Algorithmic Performance-Accuracy Trade-off in 3D Vision Applications Using HyperMapper

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Talk available on-line on my home page

In collaboration with:

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Main paper behind this talk

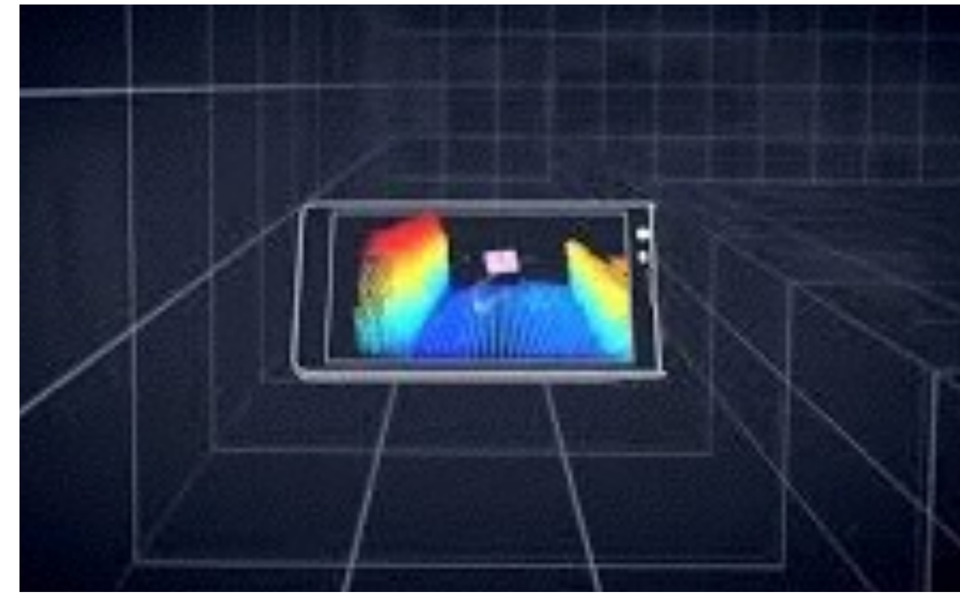
- Int. Conf. in Haifa, September 2016:
  Parallel Architectures and Compilation Techniques (**PACT**)
- Paper title:
  Integrating algorithmic parameters into benchmarking and design space exploration in dense 3D scene understanding
- Authors:
  B. Bodin, **L. Nardi**, Zia Zeeshan, H. Wagstaff, G. S. Shenoy, M. Emani, J. Mawer, C. Kotselidis, A. Nisbet, M. Lujan, B. Franke, Paul H. J. Kelly, M. O'Boyle

iWAPT paper extension:

- HyperMapper **generalisation** on multiple 3D vision applications
- **Crowd-sourcing** experiment on many smart-phones and tablets

Simultaneous localisation and mapping (SLAM)

Build a coherent world representation and localise the camera in real-time



Video:
Dyson 360 Eye

Video: **KinectFusion**
[Newcombe et al. ISMAR 2011]

Simultaneous localisation and mapping (SLAM)

Build a coherent world representation and localise the camera in real-time

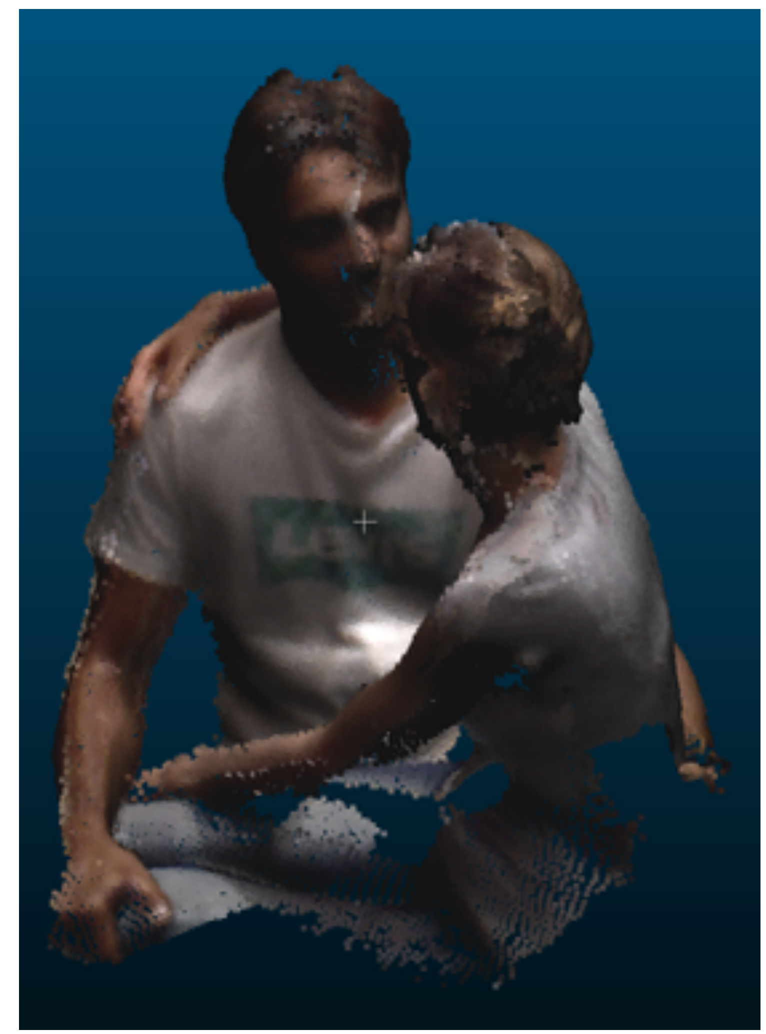
In this talk I will focus on two algorithms:

- KinectFusion [Newcombe et al. ISMAR 2011]
- ElasticFusion [Whelan et al. RSS 2015]

Jesse Clayton (NVIDIA)
3D reconstruction

Applications, e.g.:

- Robotics
- Autonomous driving
- 3D printing
- Augmented reality
- Telepresence

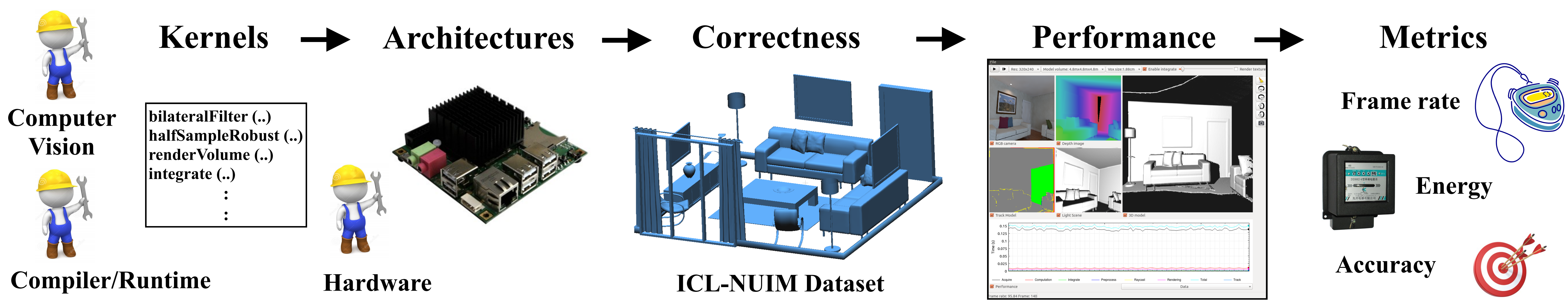


Daniele and Daniela
3D reconstruction

Pictures featured using ElasticFusion

Holistic approach to SLAM performance:

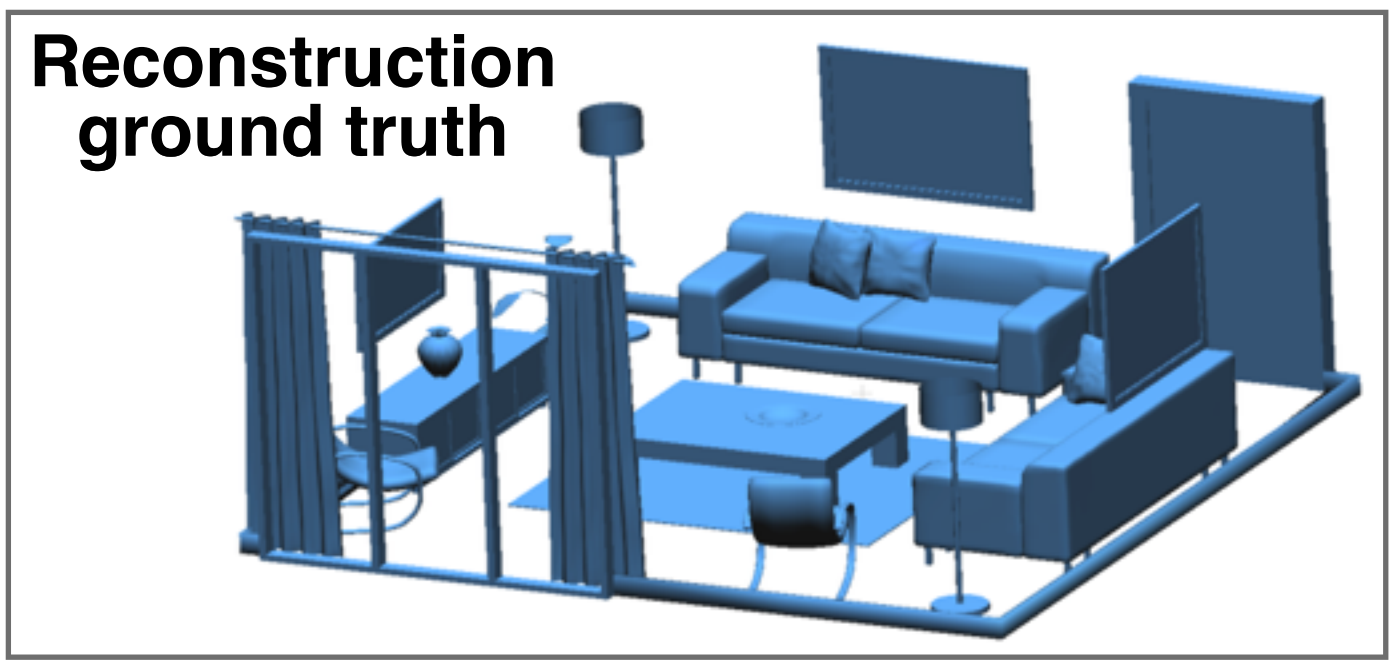
SLAMBench

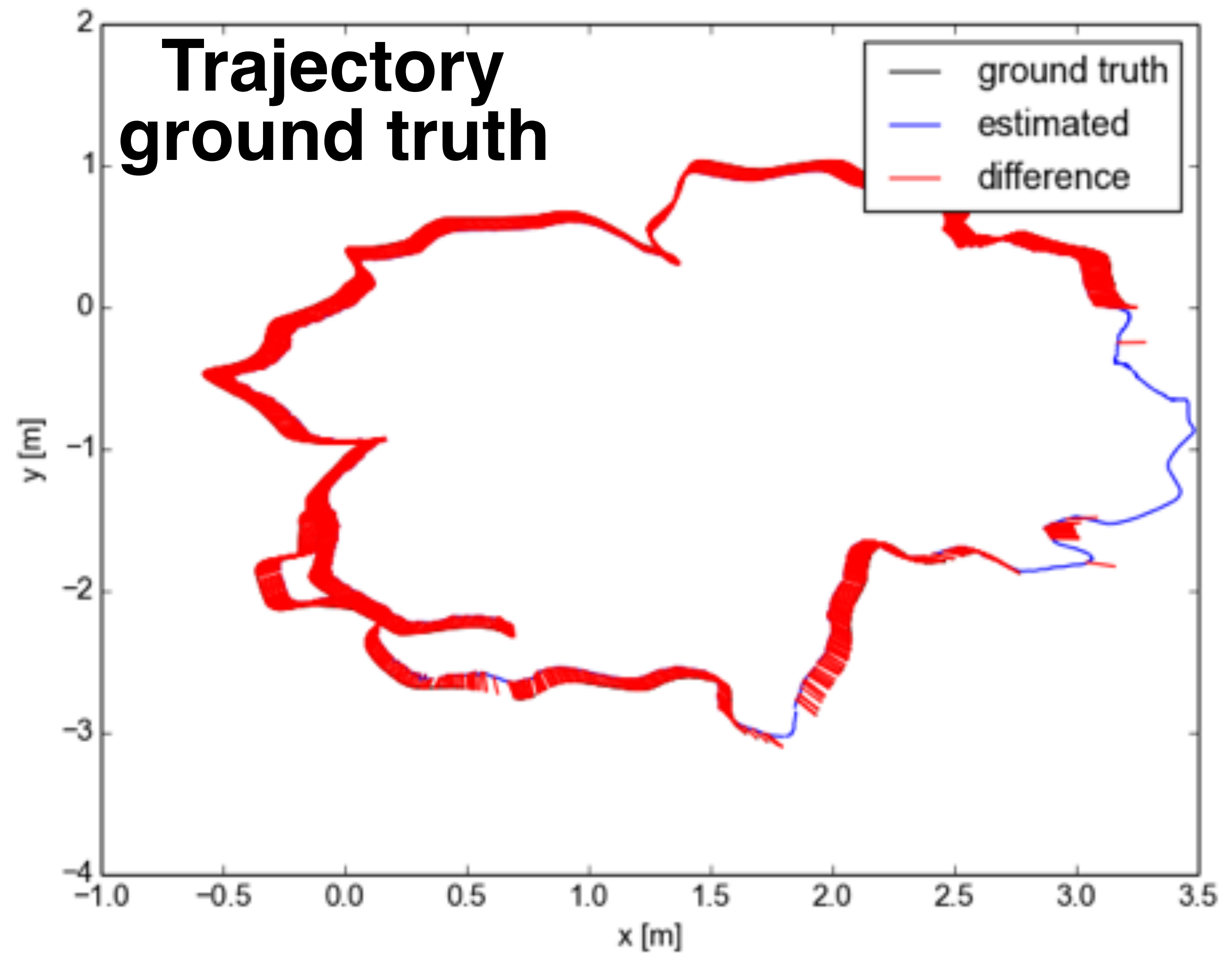


A publicly-available benchmarking framework for quantitative, comparable and validatable experimental research to investigate trade-offs in performance, accuracy and energy consumption of a SLAM system

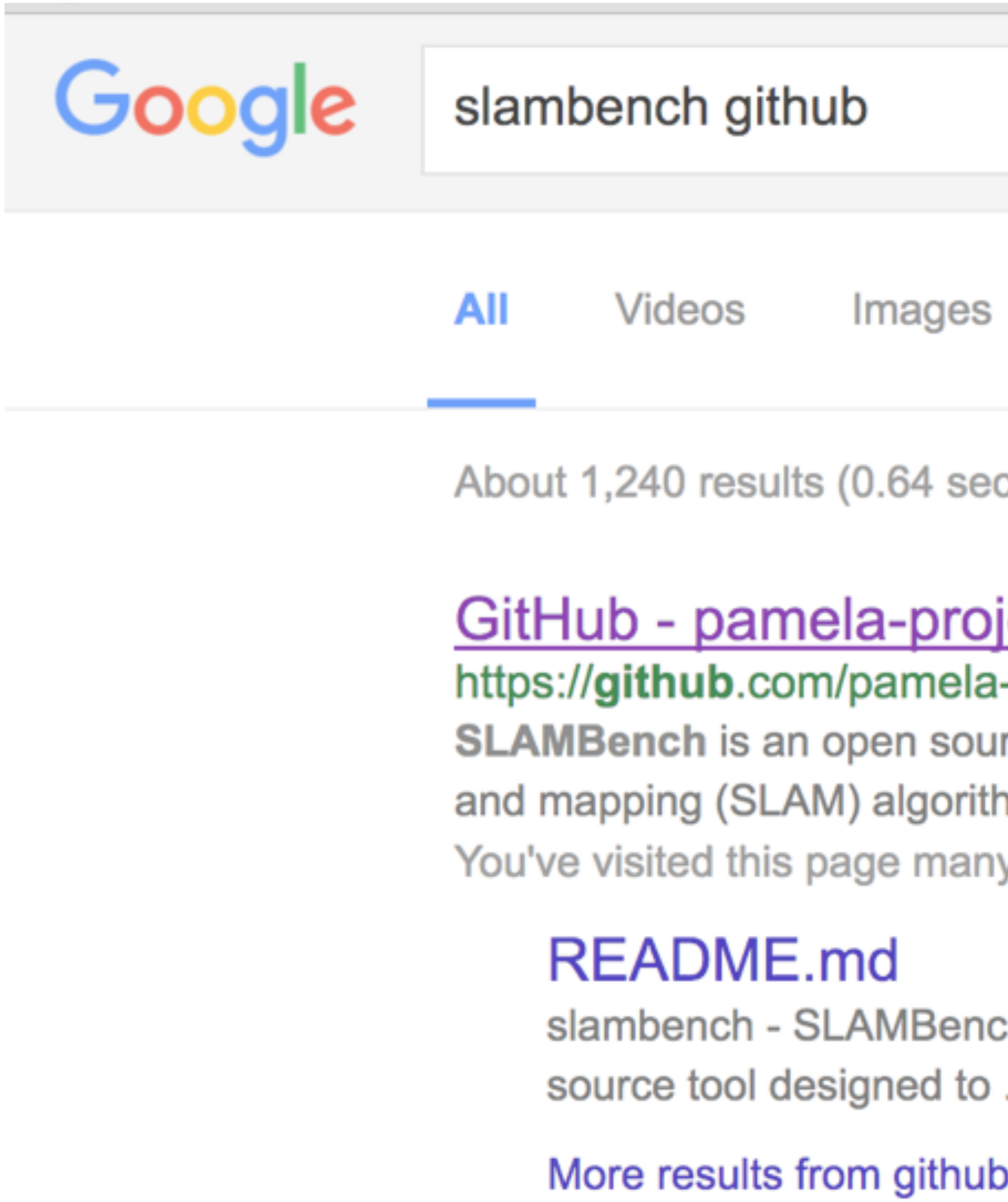
Introducing SLAMBench, a performance and accuracy benchmarking methodology for SLAM **(ICRA 2015) [Nardi et al., 2015]**

ICL-NUIM dataset





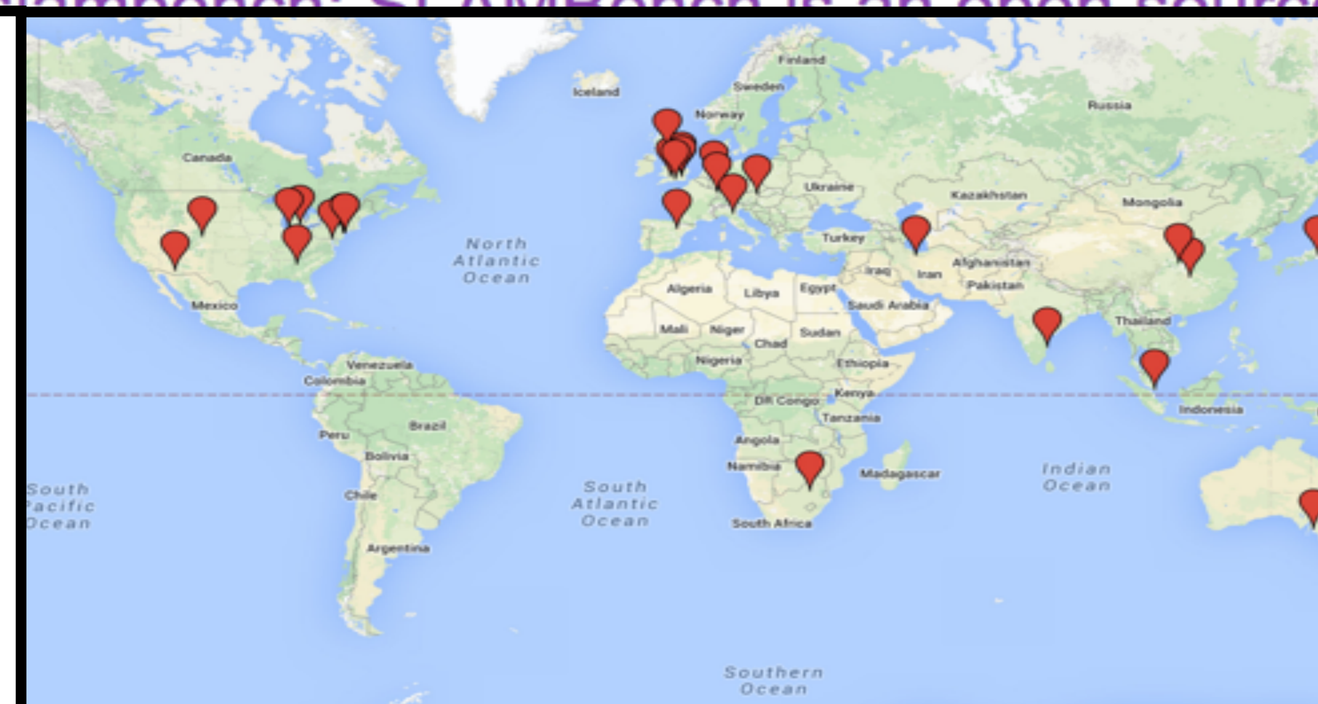
- ICL-NUIM synthetic dataset [Handa et al. 2014]
- 880 RGB-D frames at 30 FPS
- Absolute trajectory error (ATE) based on ground truth



Company users

AMD, ocado, dyson, ARM, Texas Instruments, Microsoft, amazon, NVIDIA, Qualcomm, Imagination, IBM, Google, codeplay, Movidius, Toyota, Samsung, intel, atheer labs, magic leap

Academic users



Publicly released 13/11/2014
(<u>thousands of downloads to date</u>)

What is the optimisation space?

Configuration parameters:

Co-design space

Space 1

1. Algorithmic:
   - Application-specific parameters
   - Minimisation methods
   - Early exit condition values

Space 2

2. Compilation:
   - opencl-params: -cl-mad-enable,-cl-fast-relaxed-math, etc.
   - LLVM flags: O1, O2, O3, vectorize-slp-aggressive, etc.
   - Local work group size: 16/32/64/96/112/128/256
   - Vectorisation: width (1/2/4/8), direction (x/y)
   - Thread coarsening: factor (1/2/4/8/16/32), stride (1/2/4/8/16/32), dimension (x/y)

Space 3

3. Architecture:
   - GPU frequency: 177/266/350/420/480/543/600/DVFS
   - # of active big cores: 0/1/2/3/4
   - # of active LITTLE cores: 1/2/3/4

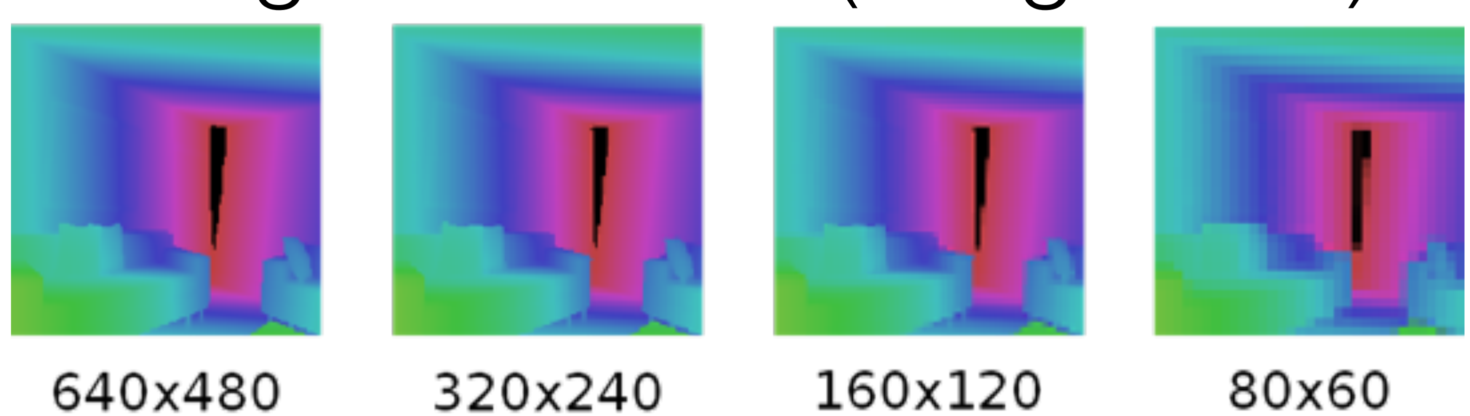
Warning: huge spaces, impossible to run exhaustively

Integrating Algorithmic Parameters into Benchmarking and Design Space Exploration in 3D Scene Understanding **[Bodin et al, 2016]**

KinectFusion algorithmic features

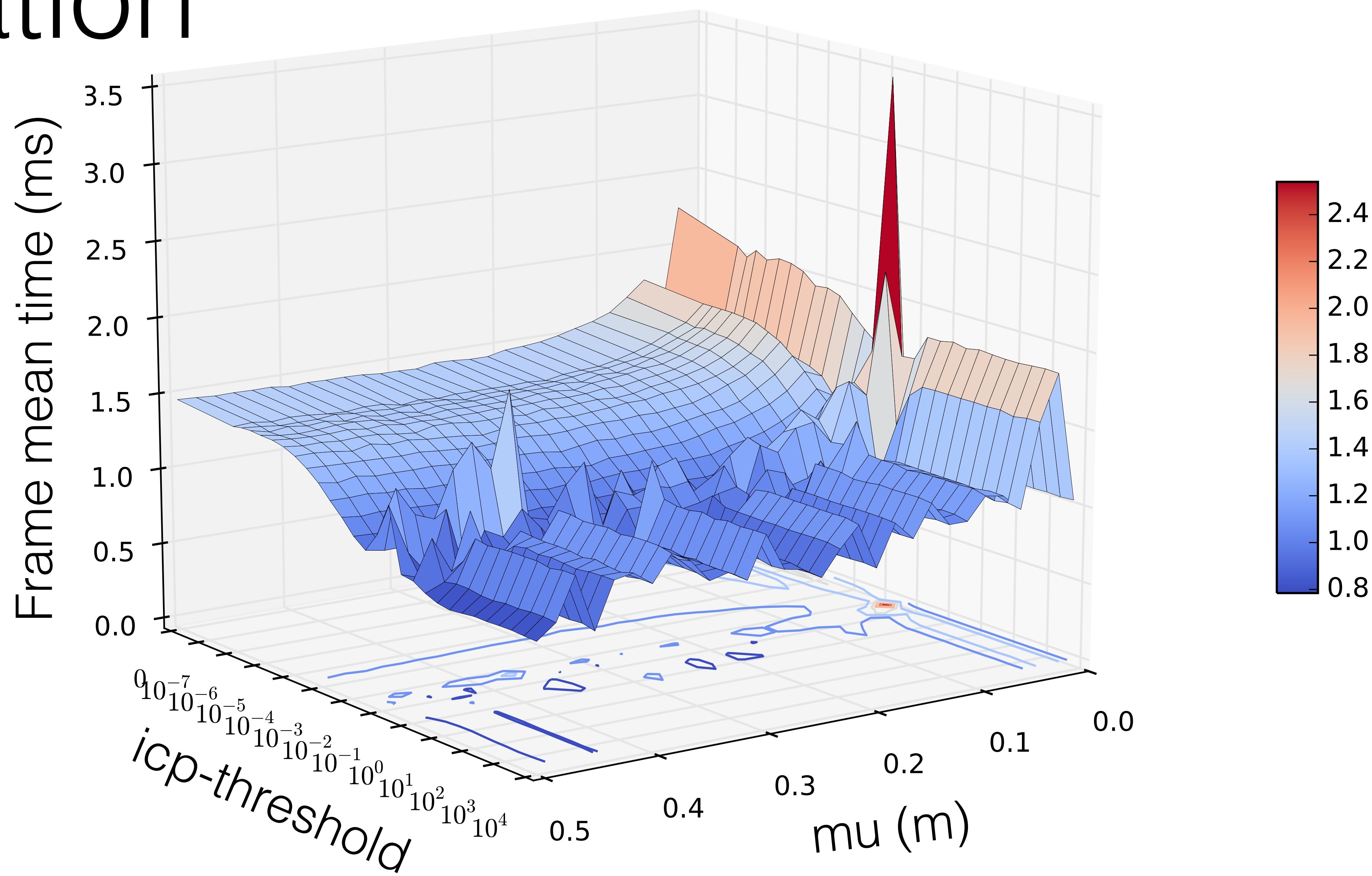
Features	Ranges
Volume resolution	64x64x64, 128x128x128, 256x256x256, 512x512x512
***μ* distance**	0 .. 0.5
Pyramid level iterations (3 levels)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Image resolution (image ratio)	1, 2, 4, 8
Tracking rate	1, 2, 3, 4, 5
ICP threshold	10^{-6} .. 10^{2}
Integration rate	1 .. 30

Image resolution (image ratio)



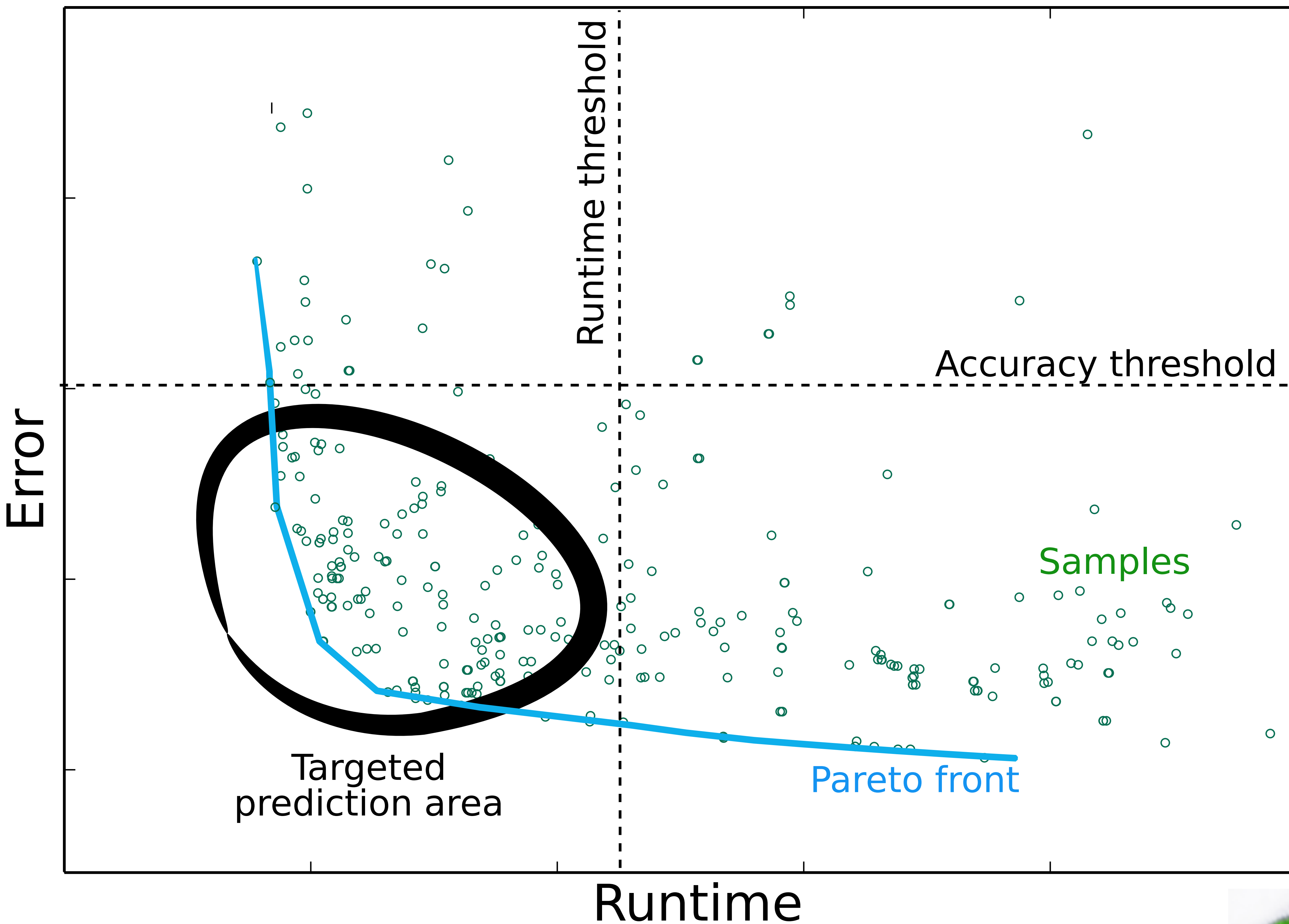
Different algorithmic features for **ElasticFusion**

Motivation

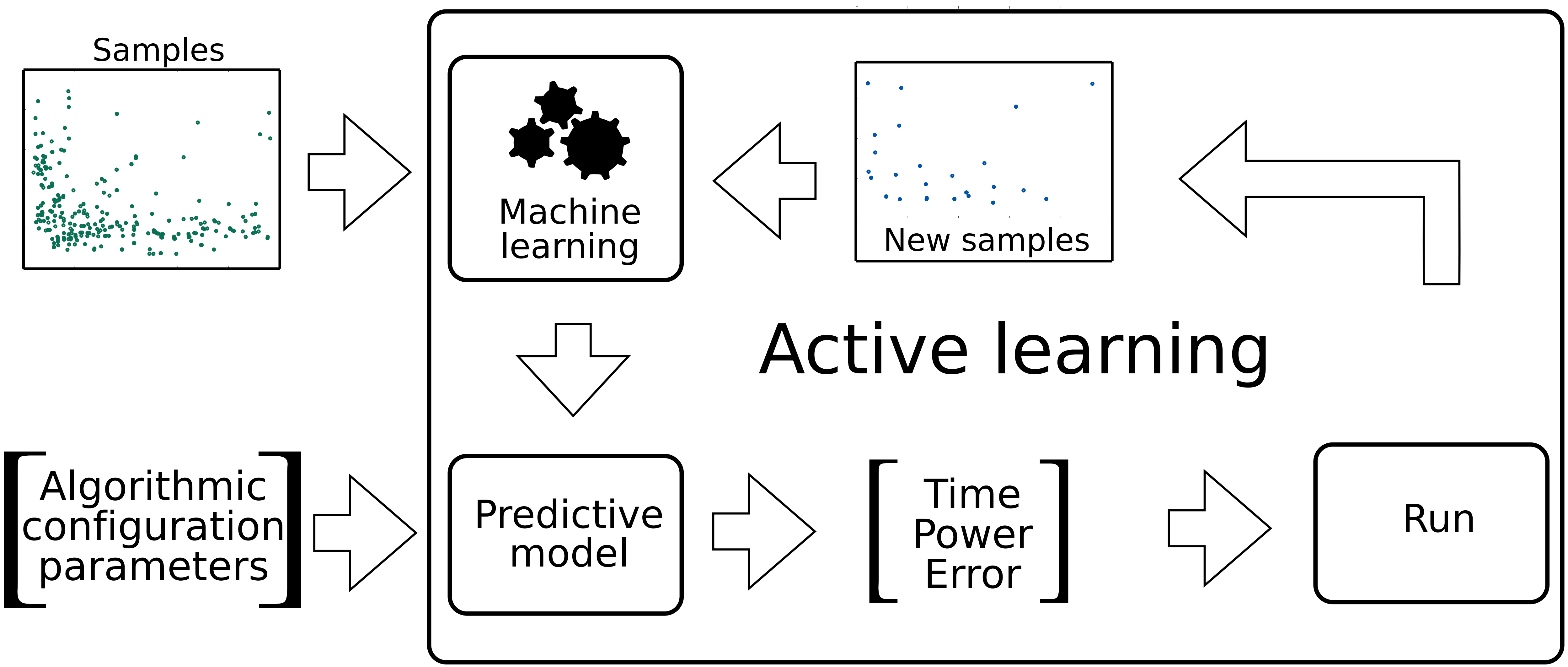


- KinectFusion runtime response surface: non-linear, multi-modal and non-smooth
- Optimal **algorithm configurability** enables better performance and better accuracy of the computation

Exploration goal



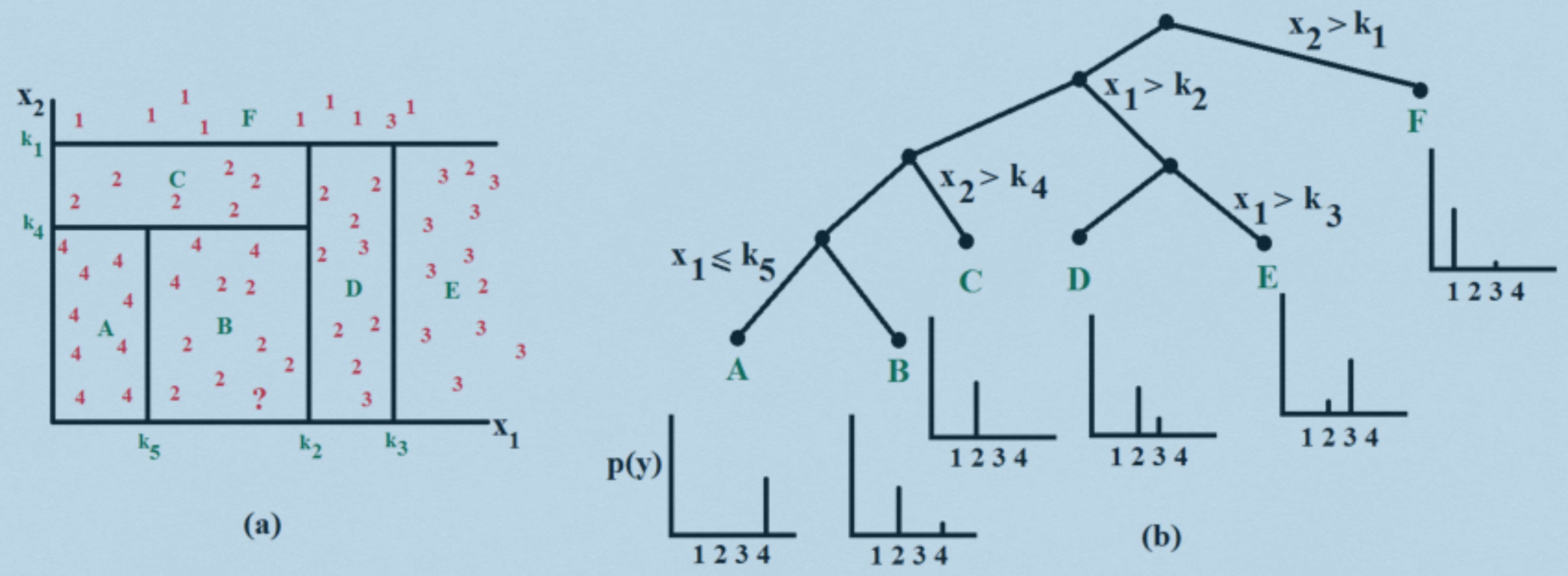
Hypermapper



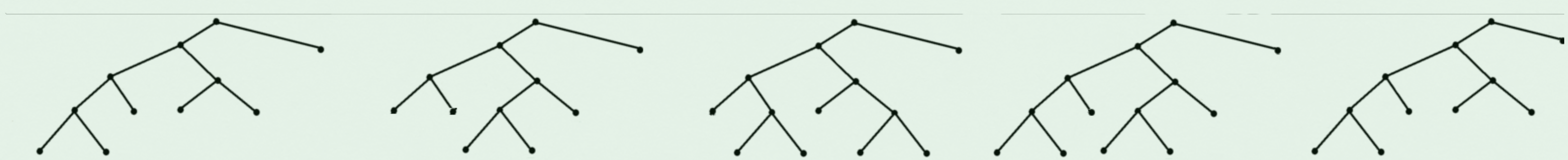
Algorithmic design-space exploration (DSE)

Machine learning methods used

Decision Tree



Random Forest



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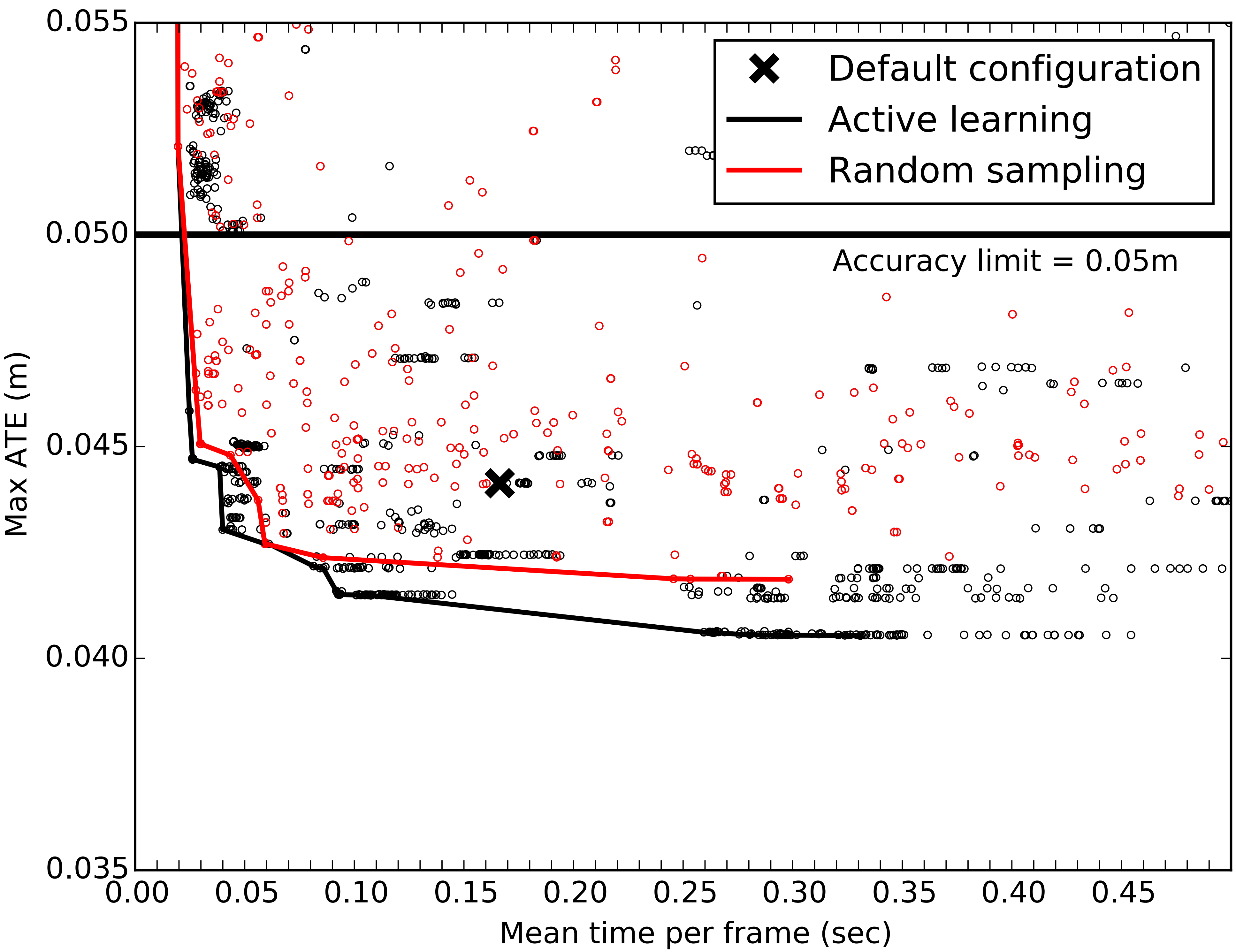
Results KinectFusion algo DSE error/runtime

Machine	Type	CPU	CPU name	CPU cores	GPU	GPU name
Hardkernel ODROID-XU3	Embedded	ARM A15 + A7	Exynos 5422	4 + 4	ARM	Mali-T628



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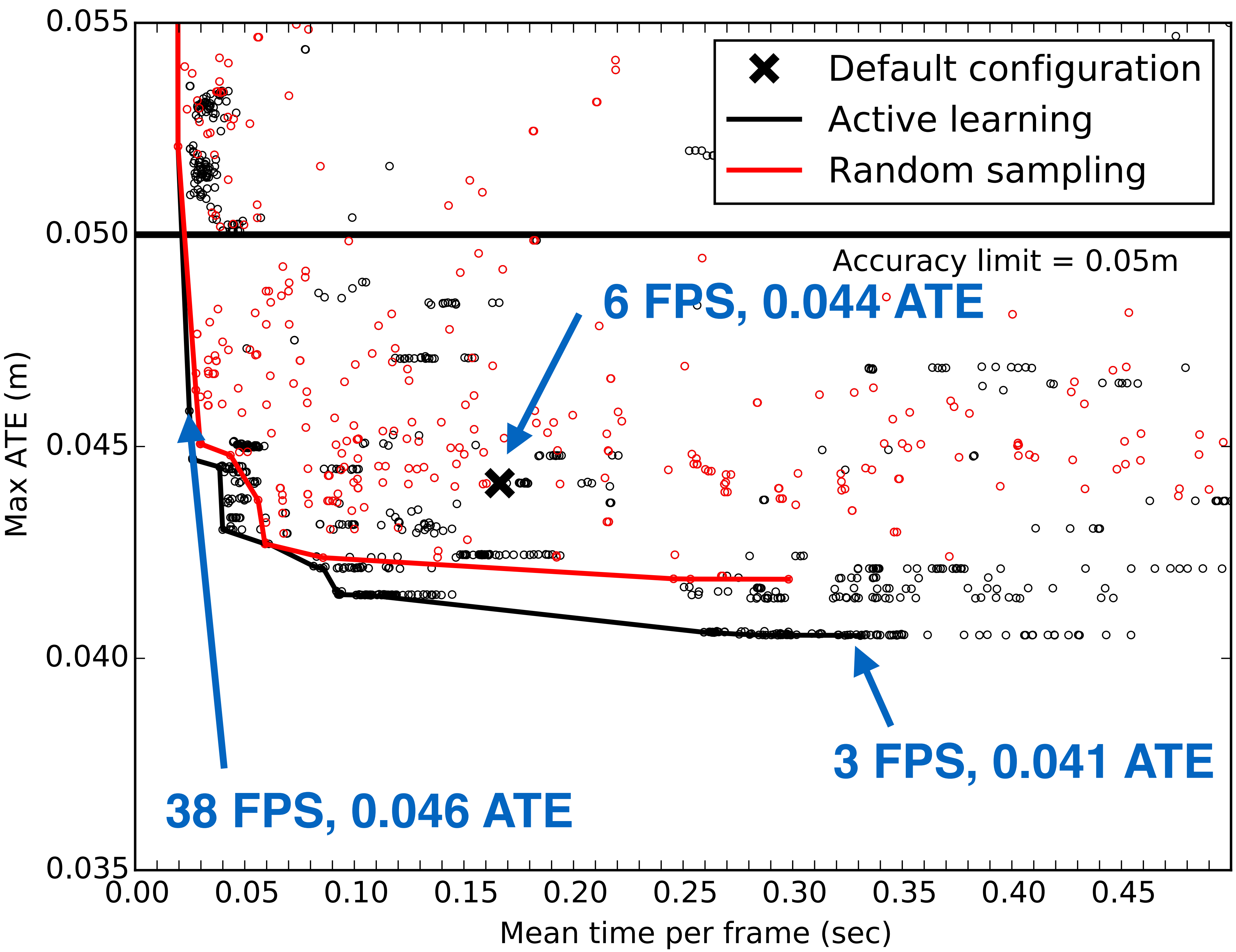

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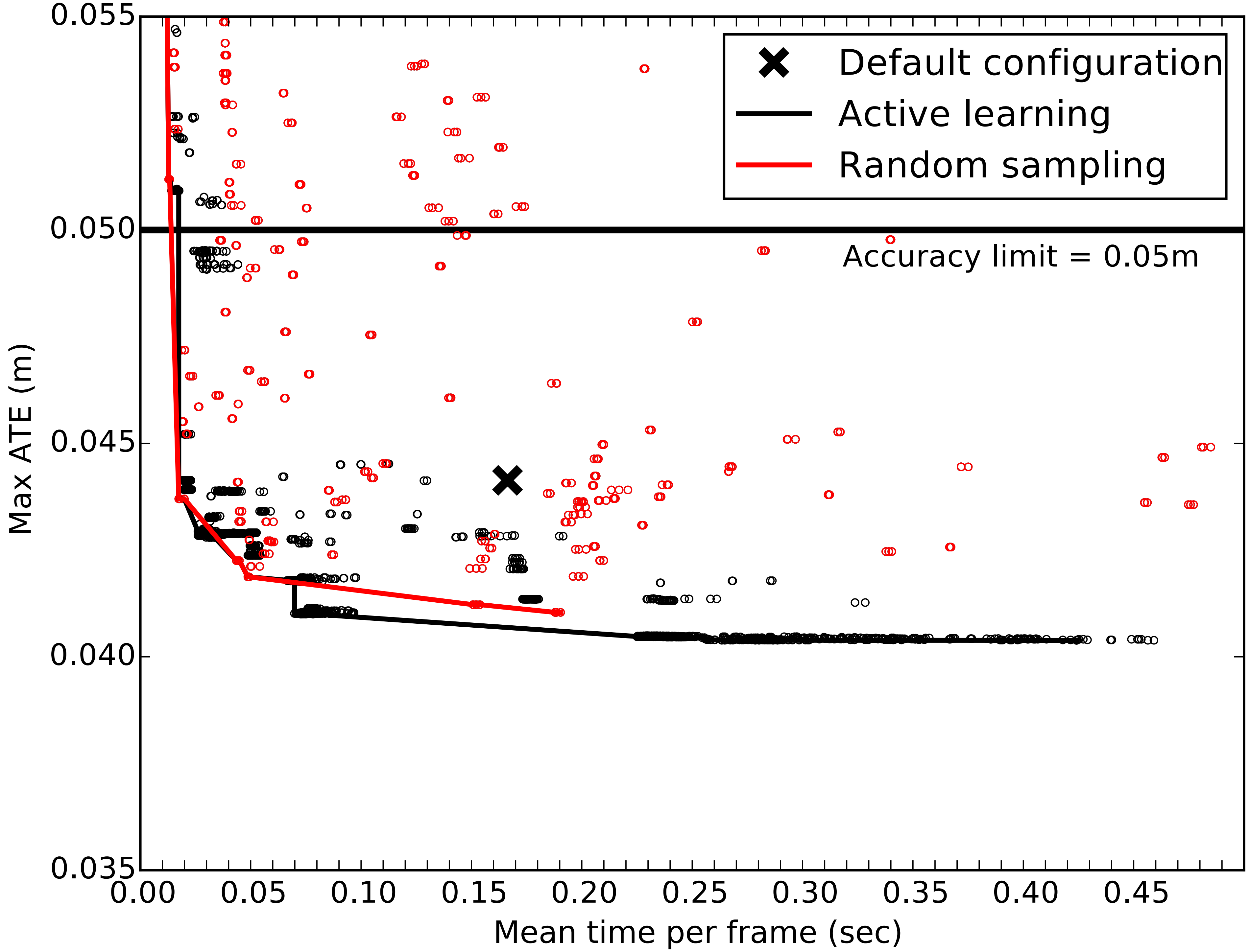
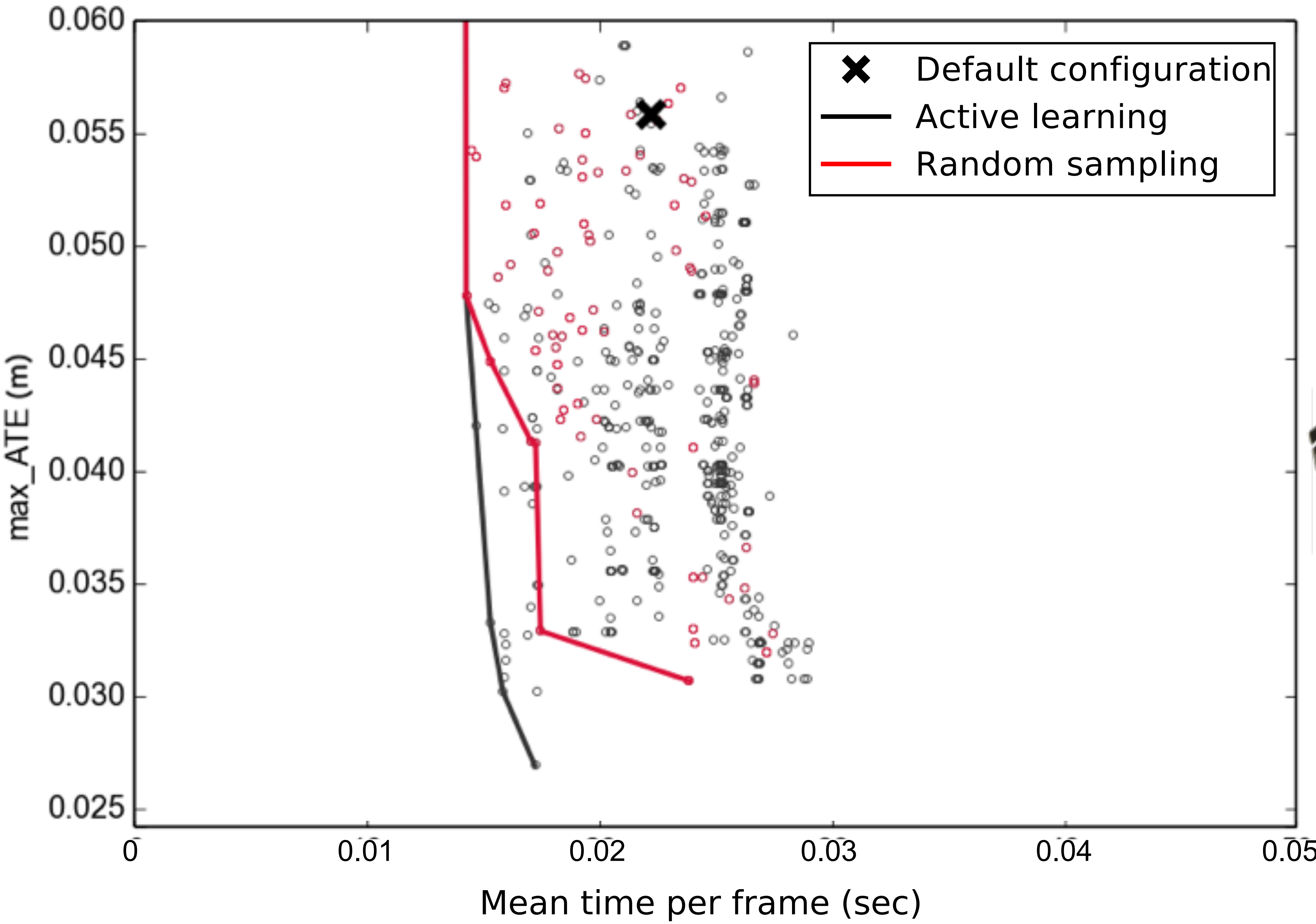
Results KinectFusion algo DSE error/runtime

Machine	Type	CPU	CPU name	CPU cores	GPU	GPU name
ASUS T200TA	Detachable laptop	Intel Silvermont	Atom Z3795	4	Intel	HD Graphics



Results ElasticFusion algo DSE error/runtime

Machine	Type	CPU	CPU name	CPU cores	GPU	GPU name
NVIDIA/Intel	Desktop	Intel Ivy Bridge	E5-1620	8	NVIDIA	GTX 780 Ti



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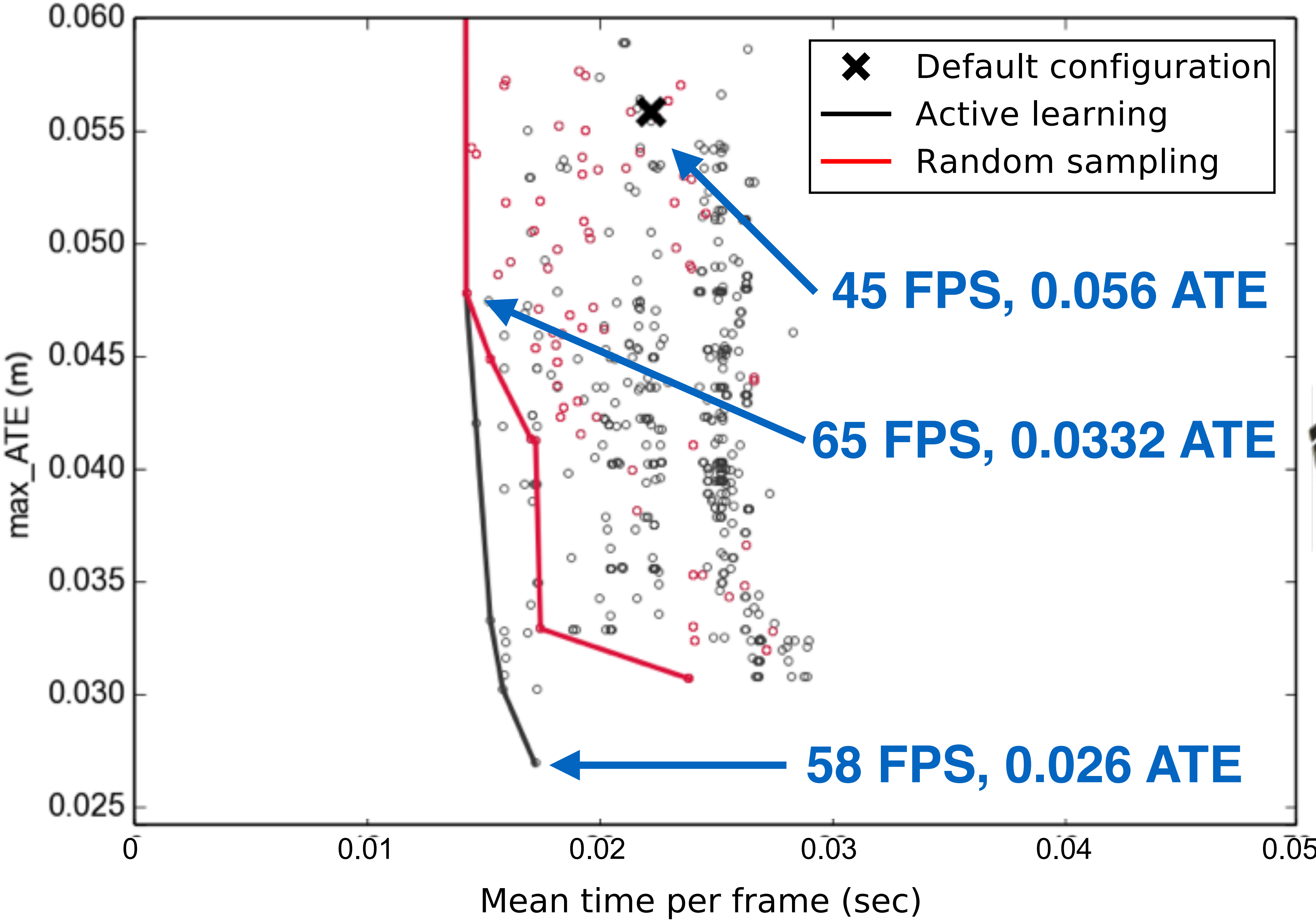
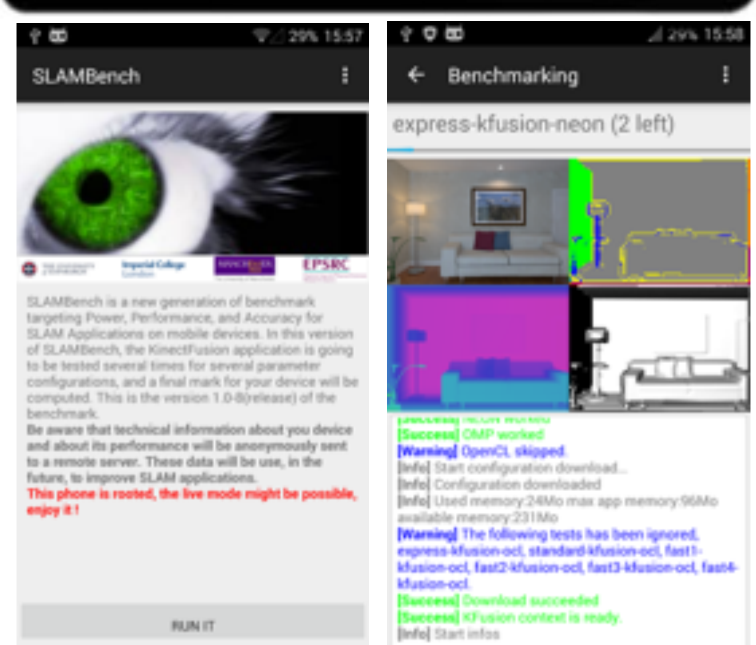


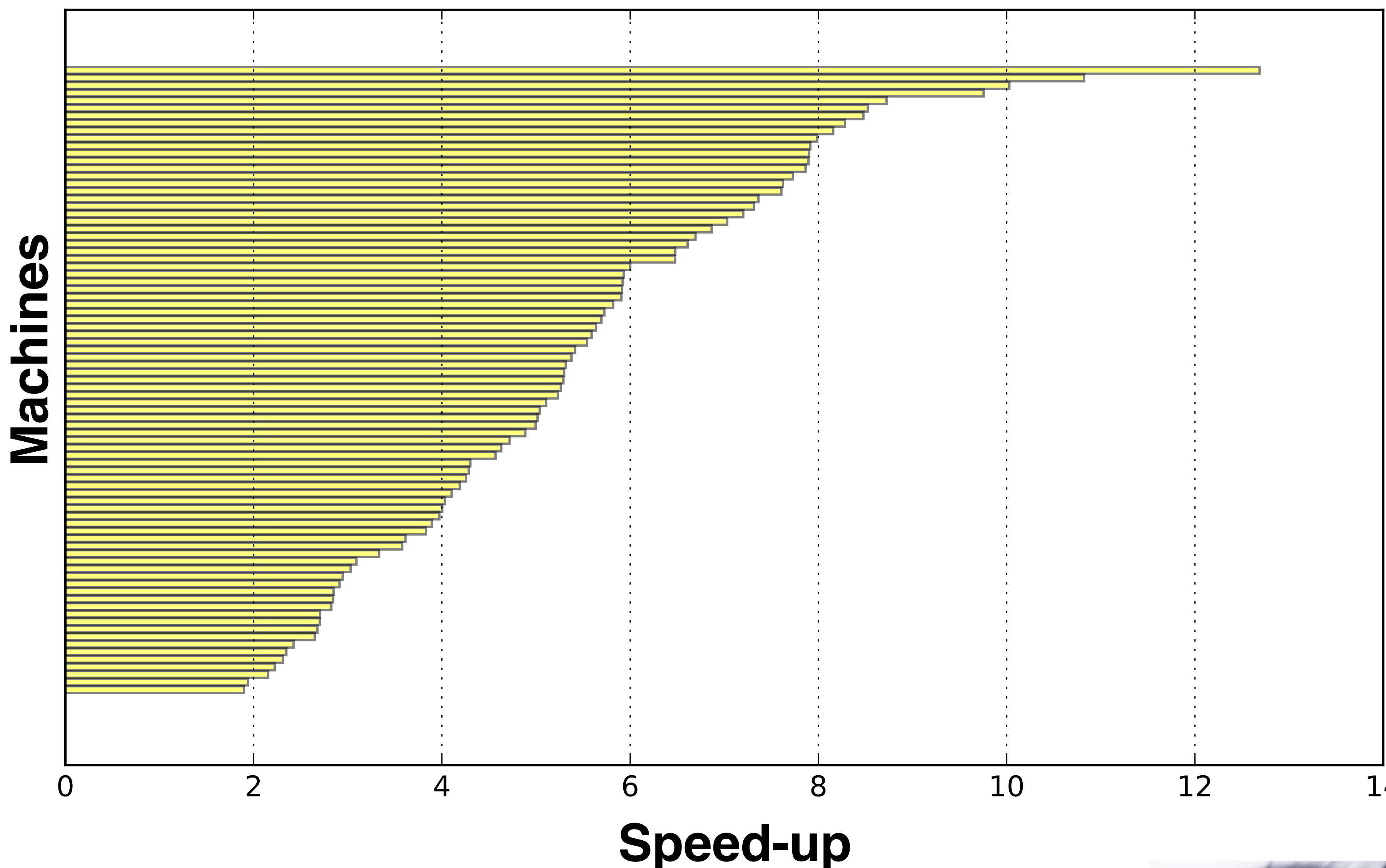
Crowdsourcing mobile Android SLAMBench

- The OpenCL KFusion was run on 83 smart-phones and tablets
- For each device, we computed the speedup of:
  - ✦ the best configuration we found for the ODROID-XU3 and
  - ✦ the original default configuration

Get it now and see how your device scores!

Get it on Google play





Conclusion - take away messages

1. Building tools to explore the performance landscape for SLAM solutions
2. Generalisation to other applications
3. Multi-objective optimisation: speed/power/accuracy
4. Semantic accuracy check is very powerful:
   - enables non bit-wise accuracy check
   - aggressive approximate computing and auto-tuning
5. Pareto maps how configurations should be adapted when objectives change - static and dynamic
6. Large improvement over default configuration

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