

# Toward Cost-Efficient Simulation-Based Inference for Robotics: Reducing Real-World and Simulation Sampling Costs

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Abstract ([should be within 1st page](#))

Simulators provides virtual environments for robotic experiments, yet their parameters need to be tuned to faithfully reproduce real-world dynamics. Traditional parameter estimation from a Bayesian perspective is difficult in robotic simulations since the internal model is inaccessible or too complex. Recently, Simulation-Based Inference (SBI) has emerged as a data-centric solution that estimates parameters from simulation data. However, conventional SBI frameworks require large amounts of simulation data to obtain accurate posterior estimation which is impractical for robot simulators where highly accurate simulations are often very computationally expensive. At the same time, the real-world data used for parameter estimation are also costly to collect. Because we do not know in advance which observations are informative about the unknown parameters, we needed to gather many real-world data under various actions and aggregate them for calibration. For real robots, such data collection is time-consuming and may lead to damage, making extensive real-world data collection undesirable. This dissertation addresses these limitations by improving real-world data efficiency and simulation efficiency in SBI. First, we propose an Active Simulation-Based Inference (ASBI) framework that actively selects informative actions by maximizing information gain, achieving accurate parameter estimation with a small amount of real-world data. Second, we develop bias-aware multi-fidelity SBI (BAMSI) framework that leverages low-fidelity simulations to efficiently narrow the parameter space and uses high-fidelity simulation for refinement, thereby reducing the overall simulation cost. We validate these frameworks in robot simulation experiments, demonstrating significant improvements in real-world and simulation data efficiency.