Syndrilla: Simulating Decoders for Quantum Error Correction using PyTorch

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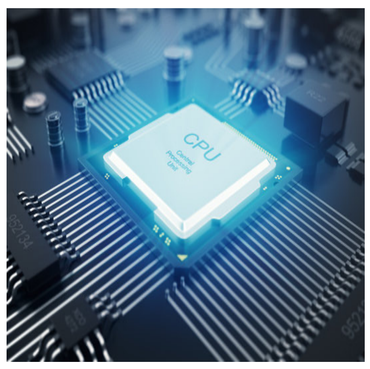
U.N.A.R.Y. LAB

Error-Correction Code: Theory & IC design Lab

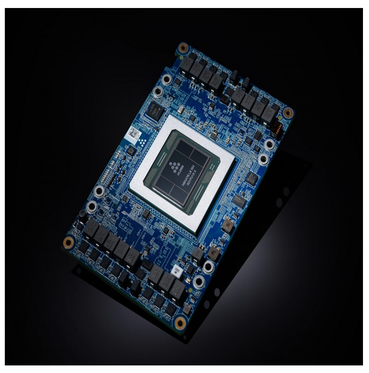
Introduction

CPU[1]



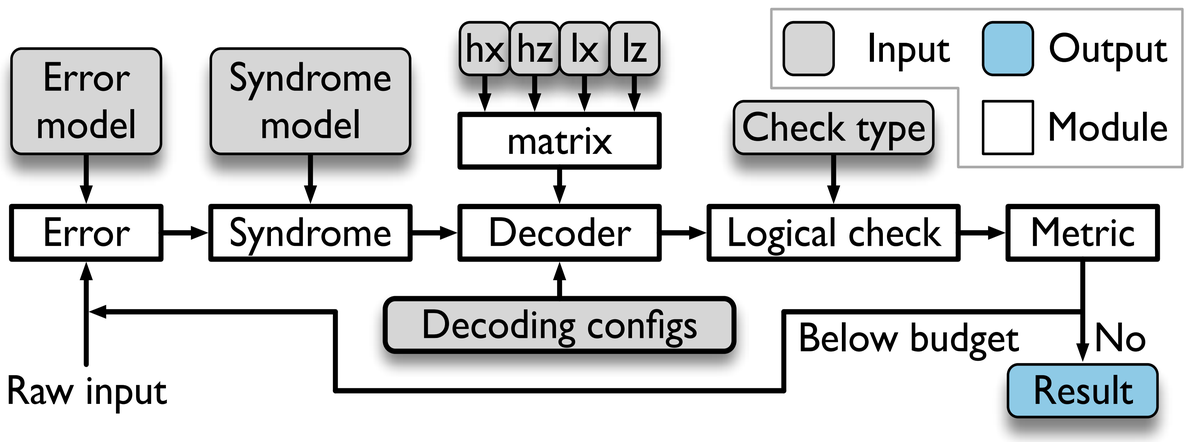
GPU[2]

AI Accelerator[3]



- Platform: PyTorch backbone
- Environments: supporting both CPU and GPU
- Performance: achieving 10× ~ 20× speedup over CPU on both AMD and NVIDIA GPUs
- Potential: working for the AI Accelerator as well
- Usage:
  - Full-stack simulation: the decoder layer
  - Code correctness: testing customized code
  - Quantum memory: allowing error evaluation
  - Algorithm testing: allowing benchmarking algorithms

Framework



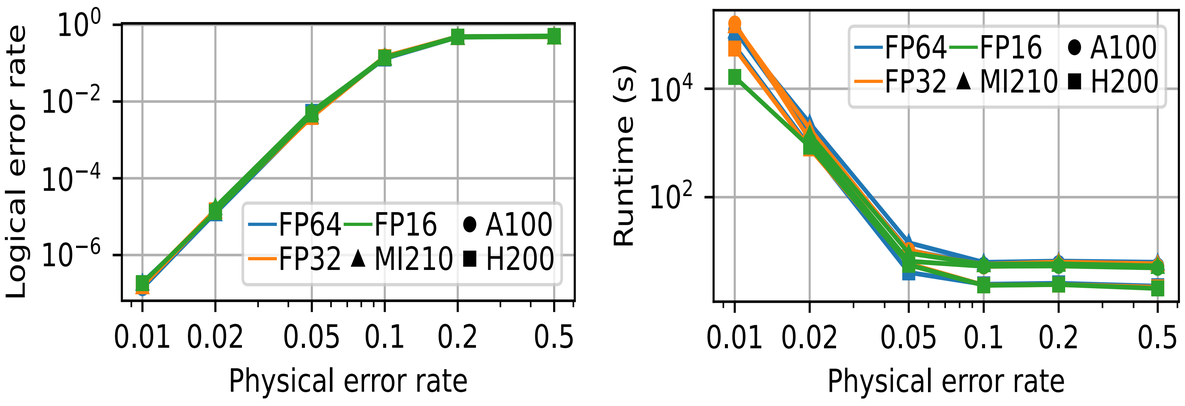
- Target area: focusing on the process from encoding to error decoding
- Modular design: allowing independent, flexible customization to enable rapid prototyping of new algorithms for each module
- Benchmark: BP + OSD
  - Belief propagation
  - Ordered Statistics Decoding
- Installation: **pip install syndrilla**

Evaluation

Environments:

1. AMD Instinct MI210 GPU
2. NVIDIA A100 GPU
3. NVIDIA H200 GPU
4. Intel i9-13900K CPU

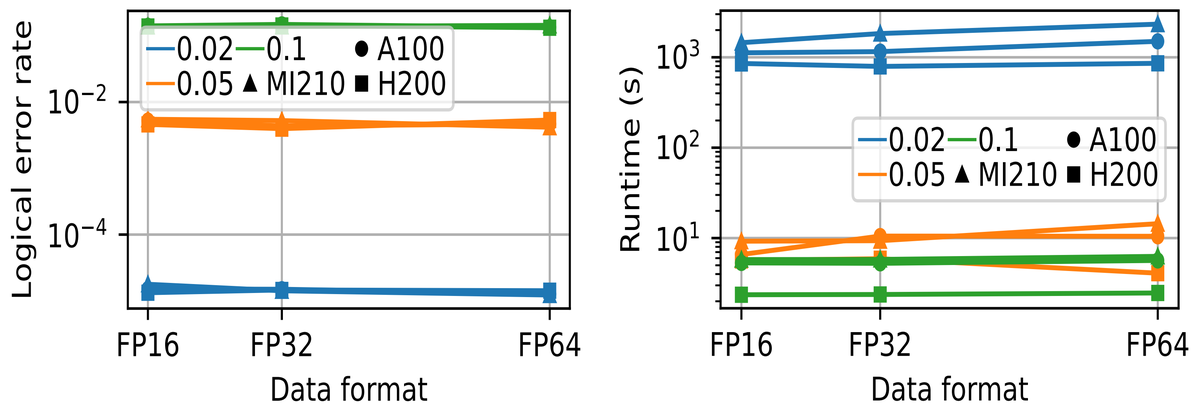
Error budget: 100 Batch size: 10000



Comparison across GPUs

Distance = 11

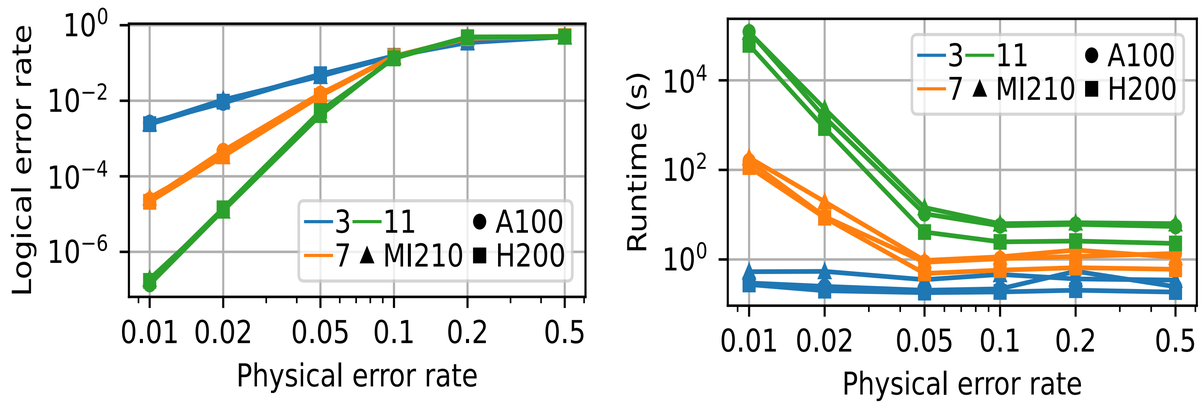
Accuracy: consistent Runtime: H200 < MI210 and A100



Comparison across data format

Distance = 11

Accuracy: consistent Runtime: FP16 < FP32 < FP64

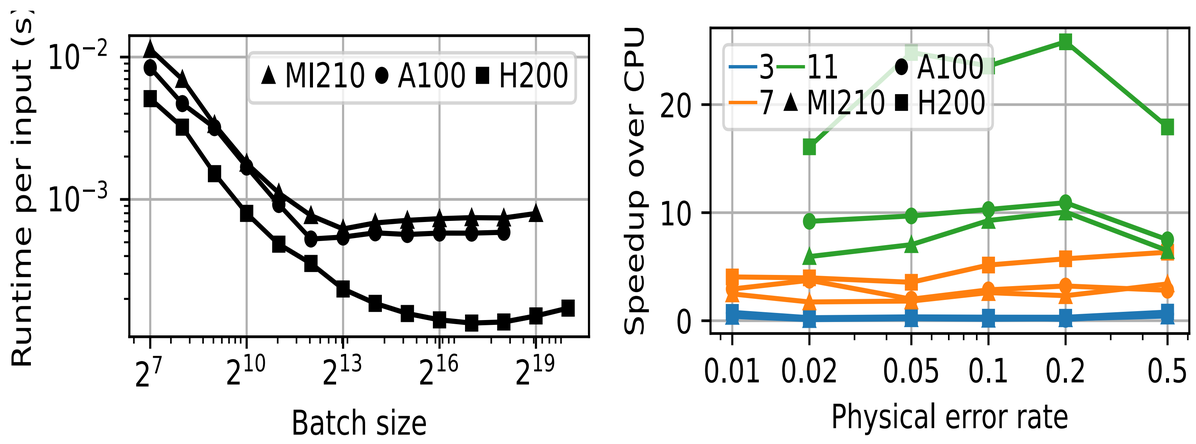


Comparison across code distance

Data format: FP64

Accuracy: high distance > low distance

Runtime: high distance > low distance



Runtime across batch sizes and speedup over CPU

Batch size test:

Physical error rate = 0.5,

Distance = 11

Runtime per input:

up to 2^{13} (M210, A100)

large batch < small batch

Speedup over CPU test:

Data format: FP64

Speedup:

High distance > low distance

Image reference:

1. https://www.google.com/imgres?q=gpu%20h200&imgurl=https%3A%2F%2Fwww.donanimhaber.com[…]1&h=752&hcb=2&ved=2ahUKEwiR_p_56KmOAxVUTTABHXXLAF4QM3oECHcQAA
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