AccelOpt

A Self-Improving LLM Agentic System for AI Accelerator Kernel Optimization

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Nandita Vijaykumar, Yida Wang, Kunle Olukotun

Stanford University aws UNIVERSITY OF TORONTO

Kernels are Central to ML Systems

Operator

AI accelerator

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PyTorch

NumPy

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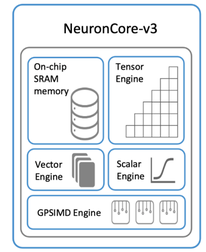

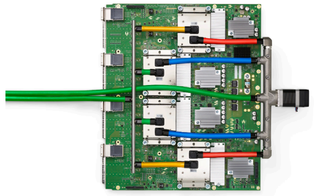

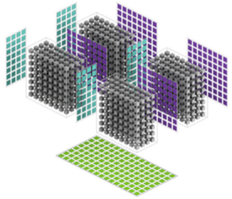

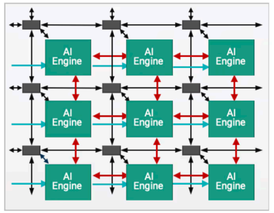

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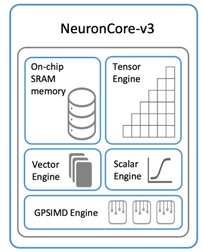

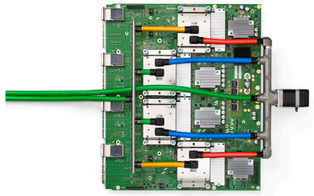

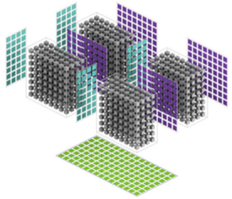

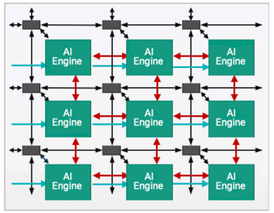

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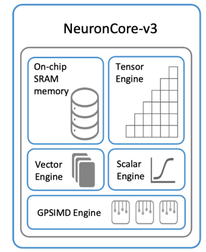

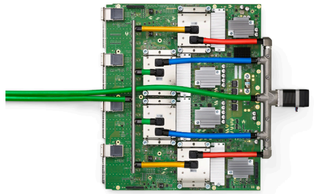

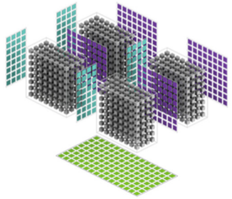

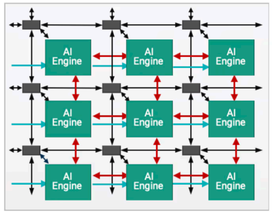

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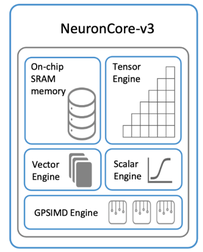

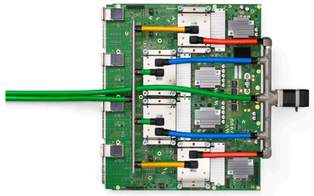

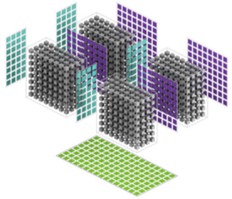

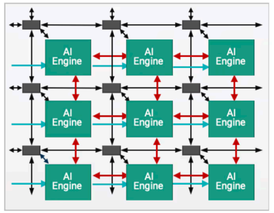

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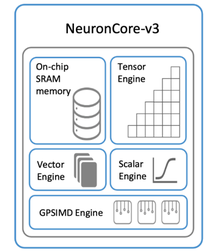

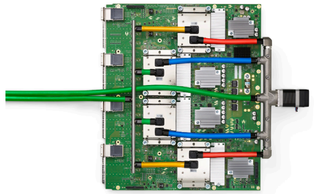

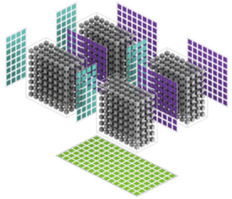

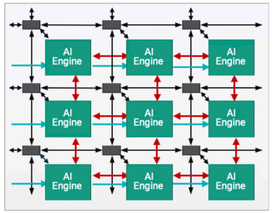

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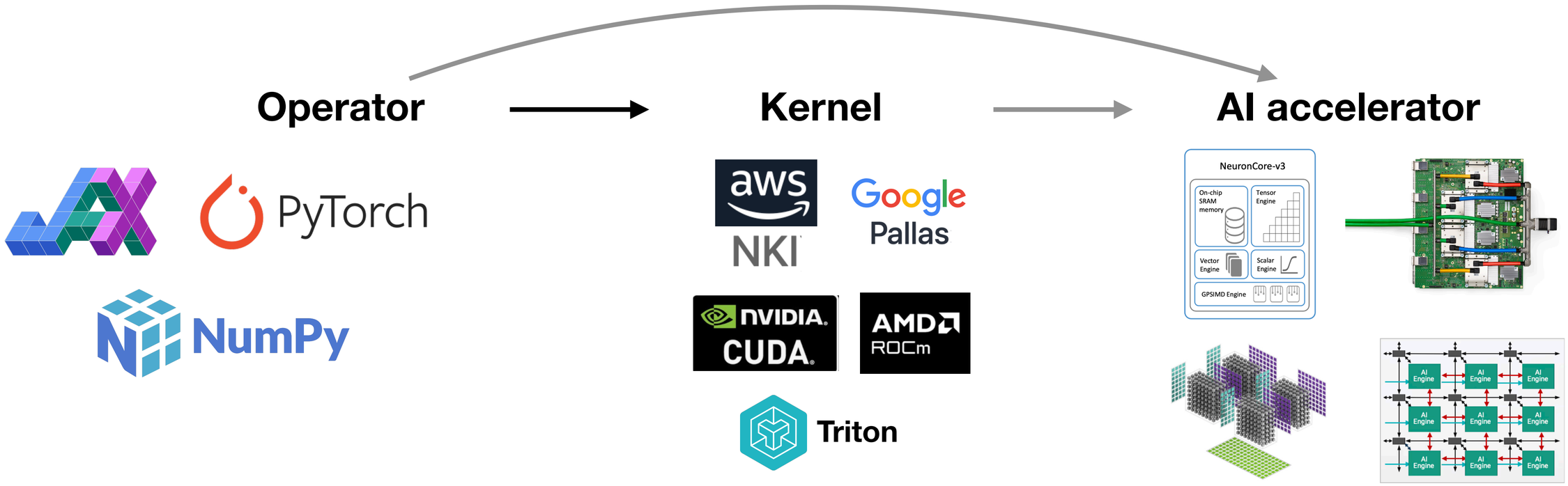

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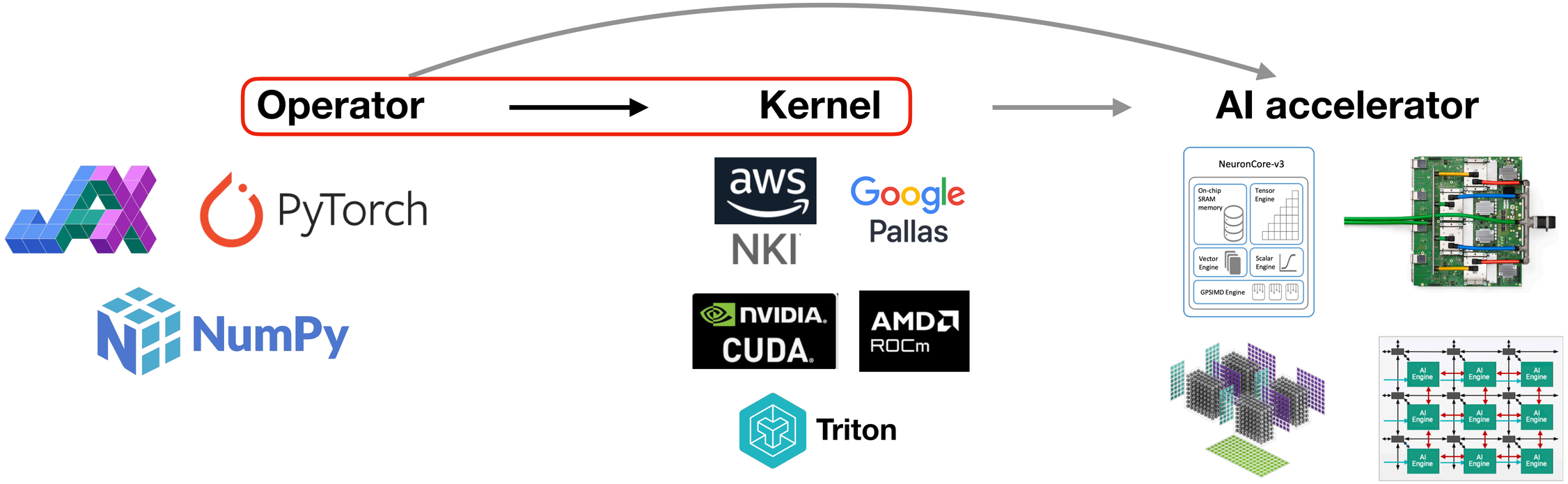

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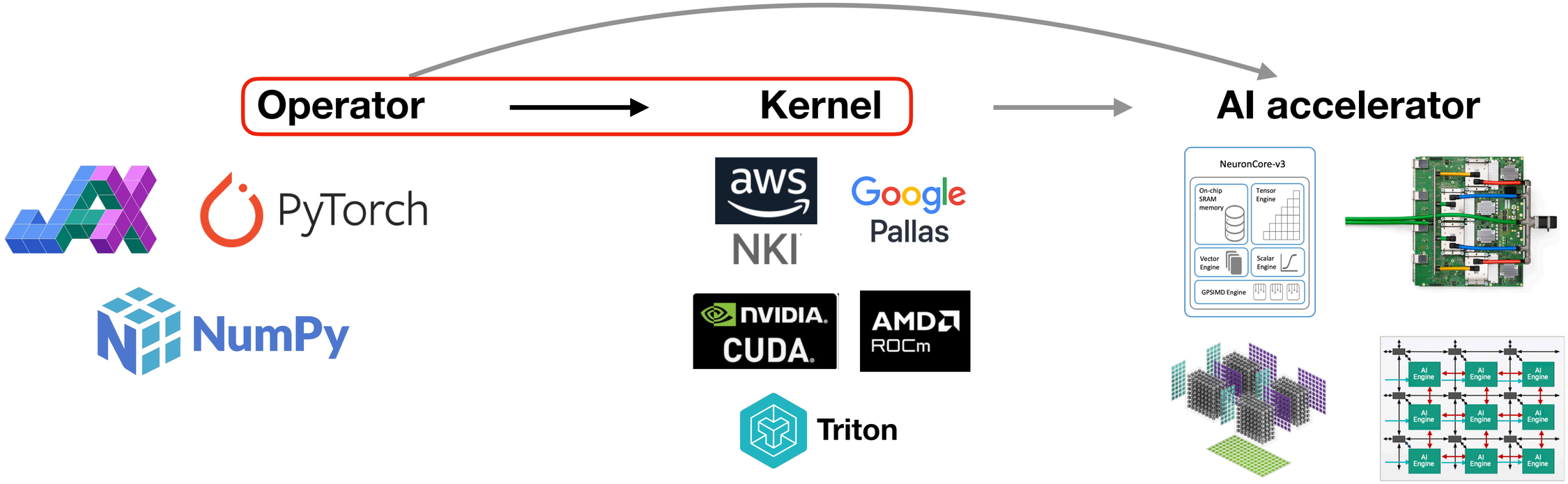
Optimizing kernels is hard, time-consuming and requires expertise!



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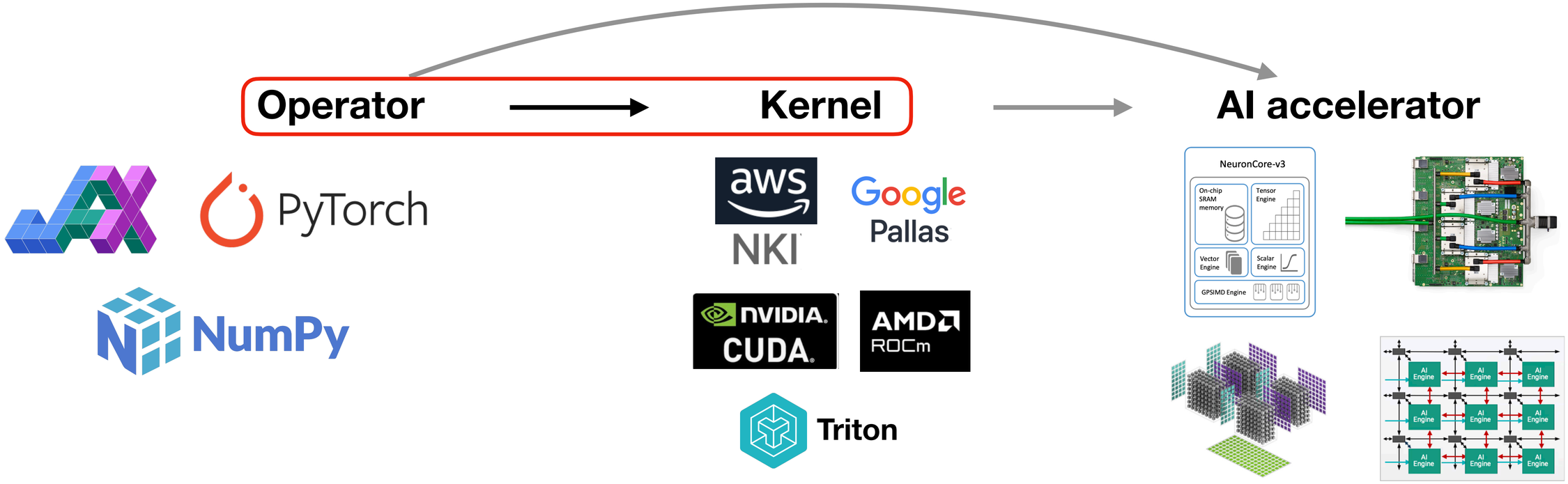

Can we build LLM agentic systems to do this?

Key techniques

Key techniques

- Beam search for fast kernels

- Decompose optimization to two agents: planner and executor

- Guide beam search with optimization memory

1. Beam search for fast kernels

Beam search: select the best performant kernels from the current iteration as the candidates for the next iteration.

Initial kernel + profile

Iter 0

Iter 1

1. Beam search for fast kernels

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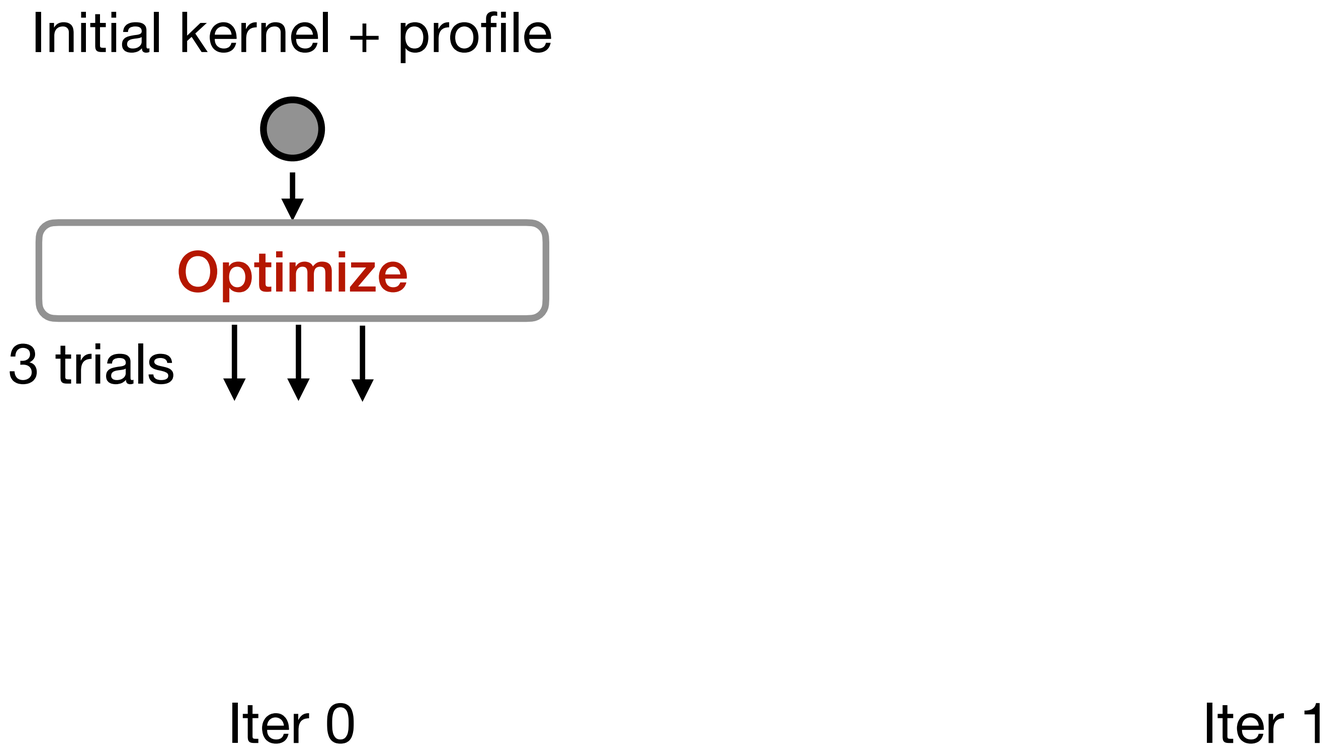

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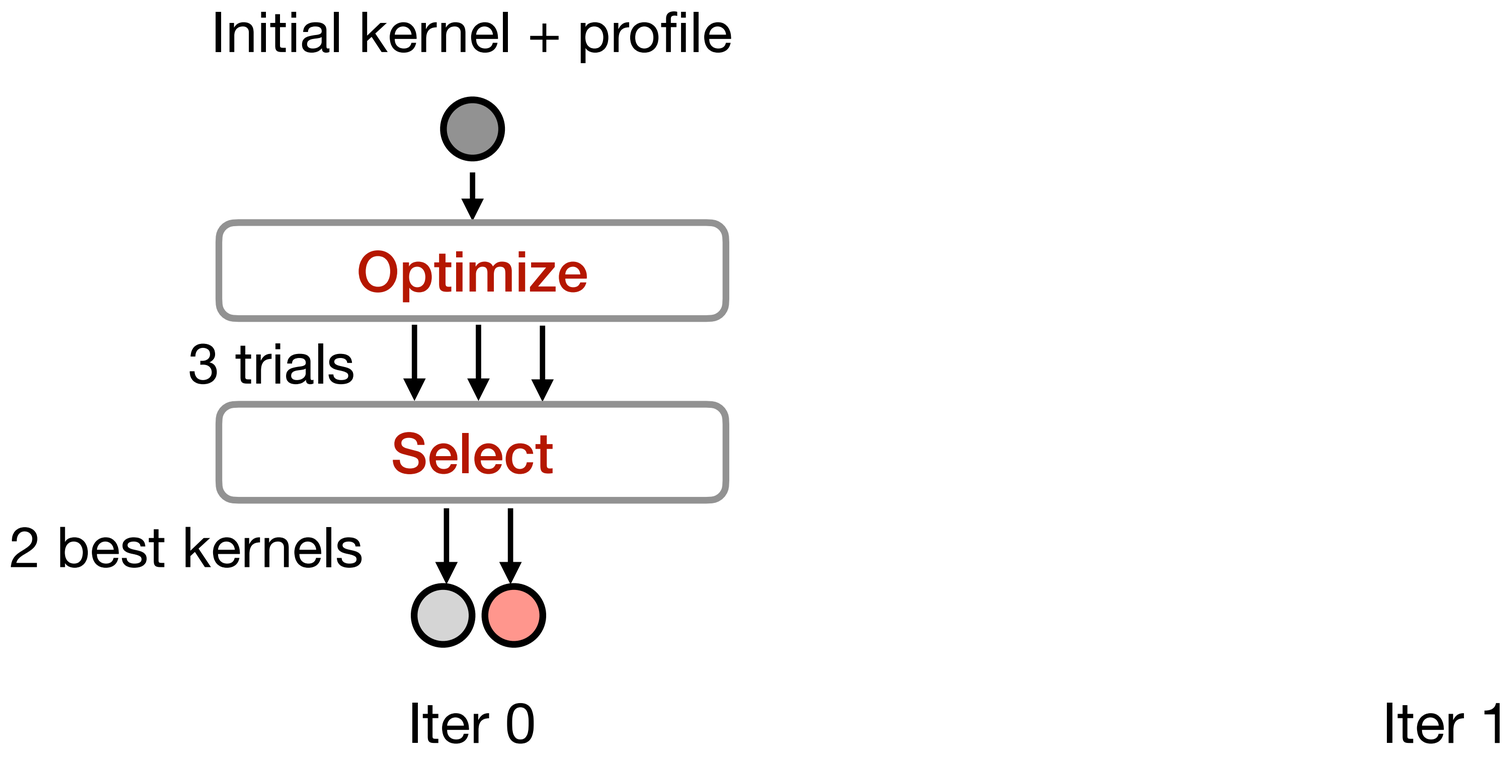

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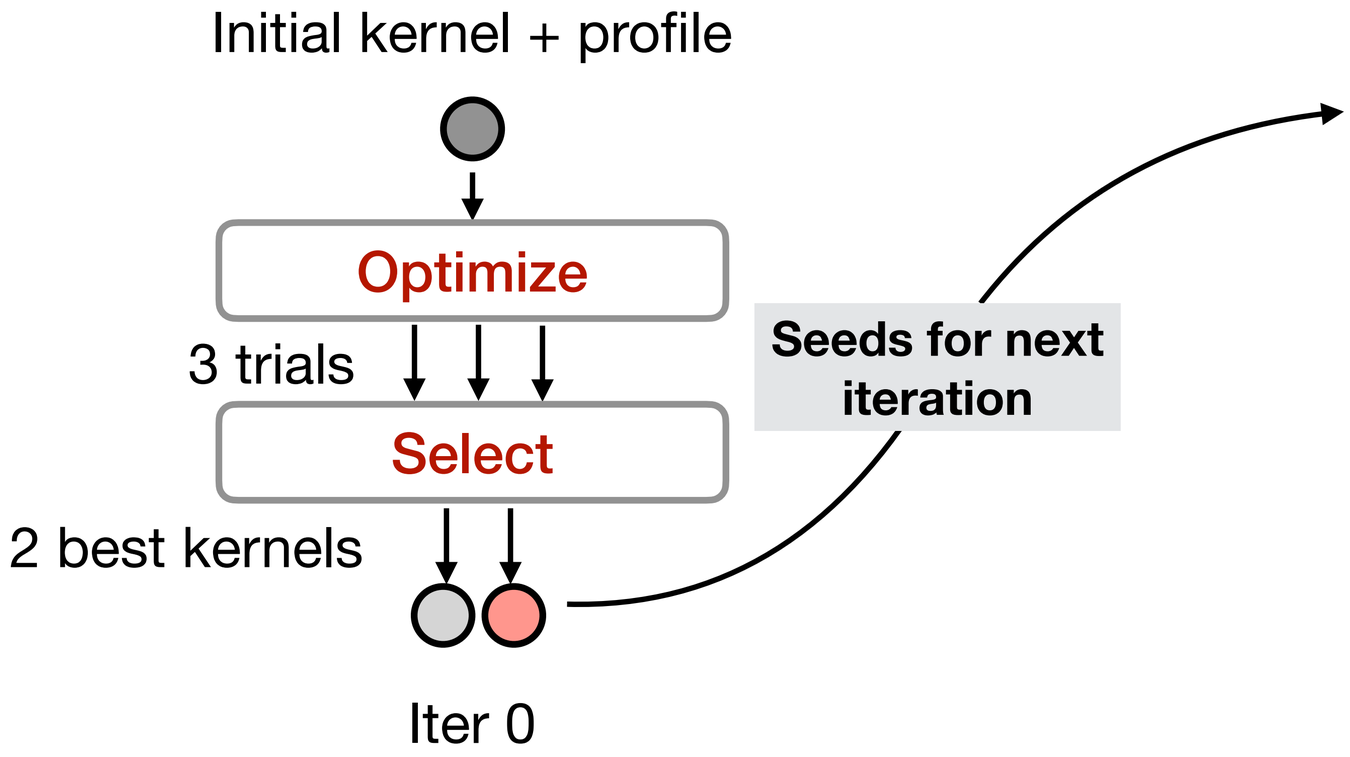

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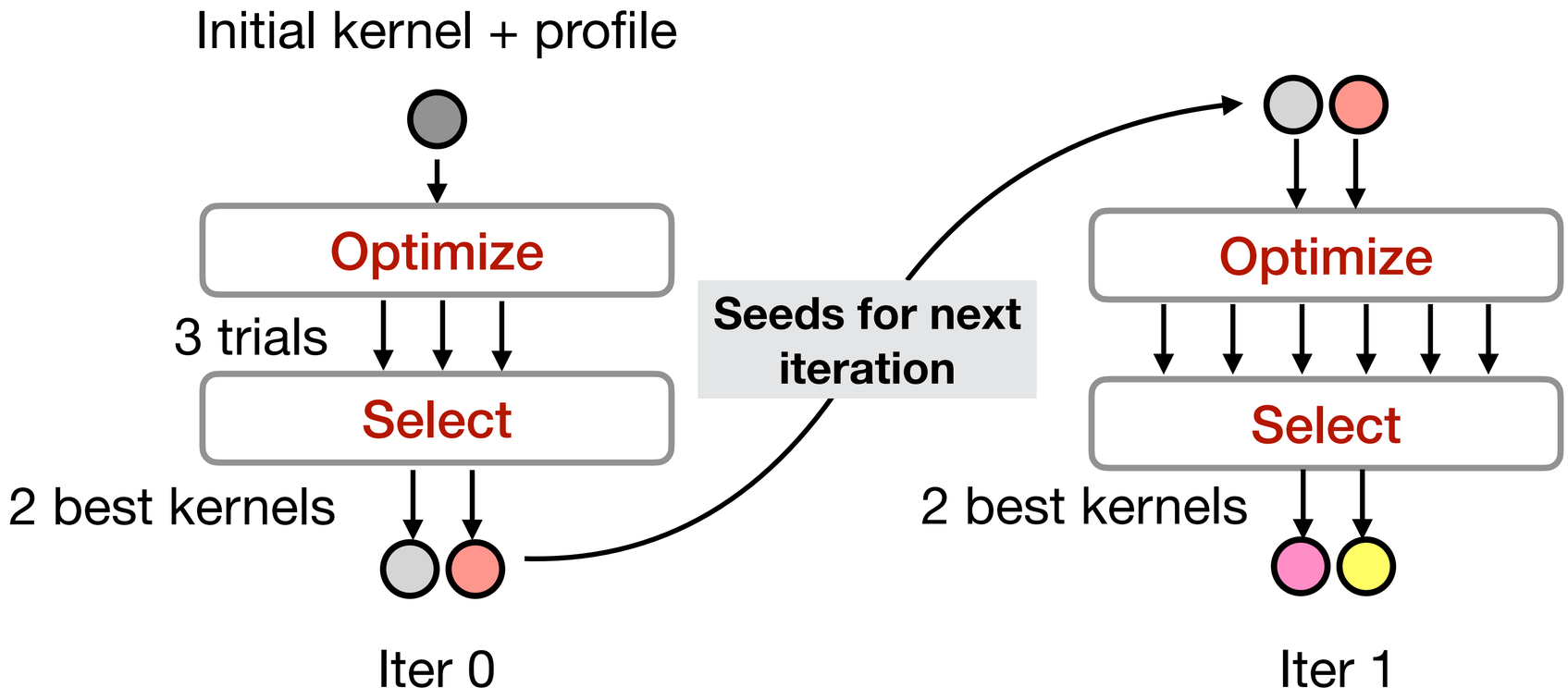

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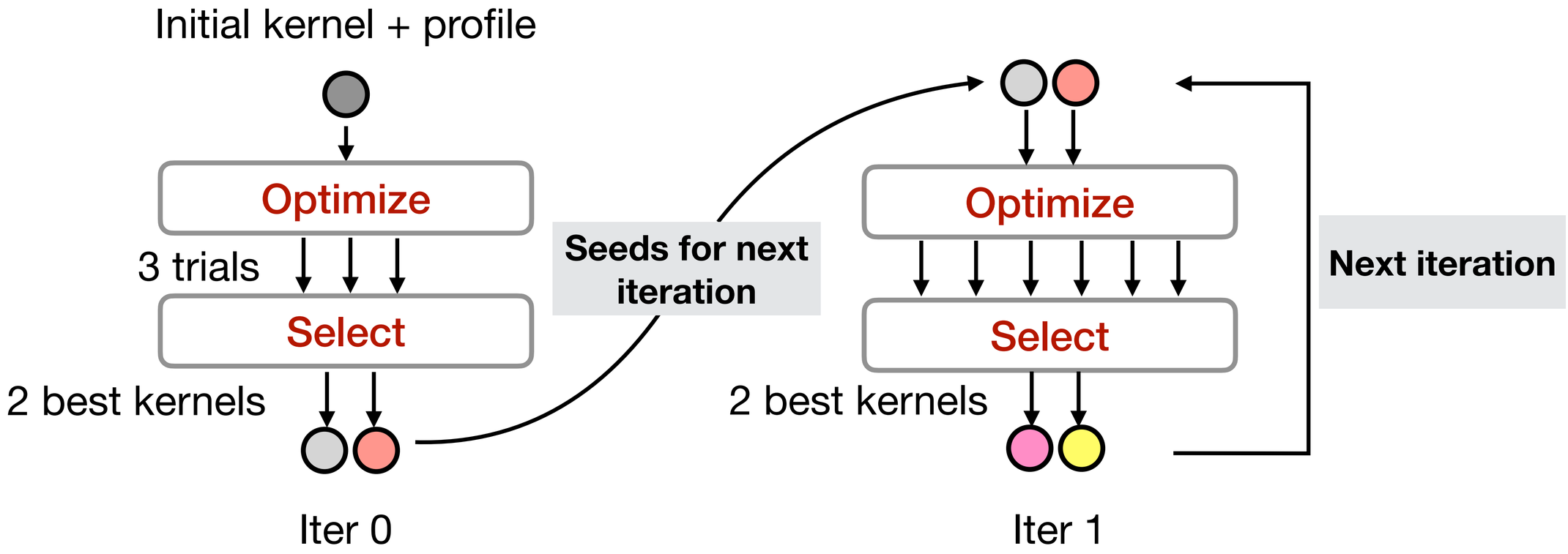
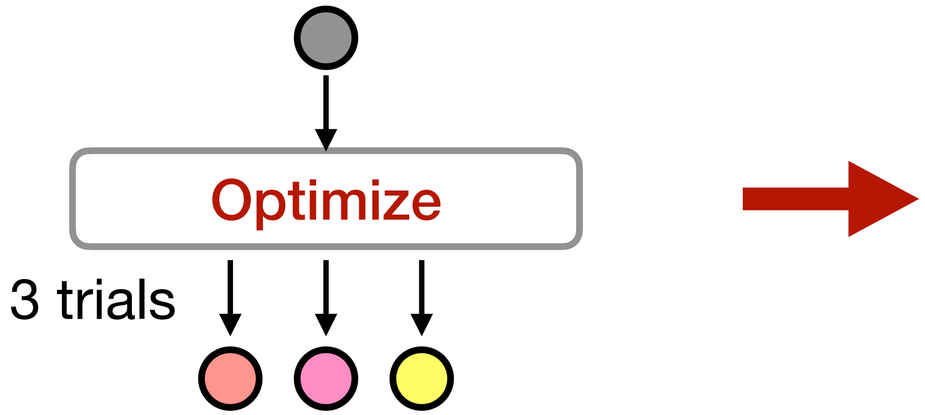


2. Decompose optimization to two agents: planner and executor



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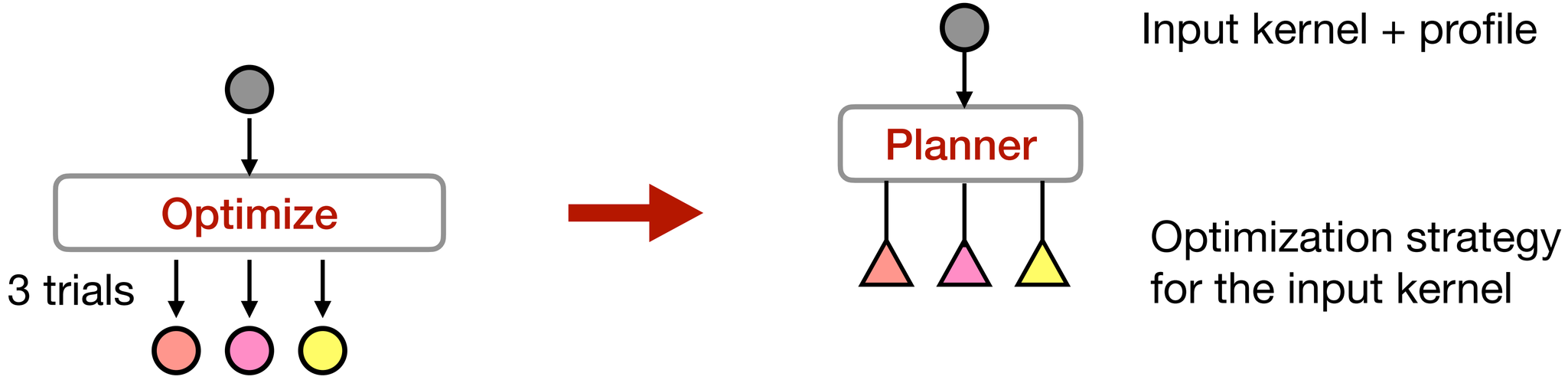

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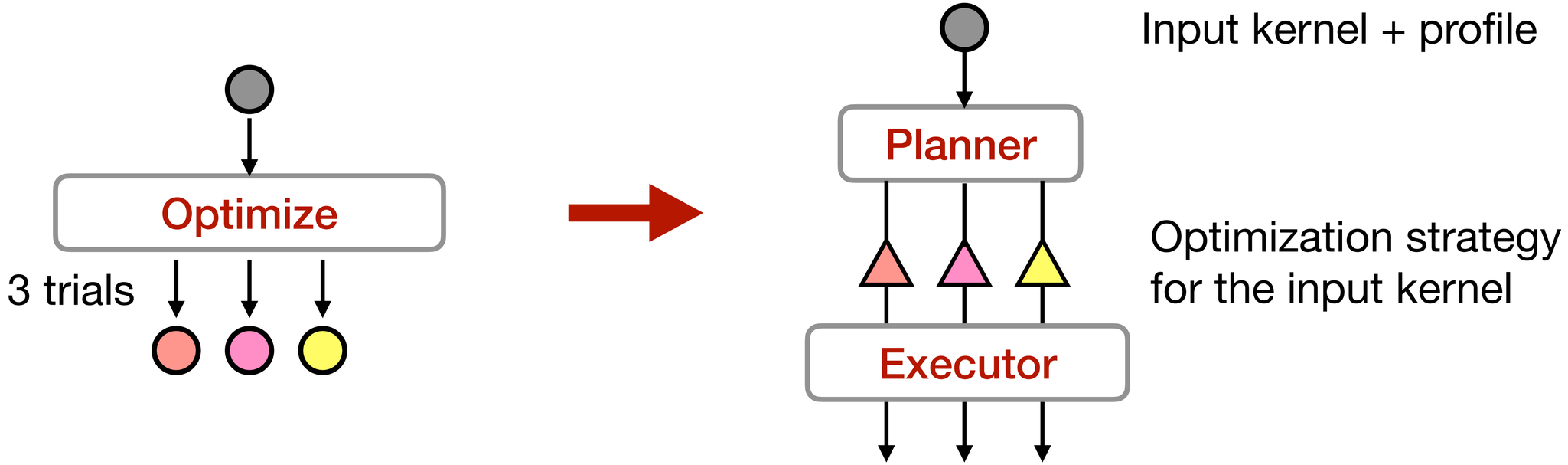

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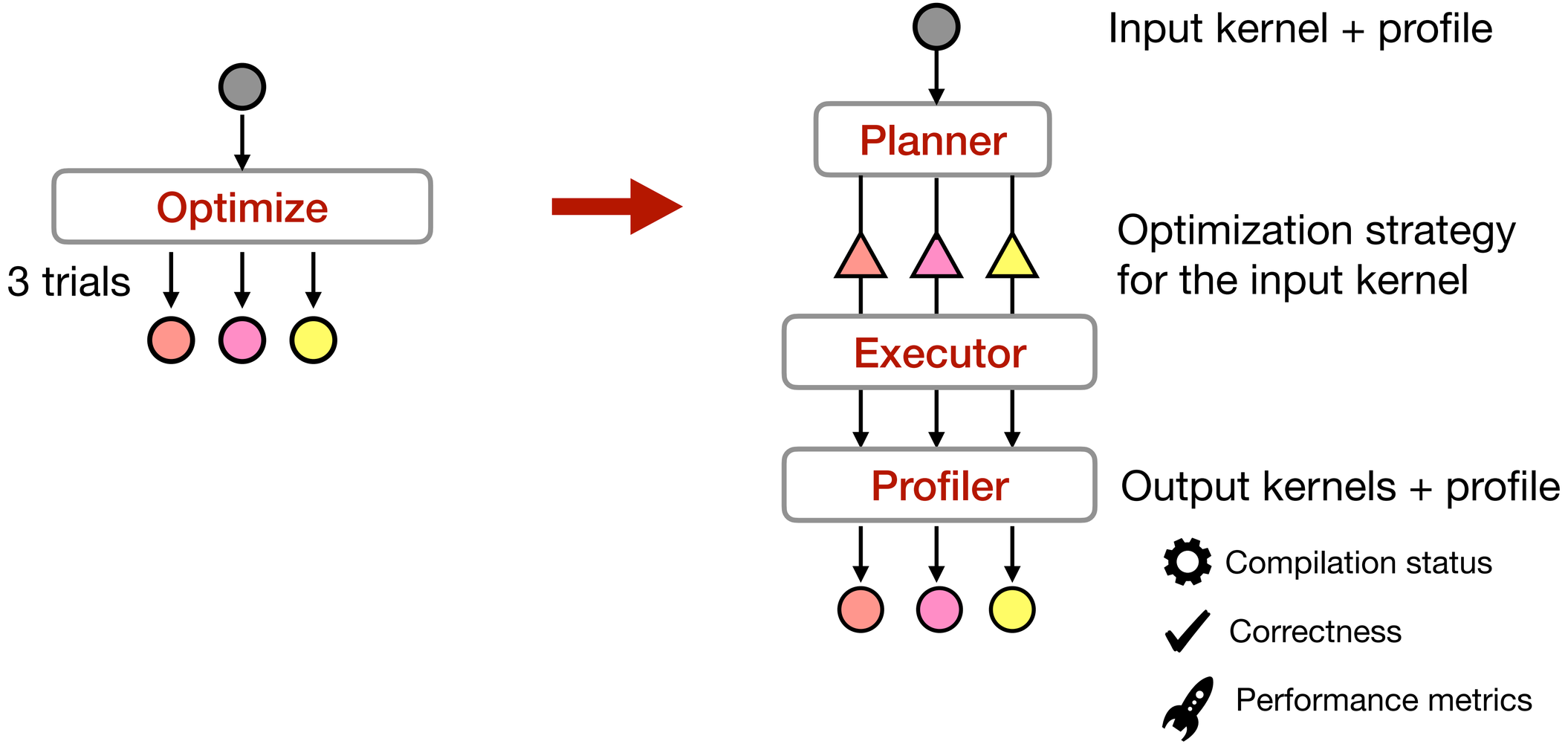
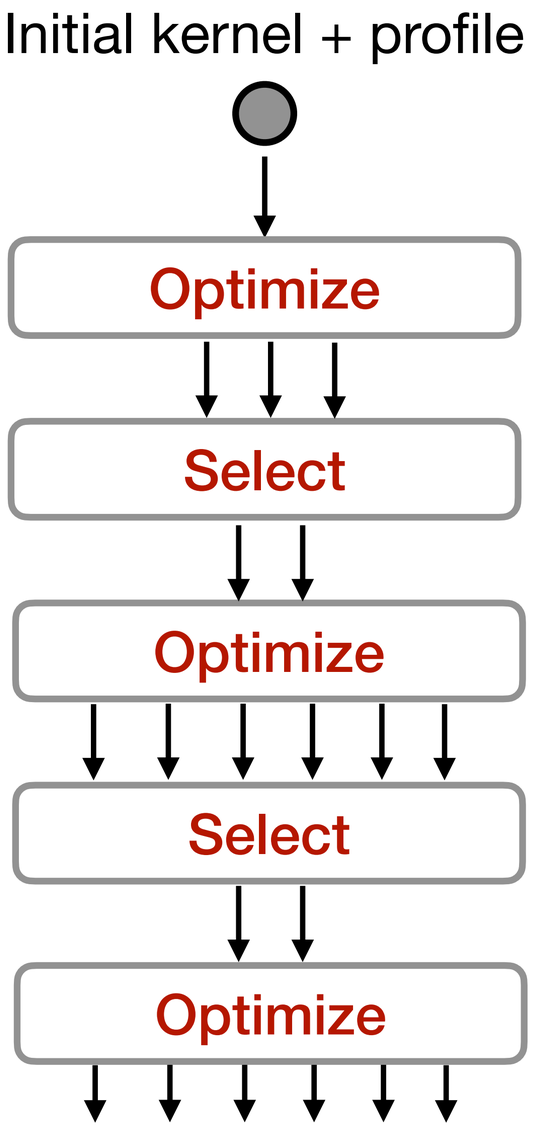
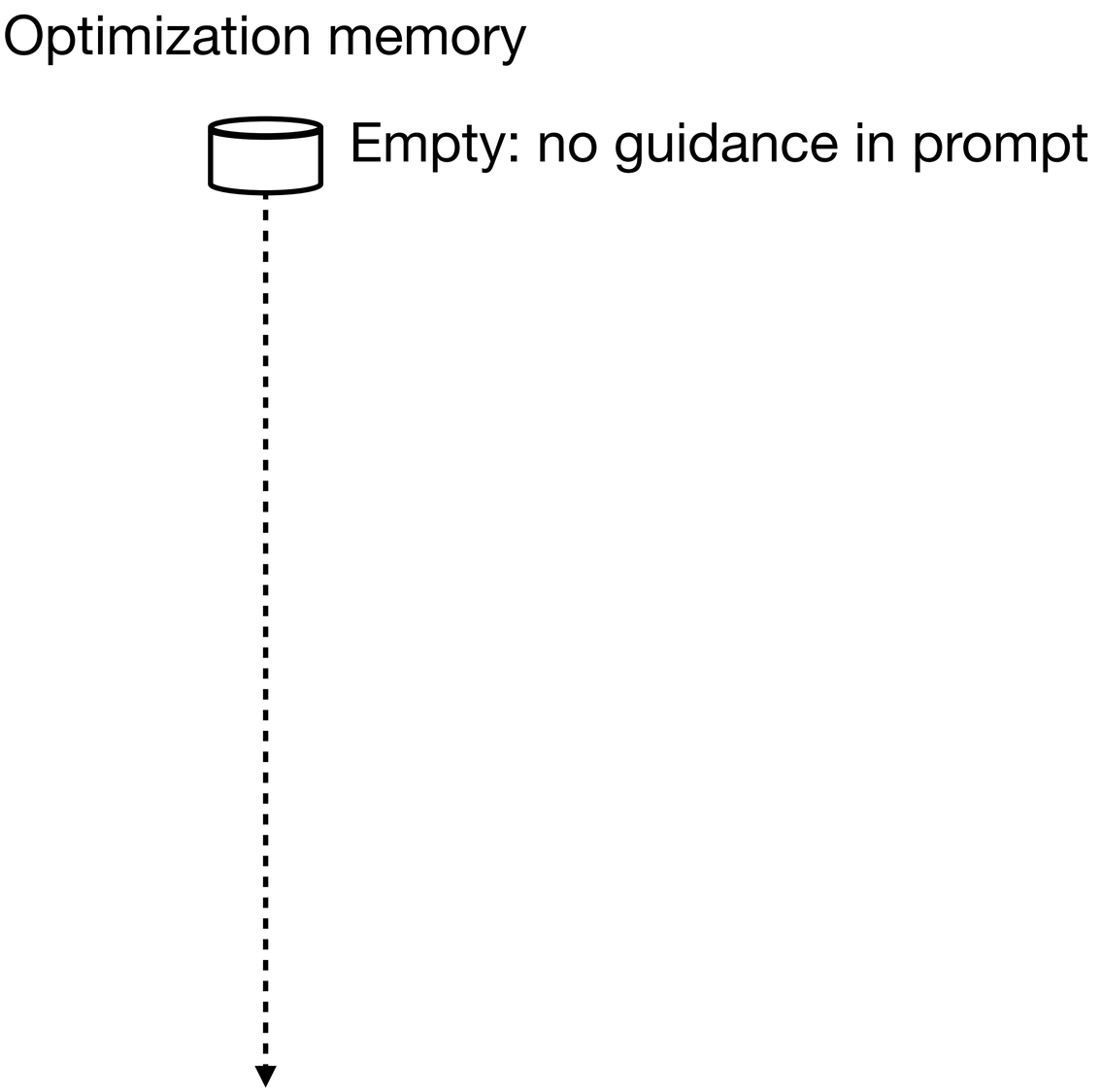


3. Guide beam search with optimization memory





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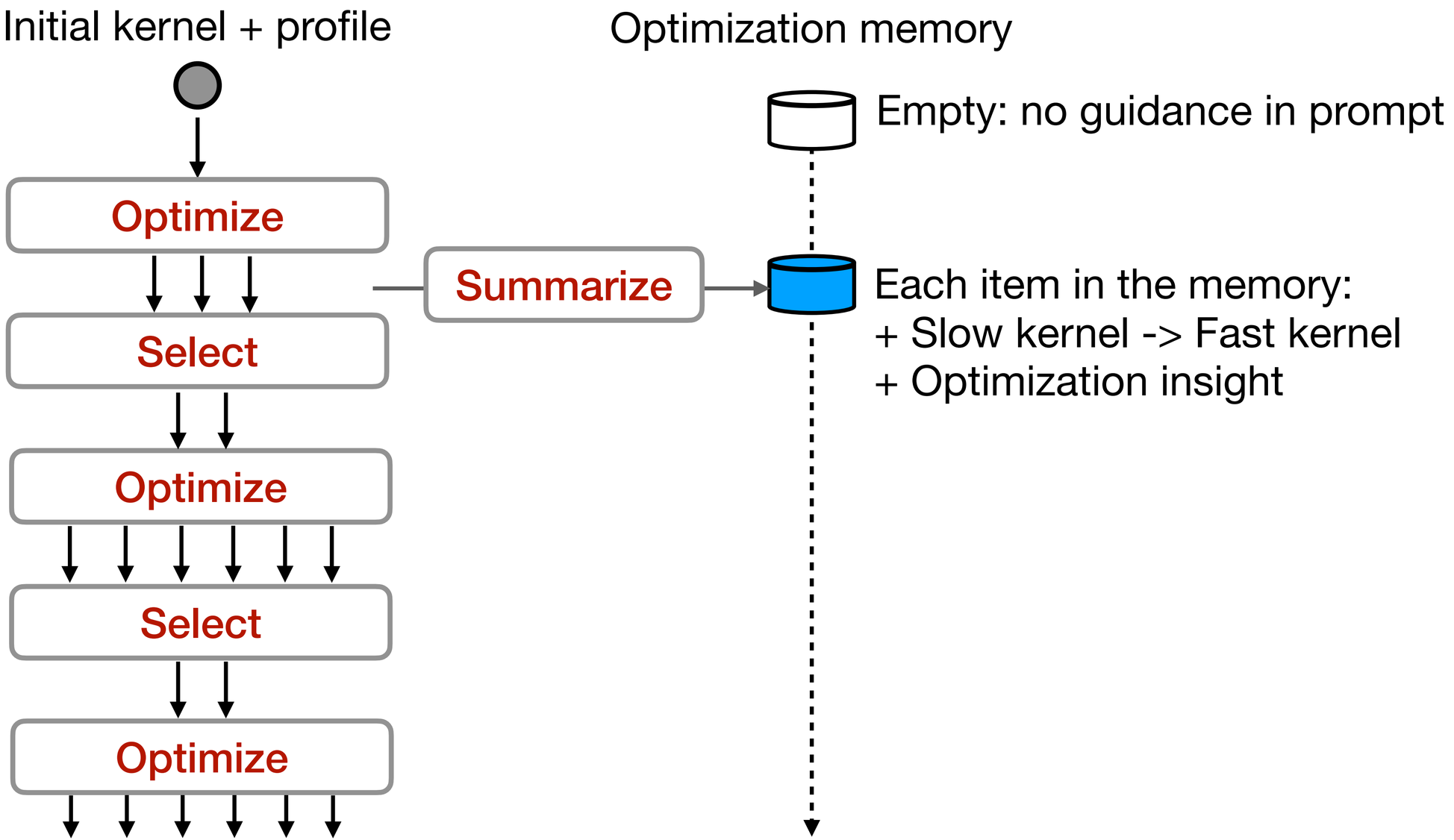

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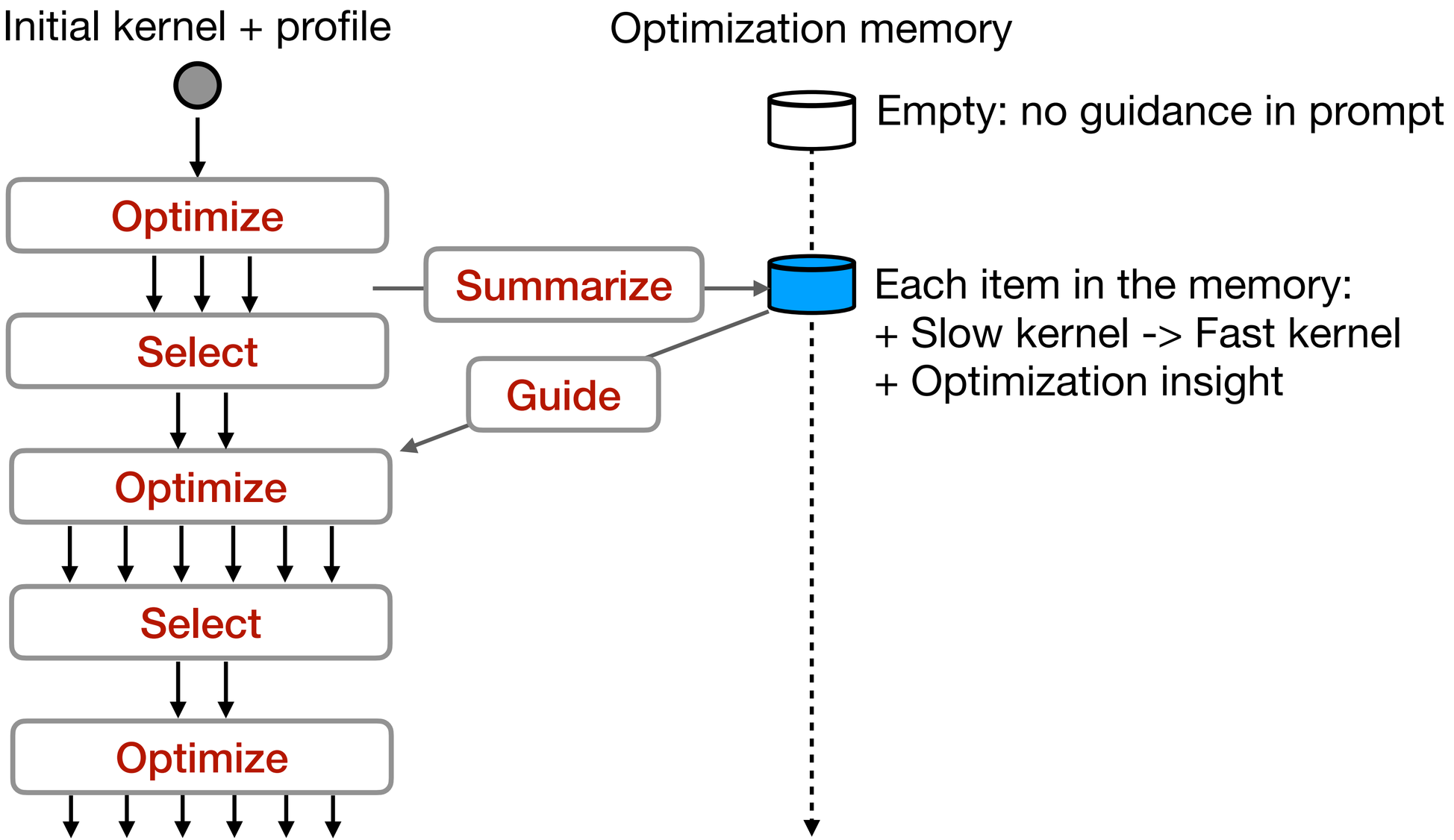
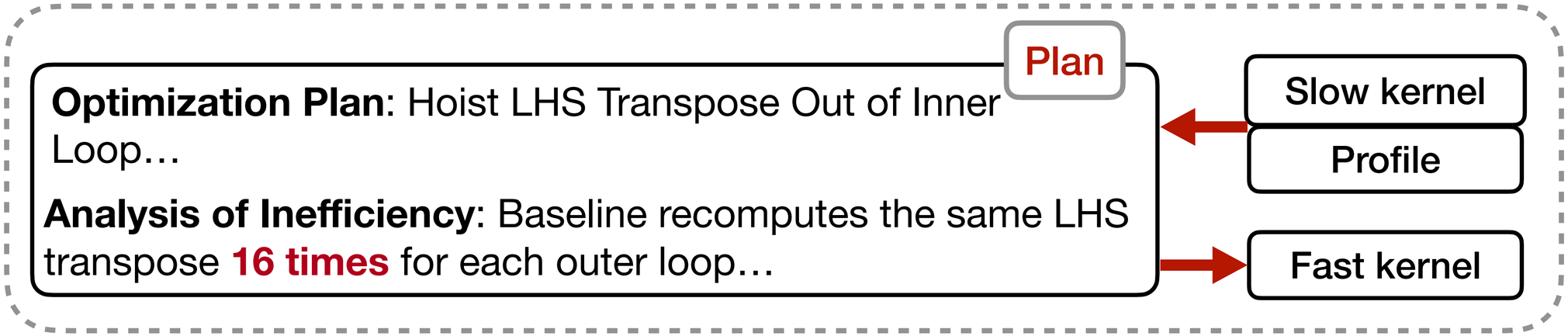


An item in the optimization memory



(All the contents were generated by agents in AccelOpt and modified a bit for demonstration.)

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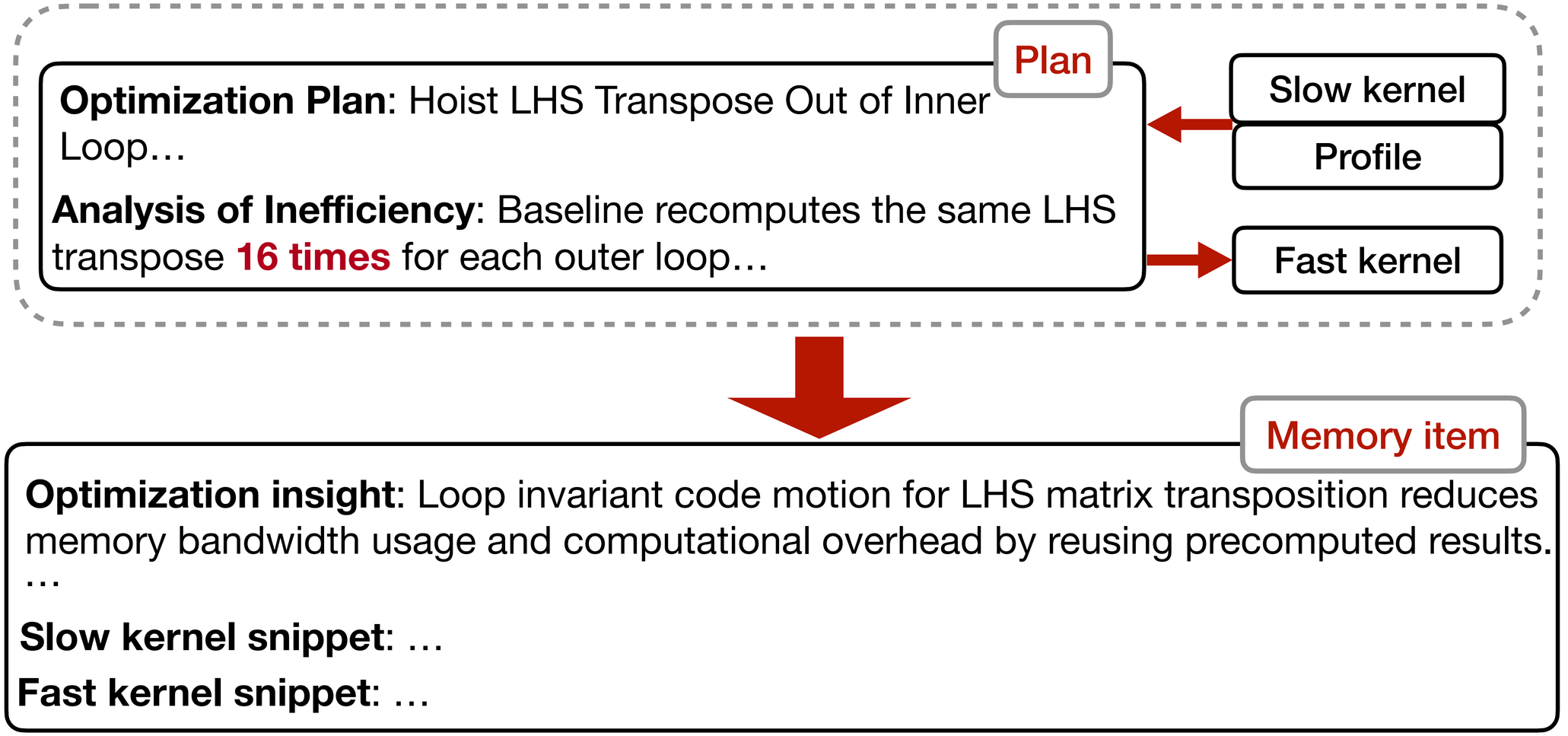

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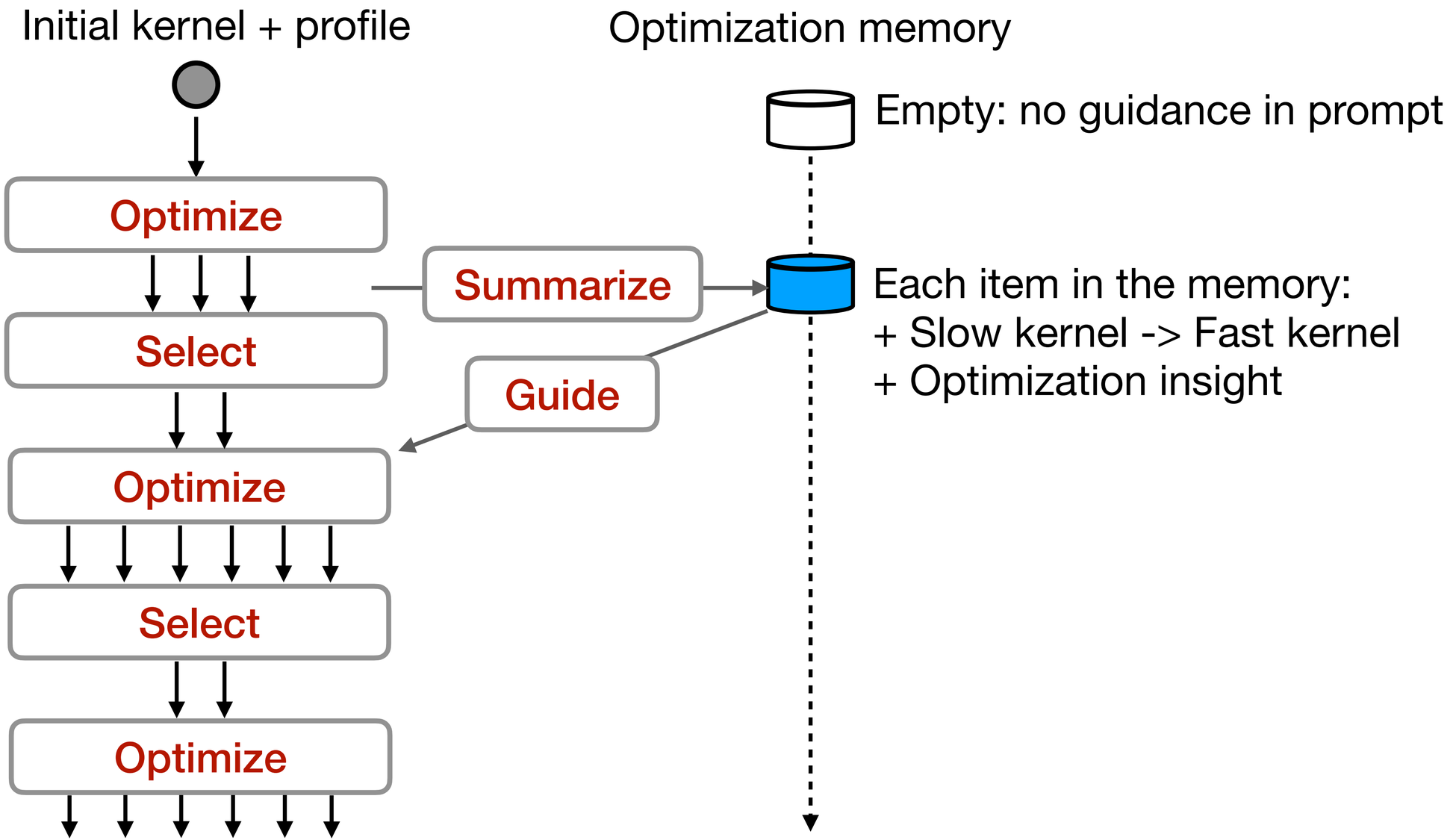

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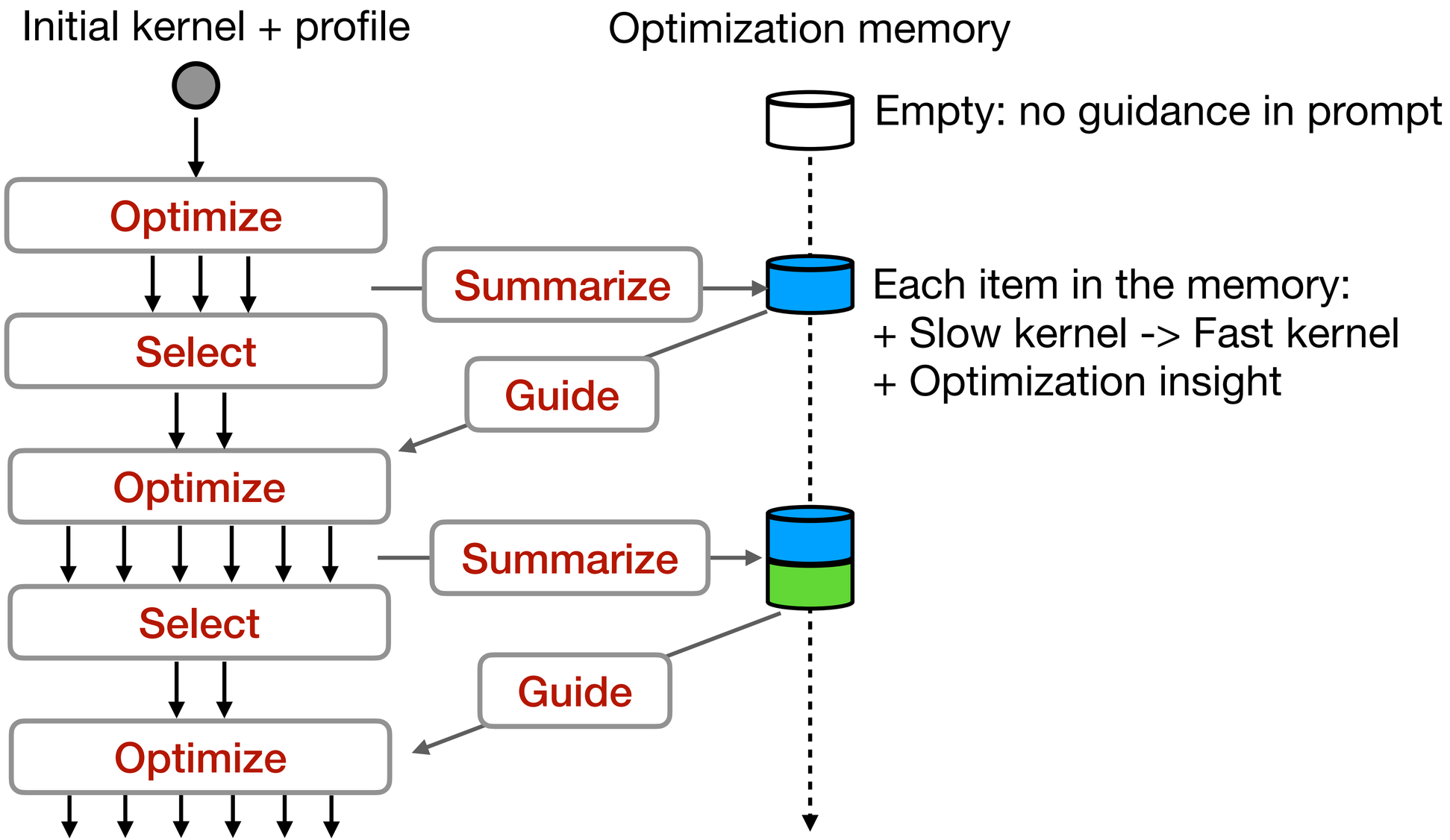

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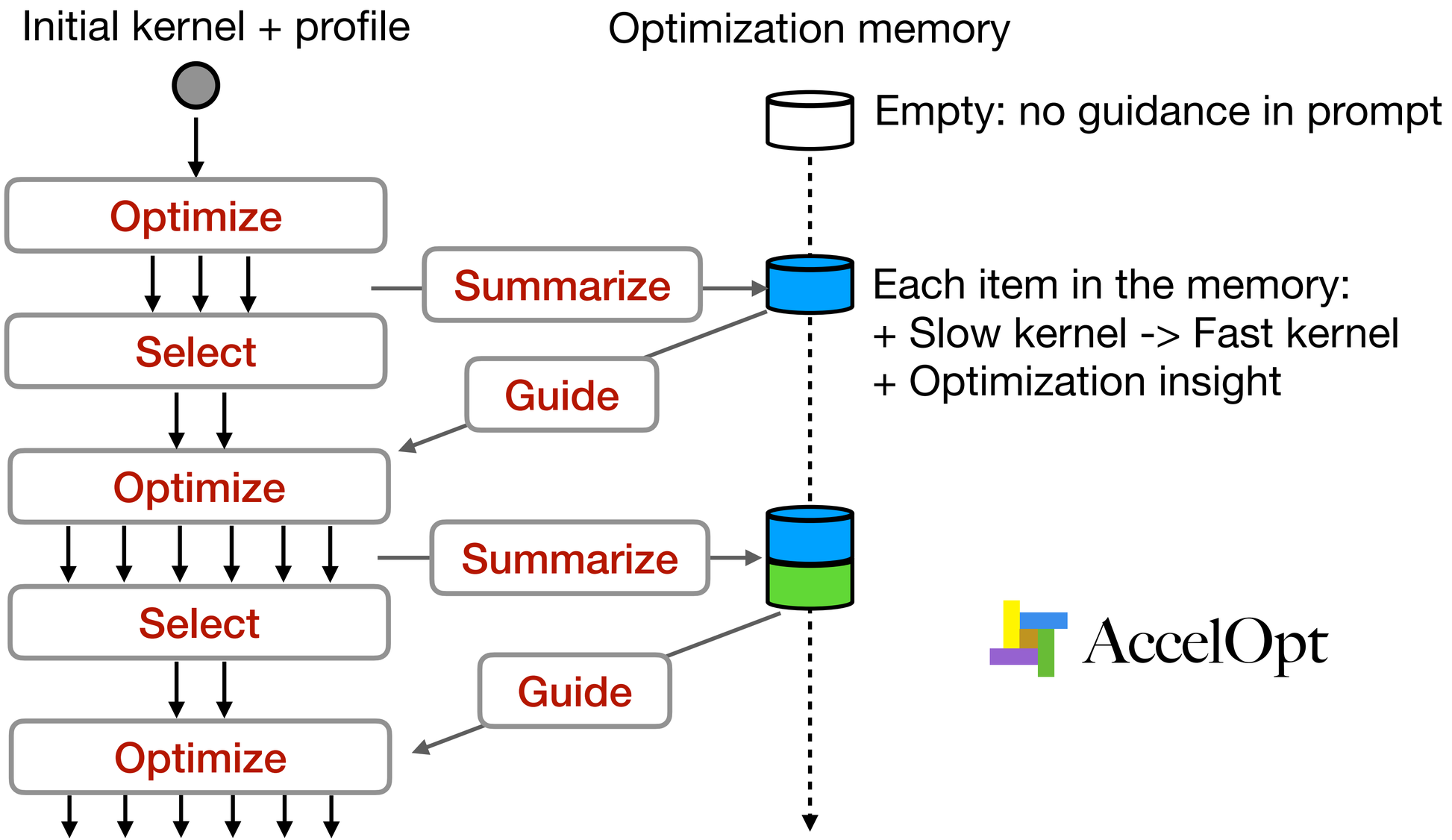
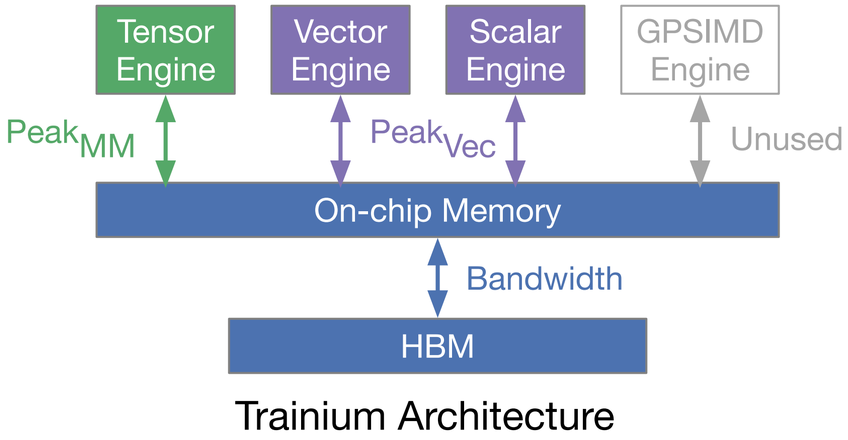


Metric: Percentage of Peak



Trainium Architecture

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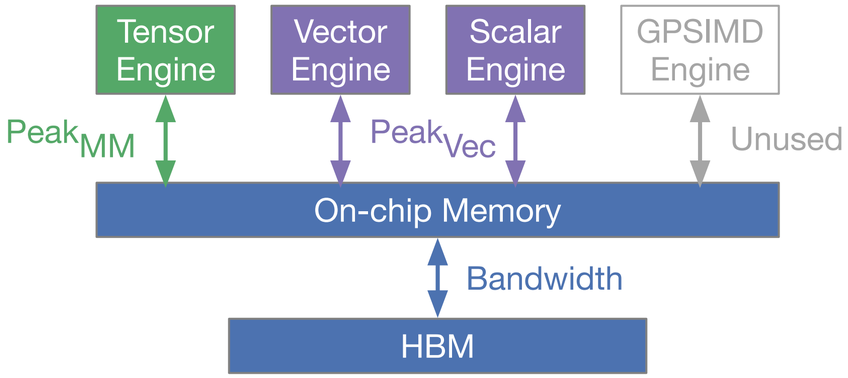

Trainium Architecture

$$\textbf{Percentage of Peak} = \frac{T}{t_{real}}$$

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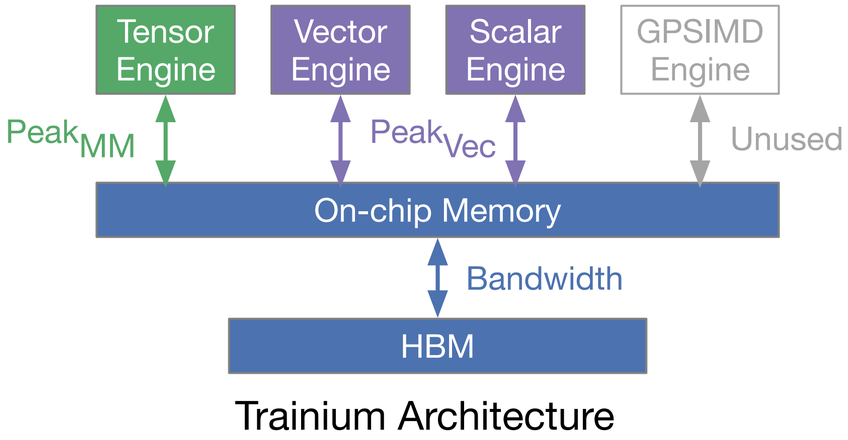

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$$T = \max\left(\frac{\text{Traffic}_{\text{Min}}}{\text{Bandwidth}}, \frac{\text{FLOPs}_{\text{MM}}}{\text{Peak}_{\text{MM}}}, \frac{\text{FLOPs}_{\text{Vec}}}{\text{Peak}_{\text{Vec}}}\right)$$

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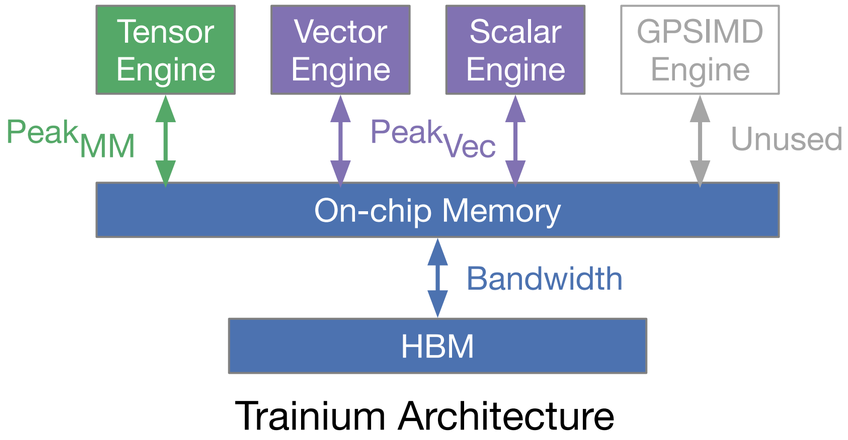

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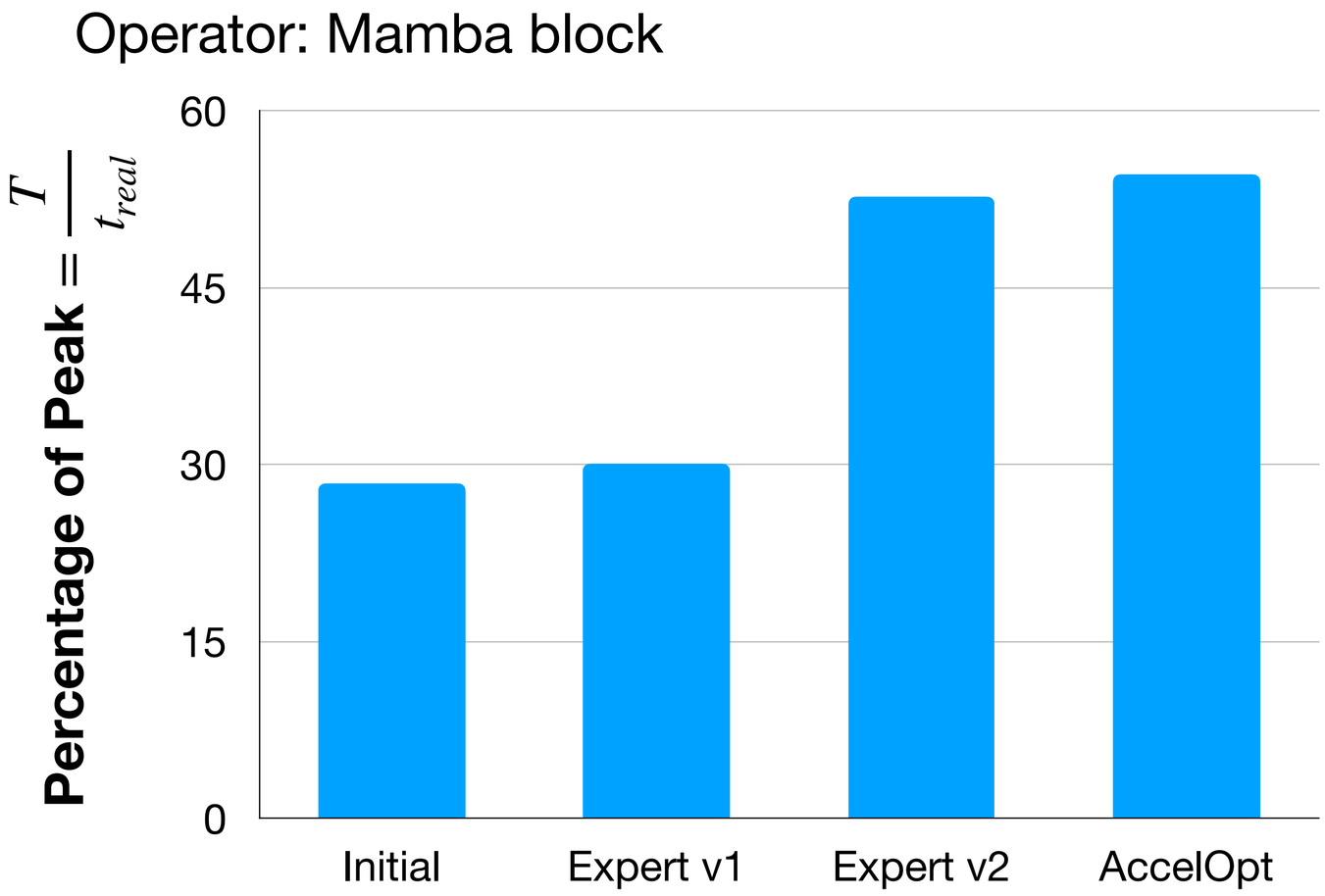
Percentage of peak provides an objective measurement of progress for kernel optimization agnostic to initial kernels.

AccelOpt can discover better kernels than human experts



AccelOpt/samples/nki

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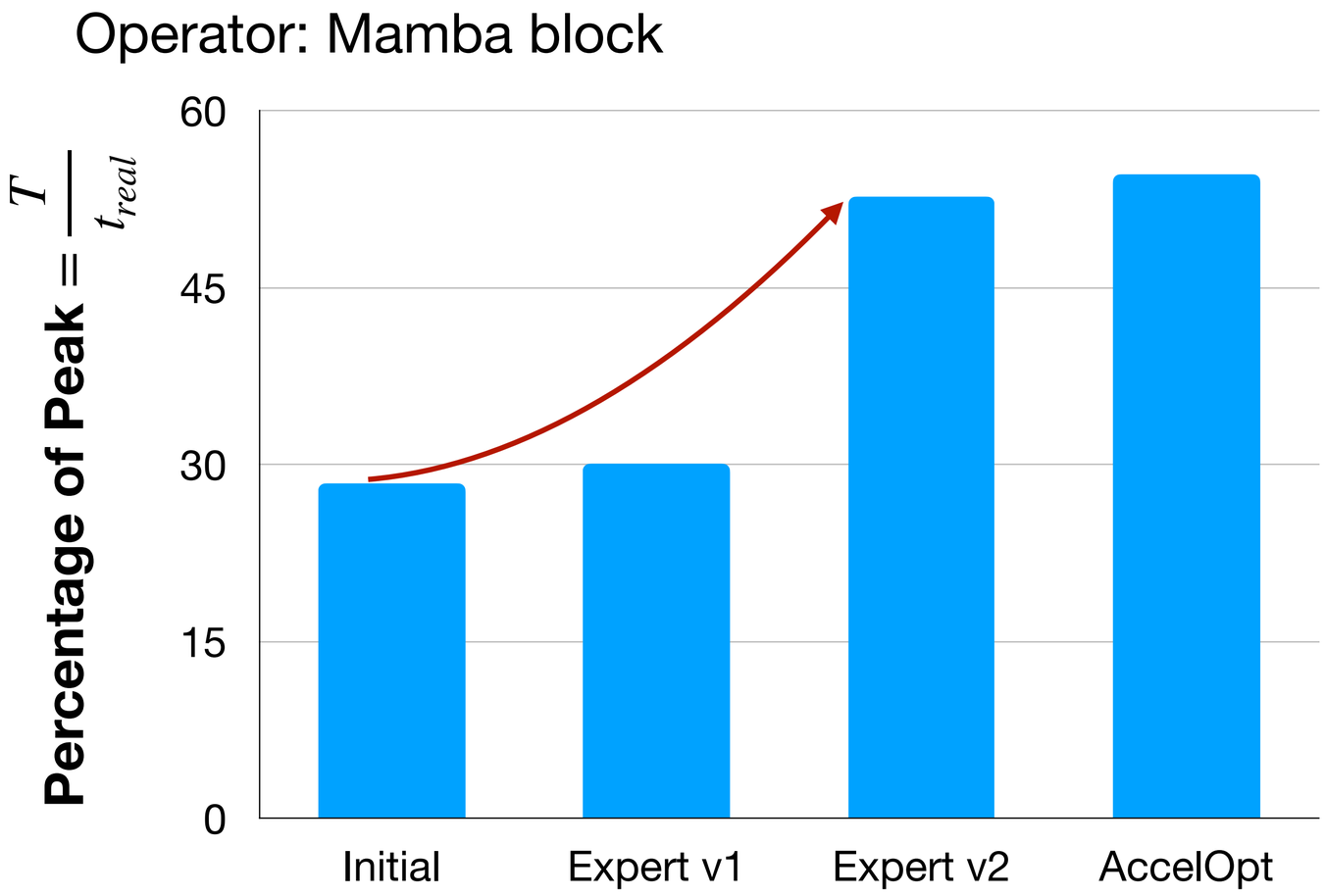

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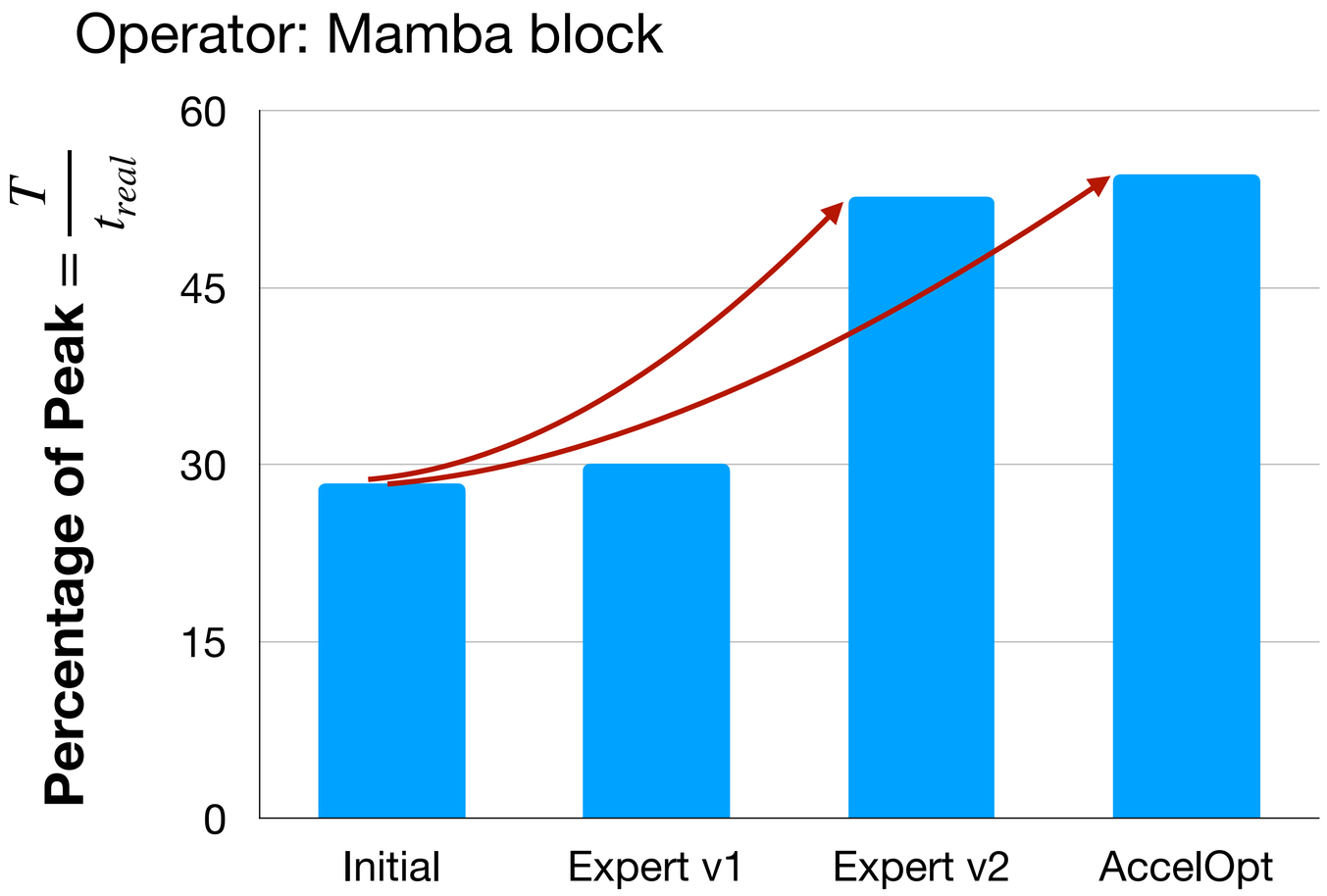
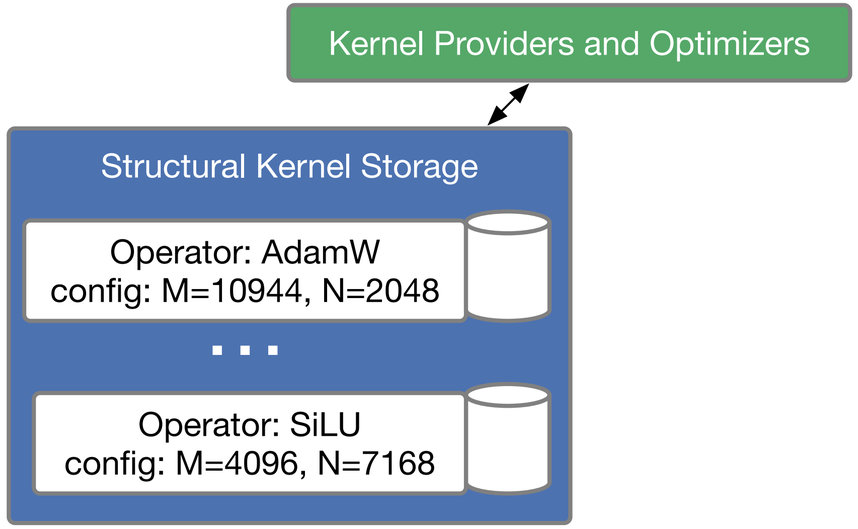


AccelOpt/samples/nki

NKIBench: a benchmark environment with realistic NKI kernels



Genghan/NKIBench

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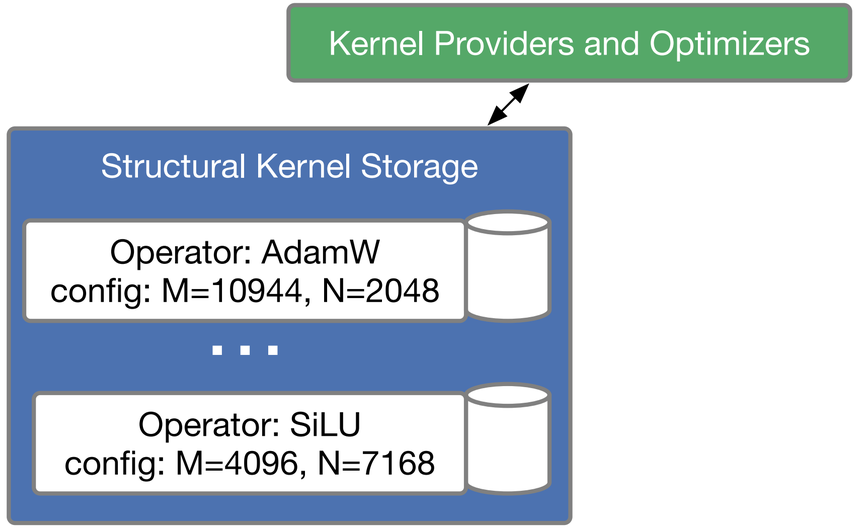
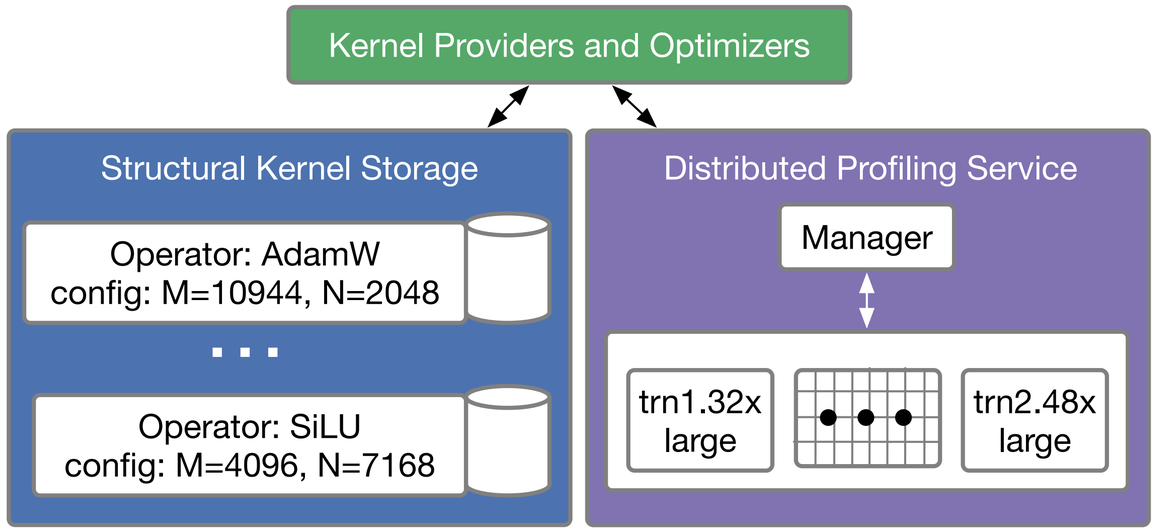


Name	Workload
AdamW	DeepSeek-MoE-16B
Add + RMSNorm + Matmul	Qwen3 0.6B
BatchMatmul	Falcon-40B
BatchMatmul + Softmax	Falcon-40B
Group Query Attention	Qwen3 0.6B/1.7B
LoRA	DeepSeek-V2.5
Mamba block	Synthesized
Matmul + Add + RMSNorm	Qwen3 1.7B
Matmul	DeepSeek-V2.5
RMSNorm + Matmul	Qwen3 0.6B
RoPE	Qwen3 32B
SiLU	DeepSeek-V3 671B
SwiGLU	Qwen3 0.6B
Transpose + Matmul	DeepSeek-MoE-16B

Genghan/NKIBench

NKIBench: a benchmark environment with realistic NKI kernels



Name	Workload
AdamW	DeepSeek-MoE-16B
Add + RMSNorm + Matmul	Qwen3 0.6B
BatchMatmul	Falcon-40B
BatchMatmul + Softmax	Falcon-40B
Group Query Attention	Qwen3 0.6B/1.7B
LoRA	DeepSeek-V2.5
Mamba block	Synthesized
Matmul + Add + RMSNorm	Qwen3 1.7B
Matmul	DeepSeek-V2.5
RMSNorm + Matmul	Qwen3 0.6B
RoPE	Qwen3 32B
SiLU	DeepSeek-V3 671B
SwiGLU	Qwen3 0.6B
Transpose + Matmul	DeepSeek-MoE-16B

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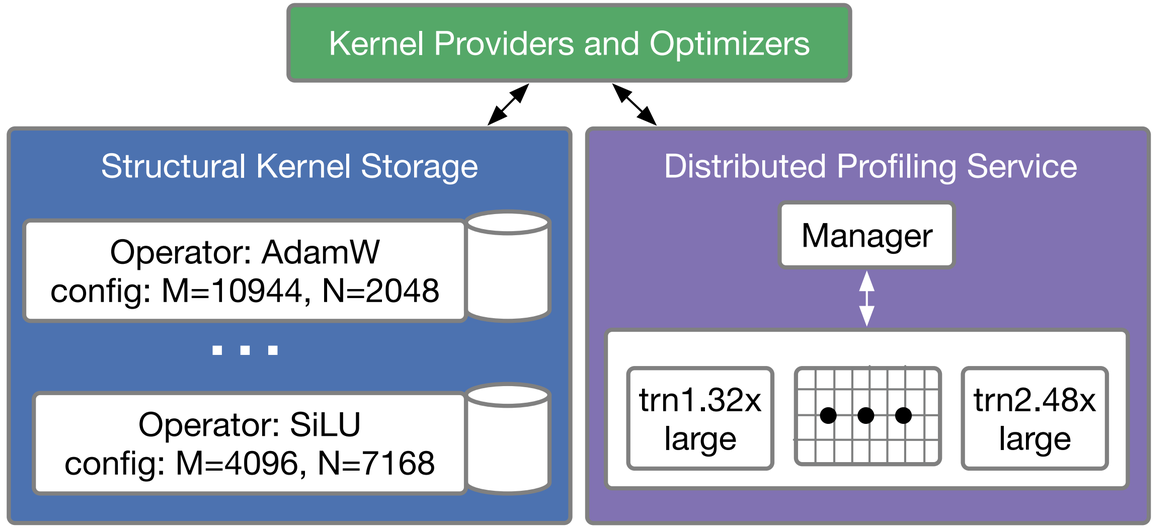

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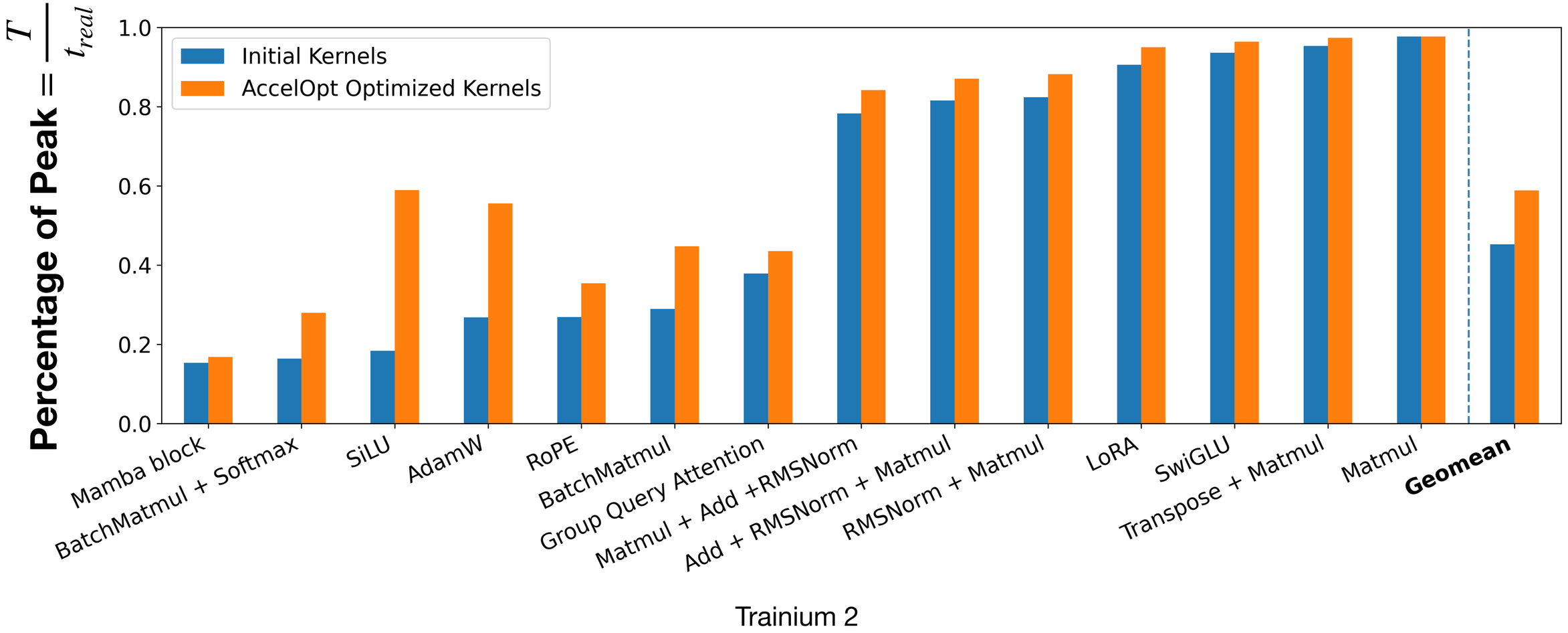
Genghan/NKIBench

AWS is working with the open-source community to maintain and expand NKIBench.

AccelOpt can optimize a broad range of NKI kernels



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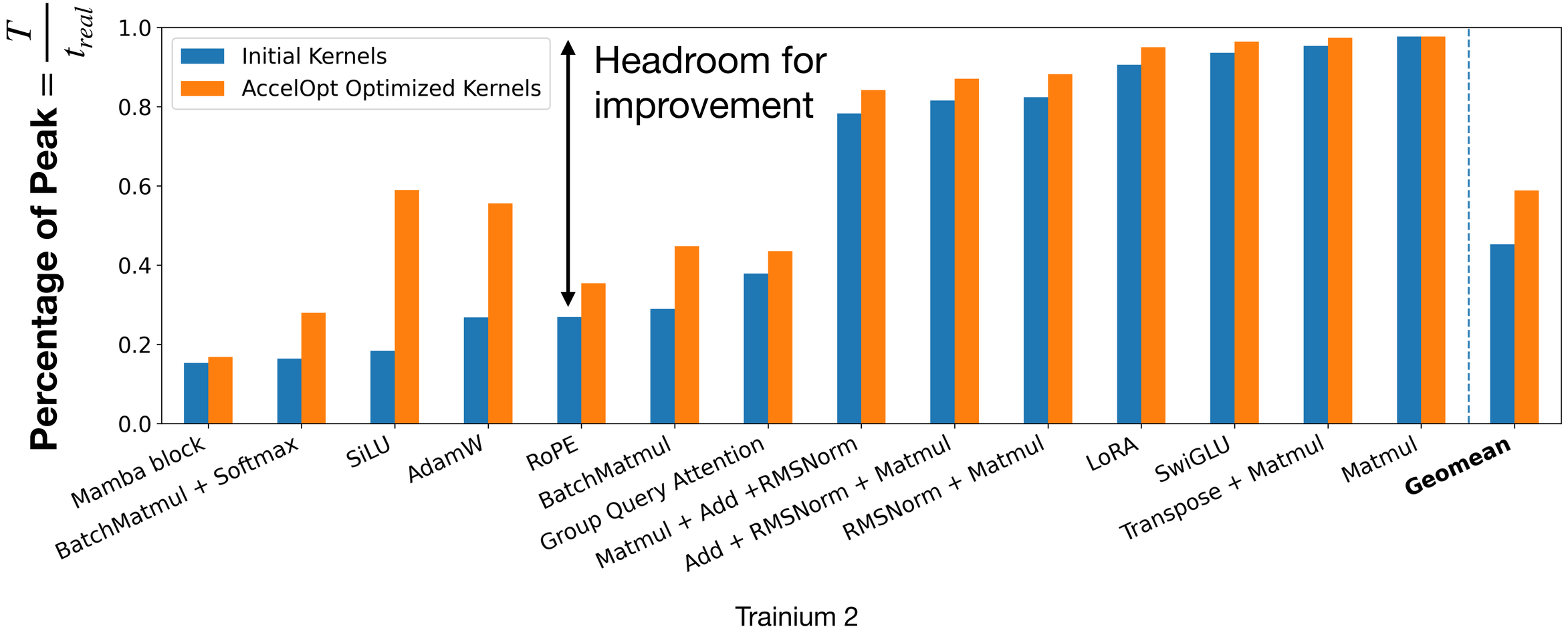

Trainium 2

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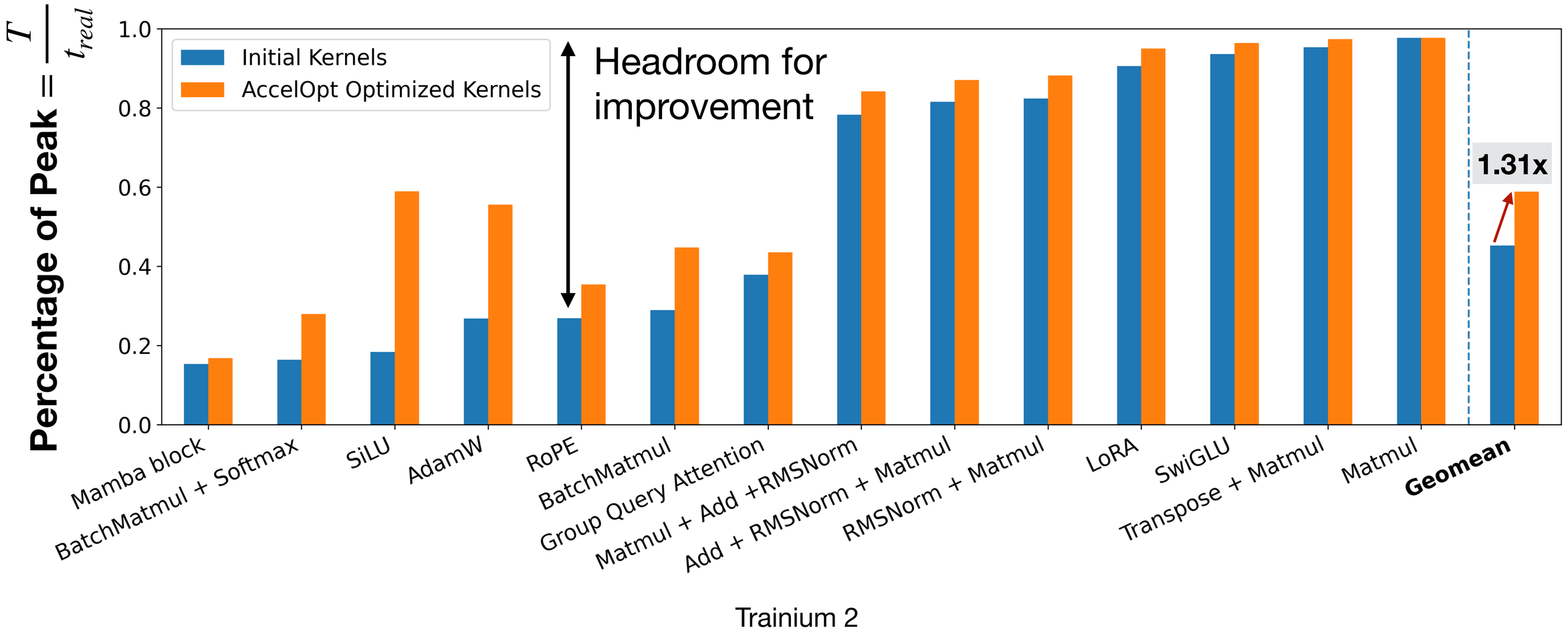
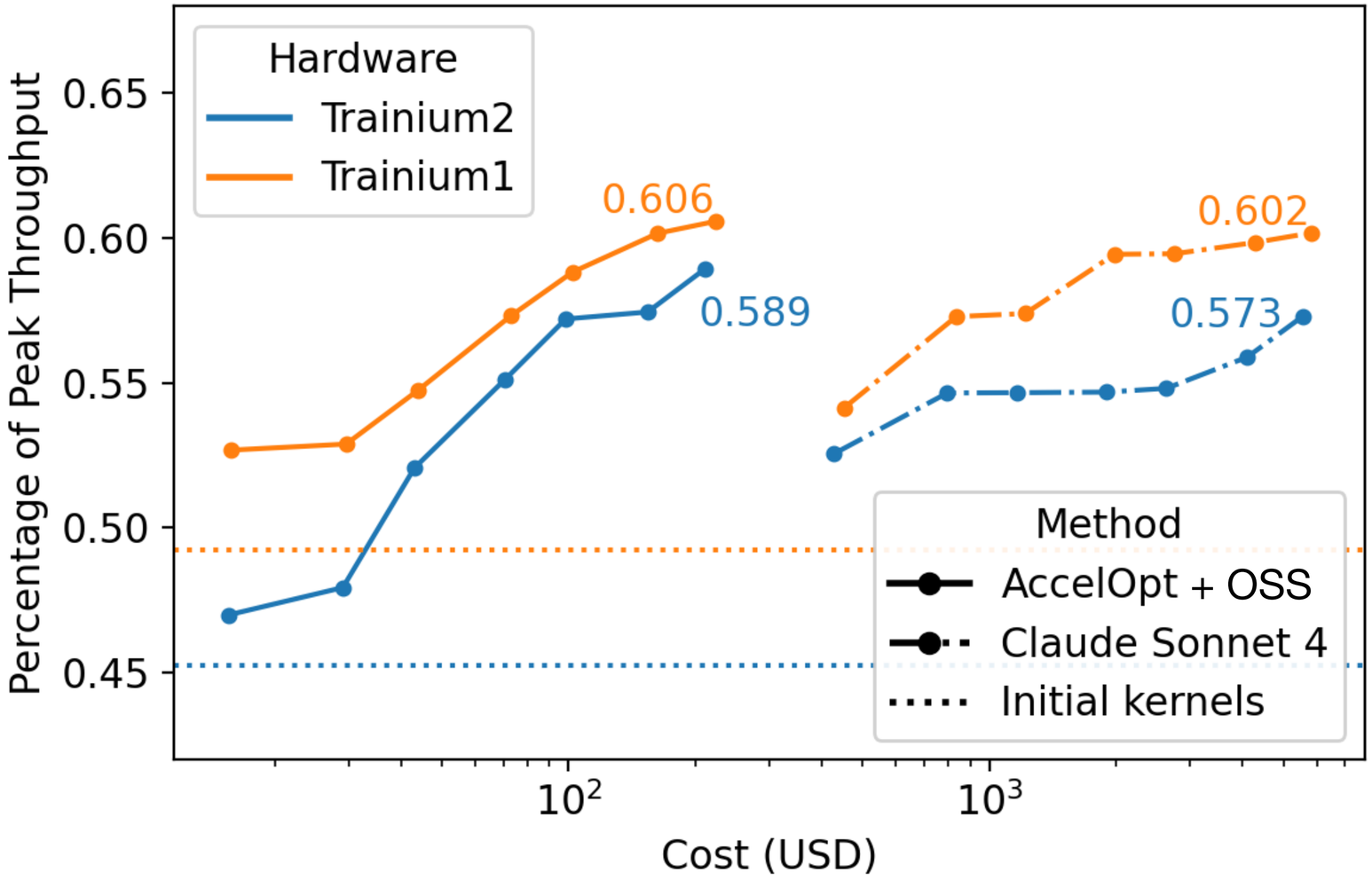


Trainium 2

AccelOpt is cost efficient and adaptive to architectural change



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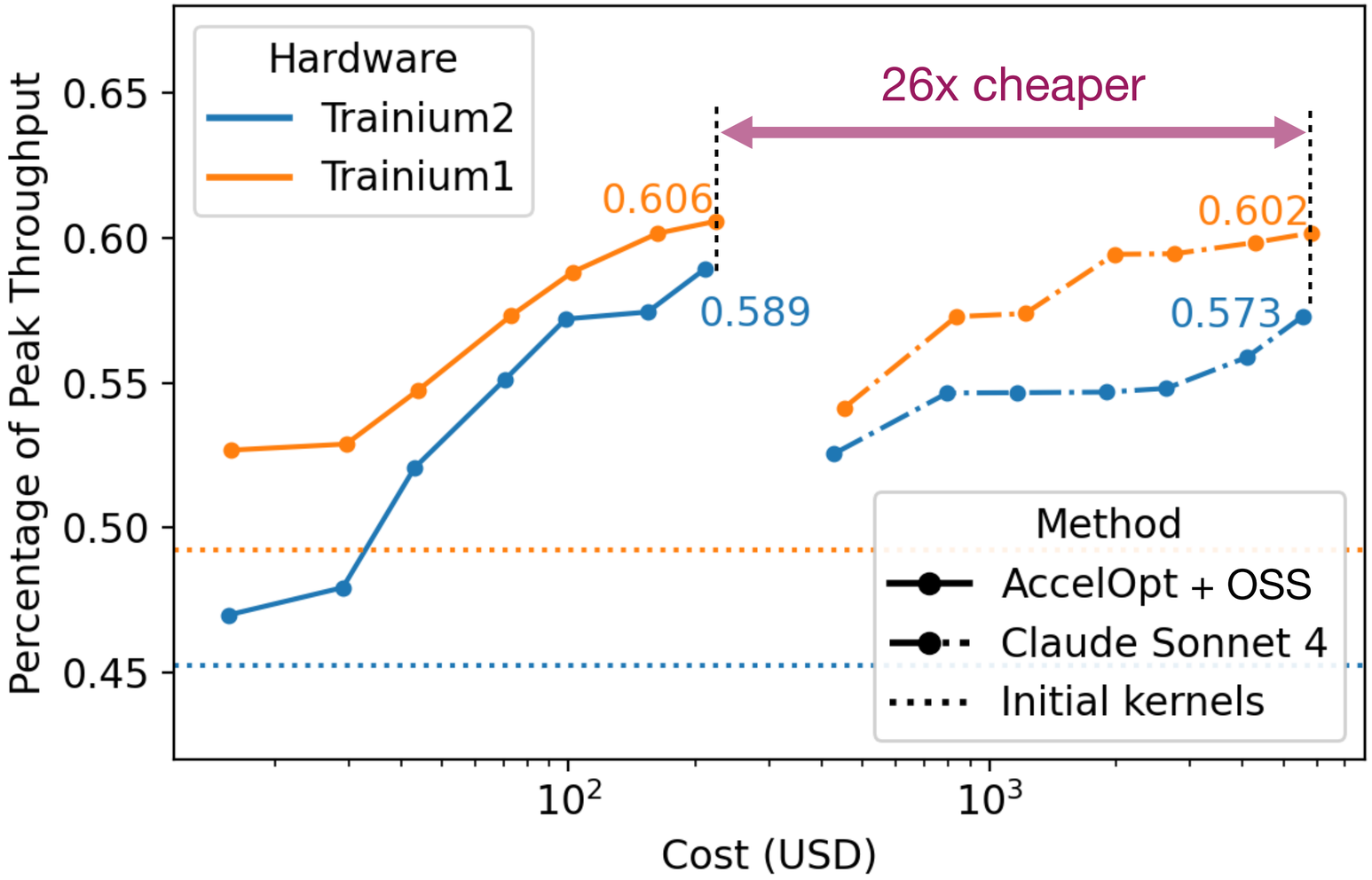

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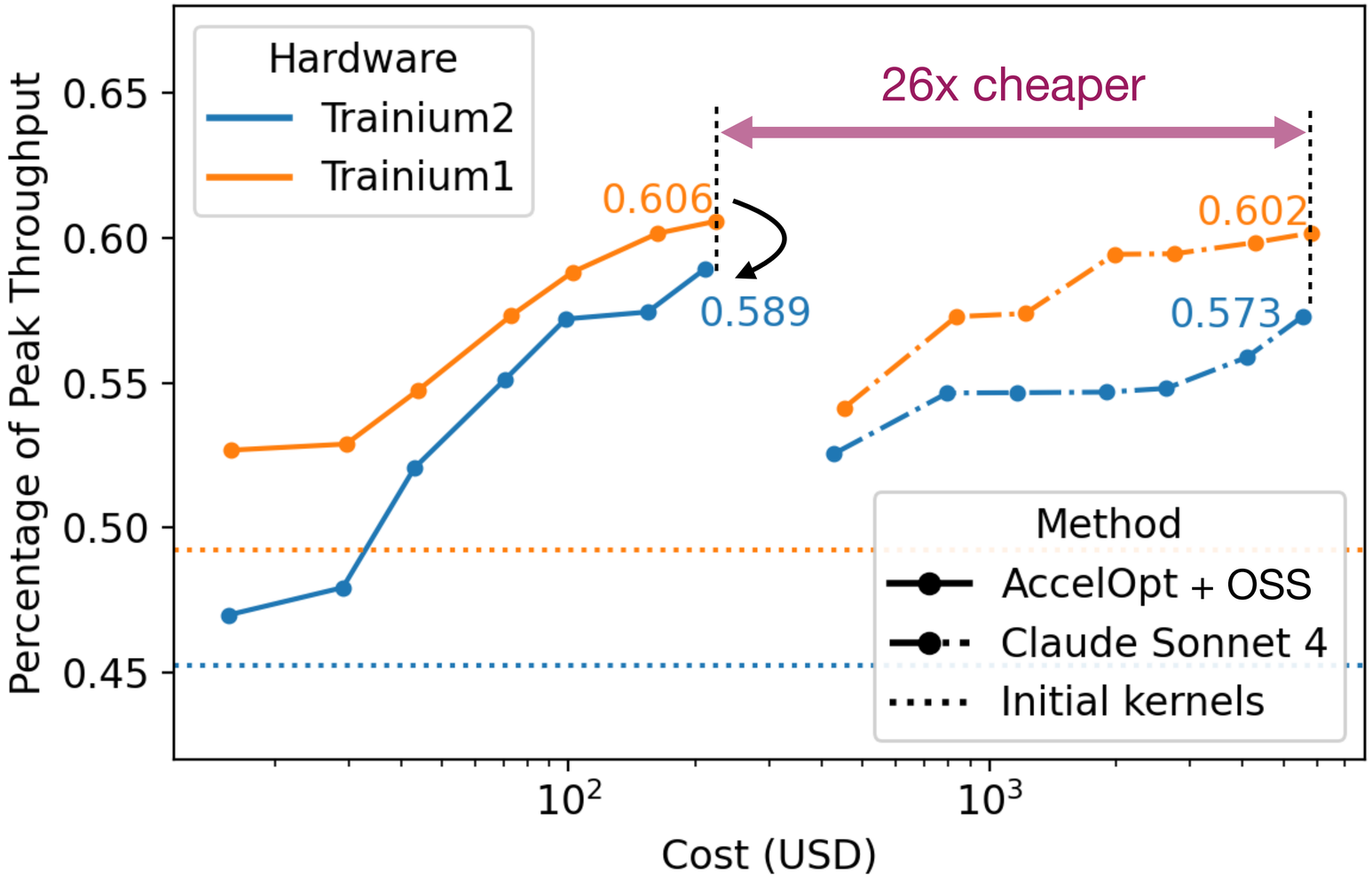

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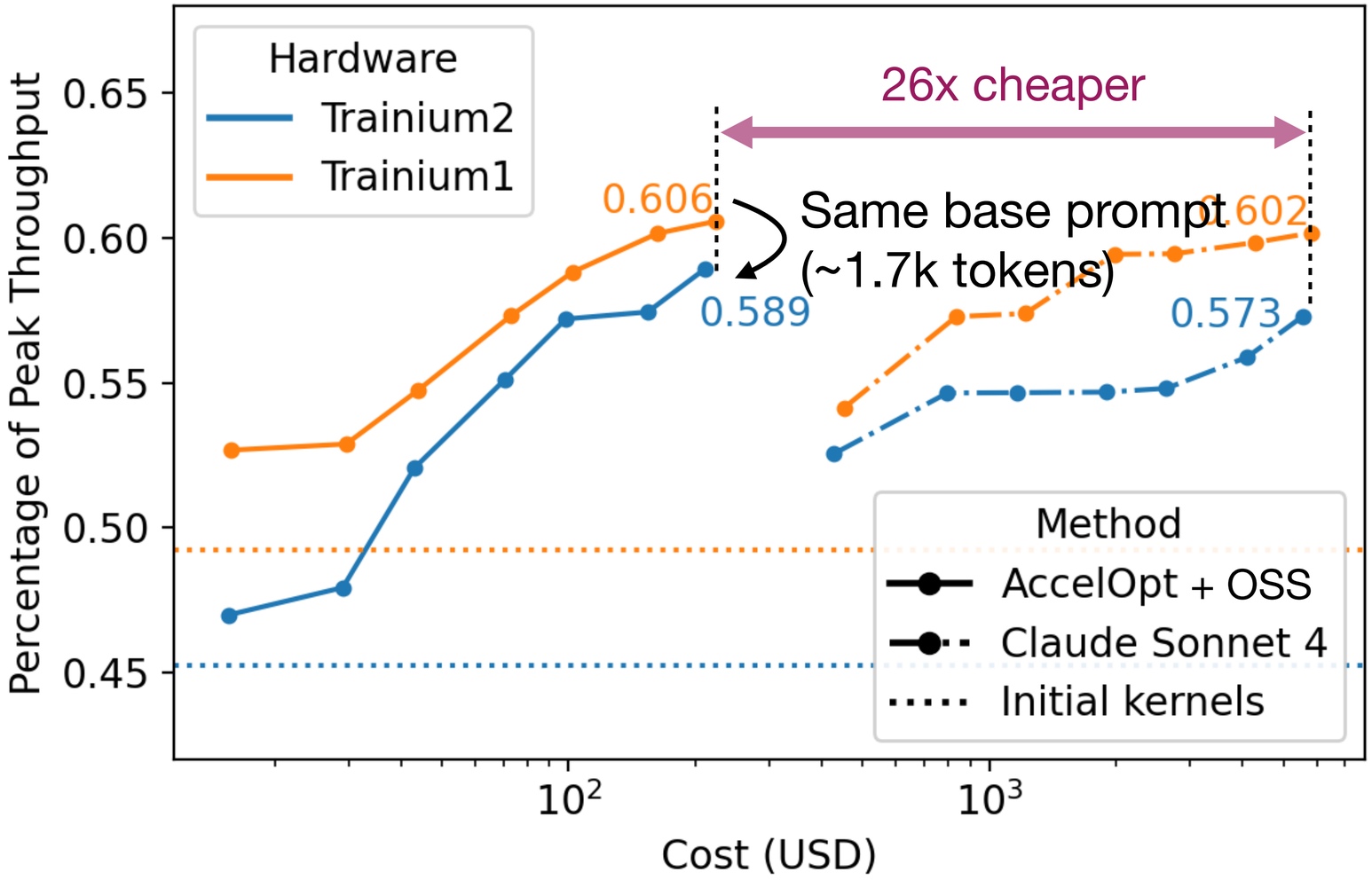

AccelOpt can be applied to any AI accelerator

Operator: Paged Grouped Query Attention on H100
Performance baseline: FlashInfer v0.5.3

Workload*	Best Triton baseline Flashinfer-Bench	AccelOpt + Gemini 3 Flash
Qwen3-30B-A3B Decode	0.26x	**1.50x**
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Qwen3-30B-A3B Prefill	0.12x	**1.38x**
Llama-3.1-8B Prefill	0.04x	0.10x

Ye Z., et al. Flashinfer: Efficient and customizable attention engine for llm inference serving *MLSys 2025*
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AccelOpt/samples/fib

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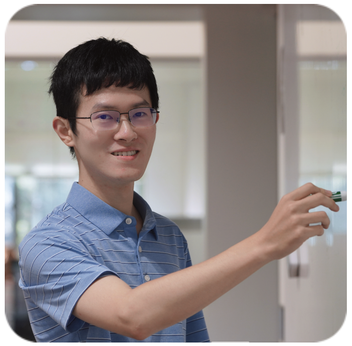
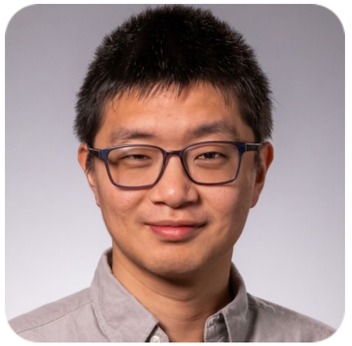
Collaborators

Genghan Zhang

Shaowei Zhu



Anjiang Wei



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UNIVERSITY OF TORONTO

AccelOpt: A Self-improving LLM Agentic System for AI Accelerator Kernel Optimization

stanford-ppl/AccelOpt

Genghan/NKIBench

zhang677/AccelOpt

AccelOpt: A Self-improving LLM Agentic System for AI Accelerator Kernel Optimization

1. Combining beam search with optimization memory, AccelOpt enables LLM agents to autonomously optimize real-world Trainium kernels in NKIBench, our curated NKI kernel environment, without requiring expert optimization knowledge.

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2. With AccelOpt, open-source models can achieve higher cost efficiency than leading proprietary coding models for kernel optimization.

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3. AccelOpt and NKIBench provide a promising foundation for automated kernel optimization on emerging AI accelerators.

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