The Impact of Time Step Frequency on the Realism of Robotic Manipulation Simulation for Objects of Different Scales

Minh Q. Ta*, Holly Dinkel*, Hameed Abdul-Rashid, Yangfei Dai, Jessica Myers, Tan Chen, Junyi Geng, and Timothy Bretl

University of Illinois Urbana-Champaign · Michigan Technological University · Penn State

← Paper

Finalist, Best Poster
Workshop on Robotics and AI in Future Factory

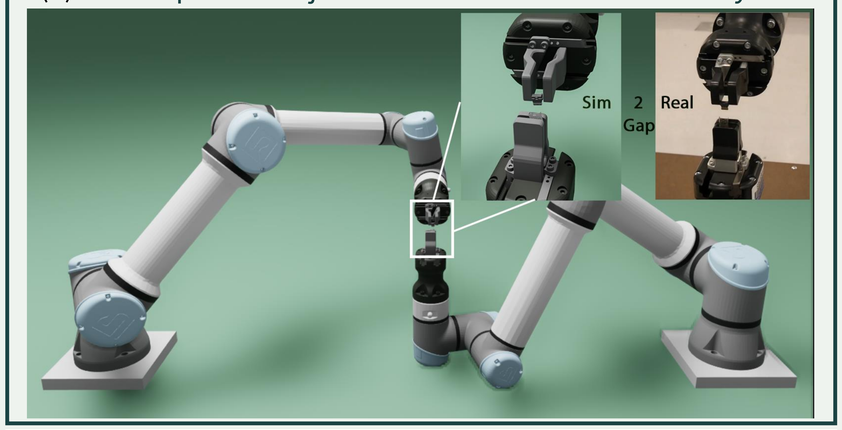
Introduction

High fidelity robotic manipulation simulators are necessary to create digital twins for smart manufacturing. This presentation uses a pre-assembly part picking task to demonstrate contact simulation for robotic manipulation. Reconciling physical behaviors in simulation with behaviors in the real world (Sim2Real) is important to increase adoption of robotic systems for manufacturing.

This work evaluates:

(i) the impact of time step frequency (TSF) on simulation accuracy, and

(ii) the impact of object scale on simulation accuracy.



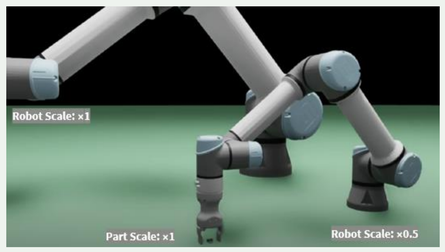
Simulation Environment

Simulator: Nvidia Isaac Sim

Robots: Two Universal Robots UR5e manipulators, each equipped with a Robotiq Hand-E Gripper

Task: Picking an inserted part and a base part

Simulation Parameters: GPU Dynamics Enabled, Convex Decomposition Collider Approximation, Dynamic Friction = 1.0, Static Friction = 1.0, and Restitution = 0.0



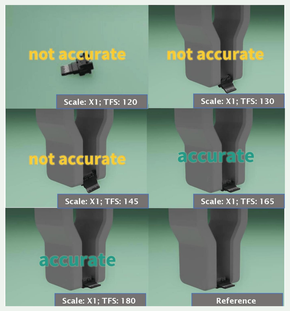
This work is a starting point to invite conversation on how to improve Sim2Real transfer for robotic assembly.

Experiments

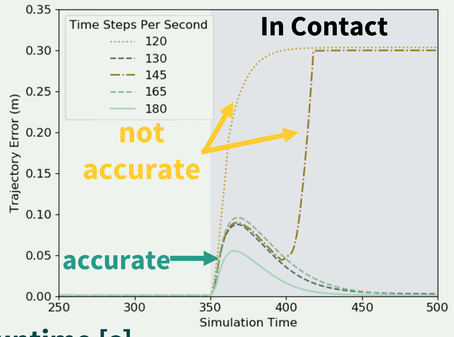
Experiments were performed on an inserted part and a base part, each with different scales and different time step frequencies.

Inserted Part Picking

Varying time step frequency for an inserted part with ×1 (original) scale



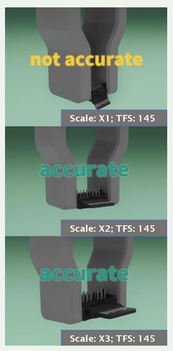
Trajectory Error



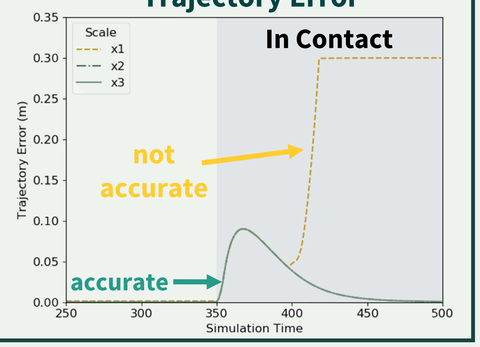
Runtime [s]

Time Step Frequency (Times Steps Per Second)				
120	130	145	165	180
10.5 ± 0.2	12.9 ± 0.1	14.8 ± 0.0	14.6 ± 0.1	18.5 ± 0.1
not accurate			accurate	

Varying scale for an inserted part with a fixed time step frequency of 145 Time Steps Per Second:



Trajectory Error



Results

- Simulations marked "accurate" according to their trajectory error
- Trajectory error measured for each scale against a reference trajectory at the same scale with 360 Time Steps Per Second.

Inserted Part Picking

Part Scale	Time Step Frequency (*Time Steps Per Second*)				
	120	130	145	165	180
×1	×	×	×	✓	✓
×2	×	×	✓	✓	✓
×3	×	✓	✓	✓	✓

Base Part Picking

Part Scale	Time Step Frequency (*Time Steps Per Second*)				
	45	60	70	80	90
×1	×	✓	✓	✓	✓
×2	✓	✓	✓	✓	✓
×3	✓	✓	✓	✓	✓

Robot Scale	Time Step Frequency (*Time Steps Per Second*)				
	120	130	145	165	180
×1	×	×	×	✓	✓
×0.5	×	×	×	×	✓

Key	
×	Not accurate
✓	Accurate

Conclusions

- Manipulated objects of small scale require a higher time step frequency for simulation accuracy
- Adaptive time stepping could balance the stability-performance tradeoff through:
  - Adaptively sub-stepping the simulation
  - Simulating different objects with different time step frequencies

Acknowledgments

The authors thank the members of the UIUC-FIT CoBot Factory Project and the teams developing the open-source software used in this project. M.T., H.A.-R., Y.D., J.M., T.C., J.G., and T.B. were supported by the Foxconn Interconnect Technology (FIT) and the Center for Networked Intelligent Components and Environments (C-NICE) at the University of Illinois Urbana-Champaign. H.D. was supported by the Graduate Assistance in Areas of National Need award P200A180050-19. H.D. and J.M. are supported by the NASA Space Technology Graduate Research Opportunity awards 80NSSC21K1292 and 80NSSC23K1191, respectively.