Bayesian Active Learning For Sim-to-Real Robotic Perception

Jianxiang Feng, Jongseok Lee, Maximilian Durner, Rudolph Triebel

Problem: Sim-to-Real Gap in Robotic Perception

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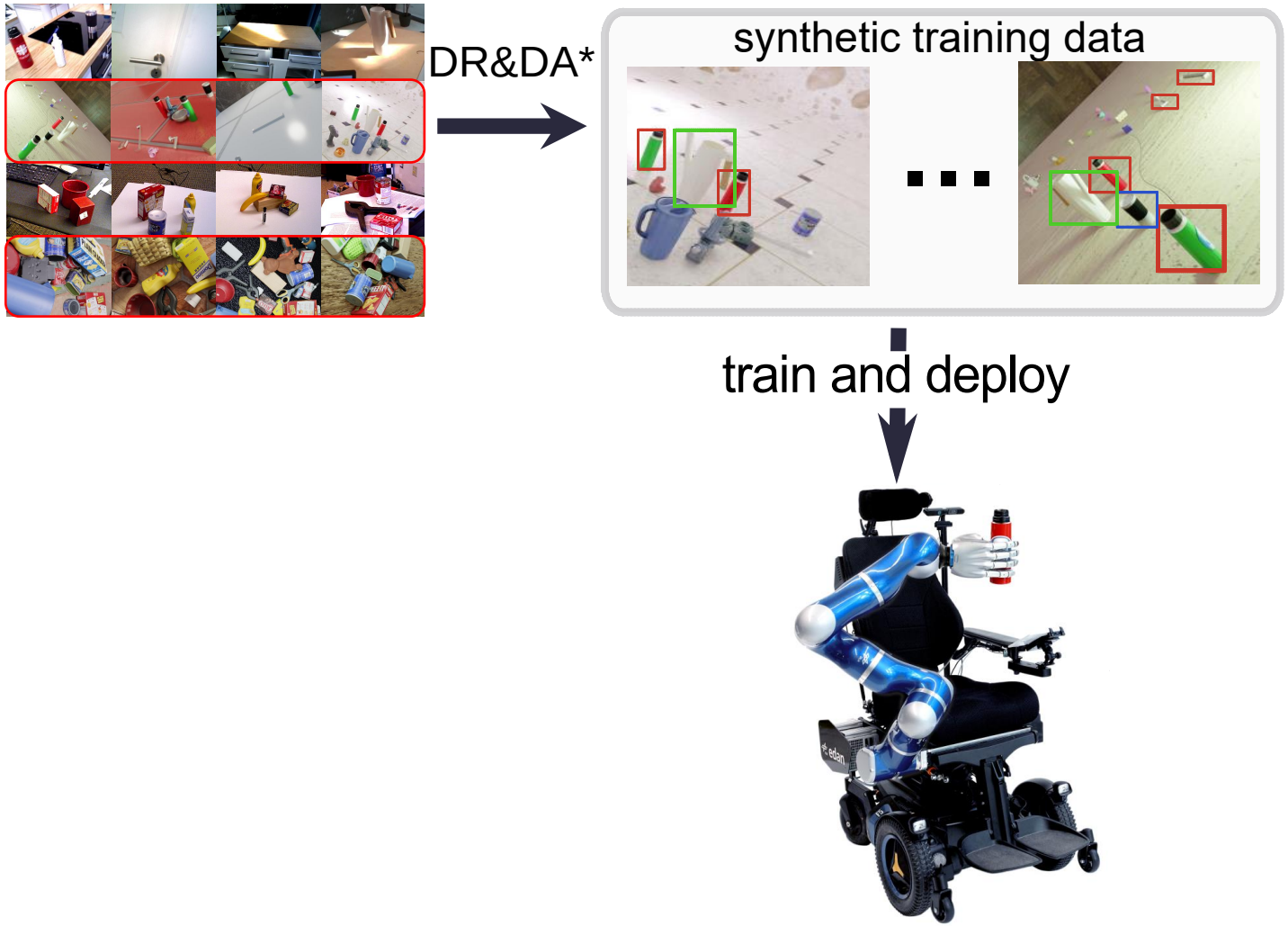


*: Domain Randomization and Data Augmentation

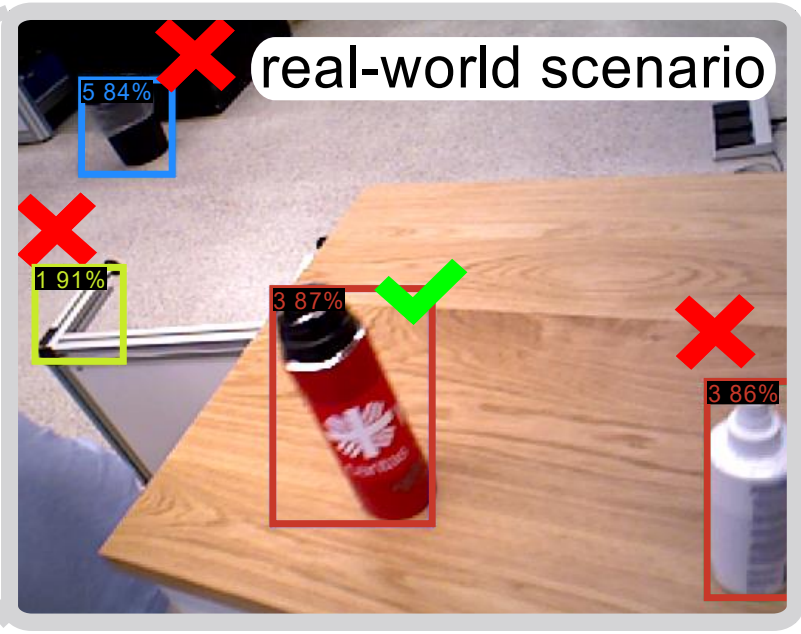
Problem: Sim-to-Real Gap in Robotic Perception

DR&DA*

synthetic training data

Sim-to-Real Gap

train and deploy

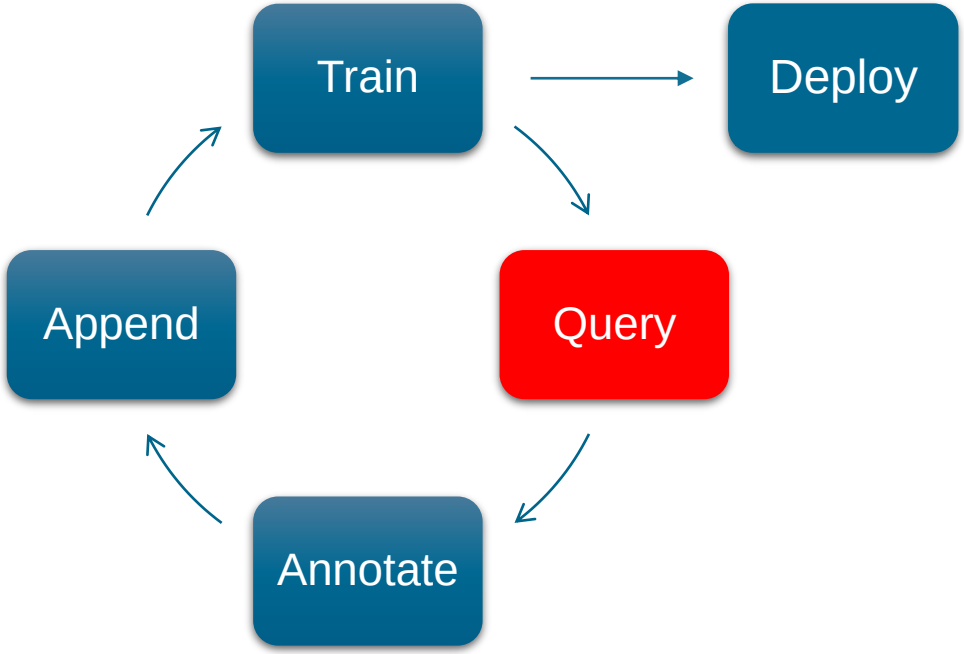


We found real data necessary, but how to get them efficiently?

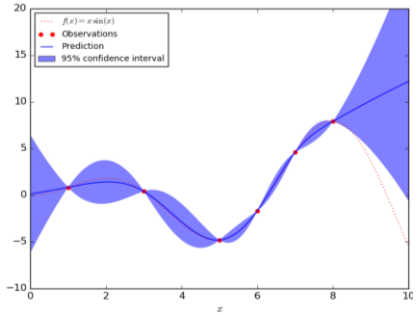
*: Domain Randomization and Data Augmentation

Idea: Bridging the Gap with Bayesian Active Learning

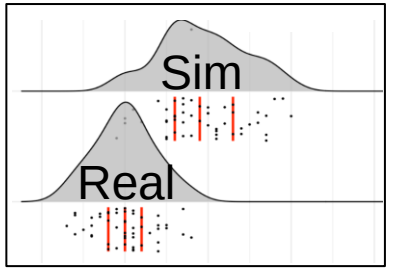
- Active learning for efficient data collection in Sim-to-Real
  1. Model predictive posterior for data query
     - ➢ Bayesian Neural Networks/Bayesian Object Detectors
  2. Mitigating label distribution shift
     - ➢ Combination of uncertainty and sub-sampling strategies



Active Learning

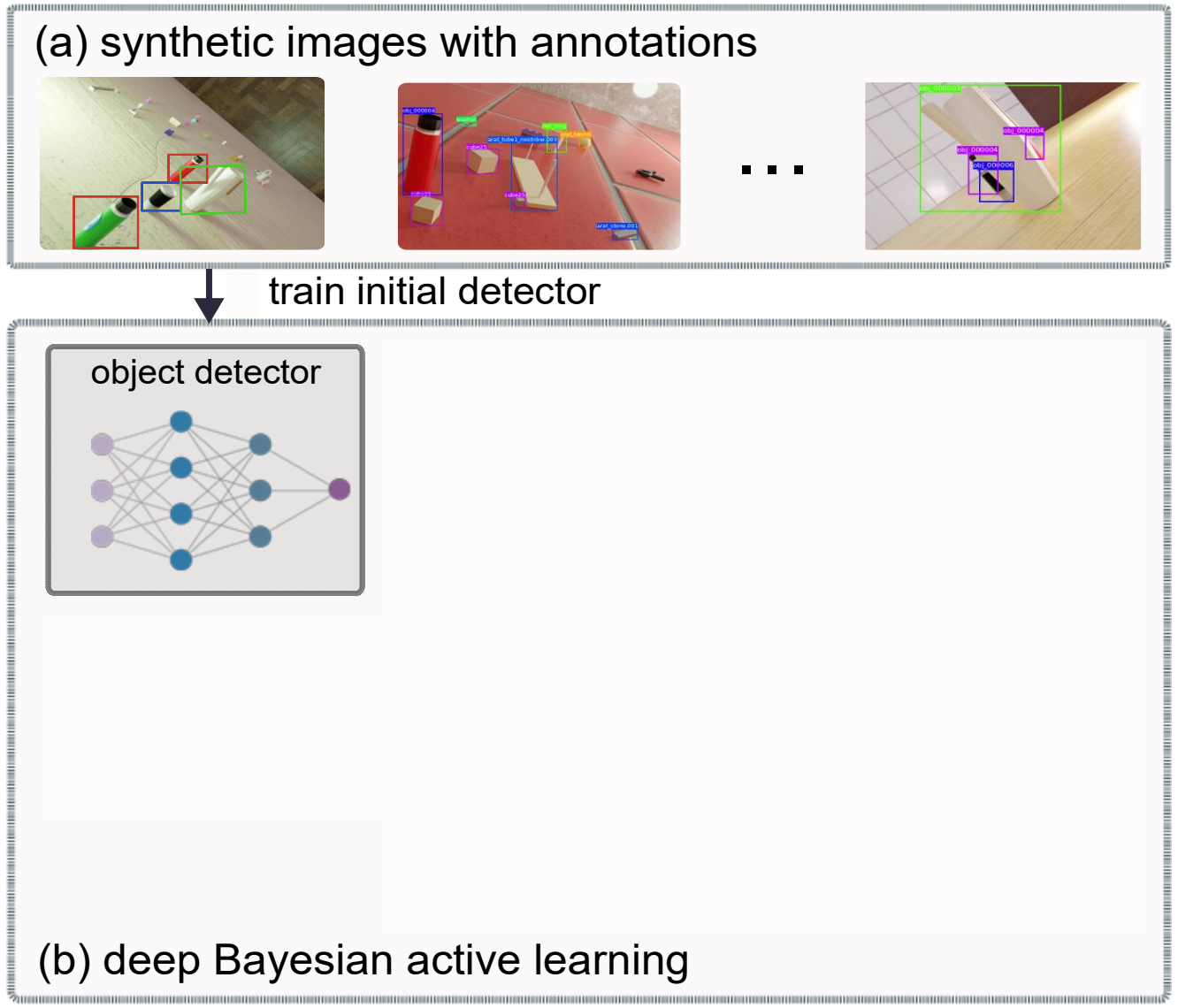


Bayesian Model

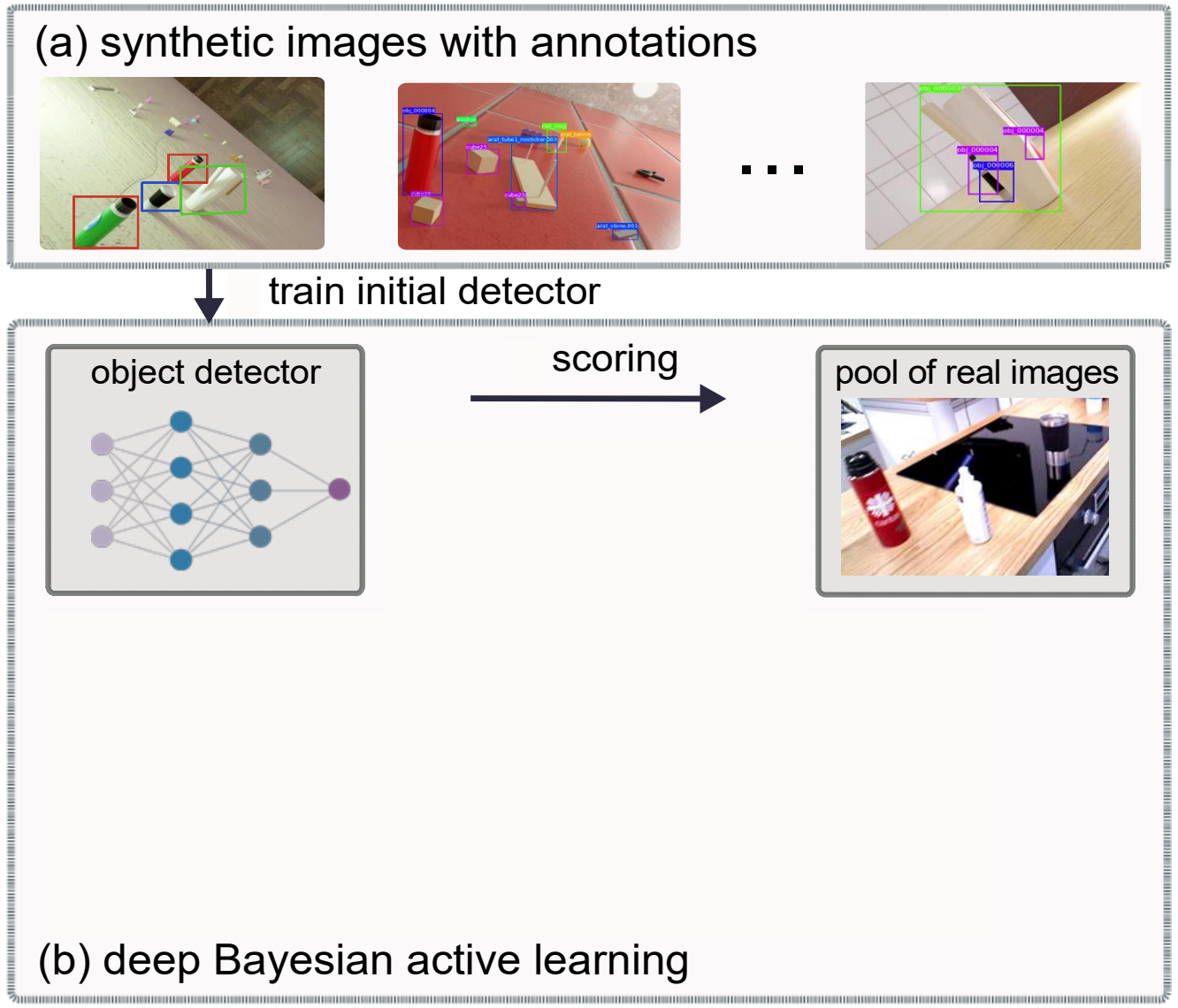


Dist. Mismatch

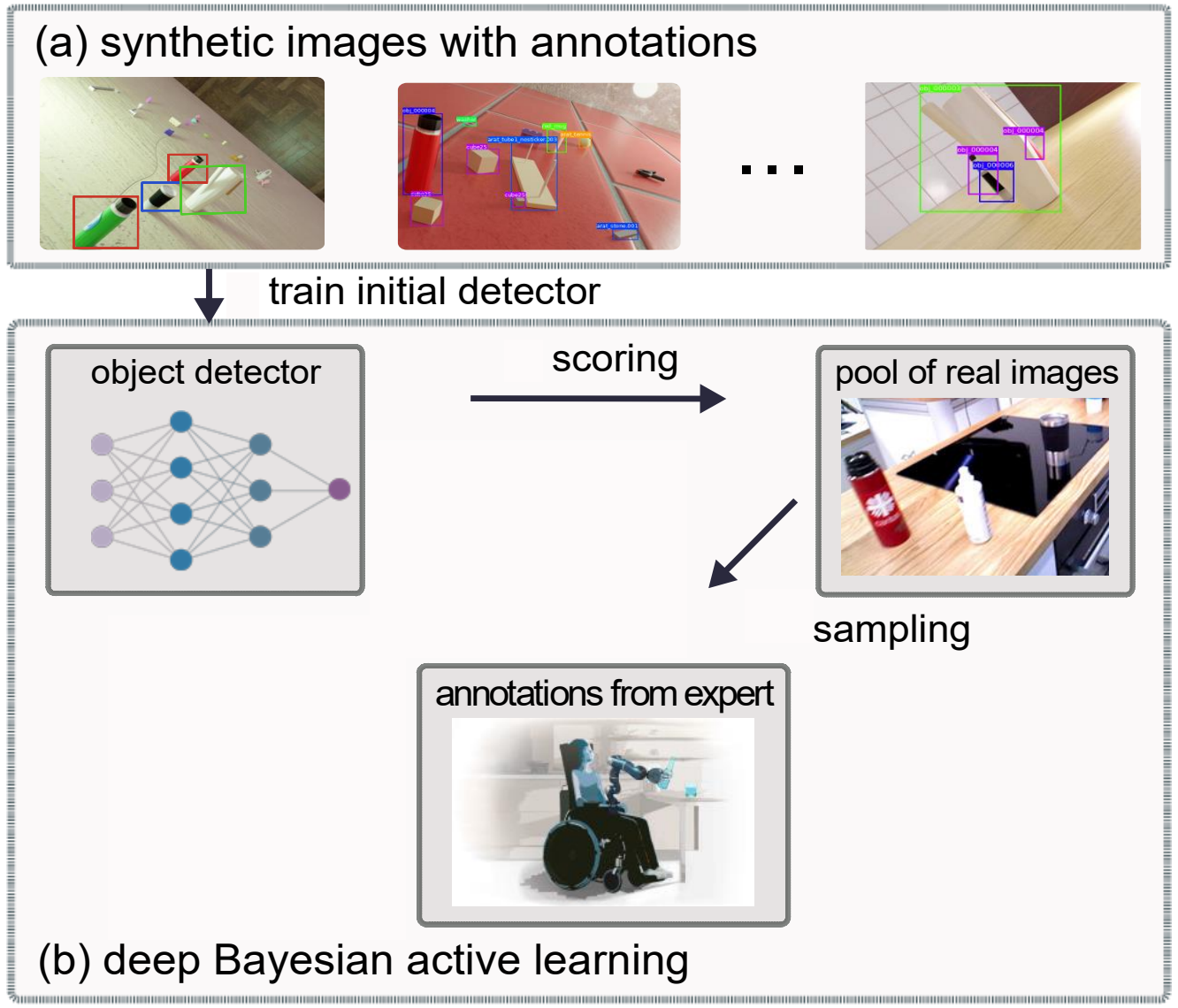
Proposed Pipeline



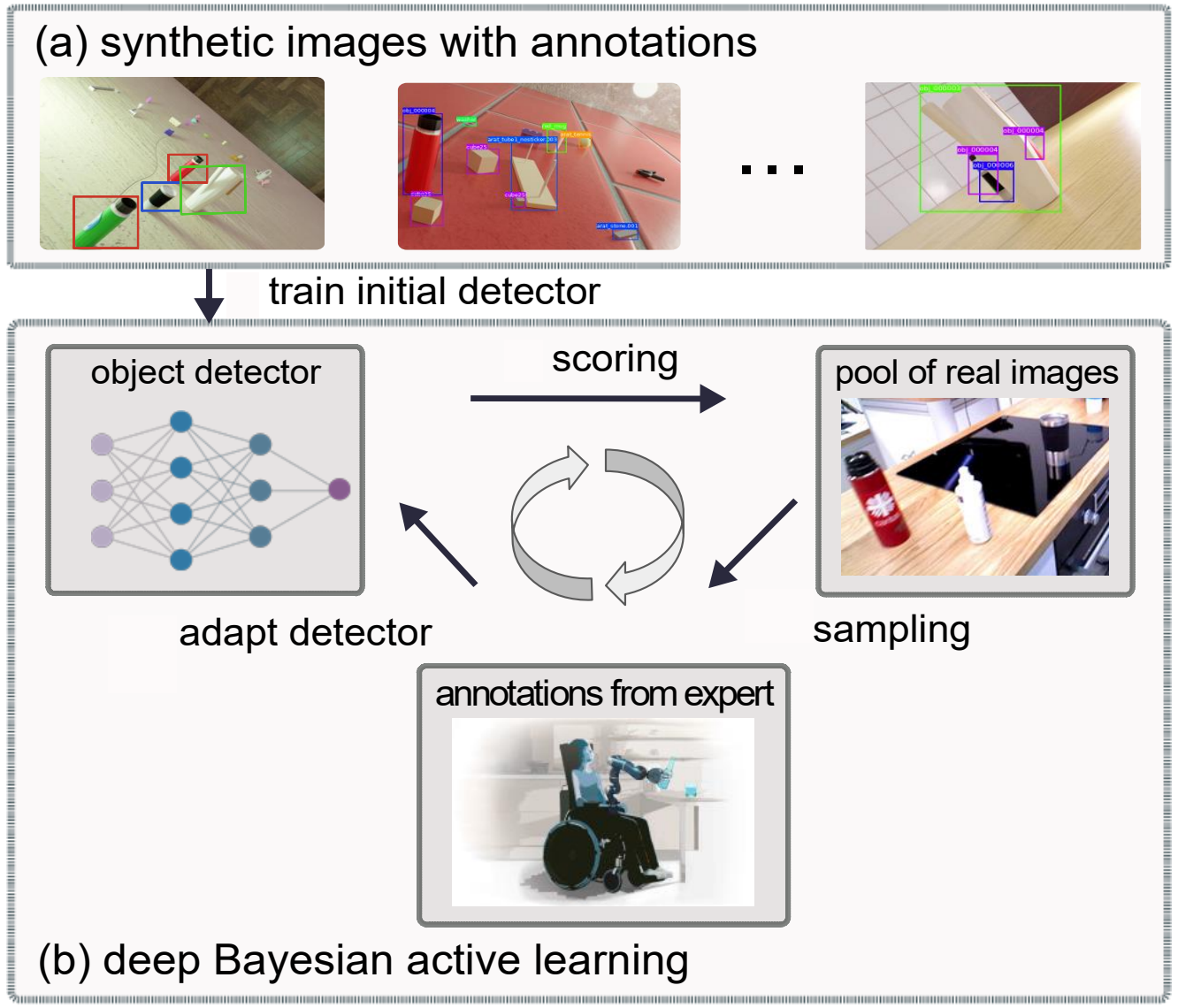
Proposed Pipeline



Proposed Pipeline



Proposed Pipeline

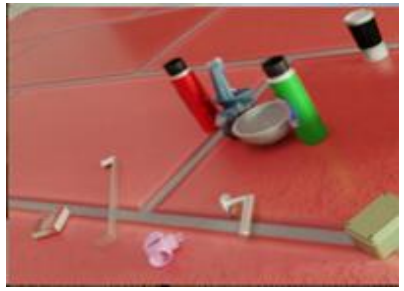


Sampling Strategy to Mitigate Label Shift

Source/Sim distribution

$p(\boldsymbol{y}|\boldsymbol{x}, \mathcal{D}_{train})$
$\neq$

Target/Real distribution



Initialize

$\mathcal{M}_\theta : \mathcal{X} \longrightarrow \mathcal{Y}$

Query/

Adapt/
Test

Sampling Strategy to Mitigate Label Shift

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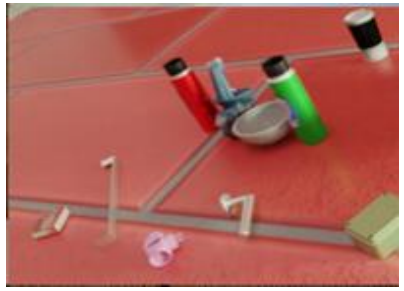

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Query/

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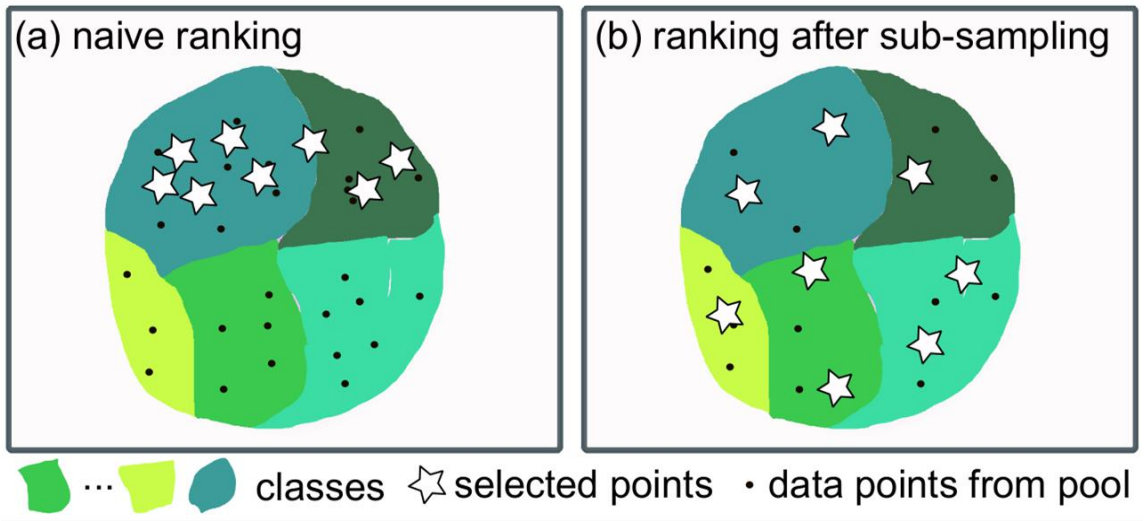
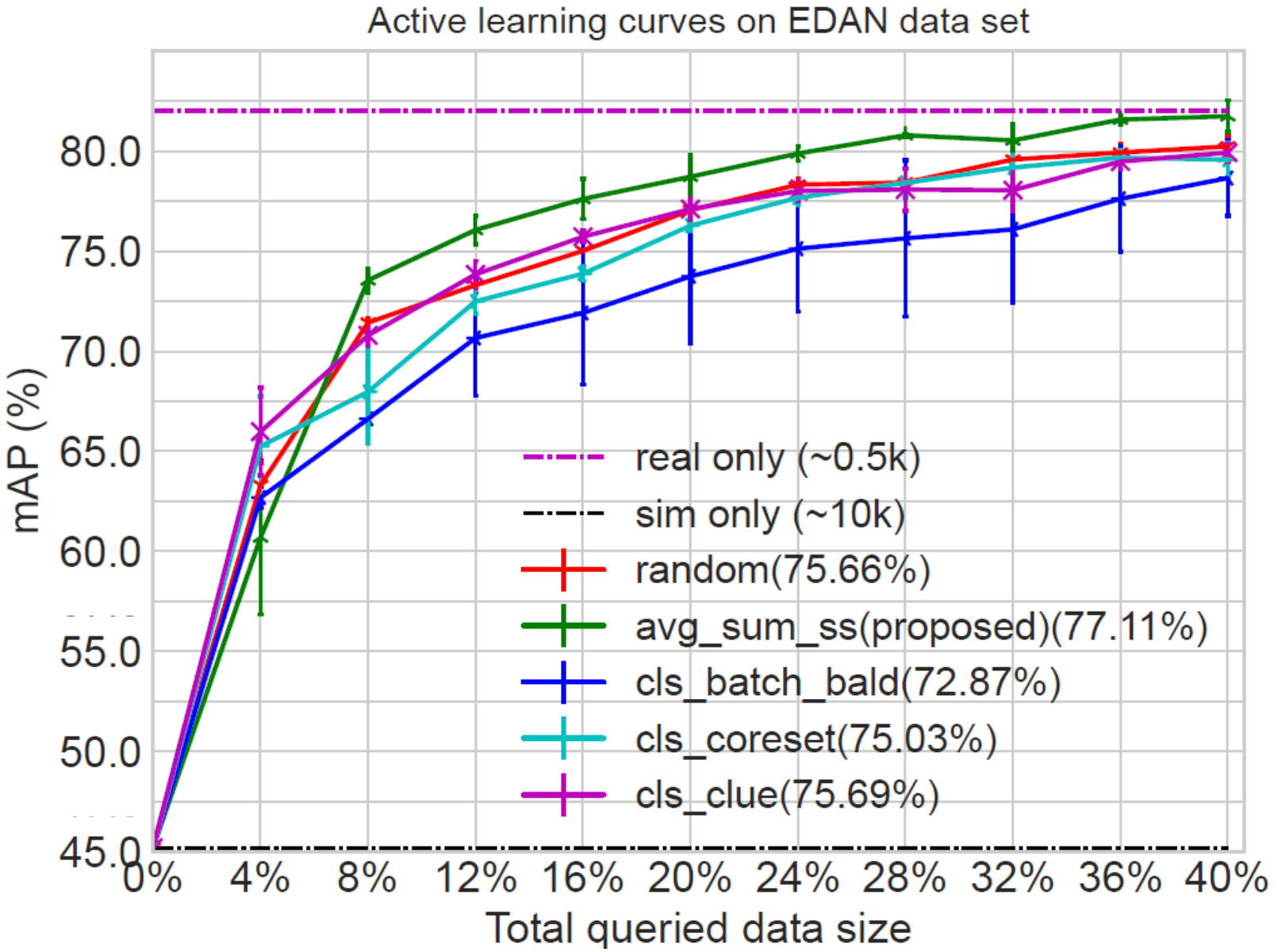
Sampling Strategy

P_{label}: target label (uniform) distribution
P_{unc}: uncertainty sampling distribution
P_{ss} : sub-sampling (uniform) distribution
$\hat{P}_{label}$: sampling label distribution

$$\hat{P}_{label} \cong P_{label} \; with \; \hat{P}_{label} \propto P_{ss} P_{unc}$$



Object Detection Experiment



Real Robot Deployment

Task 1&2:

Grasping a bottle
&
Opening a drawer

Take-away

- An active learning based pipeline to bridge Sim-to-Real gap for robotic perception.
- A simple and effective sampling strategy to mitigate label shift for active learning in Sim-to-Real.
- Extensive empirical experiments and real robot deployment along with a failure case analysis.

Thank you!
&
Questions?

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Code