

An Accuracy Reconfigurable Vector Accelerator based on Approximate Logarithmic Multipliers

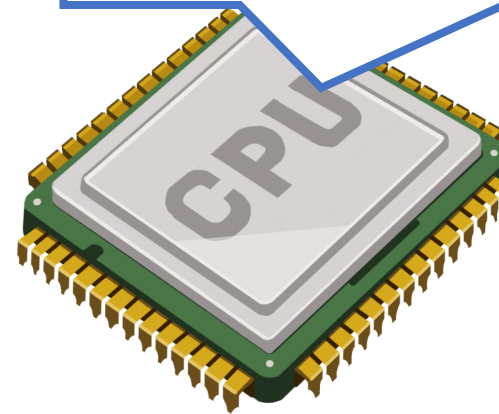
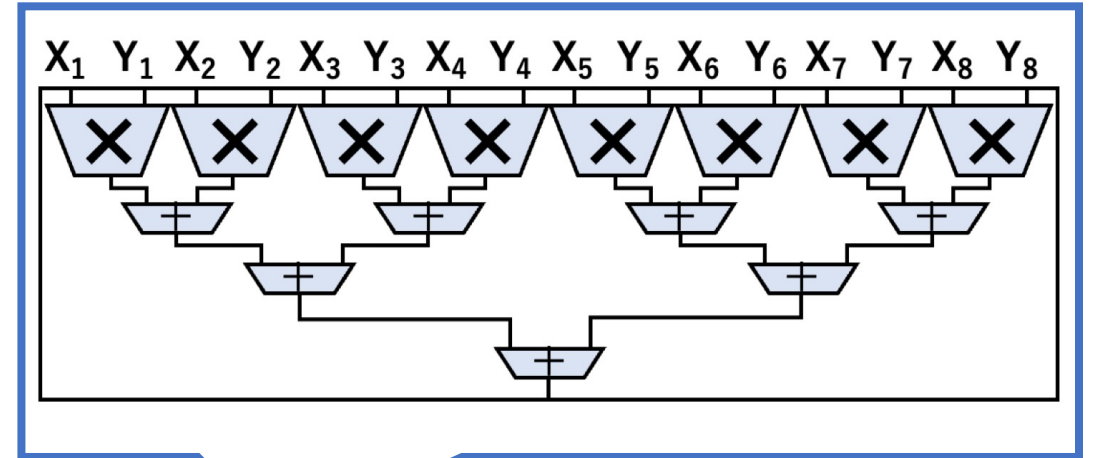
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{houlx, masuda, ishihara}@ertl.jp

Our Proposal:

A Low Average Energy & High Peak Accuracy Vector Multiply/Multiply-Accumulate Unit

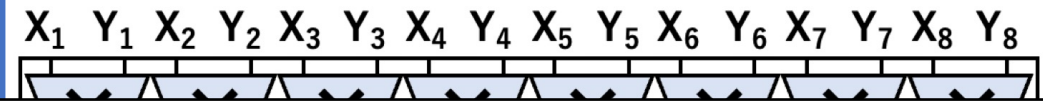
Introduction

- **Vector Multiplication Unit**
- **Conventional Multiplier**
 - Power-hungry
 - Area-expensive
- **Approximate Multiplier**
 - Smaller area
 - Higher speed
 - Effective for applications without high accuracy



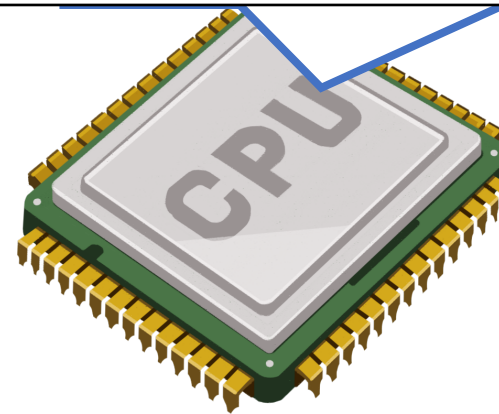
Introduction

- **Vector Multiplication Unit**



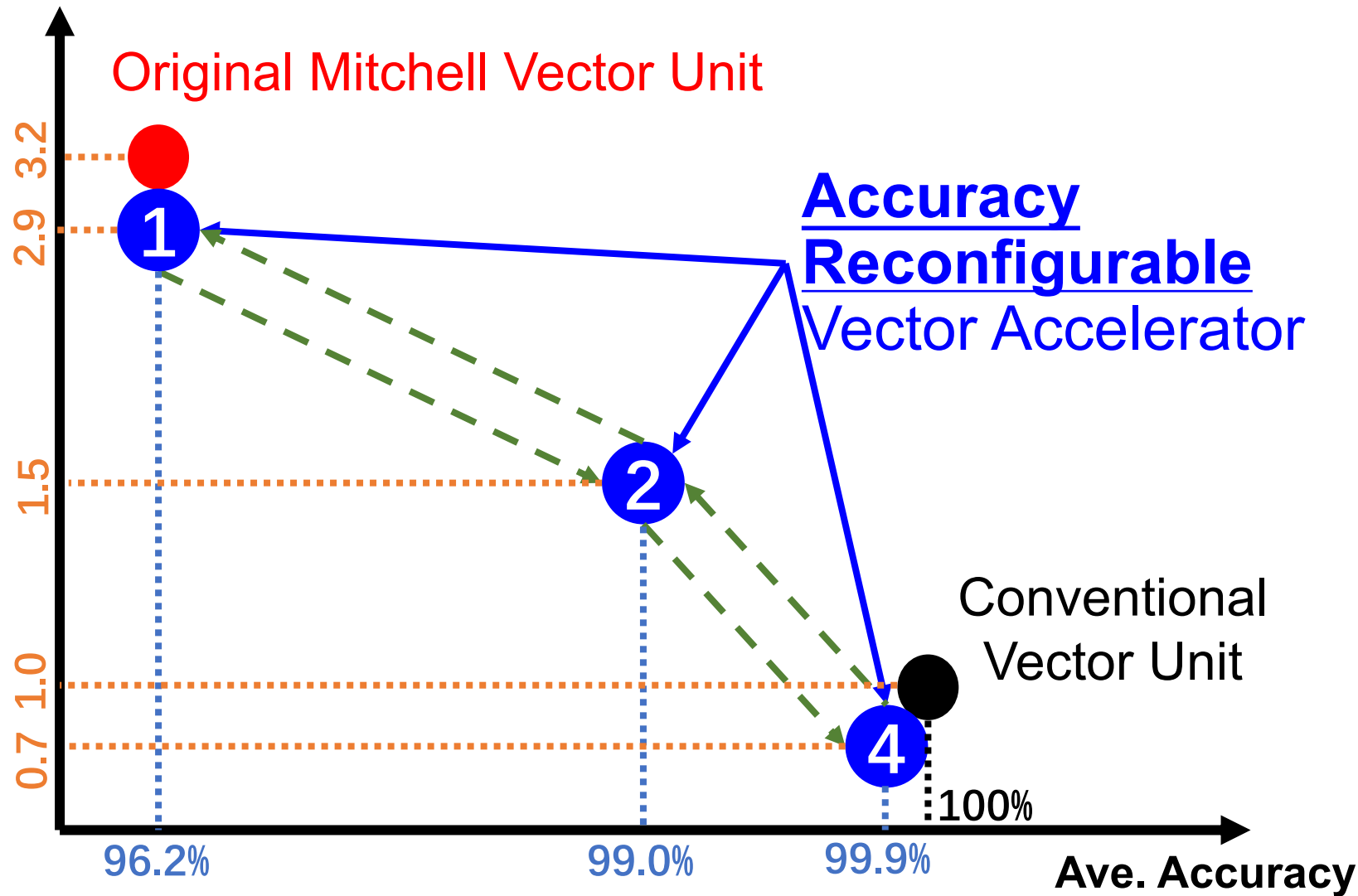
- **Approximate Multiplier**

- Smaller area
- Higher speed
- Effective for applications without high accuracy

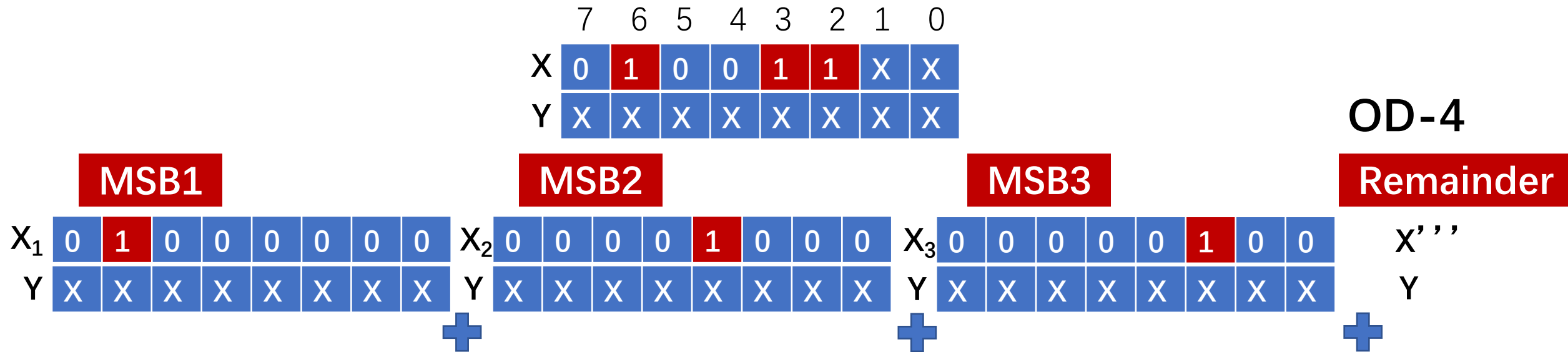
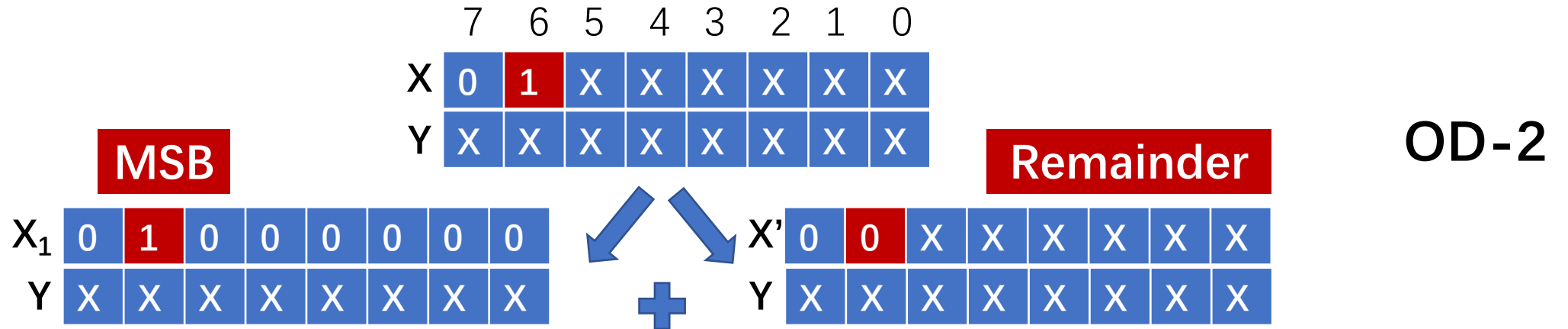


Conception

Parallelism/Area (Normalized Area-Efficiency)



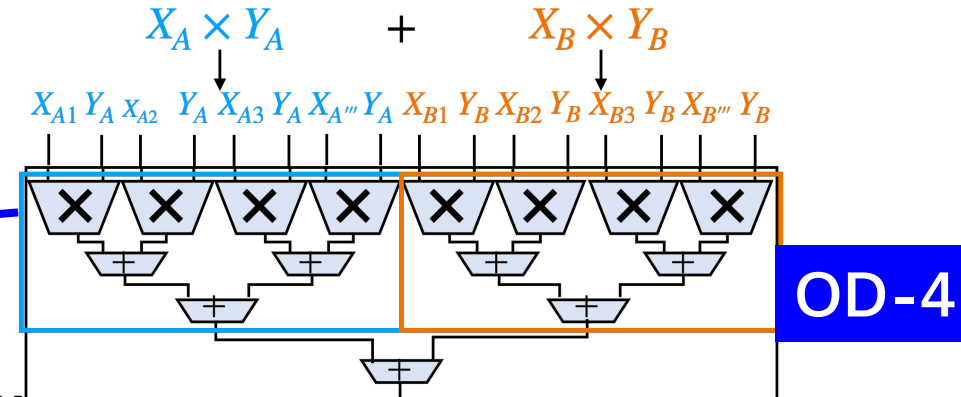
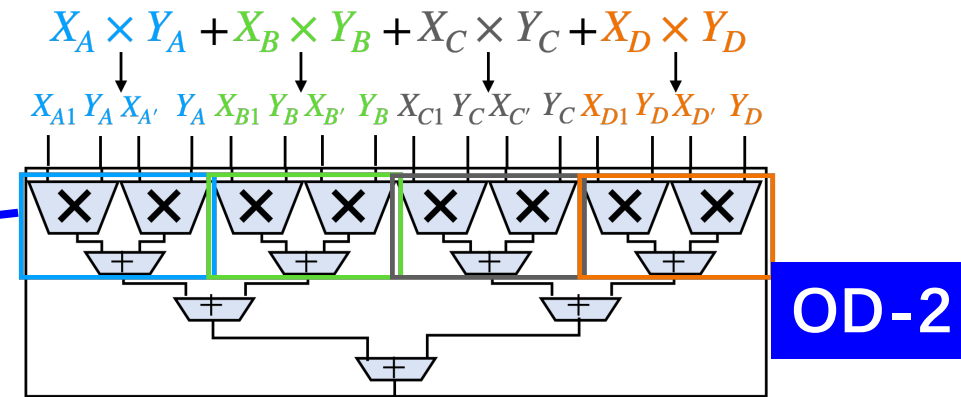
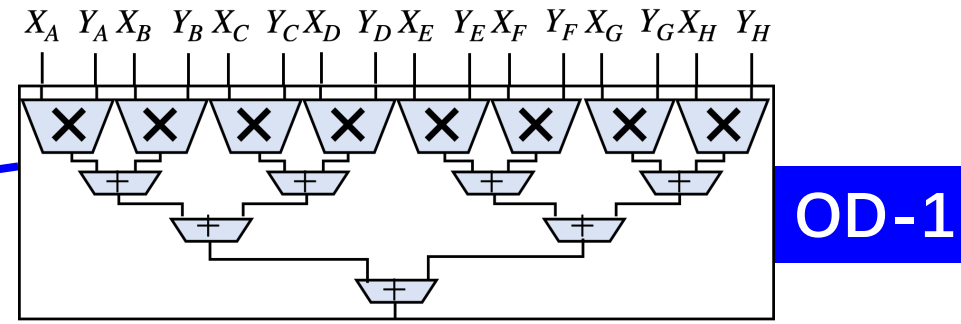
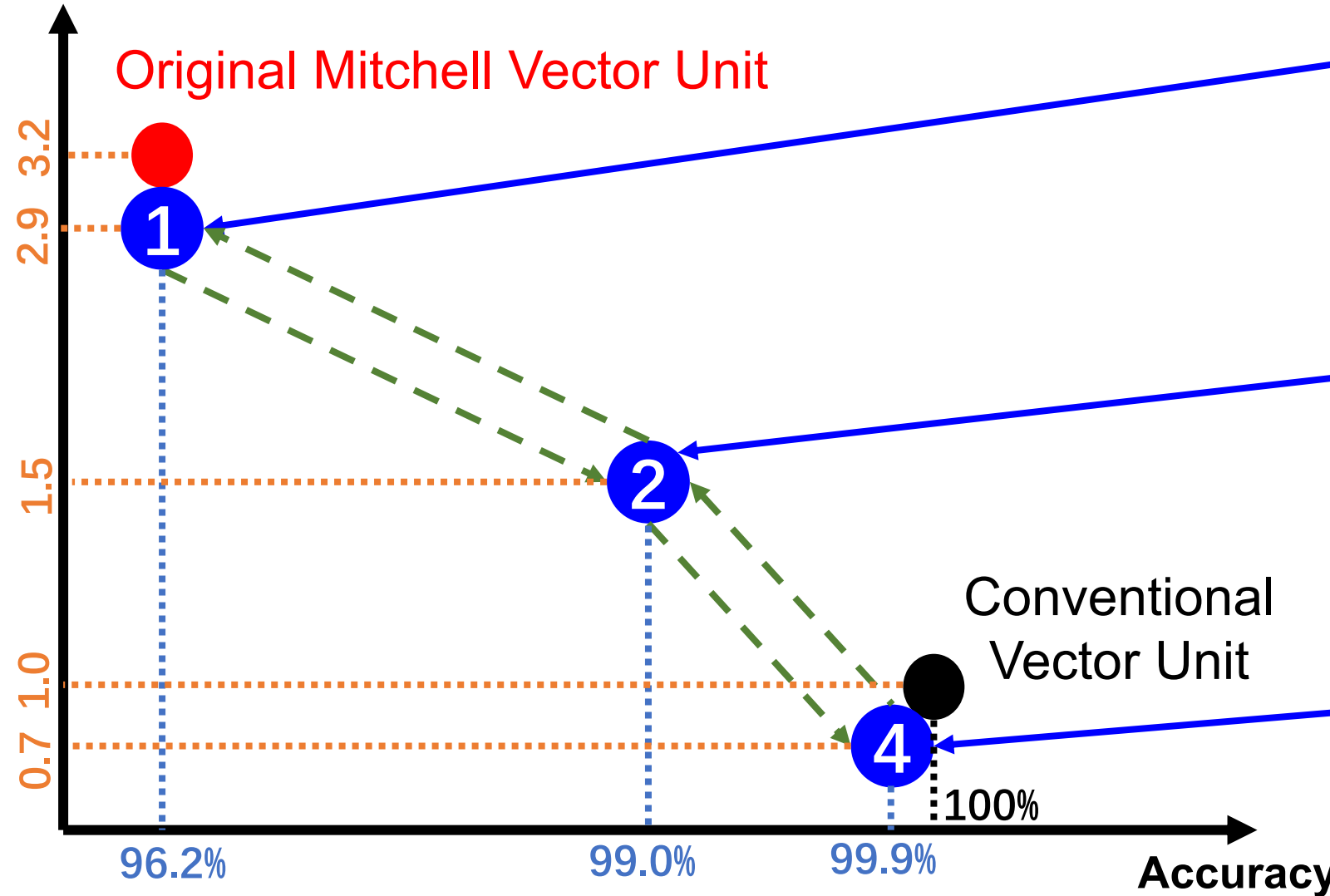
Proposed Novel Operand Decomposition (OD)



7D-3

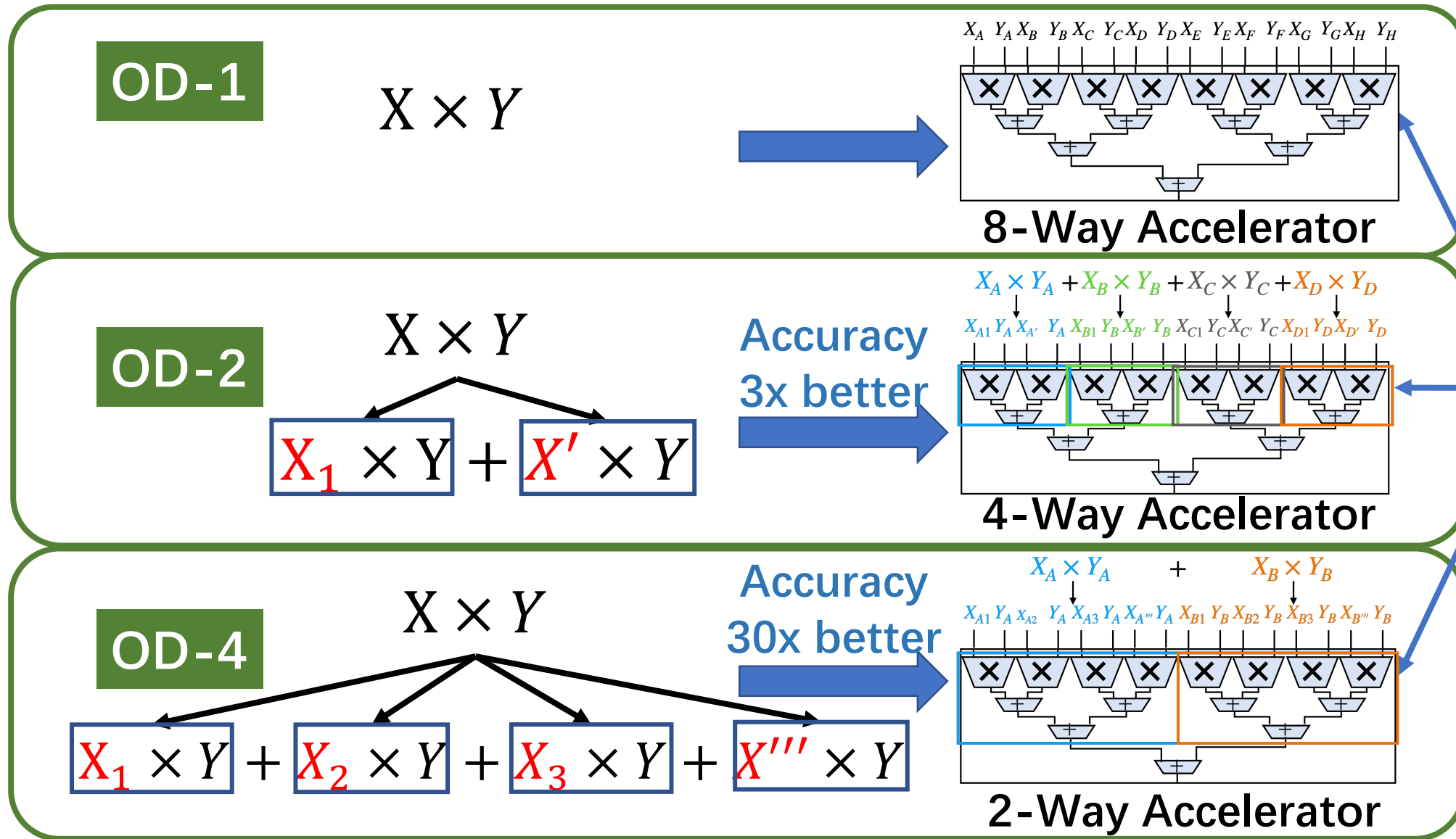
Conception

Parallelism/Area (Normalized Area-Efficiency)



Proposed Accuracy Reconfigurable Vector Accelerator

* \times is Approximate Multiplication



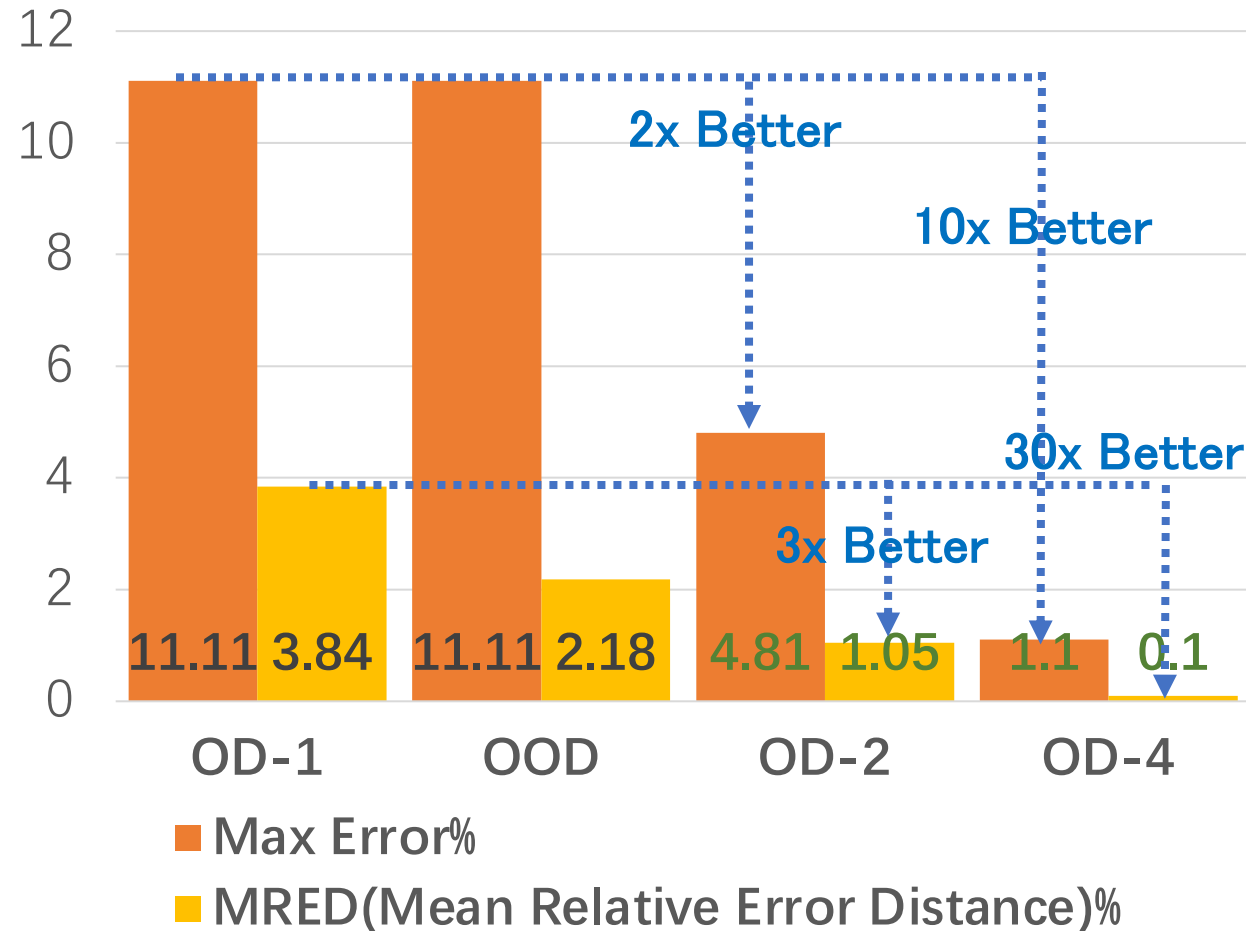
Reconfigure using Instruction Set Extension

7D-3

Evaluation

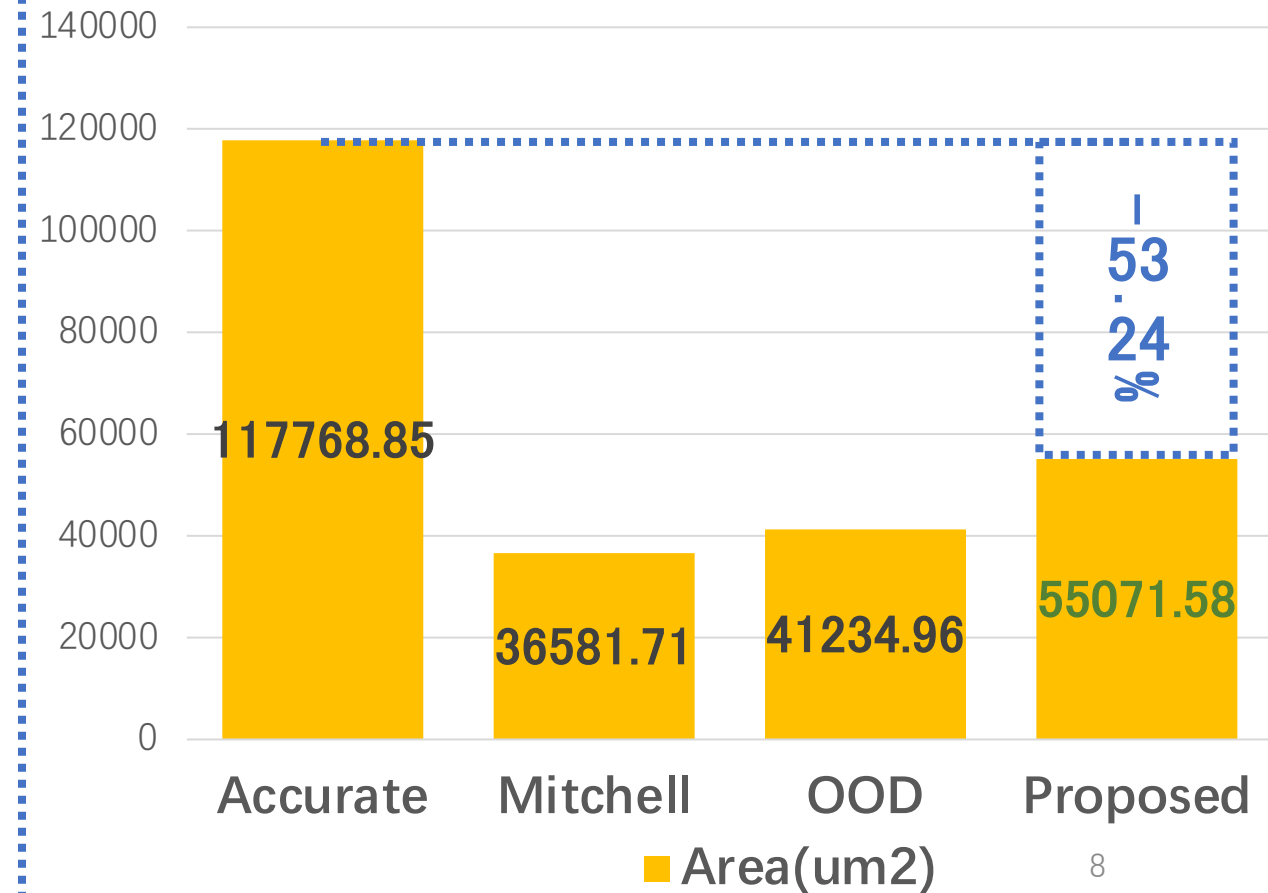
Accuracy: Max error & MRED
optimized at most 10x & 30x

Accuracy of 32-bit INT Multiplication



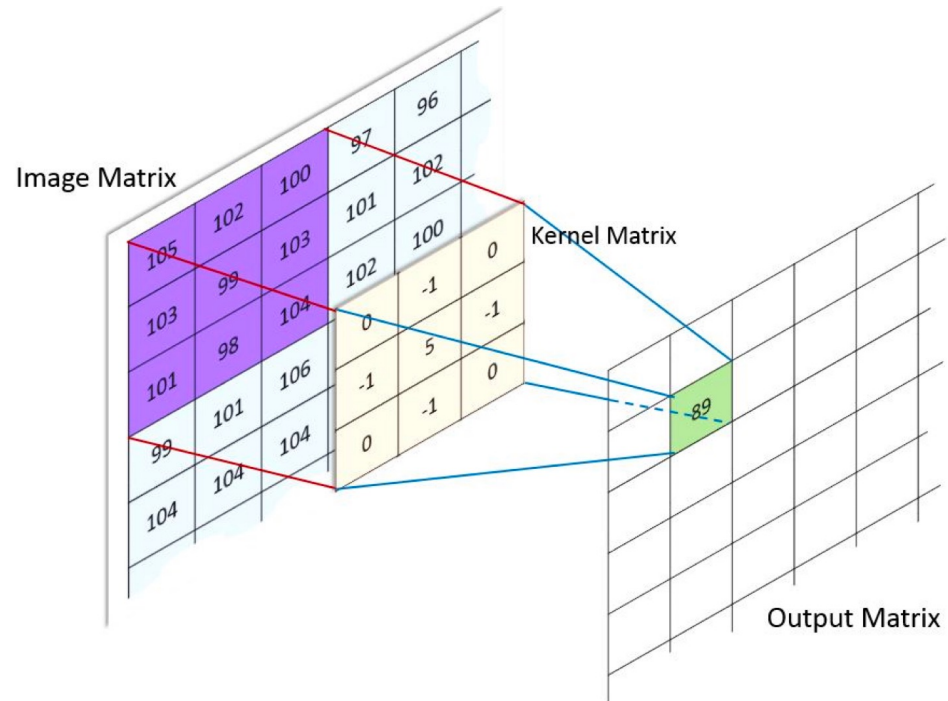
Area: Only half of the accurate unit

Area of Accurate, Mitchell, OOD and Proposed
8 Parallel Vector Unit

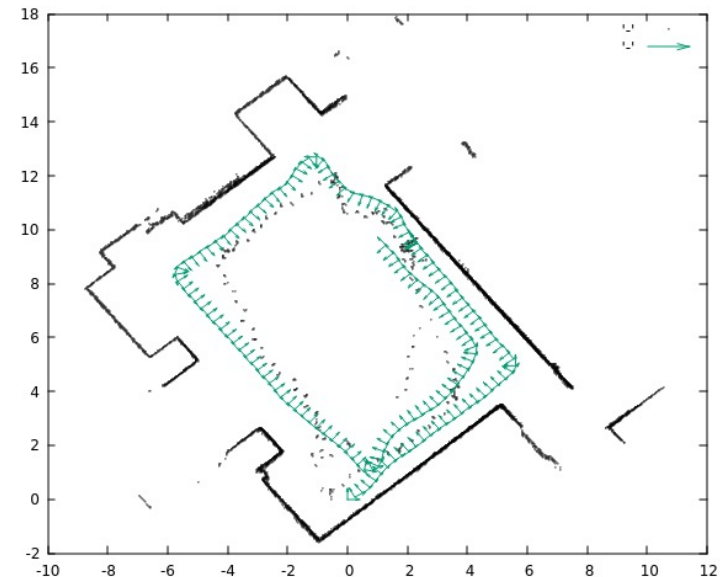
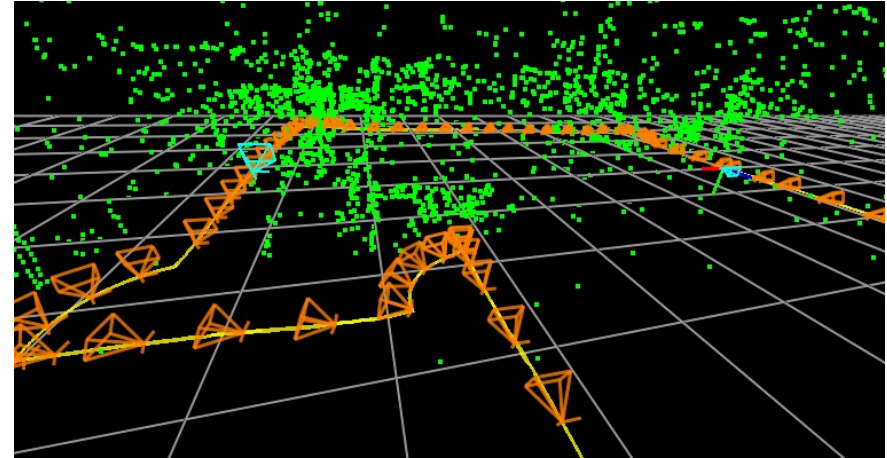


Application Case Study

Gaussian Blur

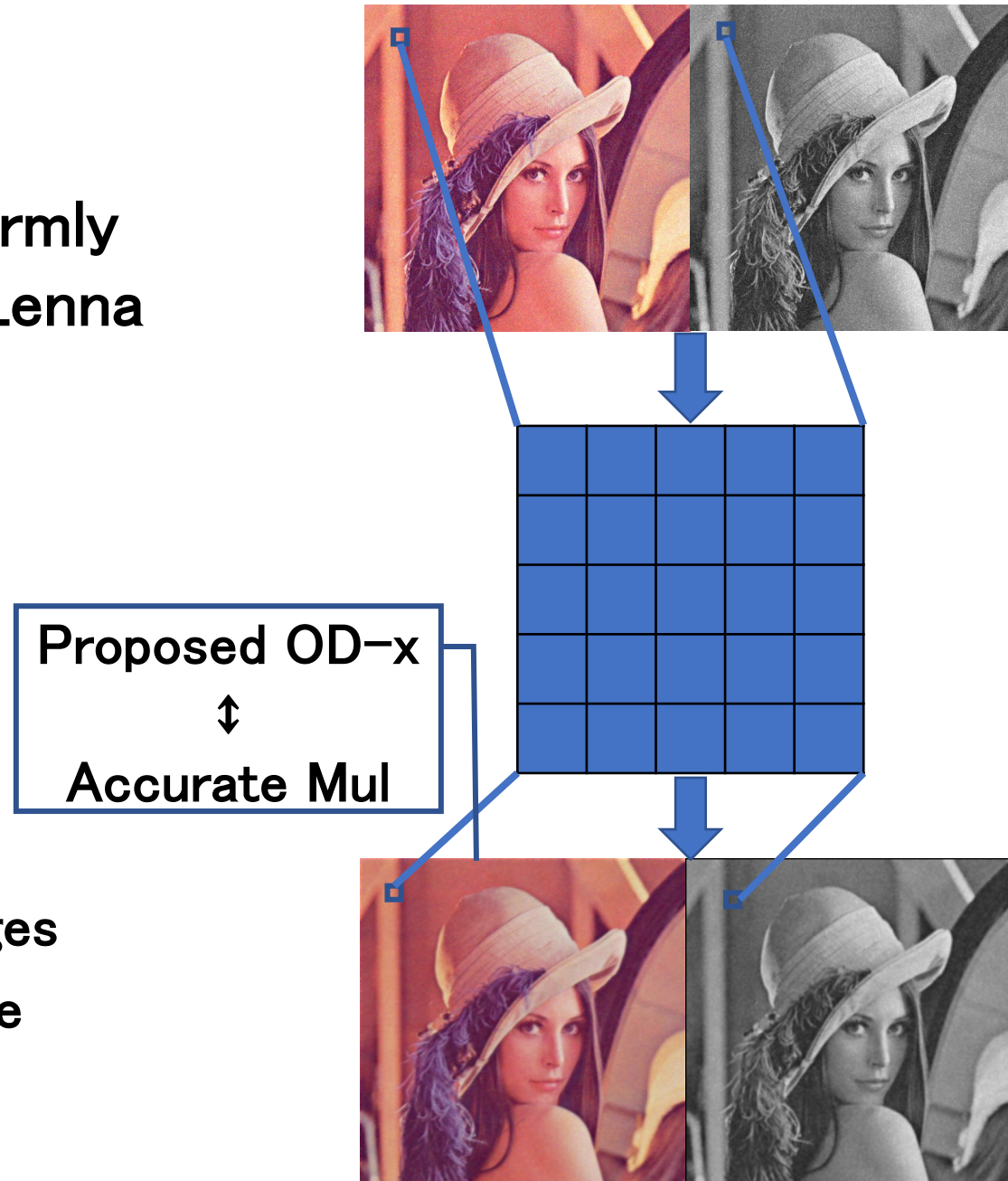


Simultaneous Localization and Mapping



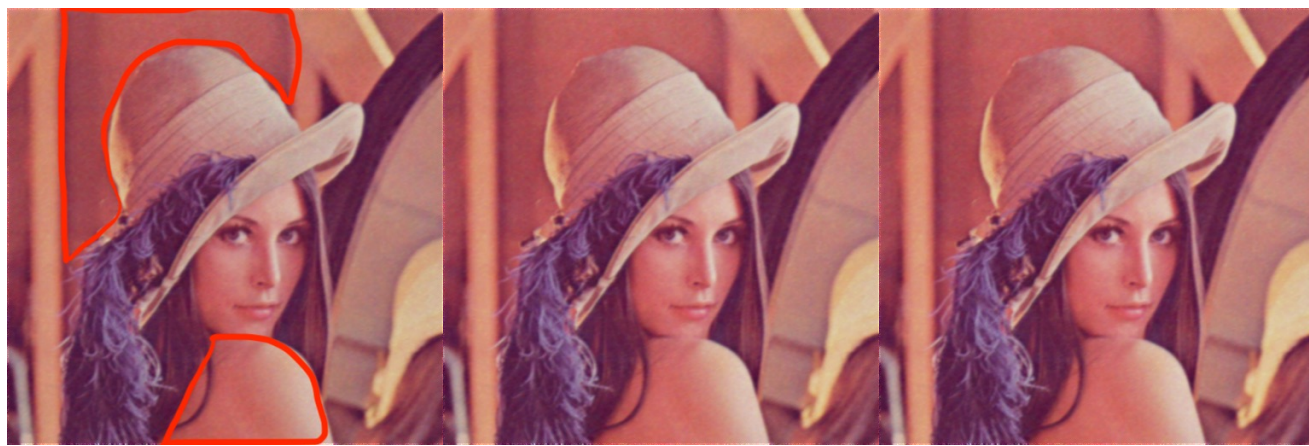
Gaussian Blur

- Input data: 512×512 Uniformly distributed noise polluted Lenna
 - Color Image
 - Grayscale Image
- Gaussian Kernel
 - 5×5 size
 - Quantified to integer
- Evaluation Metrics
 - SSIM: Similarity of two images
 - PSNR: Peak Signal-to-Noise Ratio



7D-3

Gaussian Blur



OD-1

OD-2

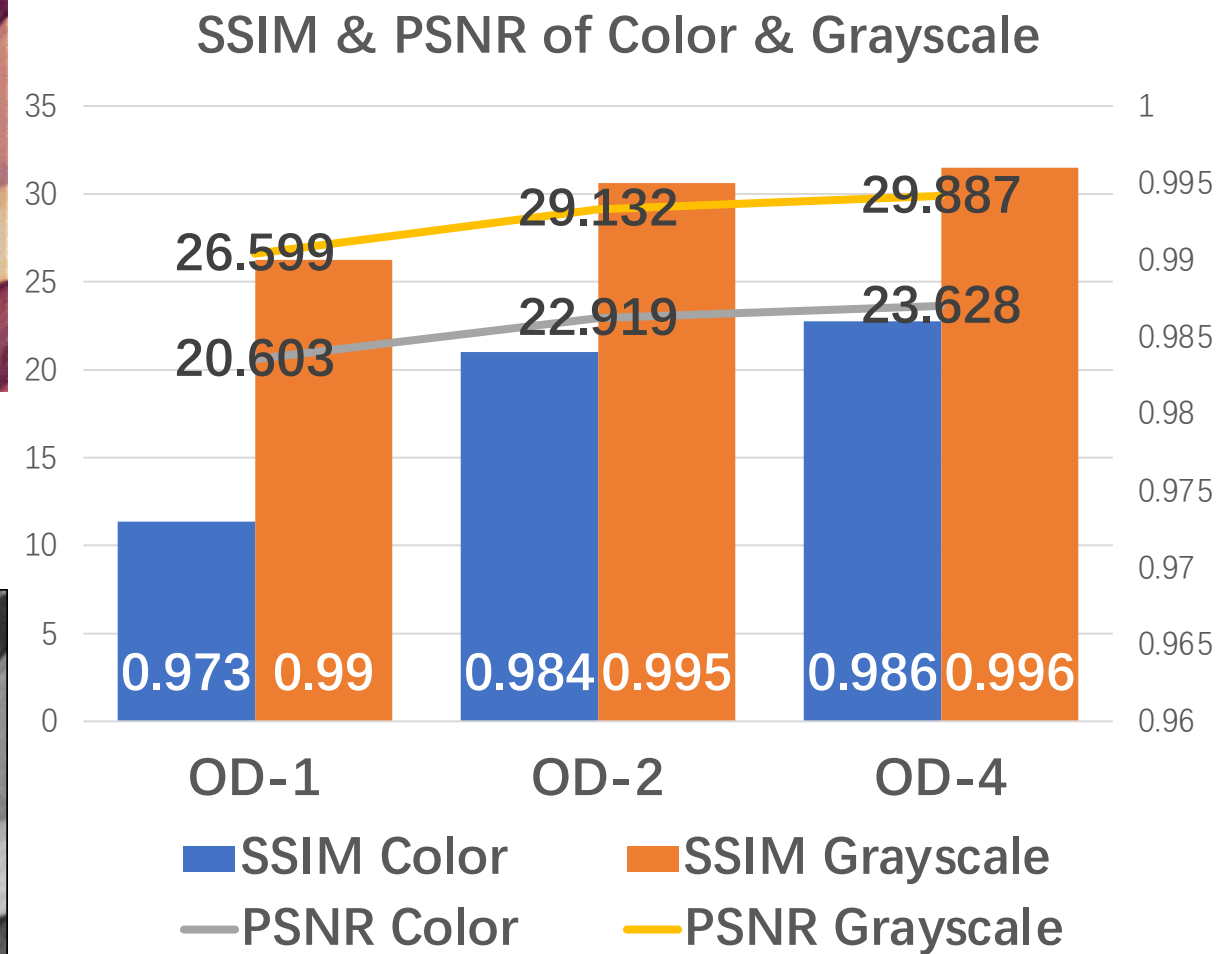
OD-4



OD-1

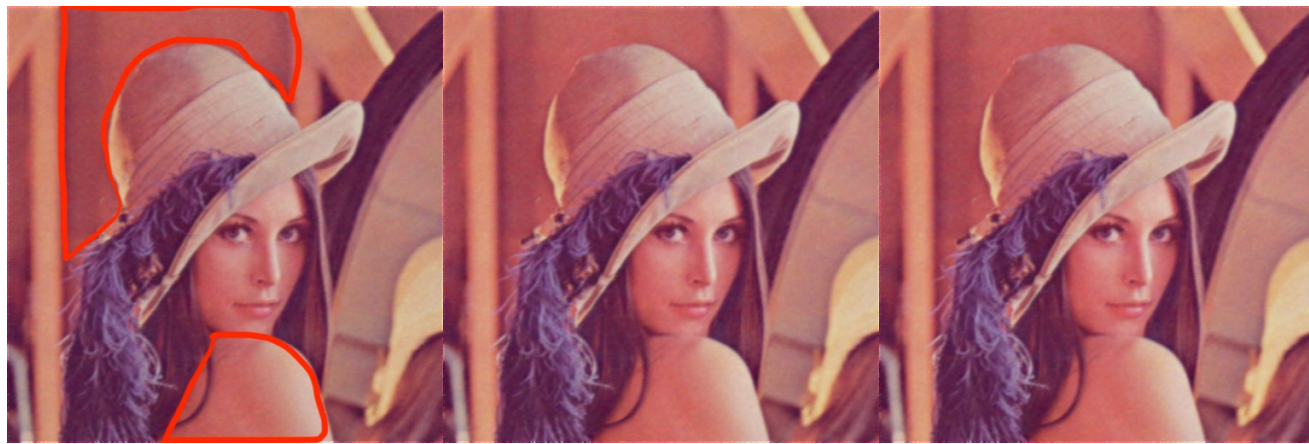
OD-2

OD-4



7D-3

Gaussian Blur



OD-1

OD-2

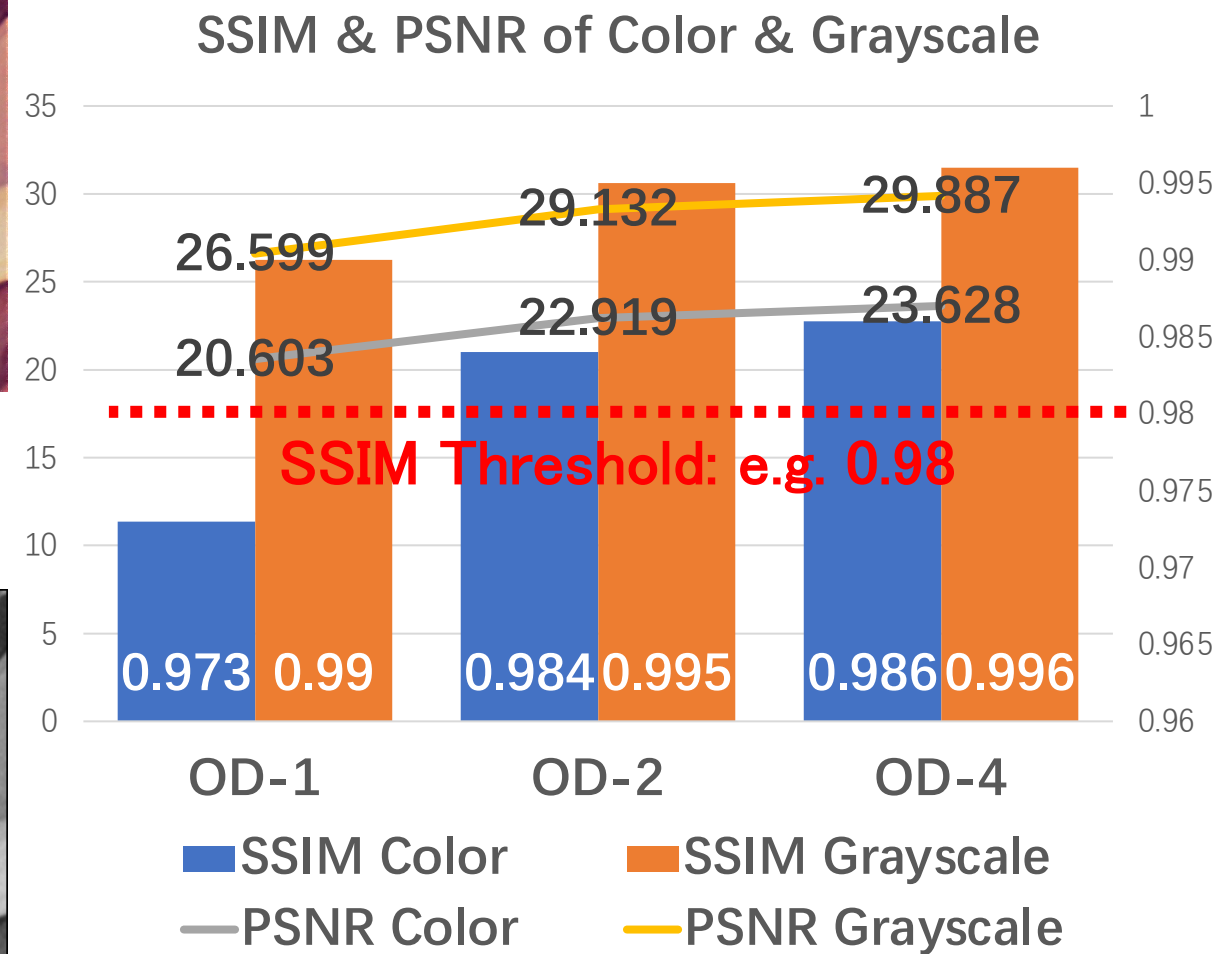
OD-4



OD-1

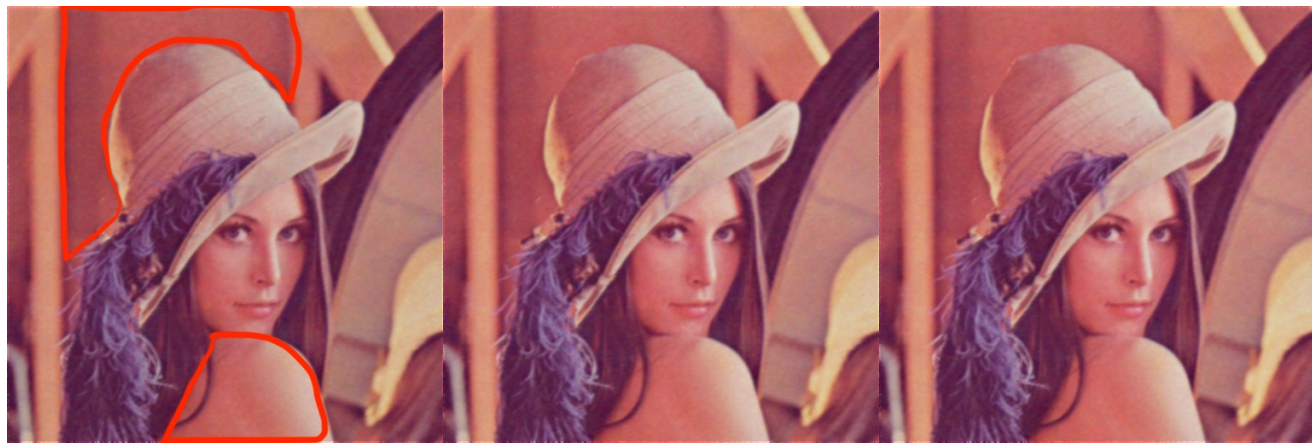
OD-2

OD-4



7D-3

Gaussian Blur



OD-1

OD-2

OD-4

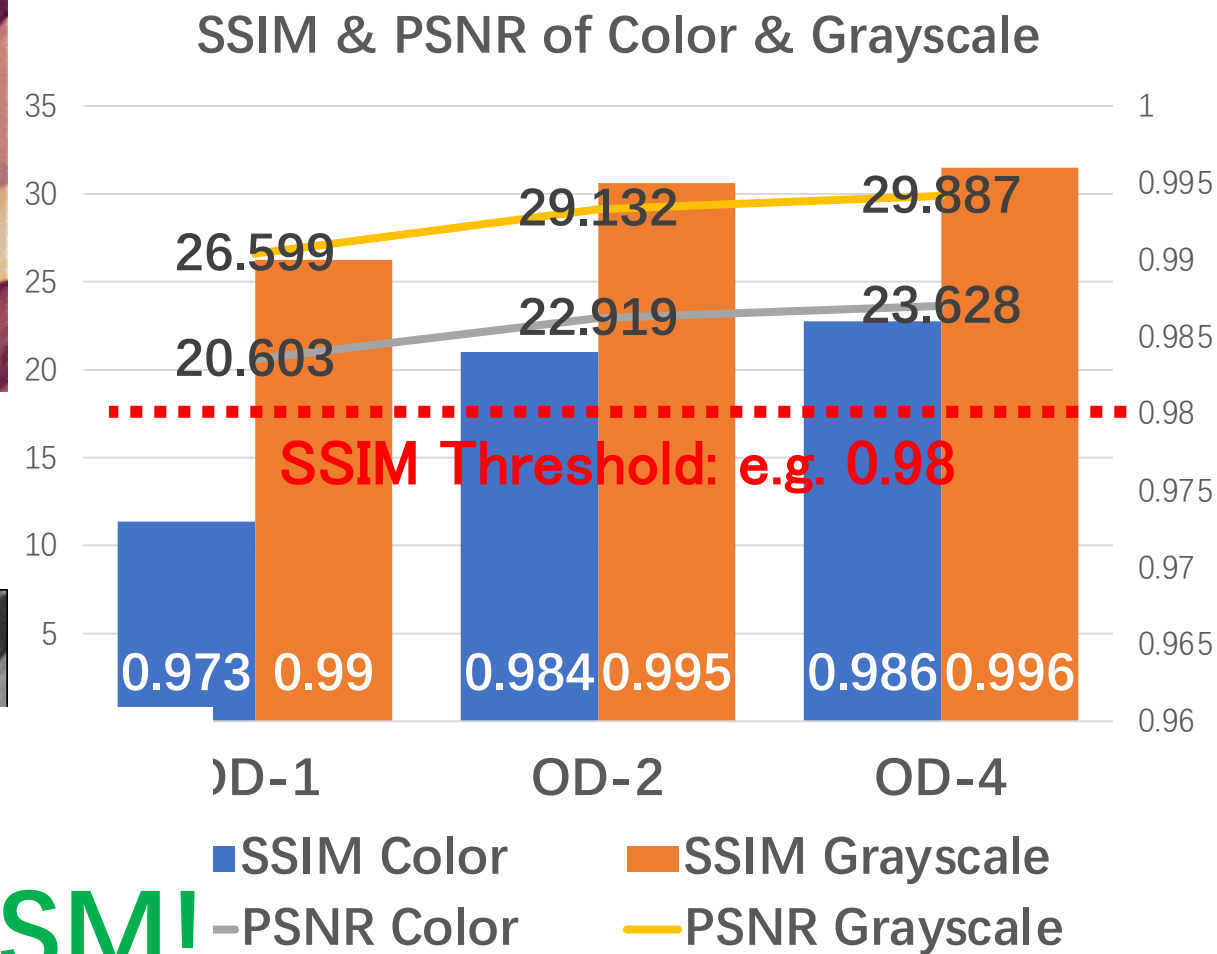


OD-1

OD-2

OD-4

OD-1
MAX PARALLELISM!



7D-3

Gaussian Blur

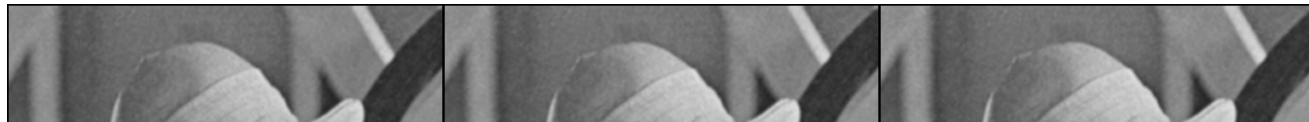


OD-1

OD-2

OD-4

Color Bias



OD-1

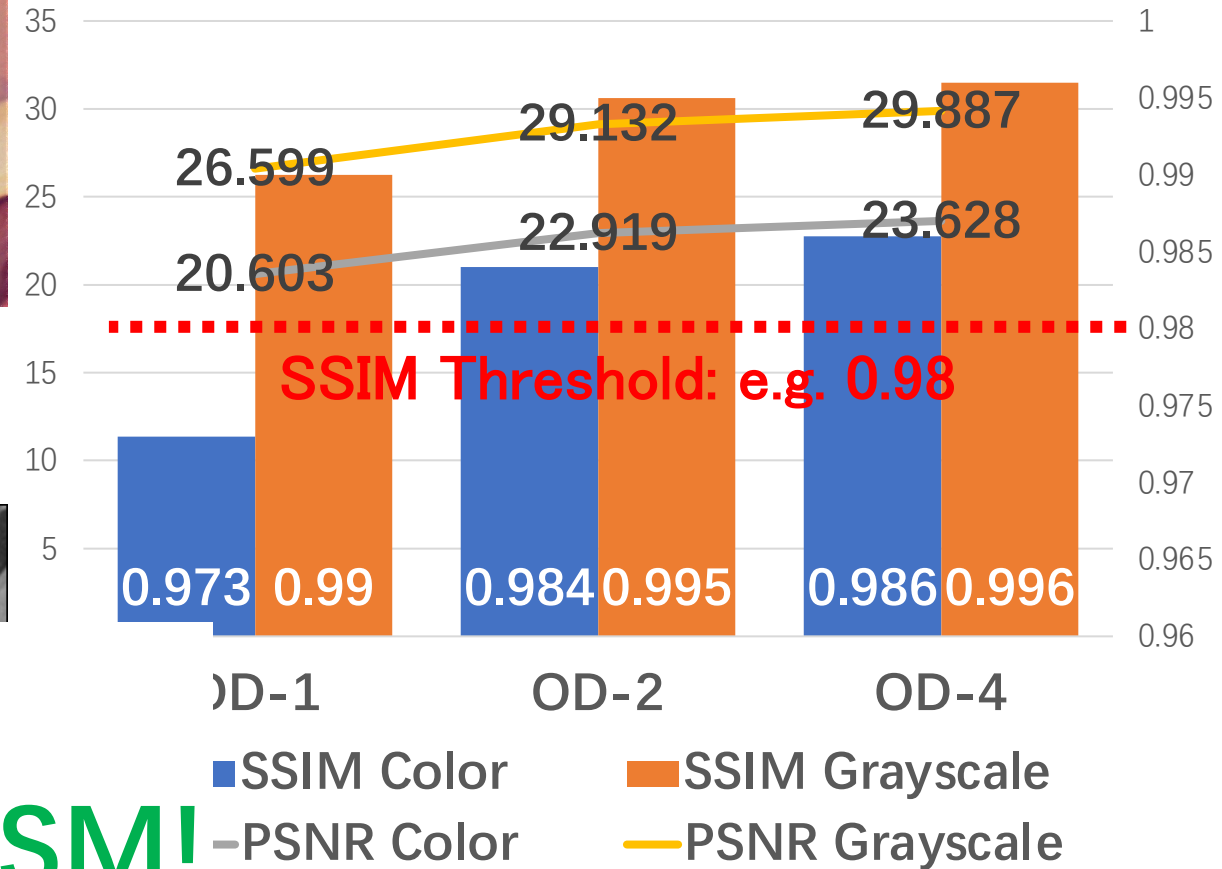
MAX PARALLELISM!

OD-1

OD-2

OD-4

SSIM & PSNR of Color & Grayscale



7D-3

Gaussian Blur

OD-2/4 QUALITY UP!



OD-1

OD-2

OD-4

Color Bias



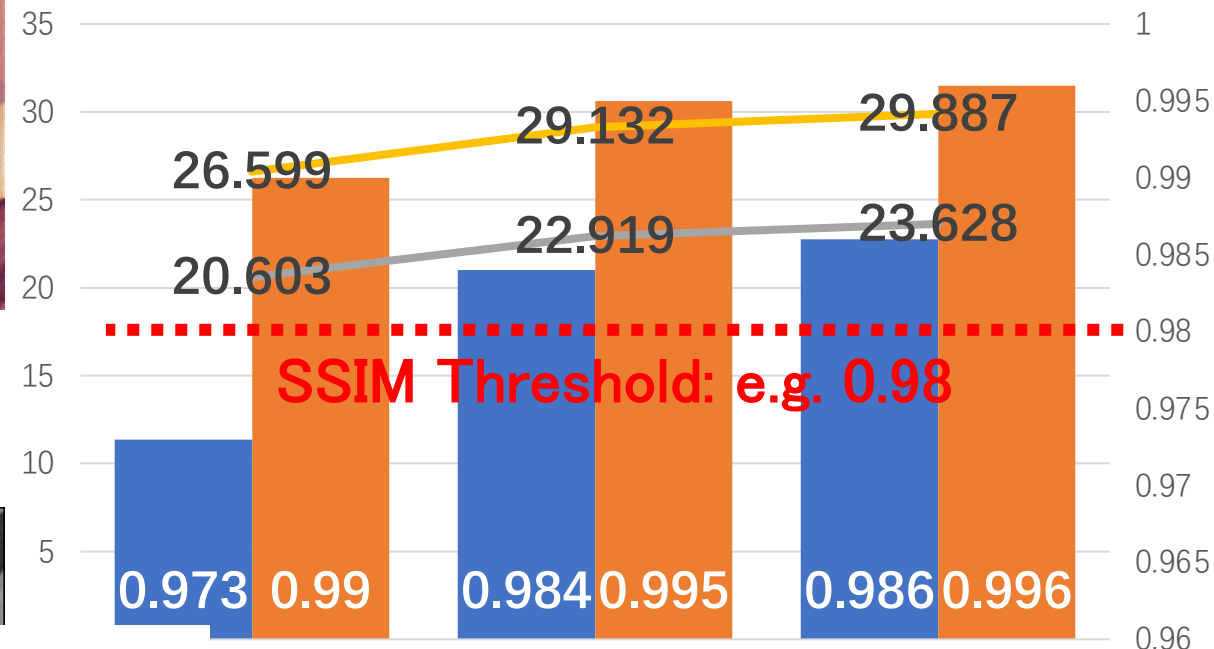
OD-1

OD-2

OD-4

OD-1 MAX PARALLELISM!

SSIM & PSNR of Color & Grayscale



OD-1

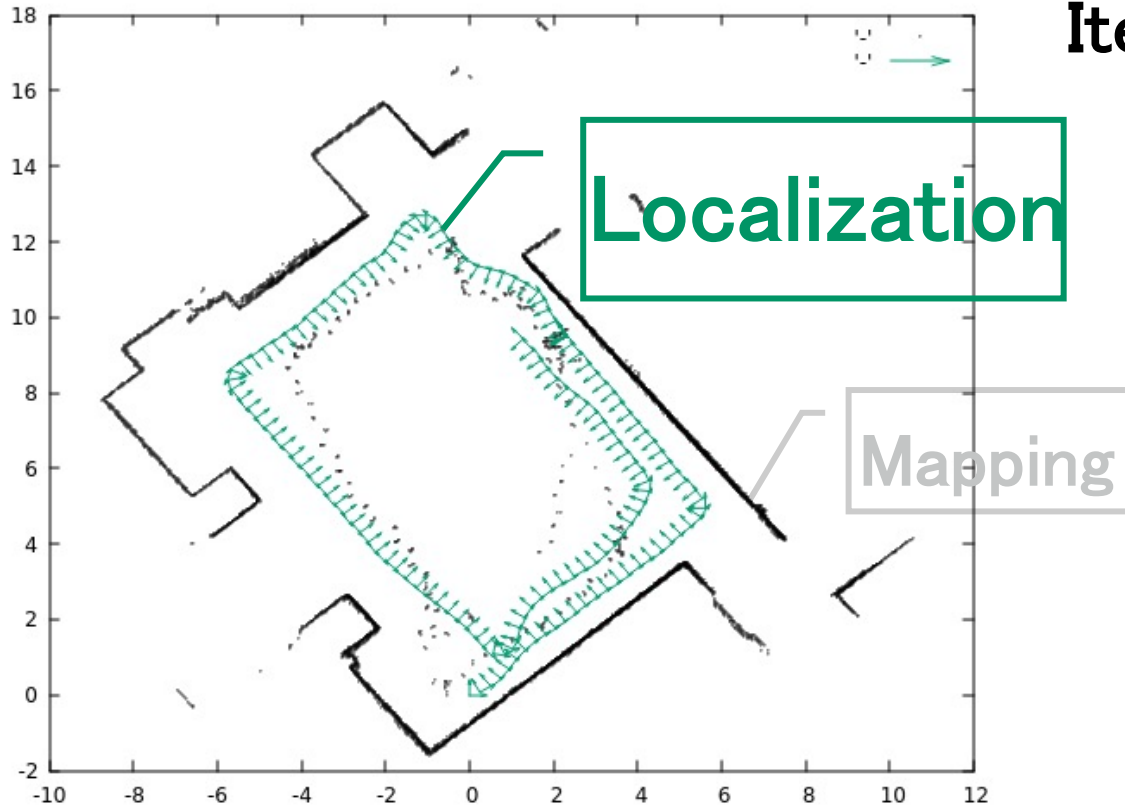
OD-2

OD-4

■ SSIM Color
 ■ PSNR Color

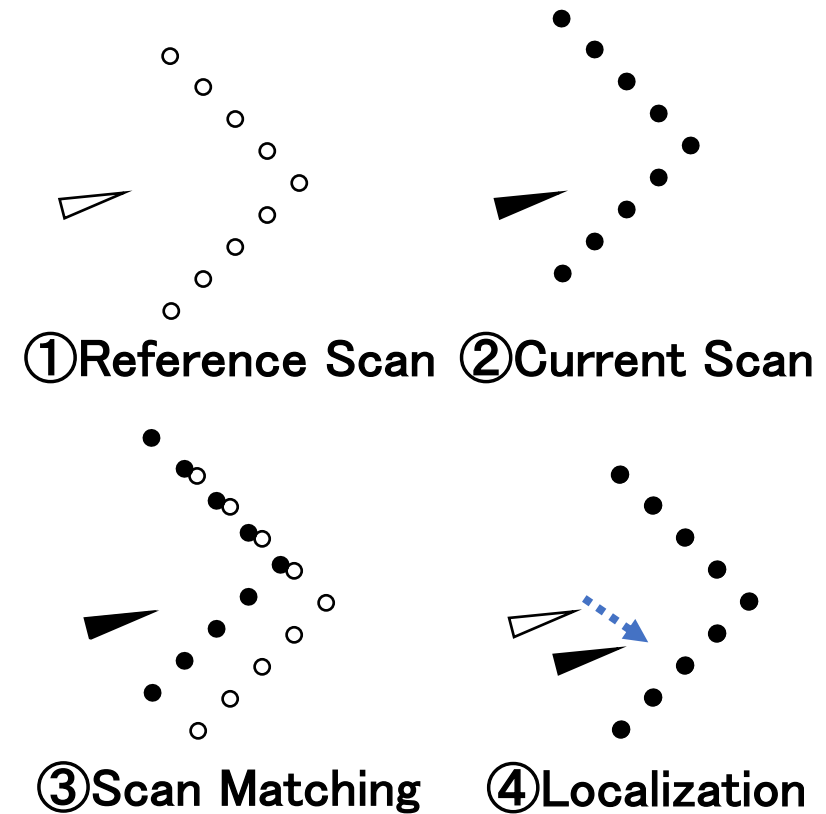
■ SSIM Grayscale
 — PSNR Grayscale

SLAM: Localization

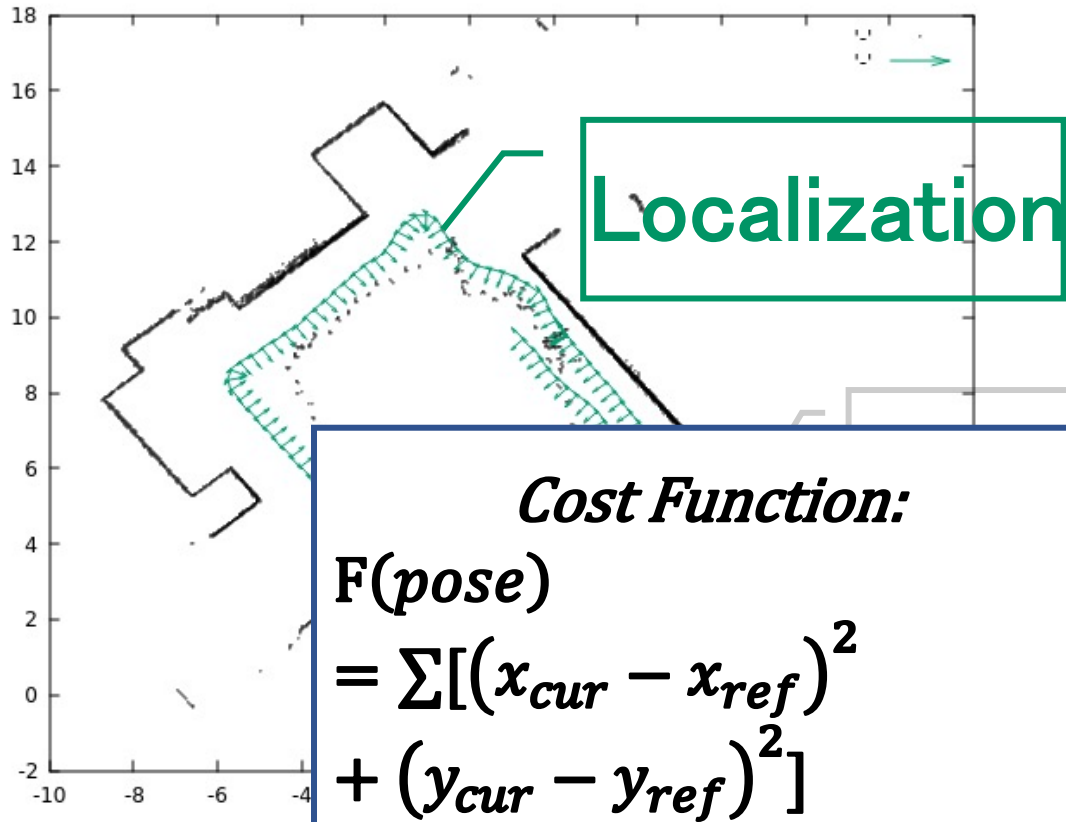


A SLAM Result consisting of Pose Trajectory and Map

Iterative Closest Point (ICP)

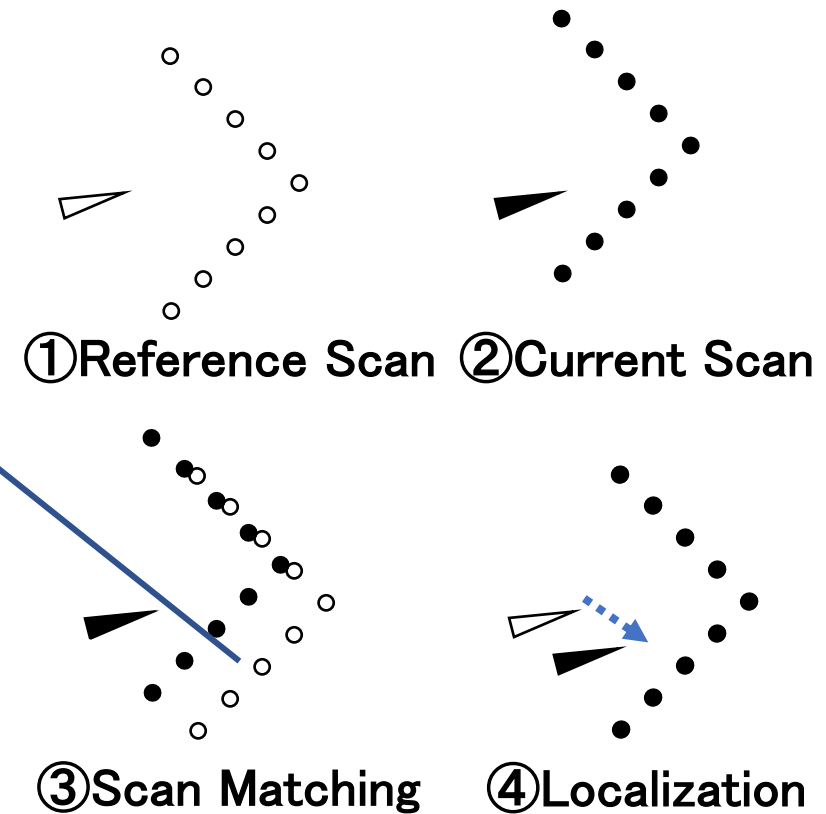


SLAM: Localization



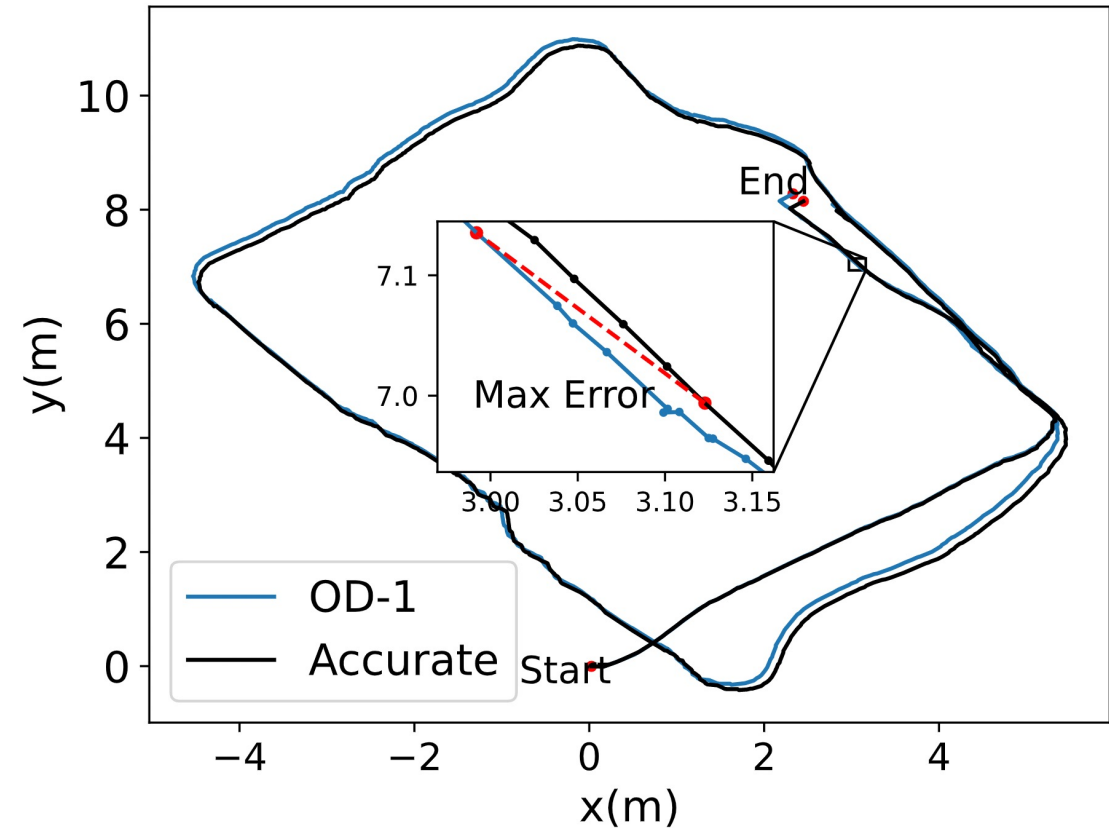
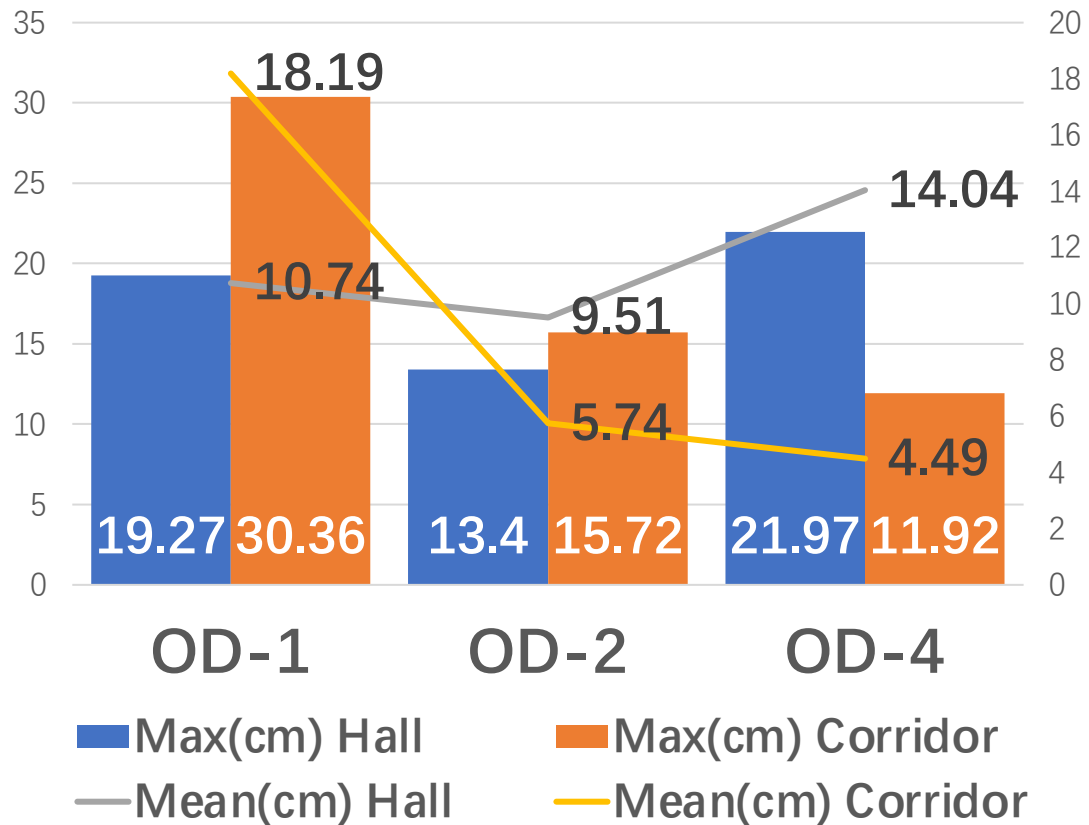
Proposed OD-x ↔ Accurate Mul

Iterative Closest Point (ICP)



SLAM: Localization

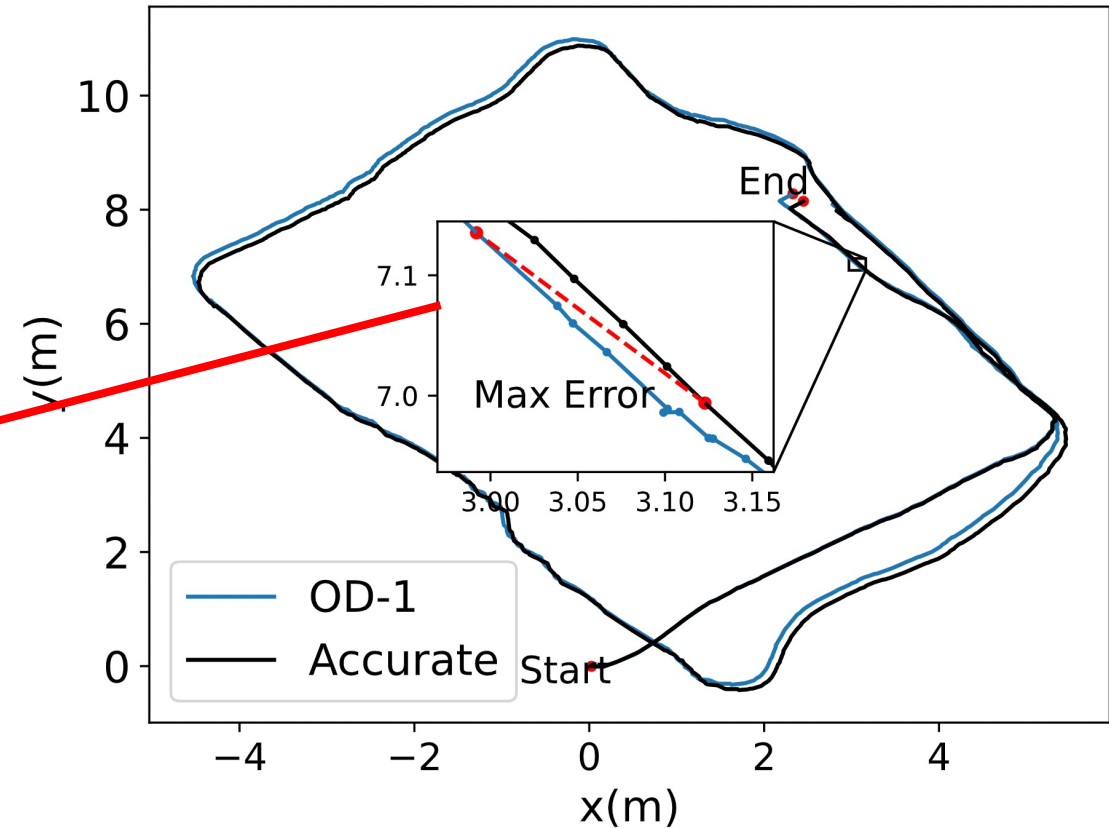
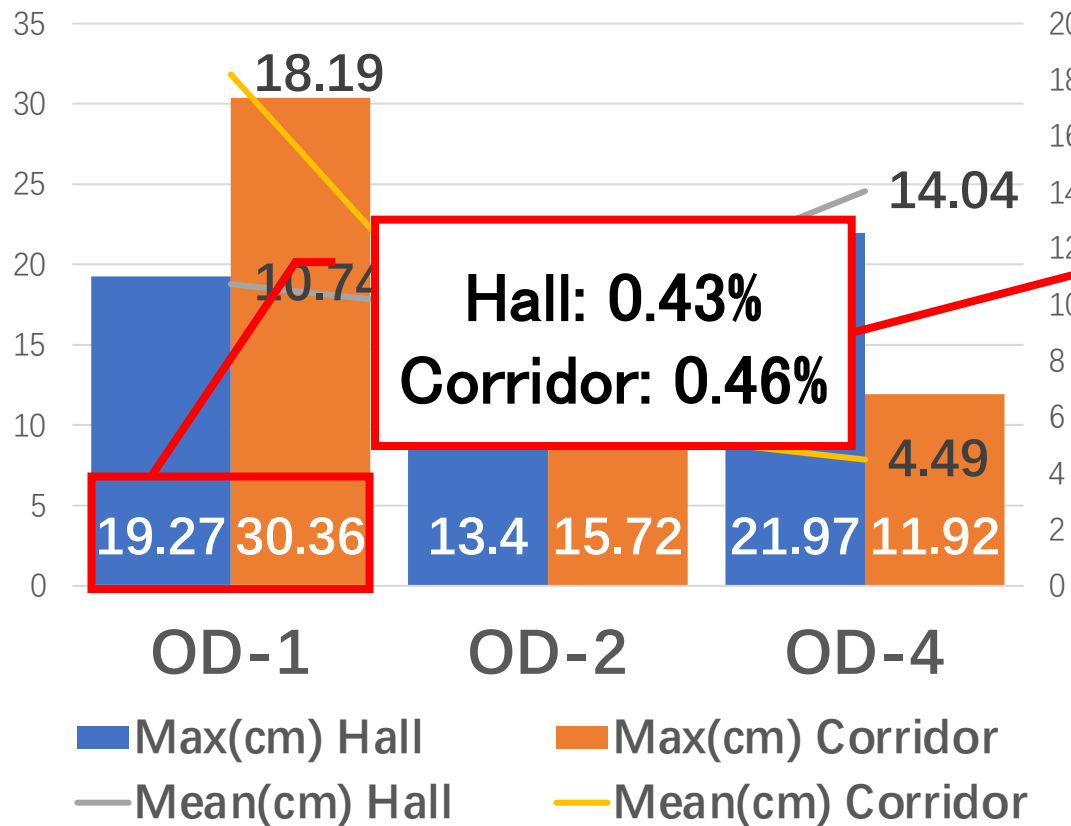
Pose Trajectory distance from which using Accurate Multipliers



Pose Trajectory localized using OD-1 and Accurate Multipliers

SLAM: Localization

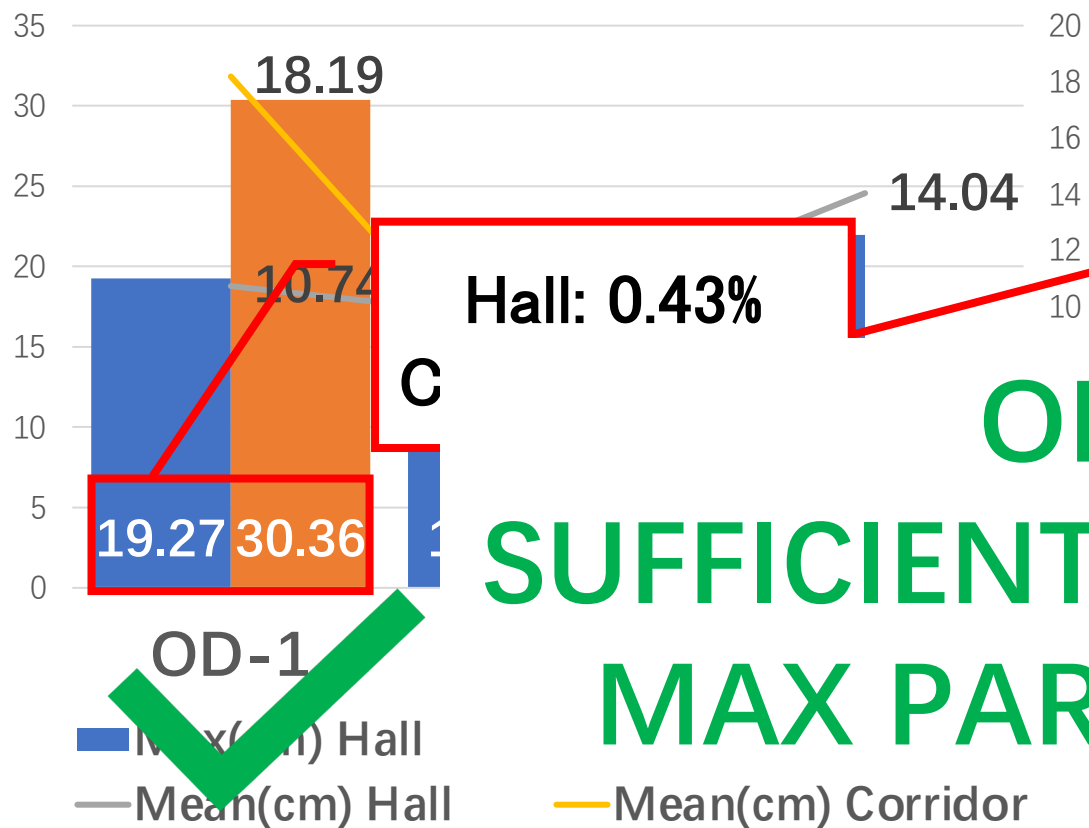
Pose Trajectory distance from
which using Accurate Multipliers



**Pose Trajectory localized using
OD-1 and Accurate Multipliers**

SLAM: Localization

Pose Trajectory distance from which using Accurate Multipliers

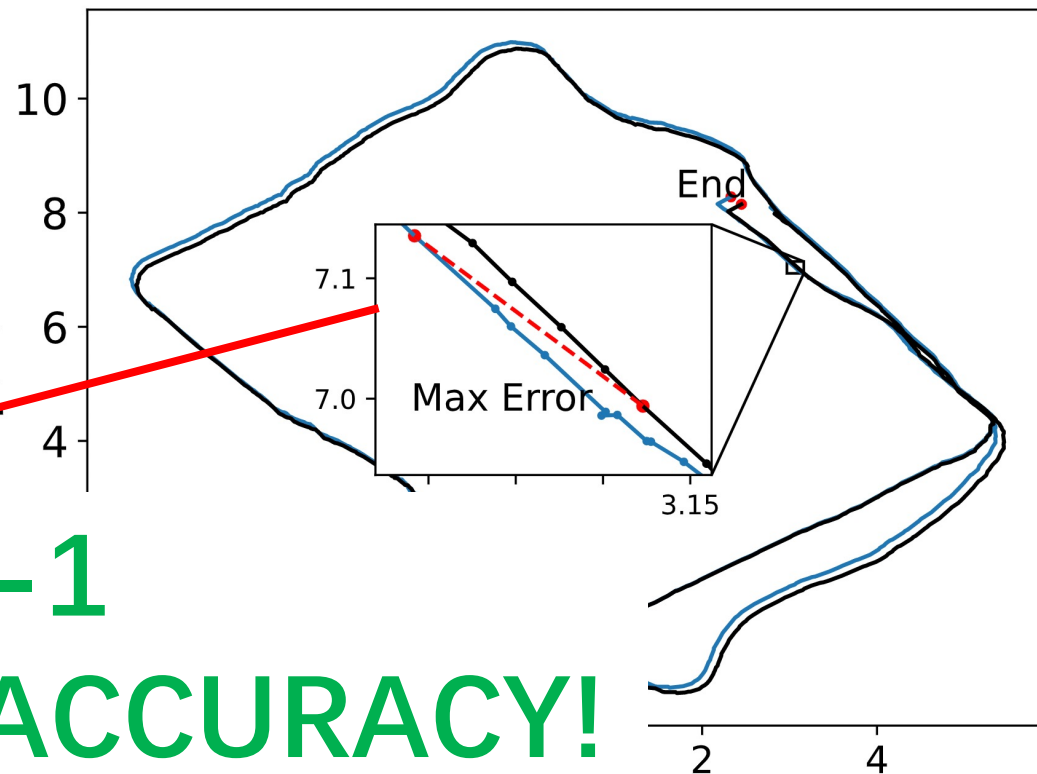


Hall: 0.43%

OD-1

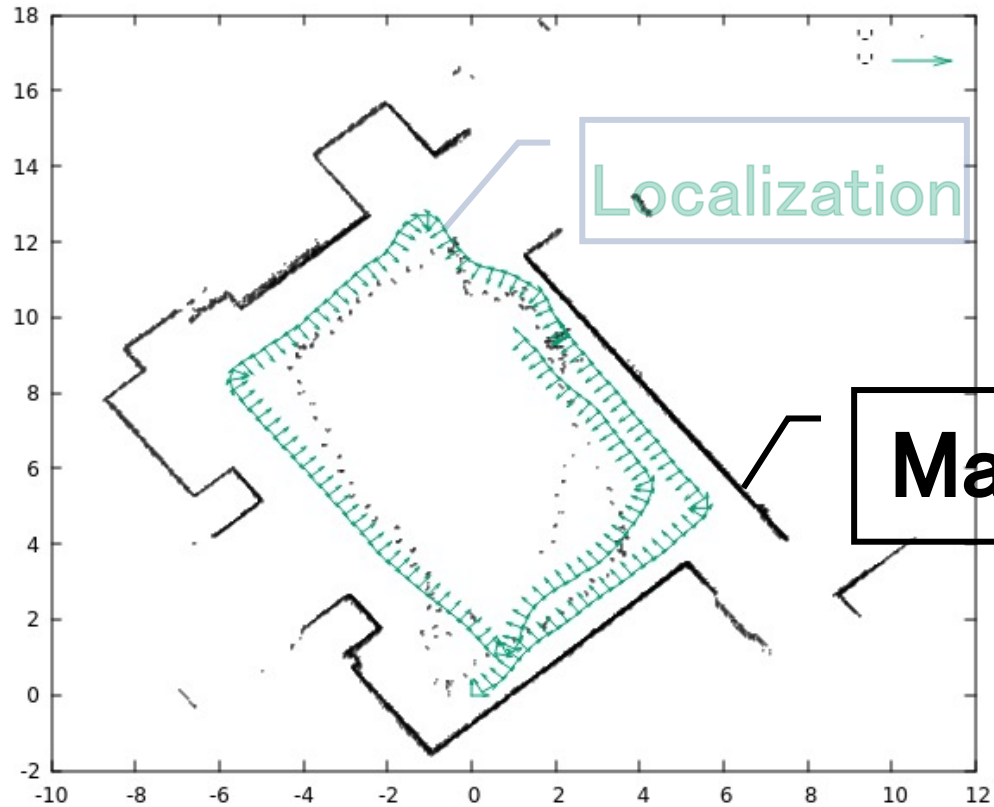
SUFFICIENT ACCURACY!

MAX PARALLELISM!



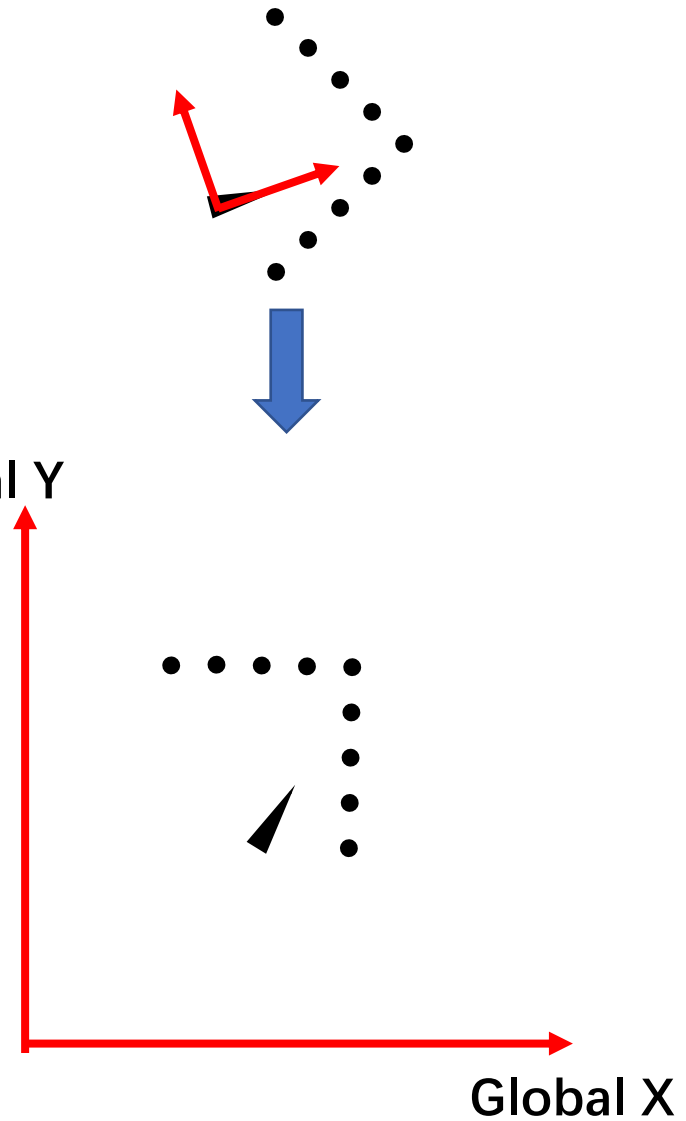
calized using
OD-1 and Accurate Multipliers

SLAM: Mapping

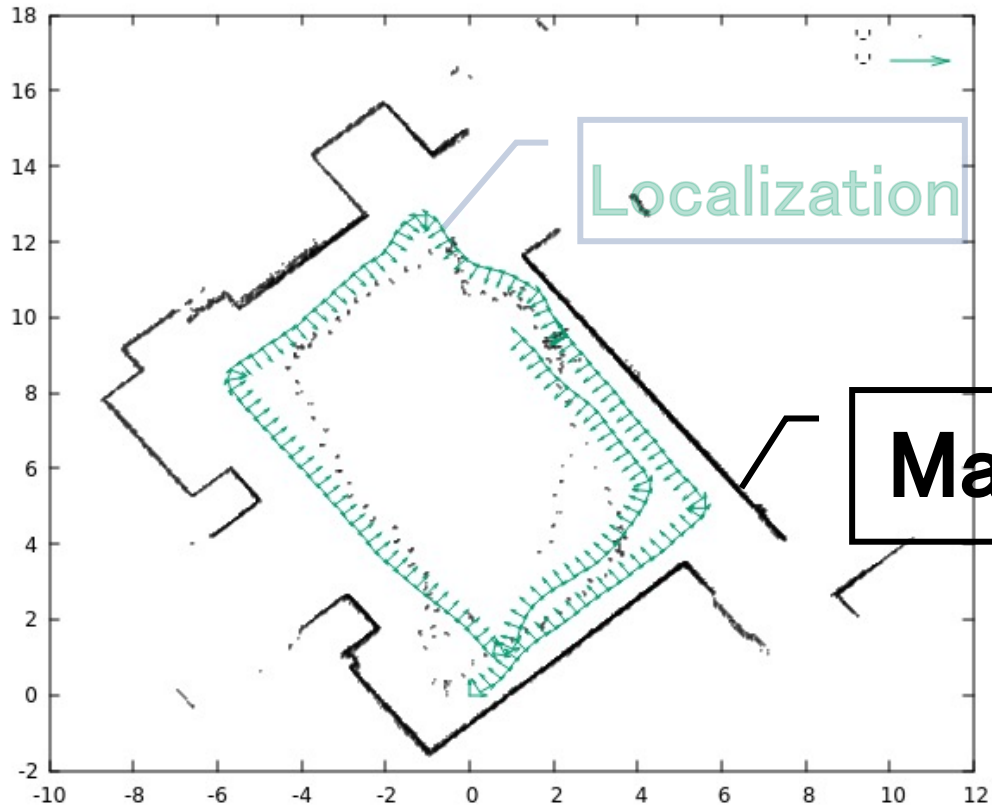


A SLAM Result consisting of Pose Trajectory and Map

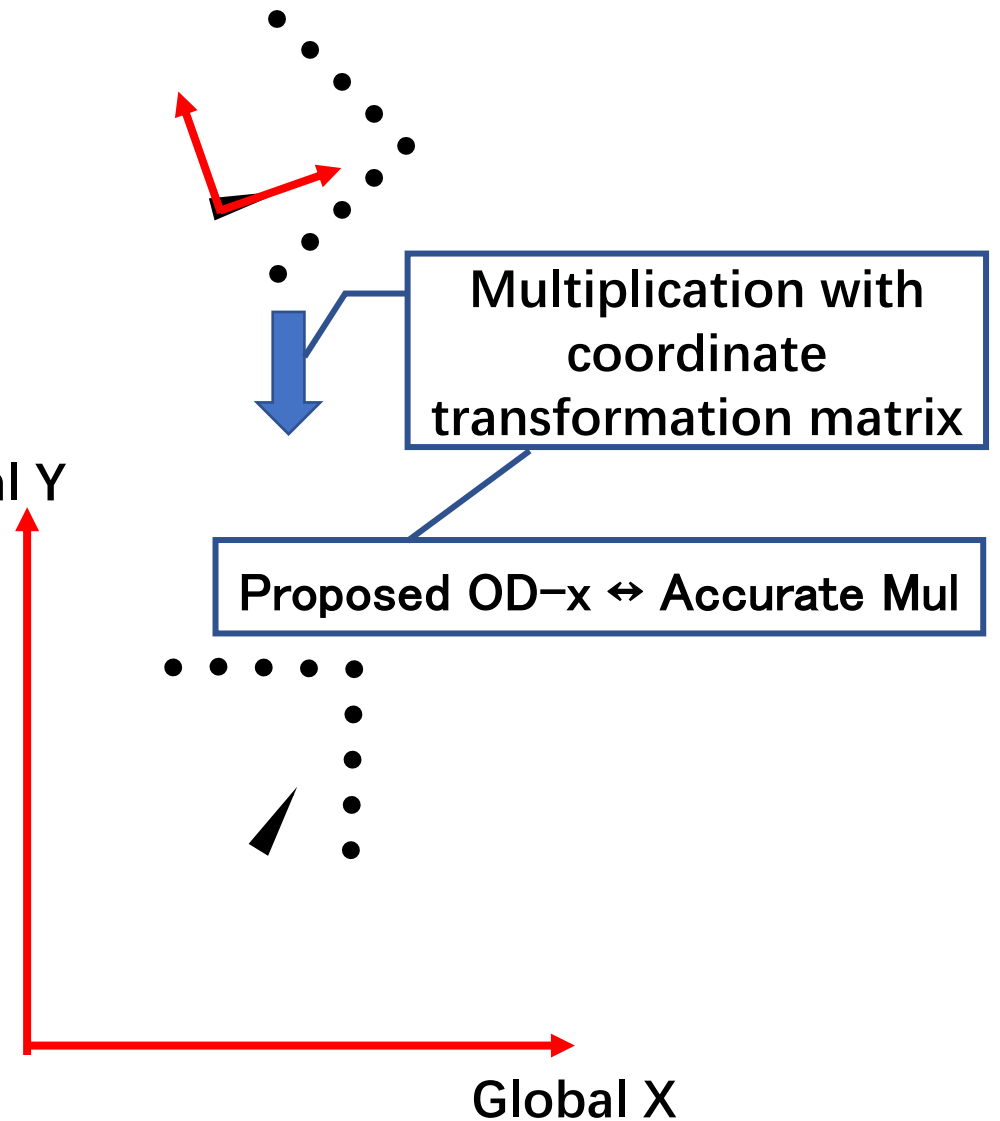
Global Y



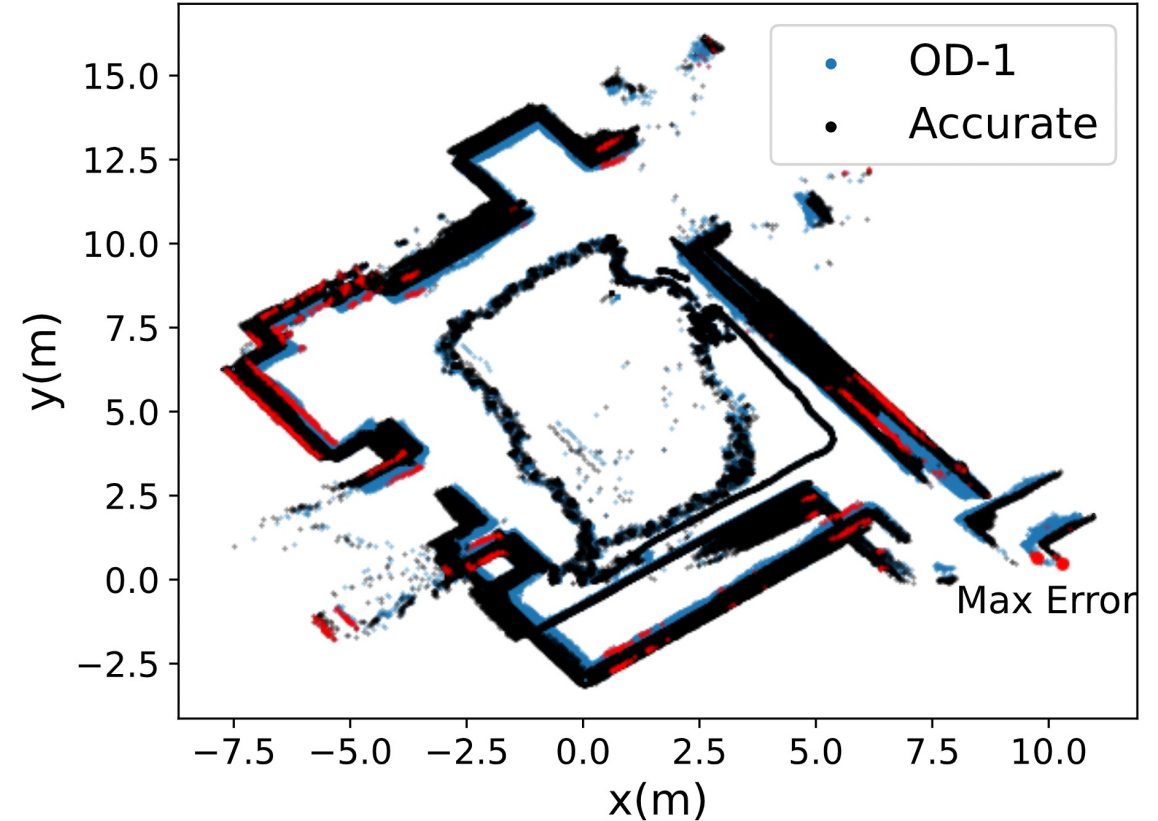
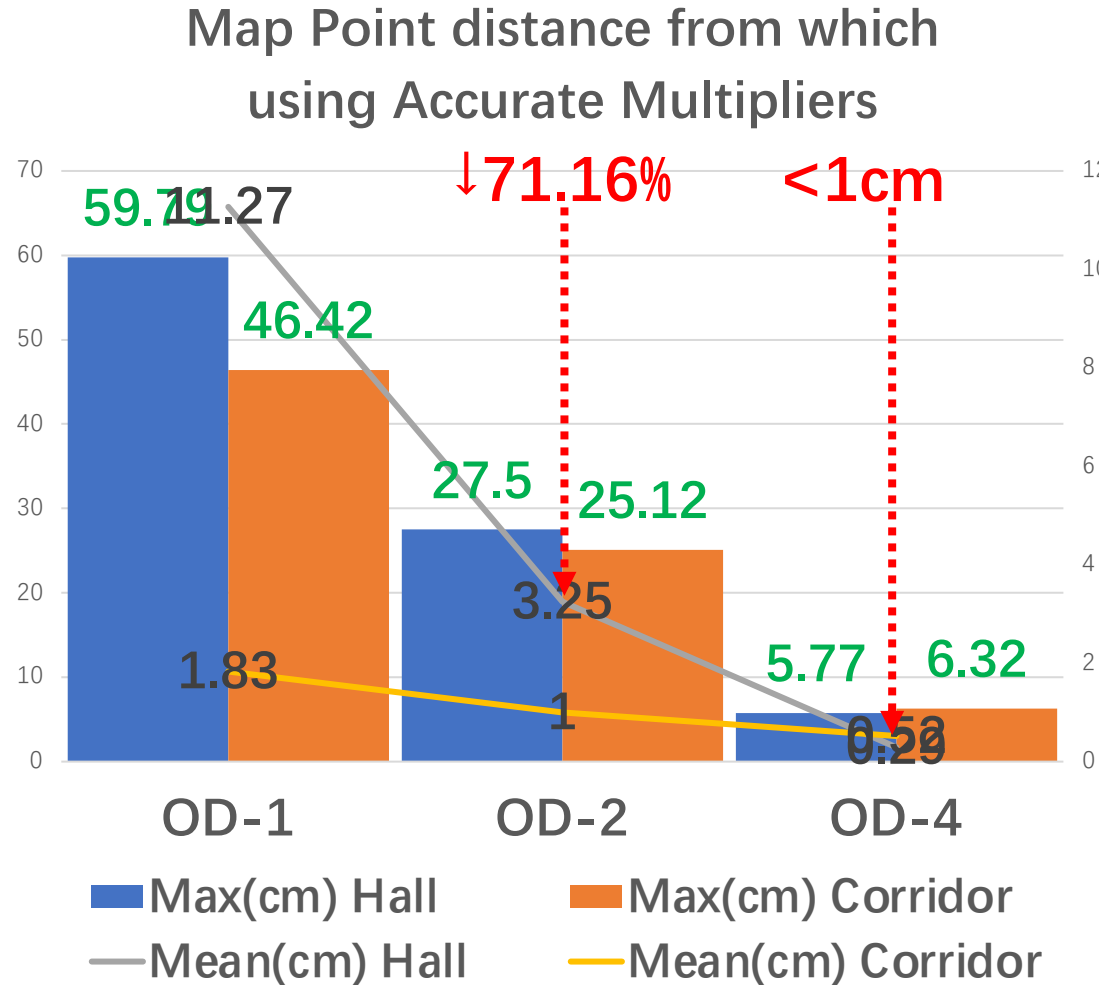
SLAM: Mapping



A SLAM Result consisting of Pose Trajectory and Map

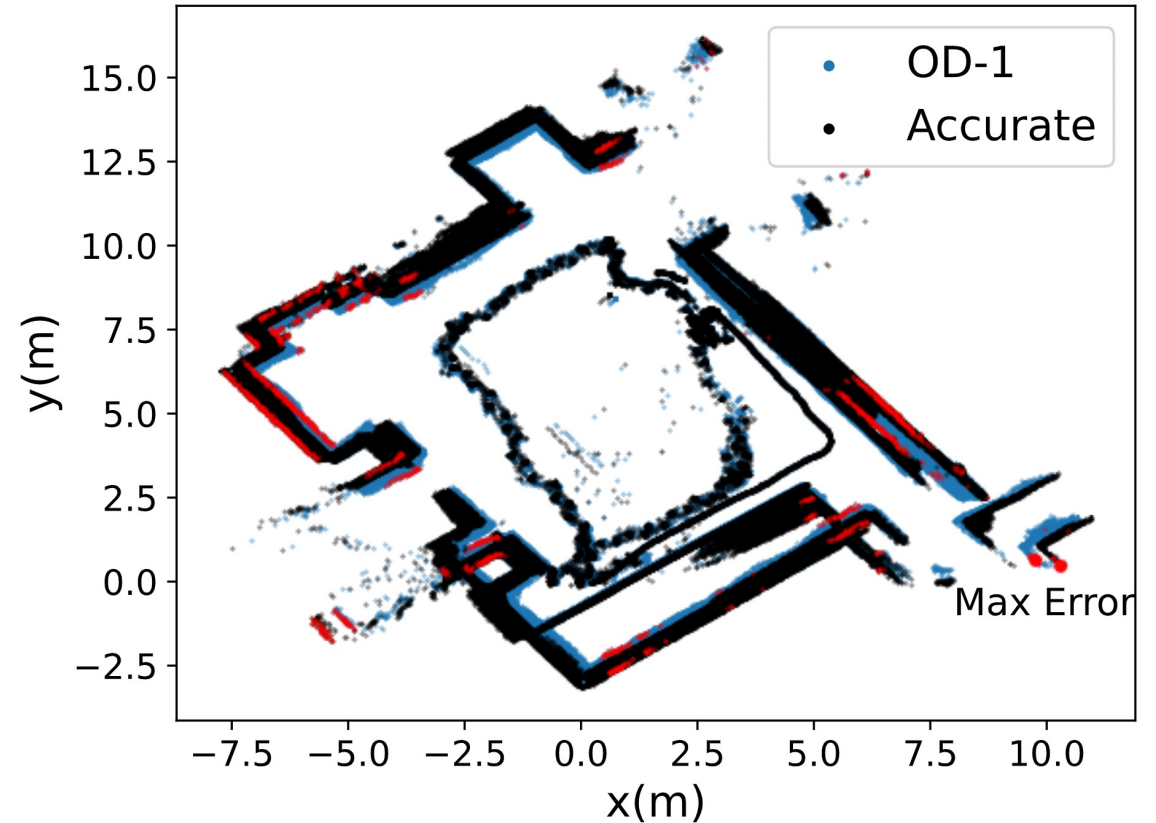
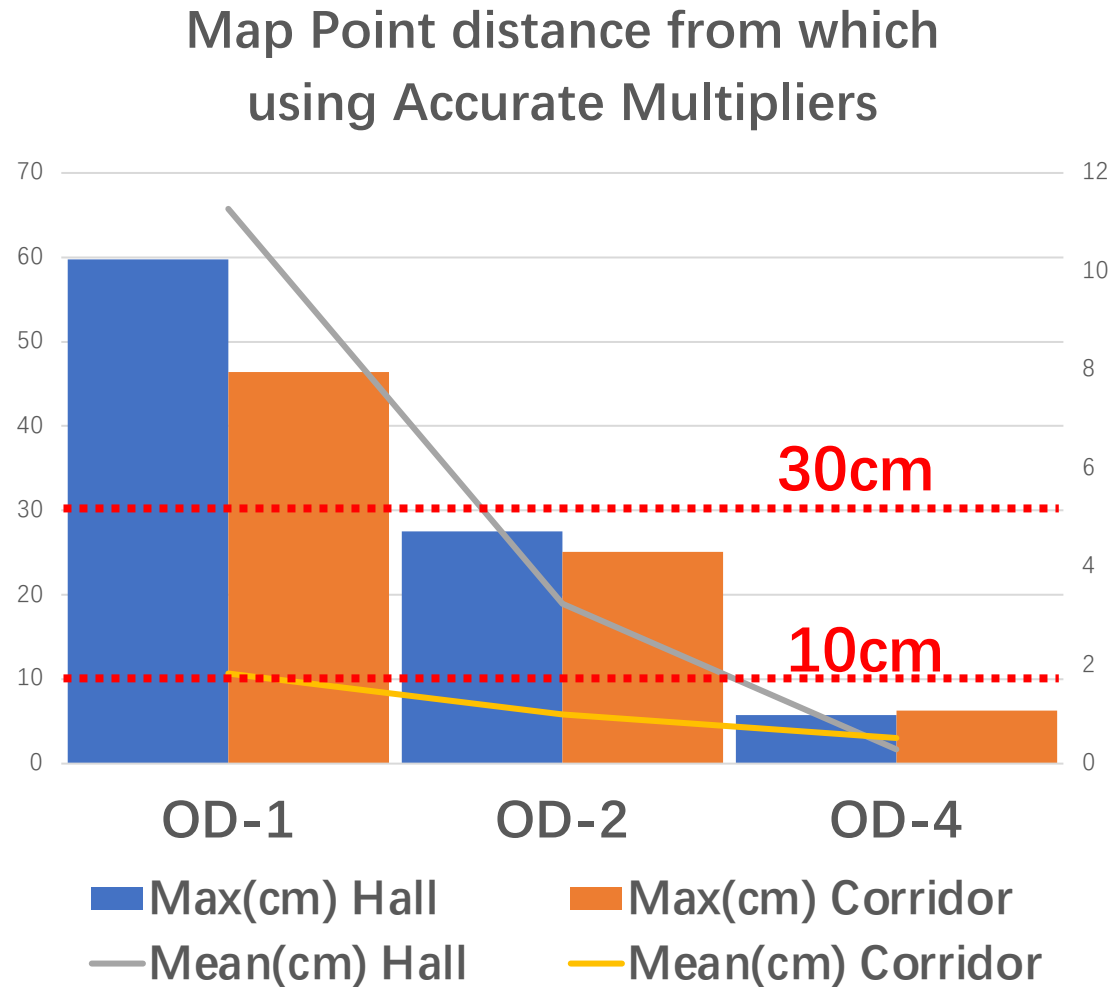


SLAM: Mapping



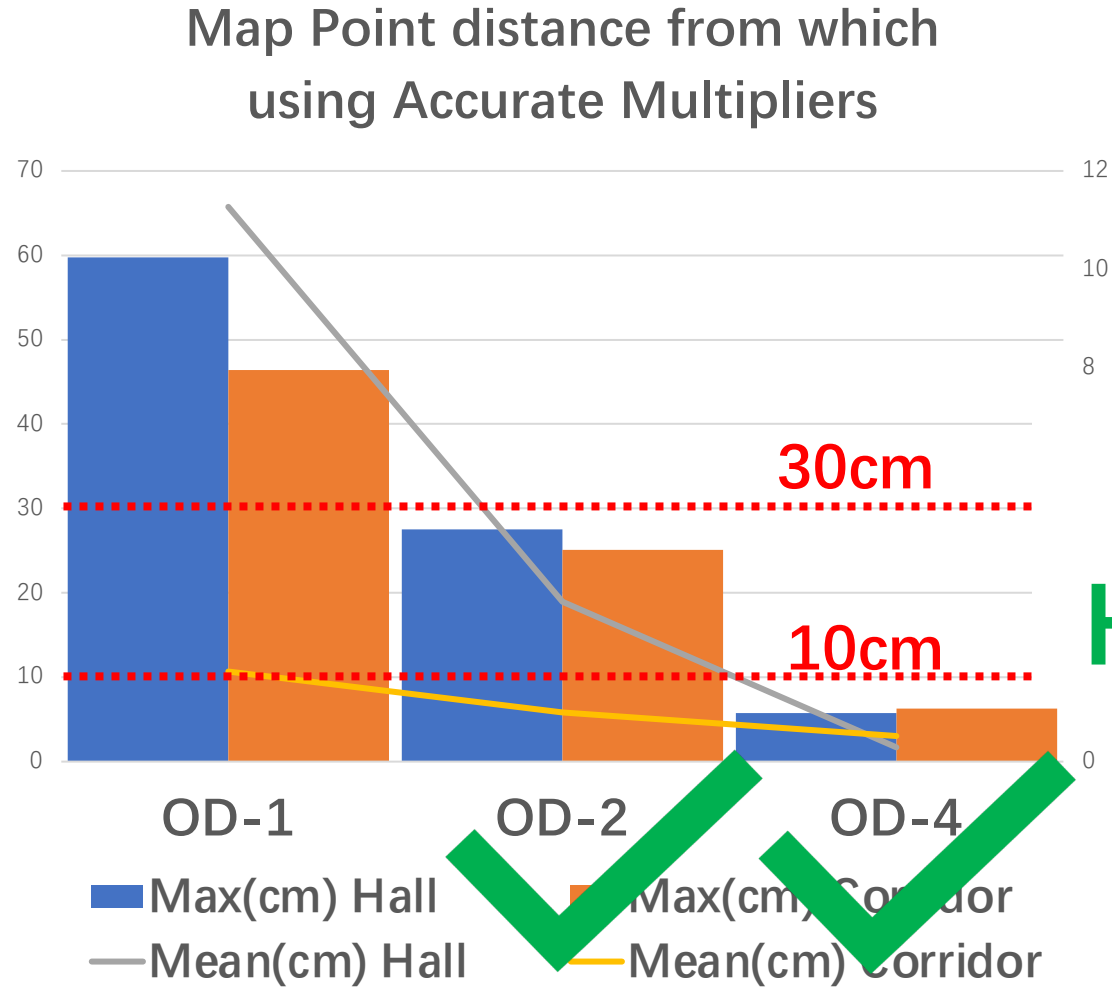
Map constructed using
OD-1 and Accurate Multipliers

SLAM: Mapping



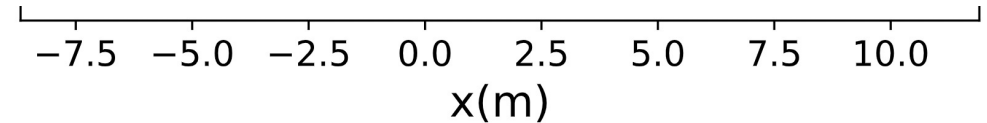
Map constructed using
OD-1 and Accurate Multipliers

SLAM: Mapping



OD-2/4

HIGHER QUALITY MAP



Map constructed using OD-1 and Accurate Multipliers

Conclusions

- **A Novel Operand Decomposition Method**
 - Improves the Accuracy of Existing Approximation
- **Accuracy Reconfigurable Vector Accelerator**
 - Suit Various Accuracy Requirements
 - Trade-off Between Accuracy & Parallelism
- **Application Case Studies**
 - Gaussian Blur
 - SLAM