

RoboGPU

Accelerating GPU Collision Detection for Robotics

Lufei Liu, Liwei Xue, Yuan Hsi Chou, Jocelyn Zhao, Lara Kawasme, Youssef Mohammed, Tor M. Aamodt

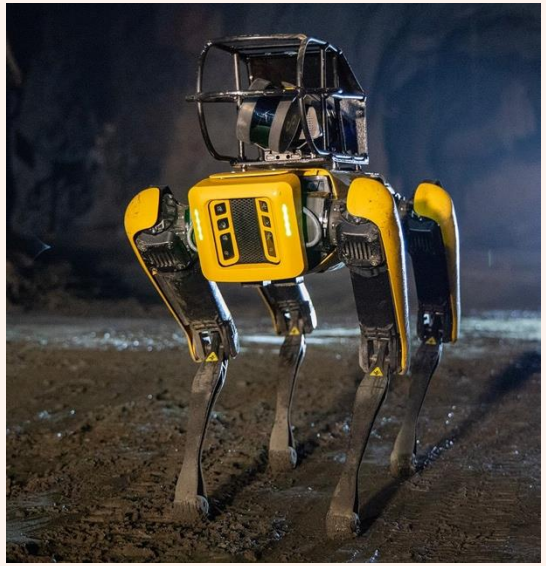


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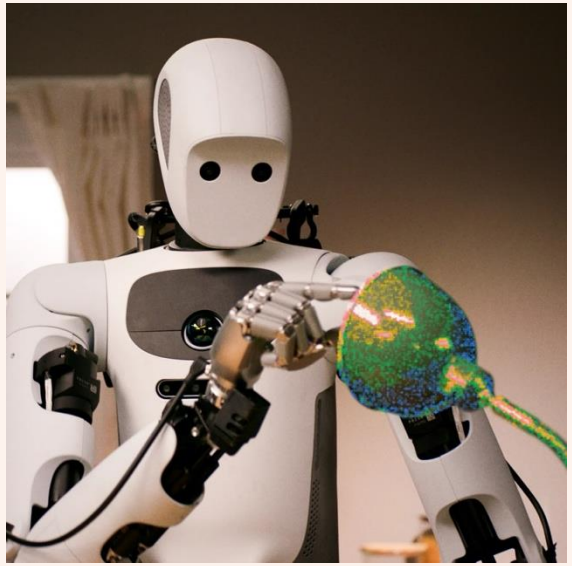
Robotics in the World

Powered by AI

"Robots succeed in only 12% of real household tasks, highlighting how far AI is from mastering the physical world." *– AI Index Report 2026*



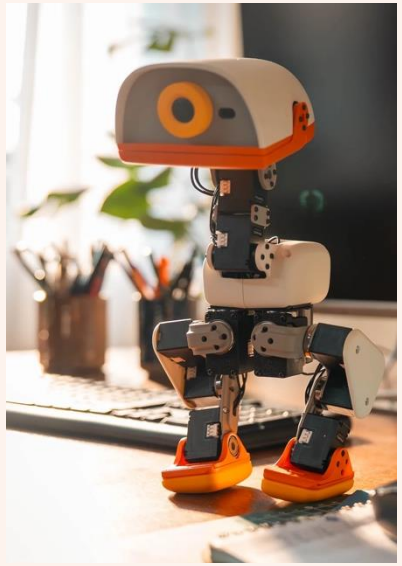
https://bostondynamics.com /products/spot/



https://deepmind.google/ models/gemini-robotics

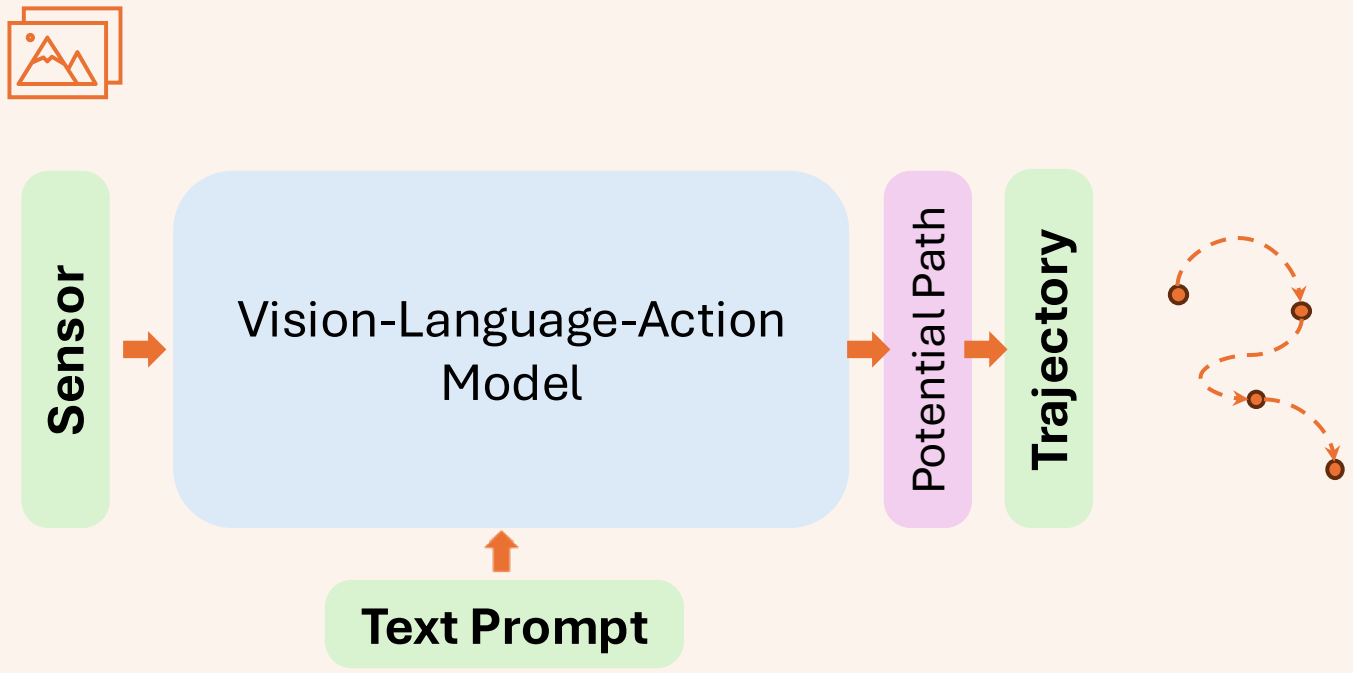


https://waymo.com/blog/shorts/ silver-ojai/



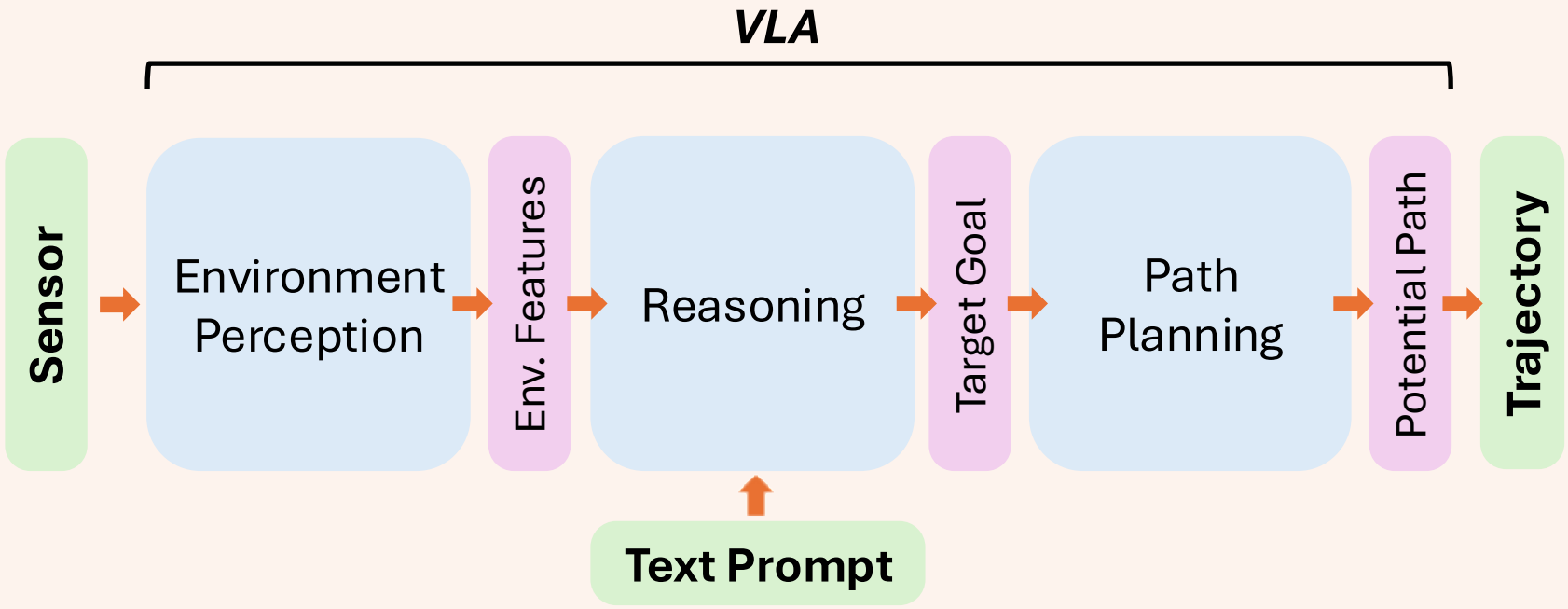
https://pollen-robotics.com/microduck/

Neural Planning in Robotics



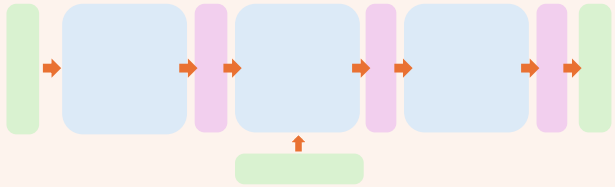
“pick up this object and place it on the table”

Neural Planning in Robotics



Neural Planning in Robotics

Neural Planners



- Generalize across environments
- Fast planning with high success rates
- Re-plan in real-time
- **No explicit collision checks**

Collision Rates

MπNet [1]
MLP-based
Cubby **14%**
Tabletop **18%**

MπFormer [2]
Transformer-based
Cubby **6%**
Tabletop **11%**

HDP [3]
Diffusion-based
Reach Target **6%**

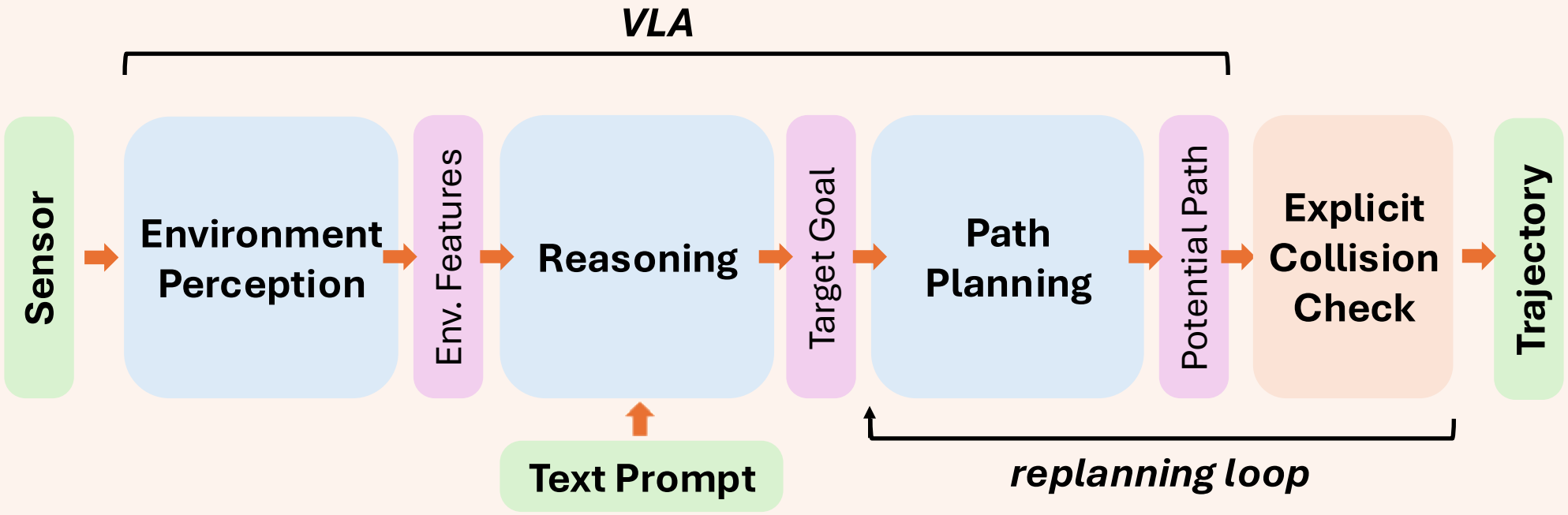
AvoidEverything [2]
Trained to avoid collisions
Cubby **3%**
Tabletop **4%**

[1] A. Fishman, A. Murali, C. Eppner, B. Peele, B. Boots, and D. Fox, "Motion policy networks," in CoRL, 2022.

[2] A. Fishman, A. Walsman, M. Bhardwaj, W. Yuan, B. Sundaralingam, B. Boots, and D. Fox, "Avoid everything: Model-free collision avoidance with expert-guided fine-tuning," in CoRL, 2024.

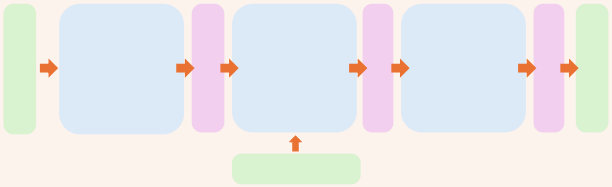
[3] X. Ma, S. Patidar, I. Haughton, and S. James, "Hierarchical diffusion policy for kinematics-aware multi-task robotic manipulation," in CVPR, 2024

Neural Planning in Robotics



RoboGPU

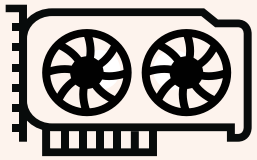
Neural Planners



Bad at avoiding collisions

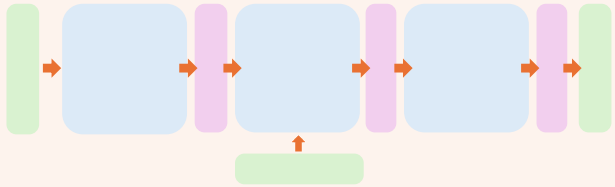
Explicit Collision Check

GPU



RoboGPU

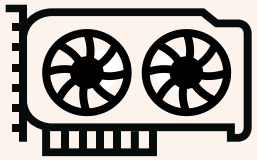
Neural Planners



+

Explicit Collision Check

GPU



Bad at irregular workloads

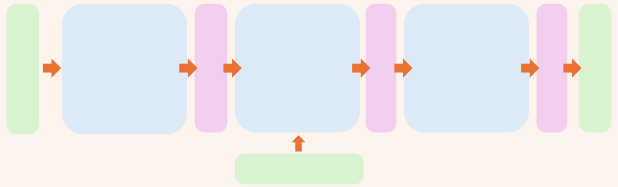
Ray Tracing Accelerator



Good at ray tracing (an irregular workload)

RoboGPU

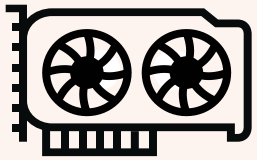
Neural Planners



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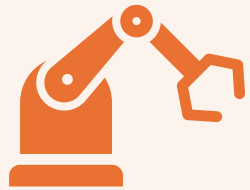
Explicit Collision Check

GPU



Bad at irregular workloads

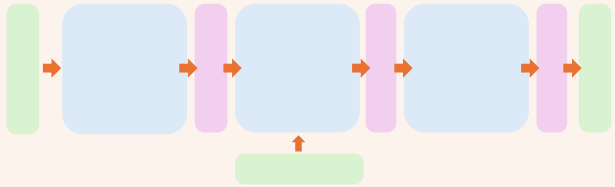
RoboCore



Robotics

RoboGPU

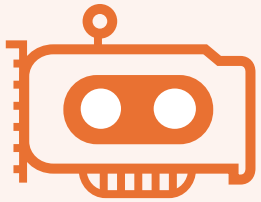
Neural Planners



+

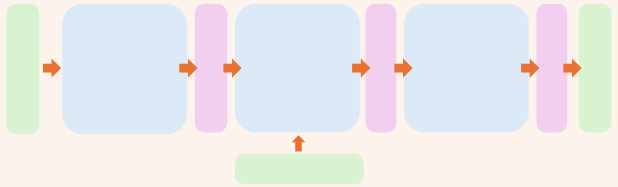
Explicit Collision Check

RoboGPU



RoboGPU

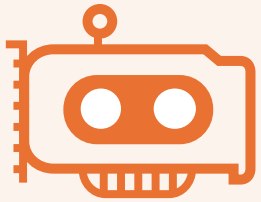
Neural Planners



+

Explicit Collision Check

RoboGPU

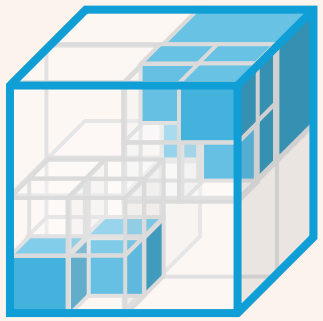


- Safety Conscious
- Latency Sensitive
- Diverse Workload
- Quickly Evolving

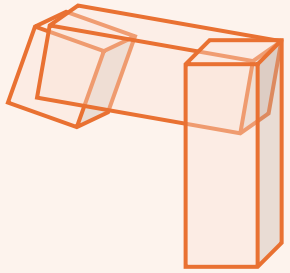
Design Goals

1. Accelerate collision detection
2. Generalize well to other robotics tasks

Collision Detection

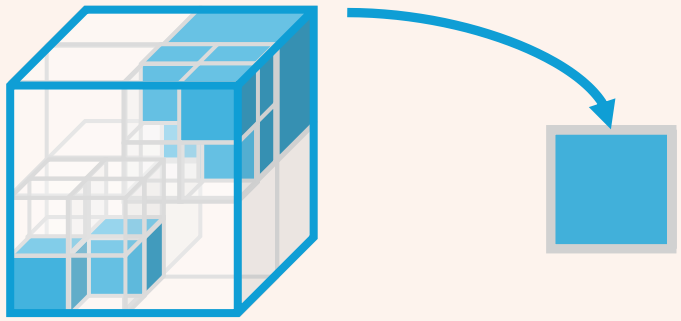


Environment Octree
(AABBs)



Robot Bounding Boxes
(OBBs)

Collision Detection

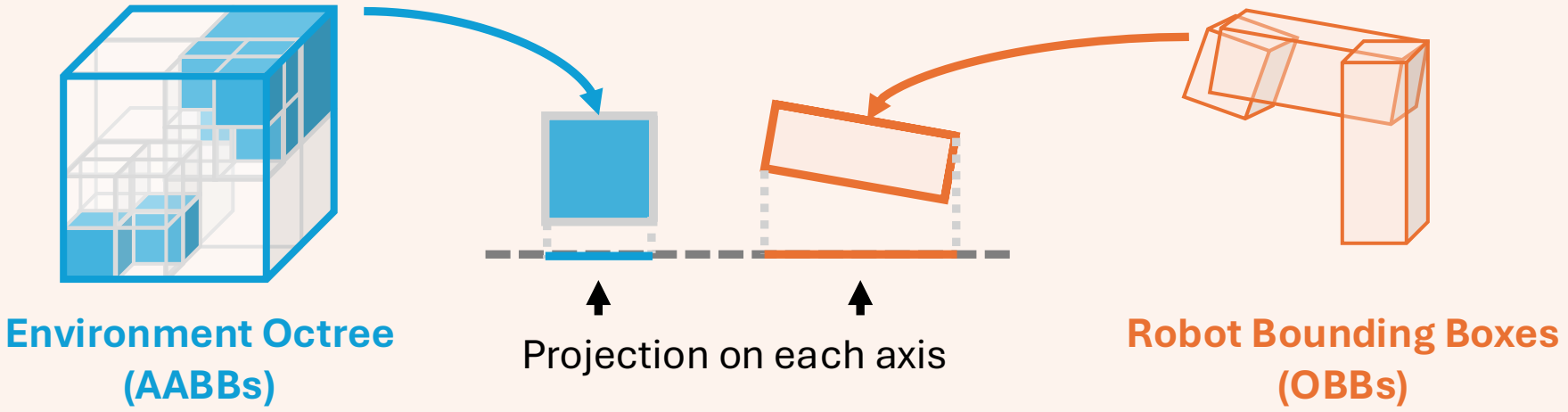


Environment Octree
(AABBs)

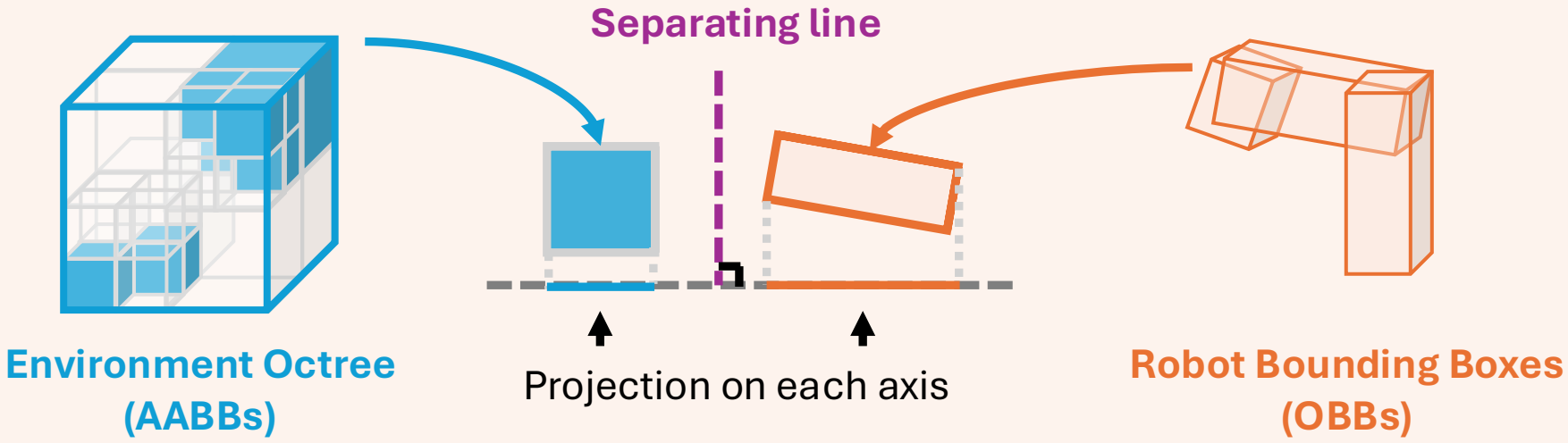


Robot Bounding Boxes
(OBBs)

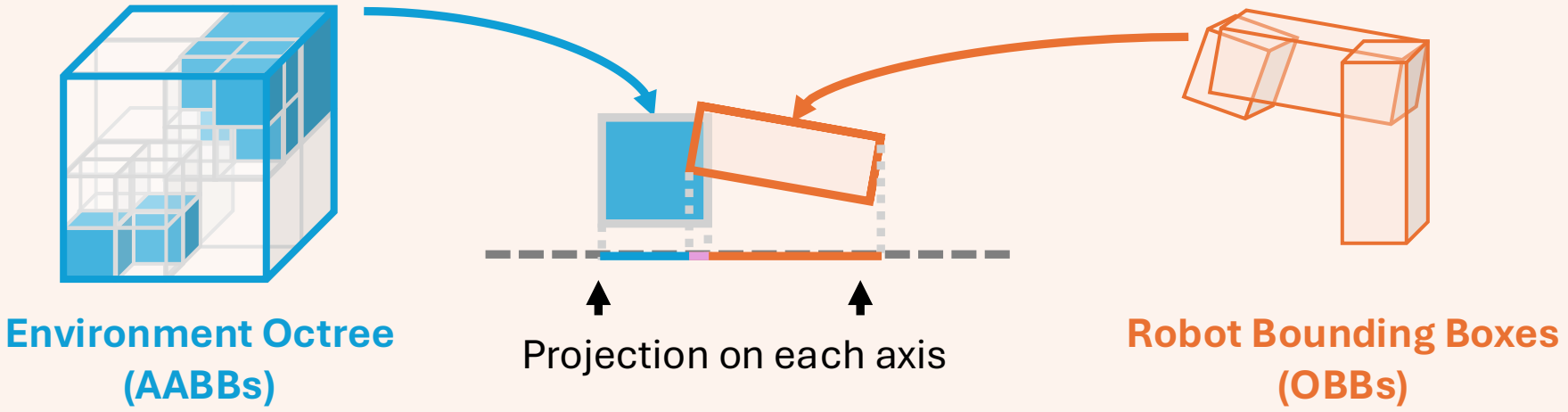
Collision Detection



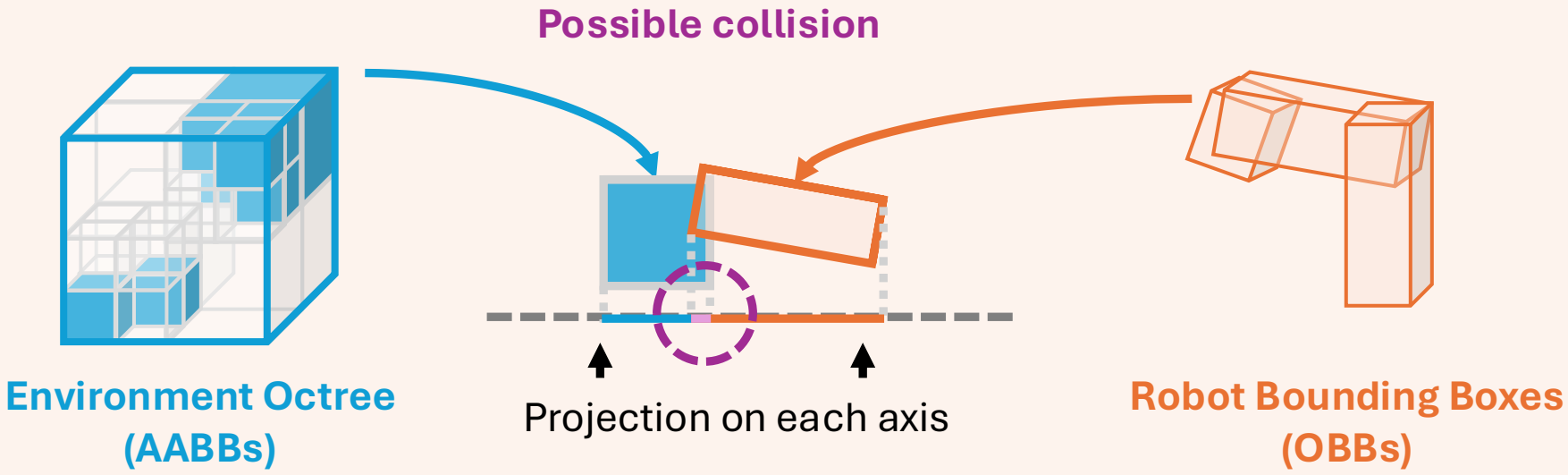
Collision Detection



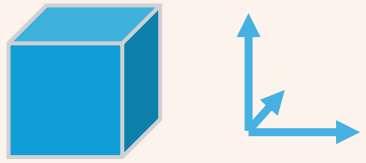
Collision Detection



Collision Detection



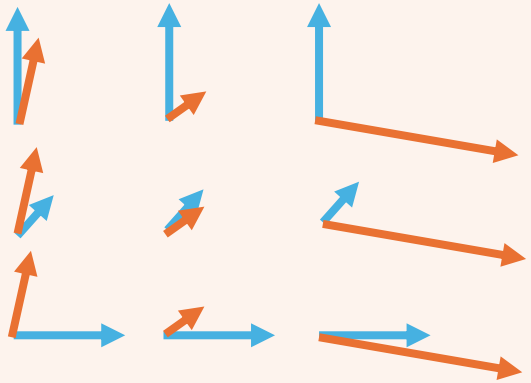
Collision Detection



Project to **3** AABB axes



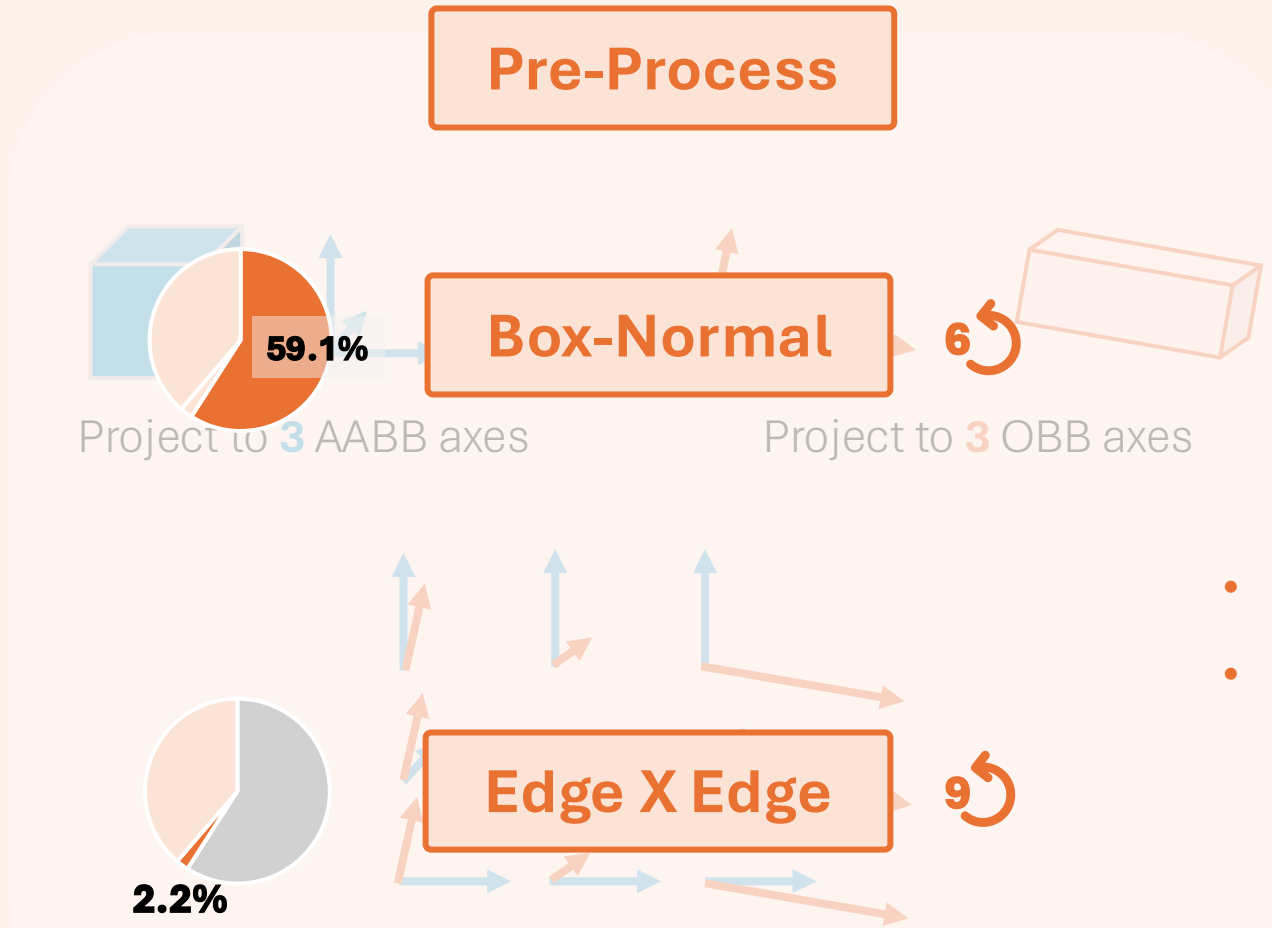
Project to **3** OBB axes



Project to **9** cross-product axes

RoboGPU: Accelerating GPU Collision Detection for Robotics

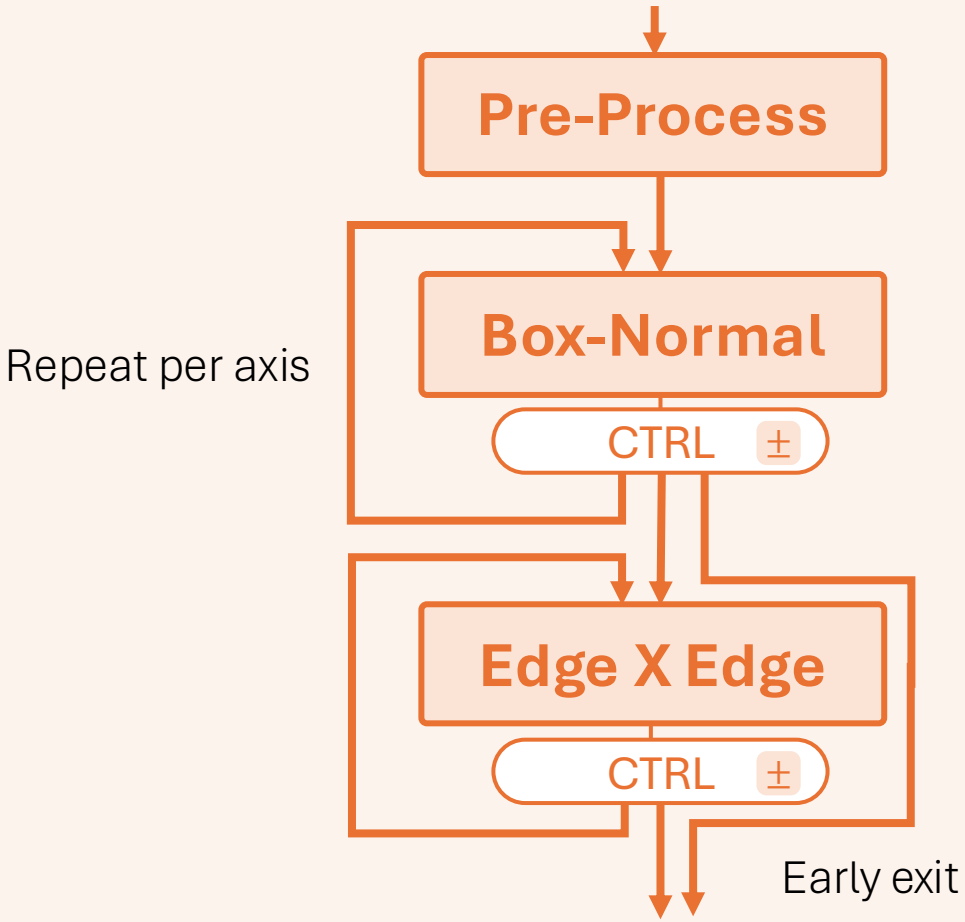
Collision Detection



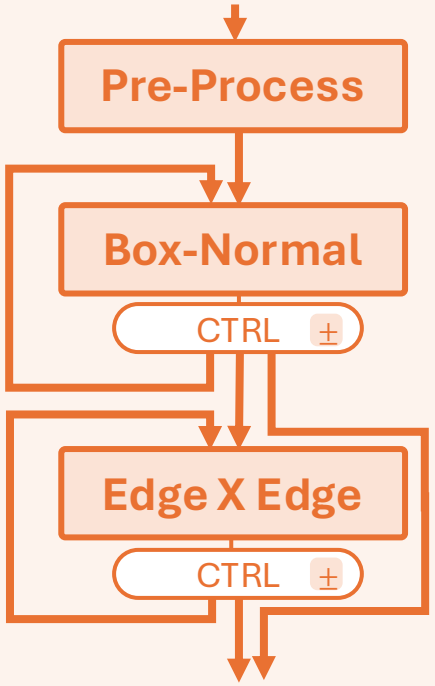
- Repeated operations
- Early exit opportunities

RoboGPU: Accelerating GPU Collision Detection for Robotics

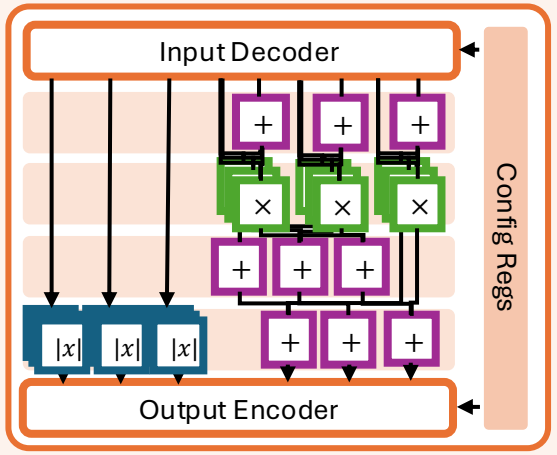
RoboCore Design



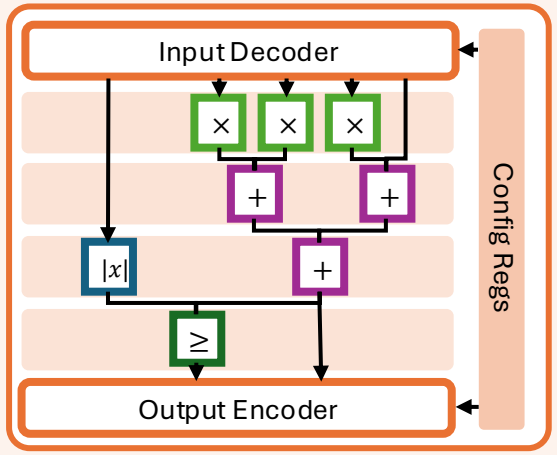
RoboCore Design



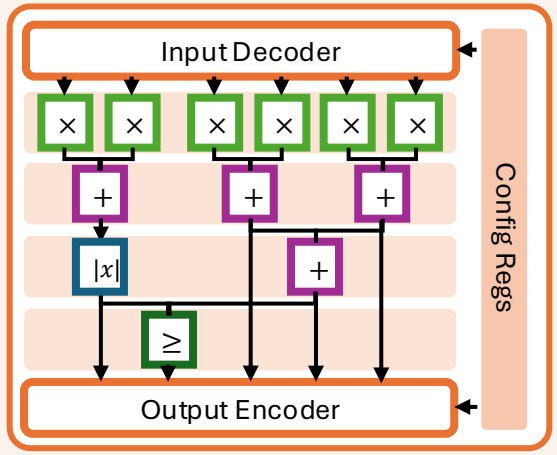
Pre-Process



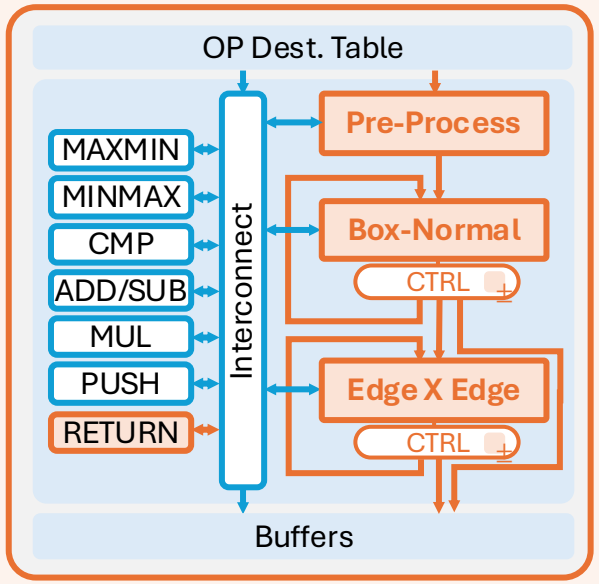
Box-Normal



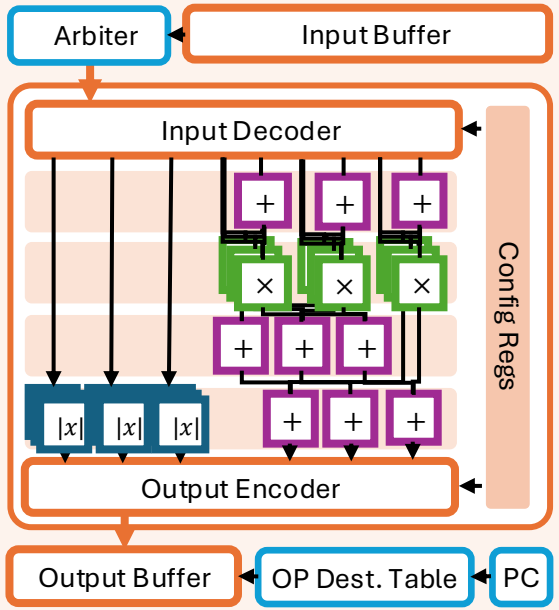
Edge X Edge



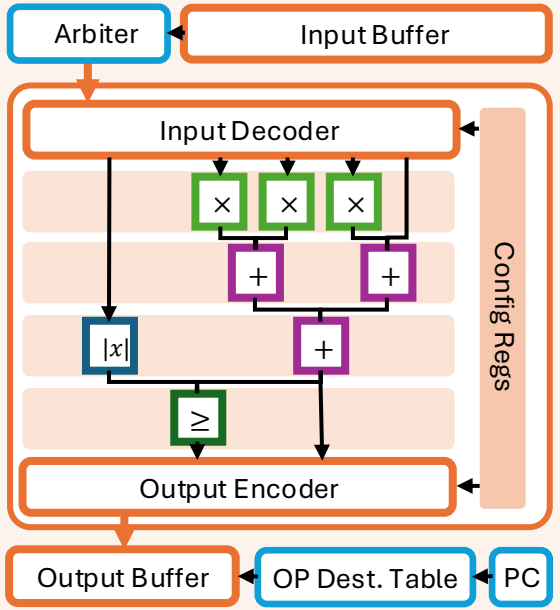
RoboCore Design



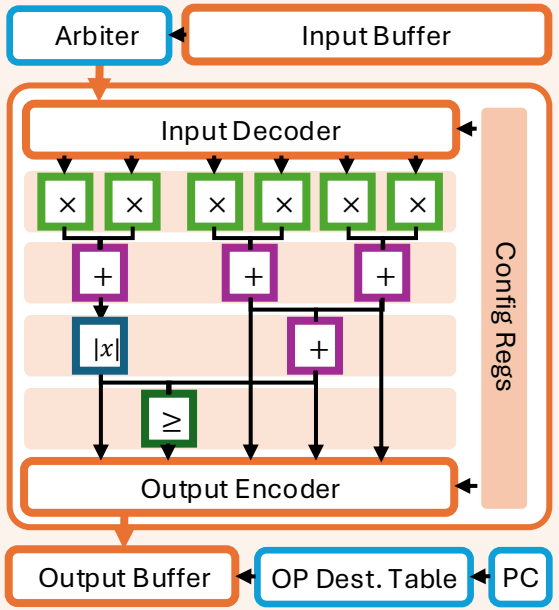
Pre-Process



Box-Normal



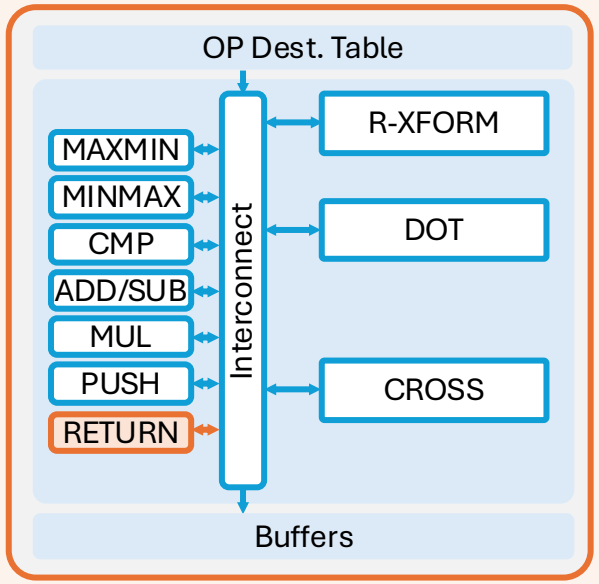
Edge X Edge

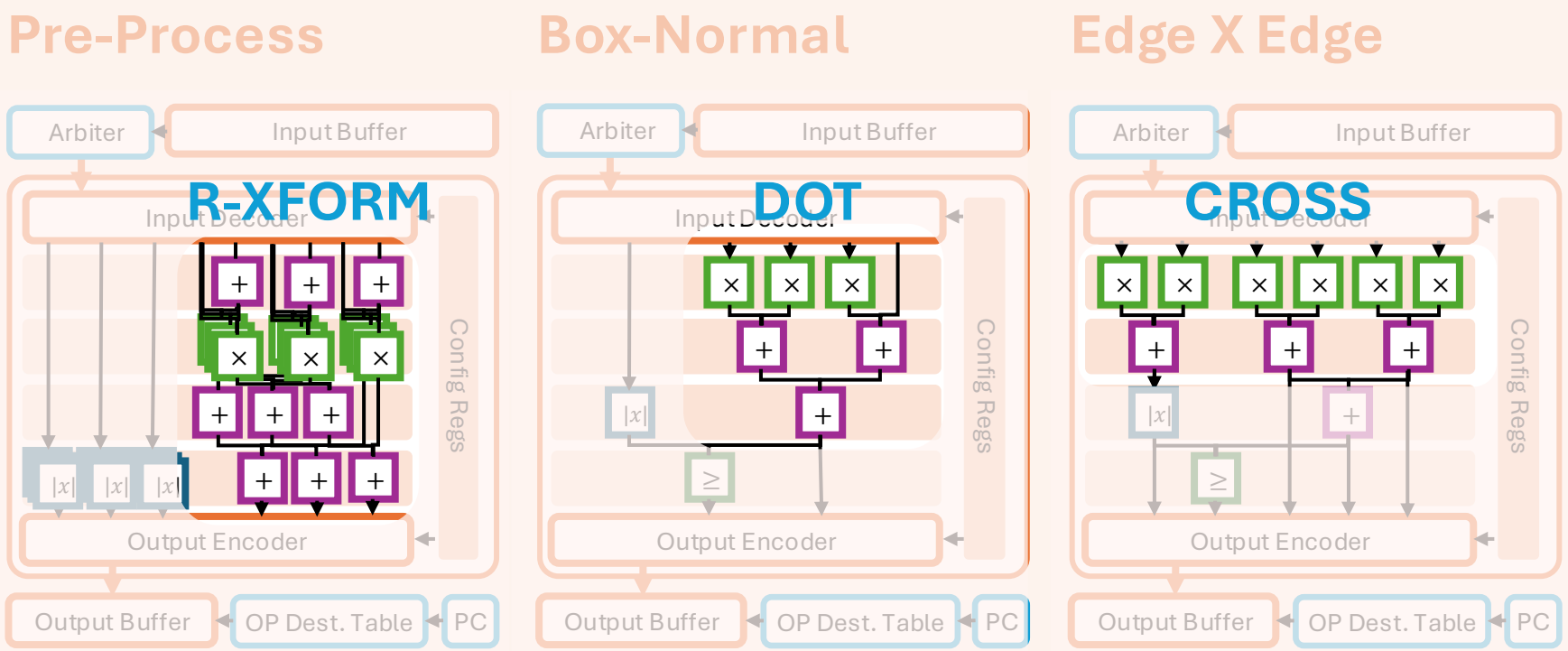


Designed as OP units to fit into the TTA+ [4] architecture

[4] D. Ha, L. Liu, Y. H. Chou, S. Go, W. W. Ro, H.-W. Tseng, and T. M. Aamodt, "**Generalizing ray tracing accelerators for tree traversals on GPUs**," in MICRO, 2024.

RoboCore Design

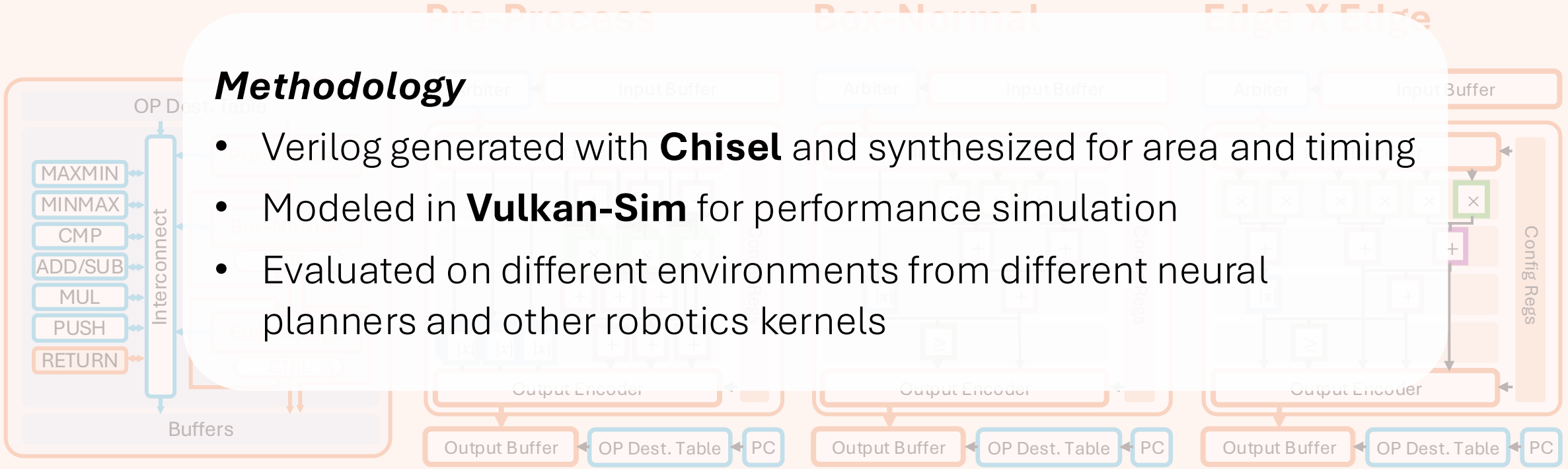




Dual function as TTA+ [4] operations for generalized programming

[4] D. Ha, L. Liu, Y. H. Chou, S. Go, W. W. Ro, H.-W. Tseng, and T. M. Aamodt, "**Generalizing ray tracing accelerators for tree traversals on GPUs**," in MICRO, 2024.

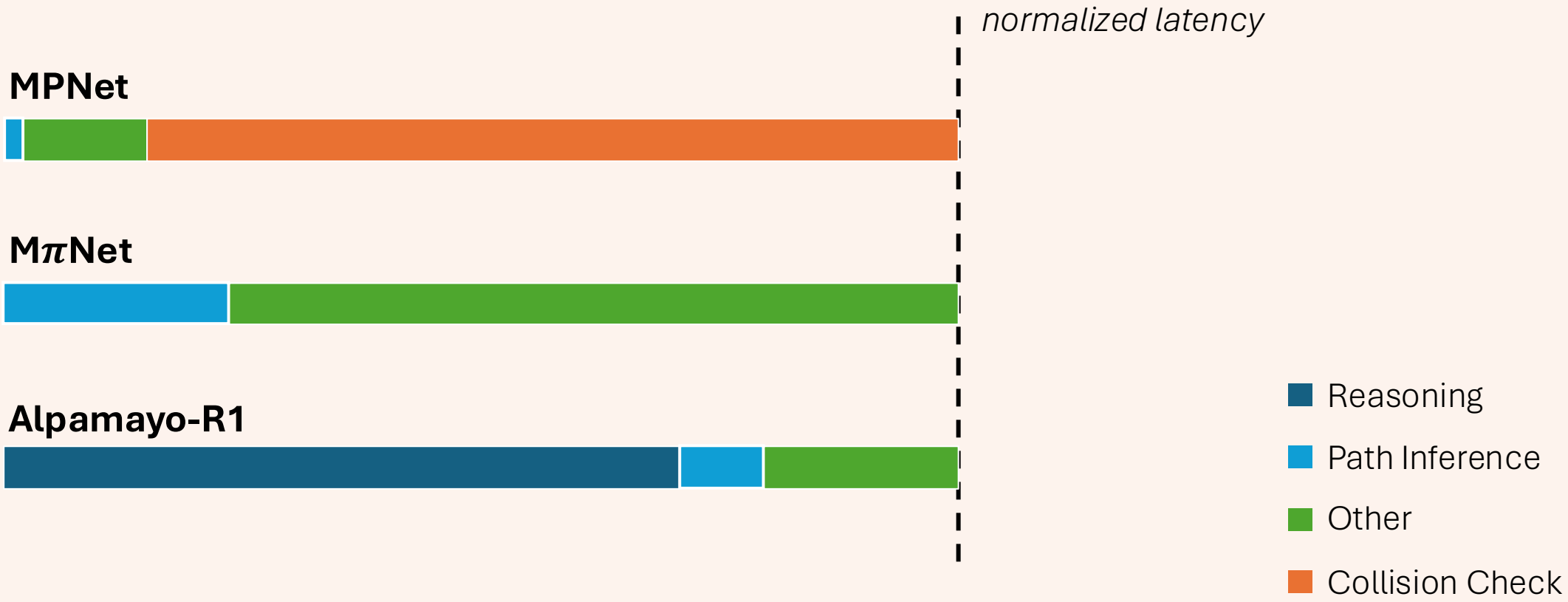
RoboCore Design



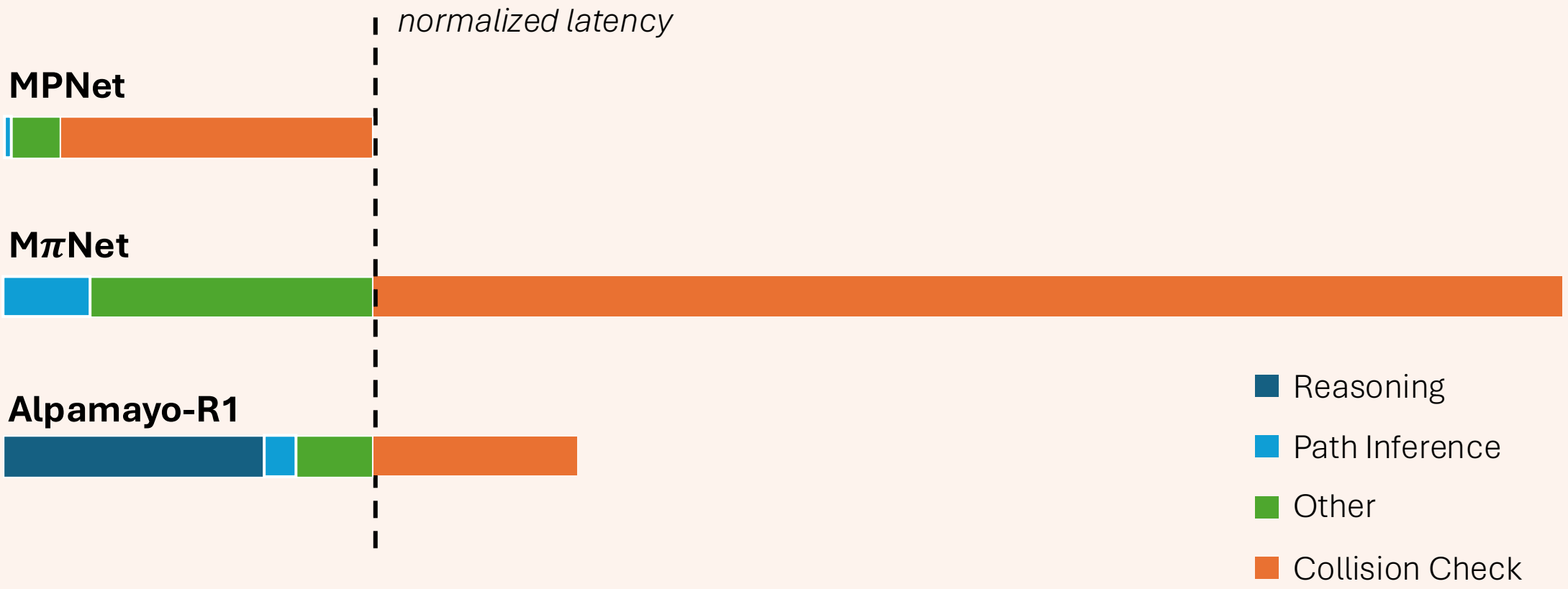
Methodology

- Verilog generated with **Chisel** and synthesized for area and timing
- Modeled in **Vulkan-Sim** for performance simulation
- Evaluated on different environments from different neural planners and other robotics kernels

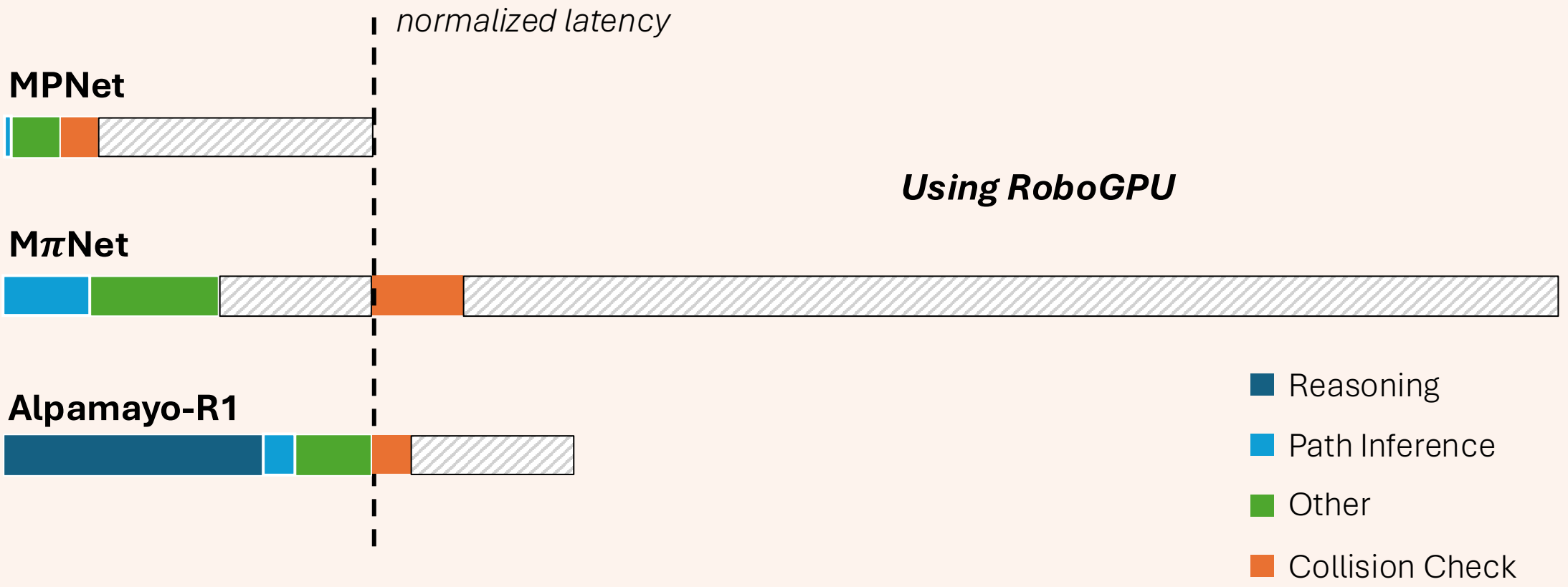
Results


normalized latency
MPNet
MπNet
Alpamayo-R1
Reasoning
Path Inference
Other
Collision Check

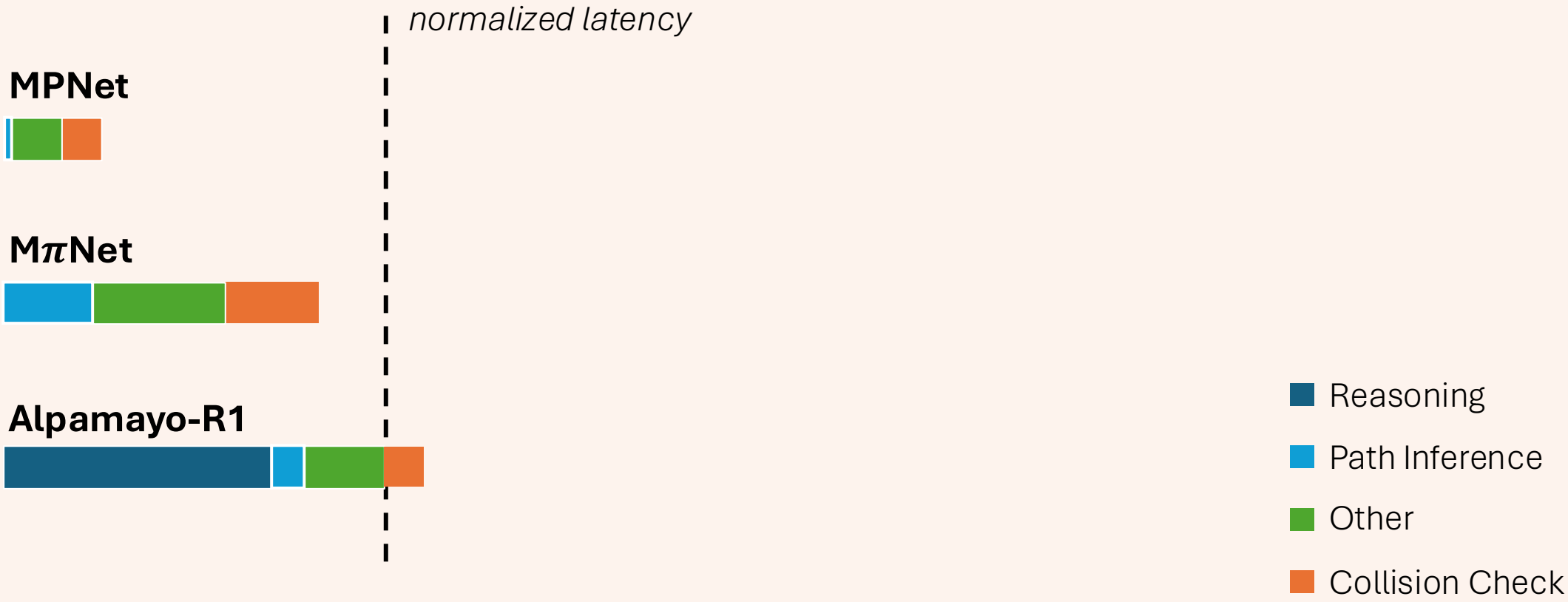
Results


normalized latency
MPNet
MπNet
Alpamayo-R1
Reasoning
Path Inference
Other
Collision Check

Results


normalized latency
MPNet
Using RoboGPU
MπNet
Alpamayo-R1
Reasoning
Path Inference
Other
Collision Check

Results


normalized latency
MPNet
MπNet
Alpamayo-R1
Reasoning
Path Inference
Other
Collision Check

Results

MPNet



8.2x faster collision detection

MπNet



1.3x end-to-end speedup *with up to* ***18% reduced collisions***

Alpamayo-R1



faster replanning

More Information

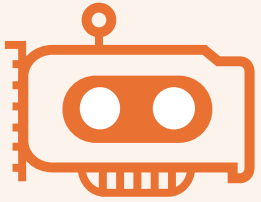
Read our paper for...

- *Details on early-exit architecture*
- *General robotics workloads support*
- *Point cloud processing and classical robotics algorithm results*
- *Area and energy analysis*
- *Comparison against other works*
- *Sensitivity study*
- ***and more!***

Thank You! *Questions?*

Visit our website for code and more!





RoboGPU

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Lufei Liu *liulufei@student.ubc.ca*