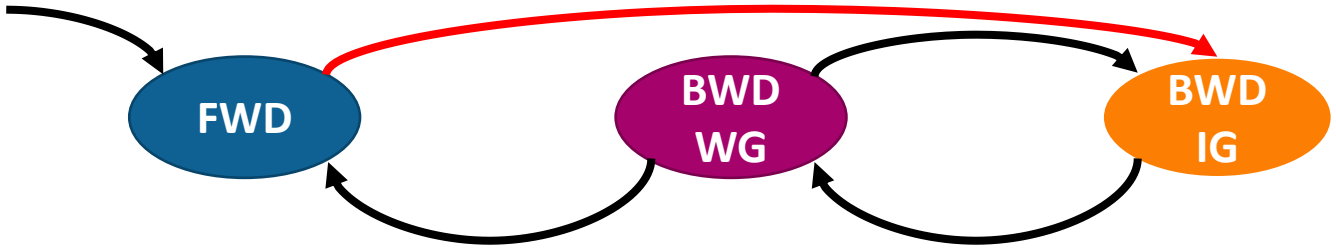
FSM Diagram



Exercise: Reorder Data-parallel Training Loop

Reordered Data-parallel Training Loop

FSM Diagram



Adding a New Training Loop

- See `astra-sim/workload/Workload.cc`
- Vanilla data-parallel loop is implemented in `iterate_data_parallel()`
- Add a reordered version, `iterate_data_parallel_reorder()`

```
void Workload::call(EventType event, CallData* data) {
  if (counter > 0) {
    generator->try_register_event(
        this, EventType::Workload_Wait, NULL, counter);
    return;
  }
  if (parallelismPolicy == ParallelismPolicy::Data) {
    iterate_data_parallel();
  } else if (parallelismPolicy == ParallelismPolicy::DataReorder) {
    iterate_data_parallel_reorder();
  } else if (parallelismPolicy == ParallelismPolicy::Transformer) {
    iterate_hybrid_parallel_Transformer();
```

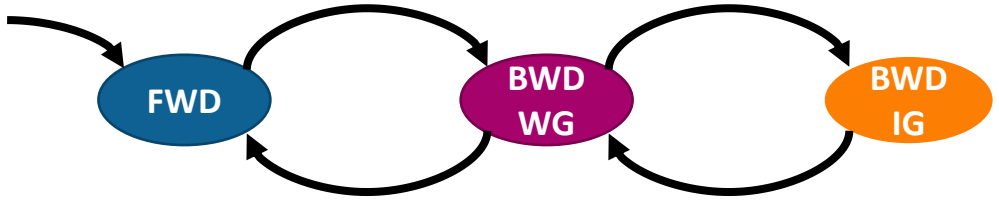
Vanilla Training Loop (iterate_data_parallel)

```
void Workload::iterate_data_parallel() {
  assert(index >= 0);
  assert(index < SIZE);
  check_for_sim_end();
  if (current_state == LoopState::Forward_Pass) {
+-- 31 lines: if (!layers[index]->is_weight_grad_comm_finished_bl
    if (index >= SIZE) {
      current_state = LoopState::Weight_Gradient;
      index--;
    }
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  } else if (current_state == LoopState::Weight_Gradient) {
+-- 14 lines: if (delay_loaded == false) {-----------------------
    if (index == 0) {
      pass_counter++;
      current_state = LoopState::Forward_Pass;
    } else {
      current_state = LoopState::Input_Gradient;
    }
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  } else if (current_state == LoopState::Input_Gradient) {
+-- 11 lines: if (delay_loaded == false) {-----------------------
    delay_loaded = false;
    index--;
    current_state = LoopState::Weight_Gradient;
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  }
}
```

- Training loop is implemented as a FSM
- `index` presents the current layer index
- `current_state` holds the current state

Vanilla Data-parallel Training Schedule

FSM Diagram



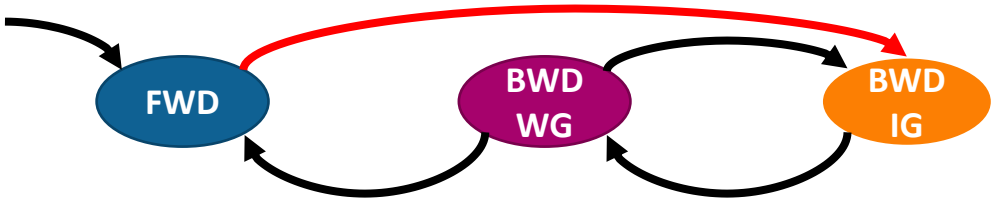
Reordered Training Loop (iterate_data_reorder)

```
void Workload::iterate_data_parallel_reorder() {
  assert(index >= 0);
  assert(index < SIZE);
  check_for_sim_end();
  if (current_state == LoopState::Forward_Pass) {
+-- 16 lines: if (!layers[index]->is_weight_grad_comm_finished_bl
    if (index >= SIZE) {
      current_state = LoopState::Input_Gradient;
      index--;
    }
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  } else if (current_state == LoopState::Weight_Gradient) {
+-- 15 lines: if (delay_loaded == false) {-----------------------
    if (index > 1) {
      index--;
      current_state = LoopState::Input_Gradient;
    } else if (index == 1) {
      index--;
      current_state = LoopState::Weight_Gradient
    } else if (index == 0) {
      pass_counter++;
      current_state = LoopState::Forward_Pass;
    }
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  } else if (current_state == LoopState::Input_Gradient) {
+-- 11 lines: if (delay_loaded == false) {-----------------------
    delay_loaded = false;
    current_state = LoopState::Weight_Gradient;
    generator->register_event(this, EventType::General, NULL, 1);
    return;
  }
}
```

- You can reorder the computation schedule by tweaking the `index` and `current_state`

Reordered Data-parallel Training Schedule

FSM Diagram



Adding Debugging Messages

```
void Workload::iterate_data_parallel_reorder() {
  assert(index >= 0);
  assert(index < SIZE);
  check_for_sim_end();
  if (current_state == LoopState::Forward_Pass) {
+--  3 lines: if (!layers[index]->is_weight_grad_comm_finished_blockin
    if (delay_loaded == false) {
      counter = layers[index]->get_fwd_pass_compute();
      delay_loaded = true;
      if (generator->id == 0)
        std::cout << "[TUTORIAL] FWD[" << index <<"]" << std::endl;
    }
+-- 13 lines: if (counter > 0) {-------------------------------------
  } else if (current_state == LoopState::Weight_Gradient) {
    if (delay_loaded == false) {
      counter = layers[index]->get_weight_grad_compute();
      delay_loaded = true;
      if (generator->id == 0)
        std::cout << "[TUTORIAL] BWD_WG[" << index <<"]" << std::endl;
    }
+-- 25 lines: if (counter > 0) {-------------------------------------
  } else if (current_state == LoopState::Input_Gradient) {
    if (delay_loaded == false) {
      counter = layers[index]->get_input_grad_compute();
      delay_loaded = true;
      if (generator->id == 0)
        std::cout << "[TUTORIAL] BWD_IG[" << index <<"]" << std::endl;
    }
+--  9 lines: if (counter > 0) {-------------------------------------
  }
}
```

- You can add debugging messages to make sure that the training loop works as expected
- Make sure to print debugging messages only when `(generator->id == 0)`
  - Each processing element is a generator
  - If you don't filter the ID, you will see debugging messages from all PEs

Adding Debugging Messages

Vanilla Data-parallel Loop

./exercise_4/exercise_4_vanilla.sh | grep TUTORIAL

```
[TUTORIAL] FWD[0]
[TUTORIAL] FWD[1]
[TUTORIAL] FWD[2]
[TUTORIAL] FWD[3]
[TUTORIAL] BWD_WG[3]
[TUTORIAL] BWD_IG[3]
[TUTORIAL] BWD_WG[2]
[TUTORIAL] BWD_IG[2]
[TUTORIAL] BWD_WG[1]
[TUTORIAL] BWD_IG[1]
[TUTORIAL] BWD_WG[0]
....
```

Reordered Data-parallel Loop

./exercise_4/exercise_4_reorder.sh | grep TUTORIAL

```
[TUTORIAL] FWD[0]
[TUTORIAL] FWD[1]
[TUTORIAL] FWD[2]
[TUTORIAL] FWD[3]
[TUTORIAL] BWD_IG[3]
[TUTORIAL] BWD_WG[3]
[TUTORIAL] BWD_IG[2]
[TUTORIAL] BWD_WG[2]
[TUTORIAL] BWD_IG[1]
[TUTORIAL] BWD_WG[1]
[TUTORIAL] BWD_WG[0]
....
```