A Practical Isaac Sim Tutorial

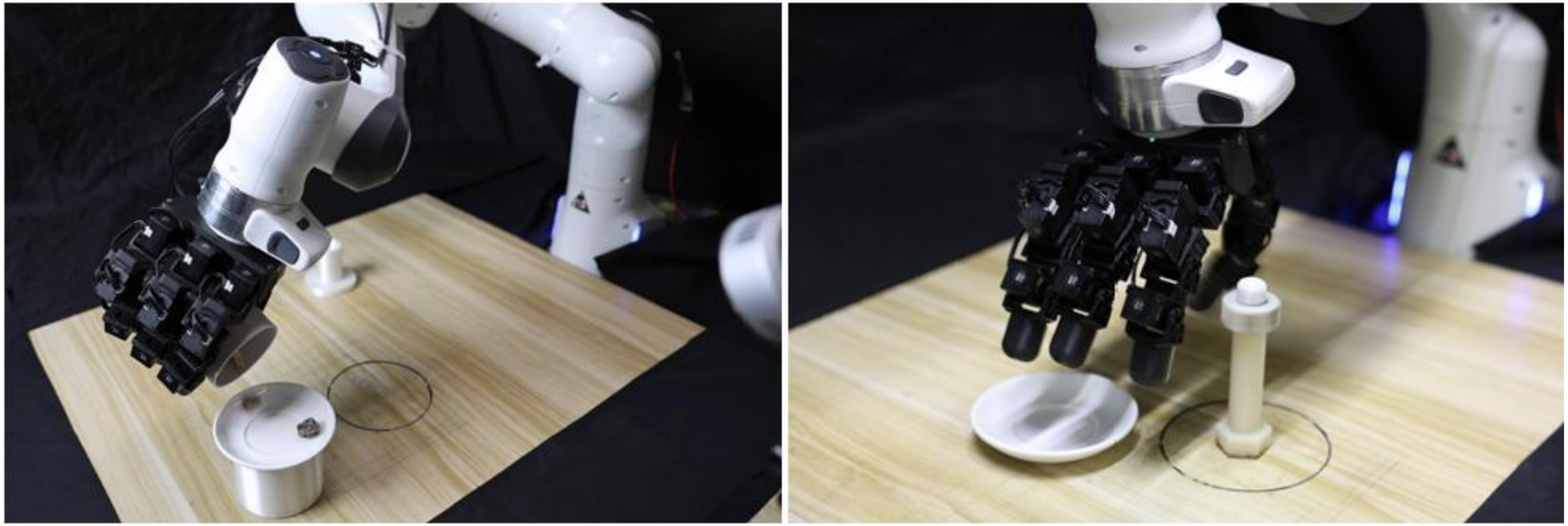
Outline

Background

High-level Structure of Issac Sim

The API of Issac Sim

Real-World Robotics Is Hard to Scale



Drawback of Real-world Robotics

Speed: Slow

Expenses: Expensive

Robustness: Fragile

An Alternative Solution – CPU Simulator

The Design Purpose of CPU Simulator:

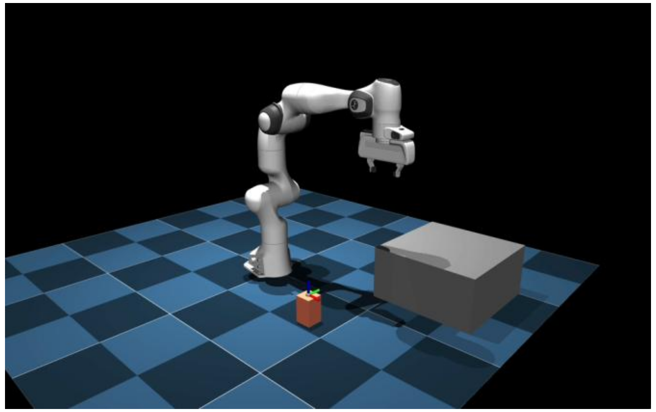
Provide a **faster**, **cheaper**, and **safer** environment than real-world robotics, enabling rapid experimentation, debugging, and early-stage development without hardware risks.

MuJoCo

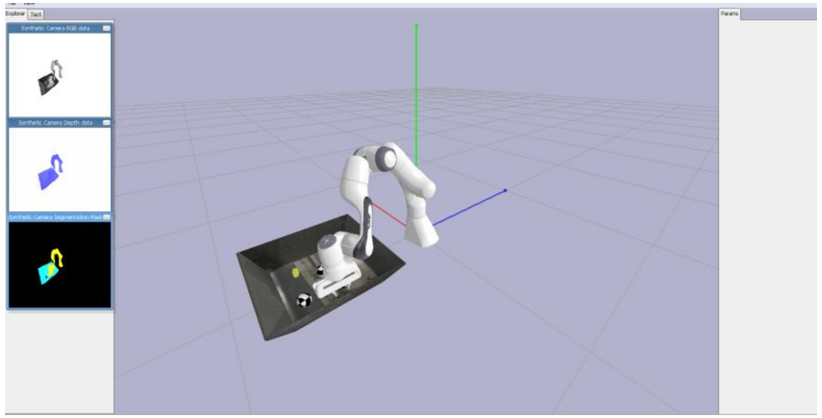
Fast, accurate rigid-body dynamics with smooth contact handling. Widely used in RL research.

PyBullet

Open-source physics engine with Python bindings. Easy to start. Popular for manipulation research.

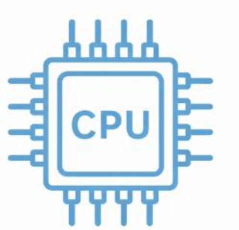


MuJoCo



PyBullet

Why choose GPU Simulator



CPU Simulator

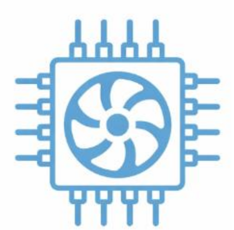
Speed: MuJoCo (~10M steps/sec)

Parallelism: Large-scale parallelism is limited by CPU cores

Rendering: Rely on simpler or external rendering pipelines

Physics Fidelity: Strong in stability and controllability

Accessibility: Easy to run



GPU Simulator

Speed: Issac Sim (~1B steps/sec)

Processes: Designed for massively parallel

Rendering: Real-time, photorealistic rendering

Physics Fidelity : Depend heavily on engine configuration

Accessibility: Require GPUs

CPU simulators are often preferred for accessibility and traditional robotics workflows, while GPU simulators excel at massively parallel RL and high-quality real-time rendering—yet neither automatically implies differentiable physics.

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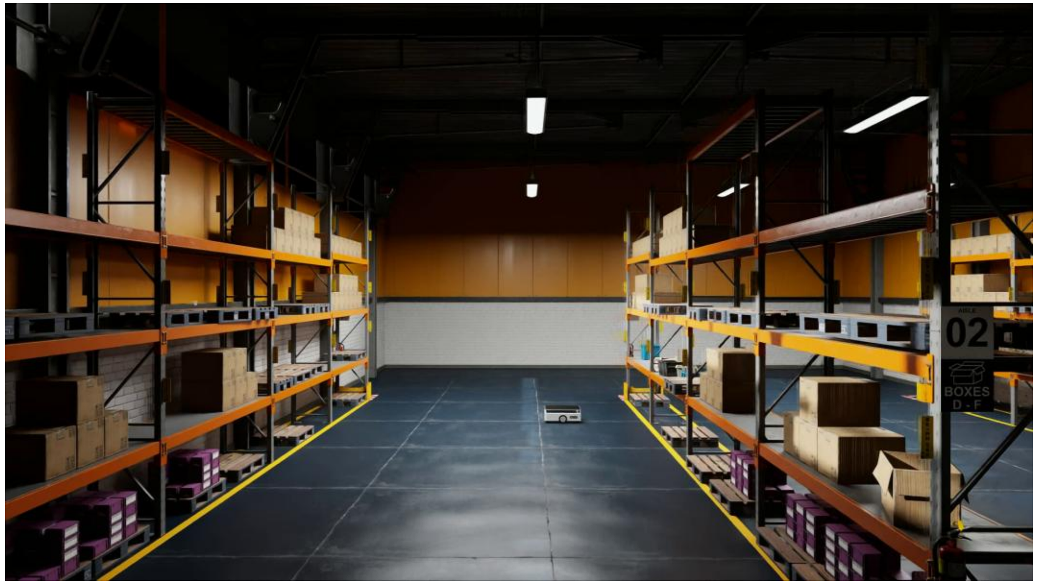
Isaac Sim: A Flagship GPU-Based Robotics Simulator

The Design Purpose of Isaac Sim:

Leverage GPU acceleration to enable **large-scale**, **highly parallel** robotics simulation for reinforcement learning, synthetic data generation, and rapid experimentation.

Highly Parallel



Photorealistic Rendering

High-Level Isaac Sim Architecture

USD defines scenes and robots:

All environments, robots, sensors, and assets are represented using USD, providing a unified scene description.

GPU physics runs dynamics:

Physics simulation is executed on the GPU, enabling fast dynamics computation and efficient large-scale simulation.

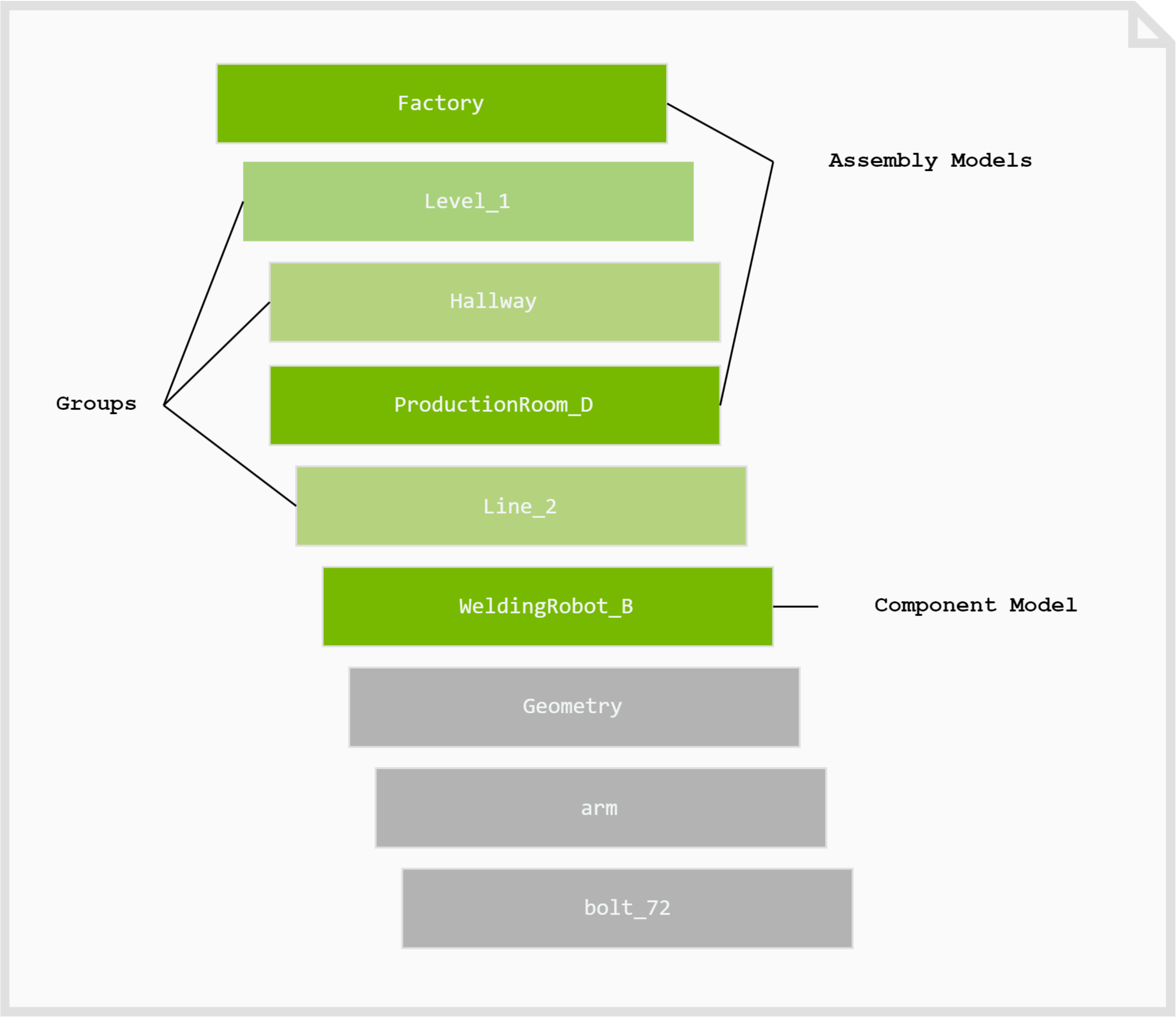
Environments are batched:

Multiple simulation environments are batched and executed in parallel, which is essential for high-throughput reinforcement learning.

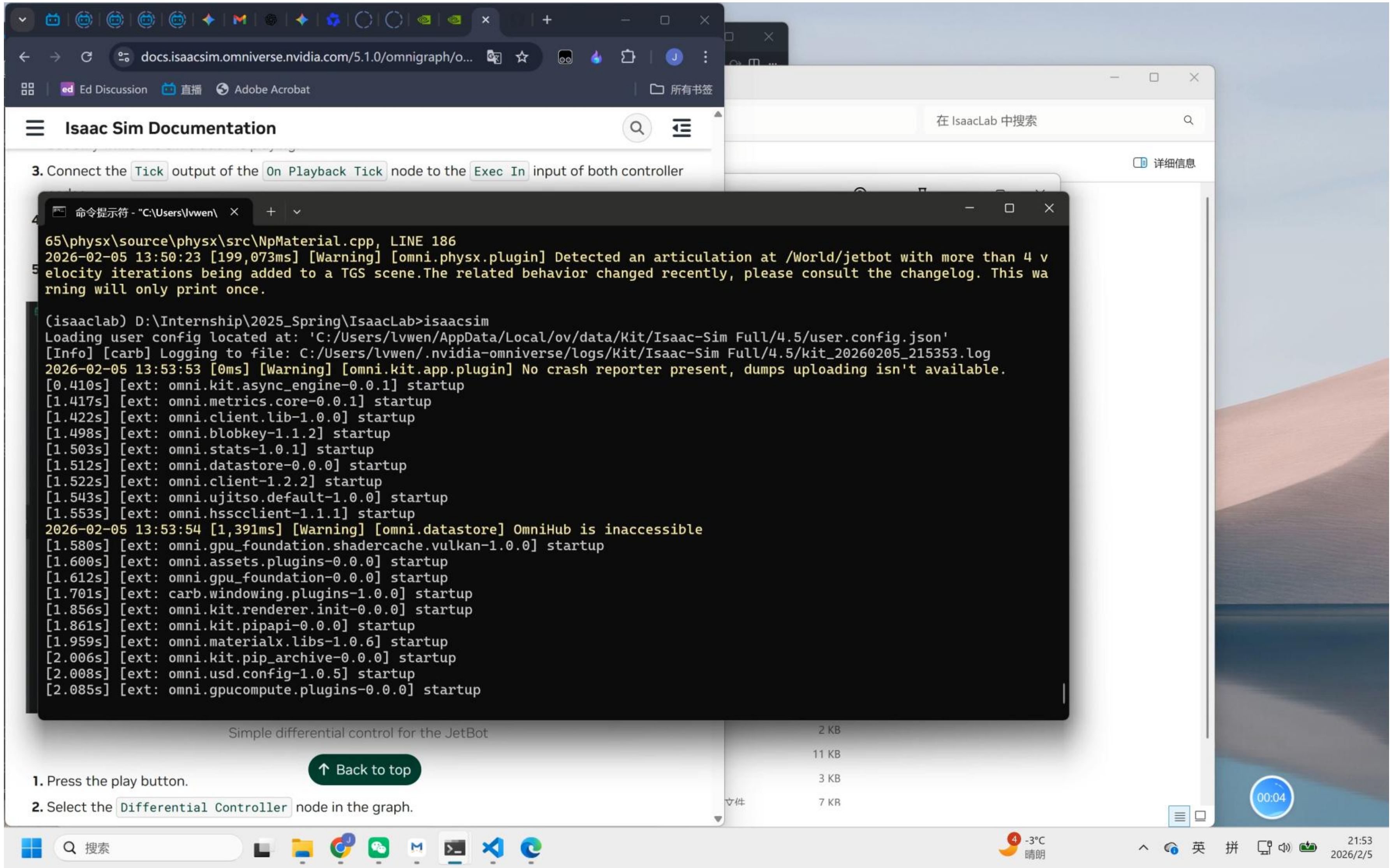
GUI and Python control the same world:

The graphical interface and Python APIs operate on the same underlying simulation state, allowing seamless switching between visual debugging and programmatic control.

USD Structure



An Example for Issac Sim GUI



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Official Example for Issac Sim (Inverse Kinematic)

https://isaac-sim.github.io/IsaacLab/main/source/tutorials/05_controllers/run_diff_ik.html

Step 0 — Launching Isaac Sim and Initializing the App

```python
from isaaclab.app import AppLauncher

parser = argparse.ArgumentParser(description="Tutorial on using the differential IK controller.")
parser.add_argument("--robot", type=str, default="franka_panda")
parser.add_argument("--num_envs", type=int, default=128)

AppLauncher.add_app_launcher_args(parser)
args_cli = parser.parse_args()

app_launcher = AppLauncher(args_cli)
simulation_app = app_launcher.app
```

add_app_laucher_args helps us to add basic Issac Sim argument like the device and the type of renderer.

Instantiate APPLaucher to create the environments.

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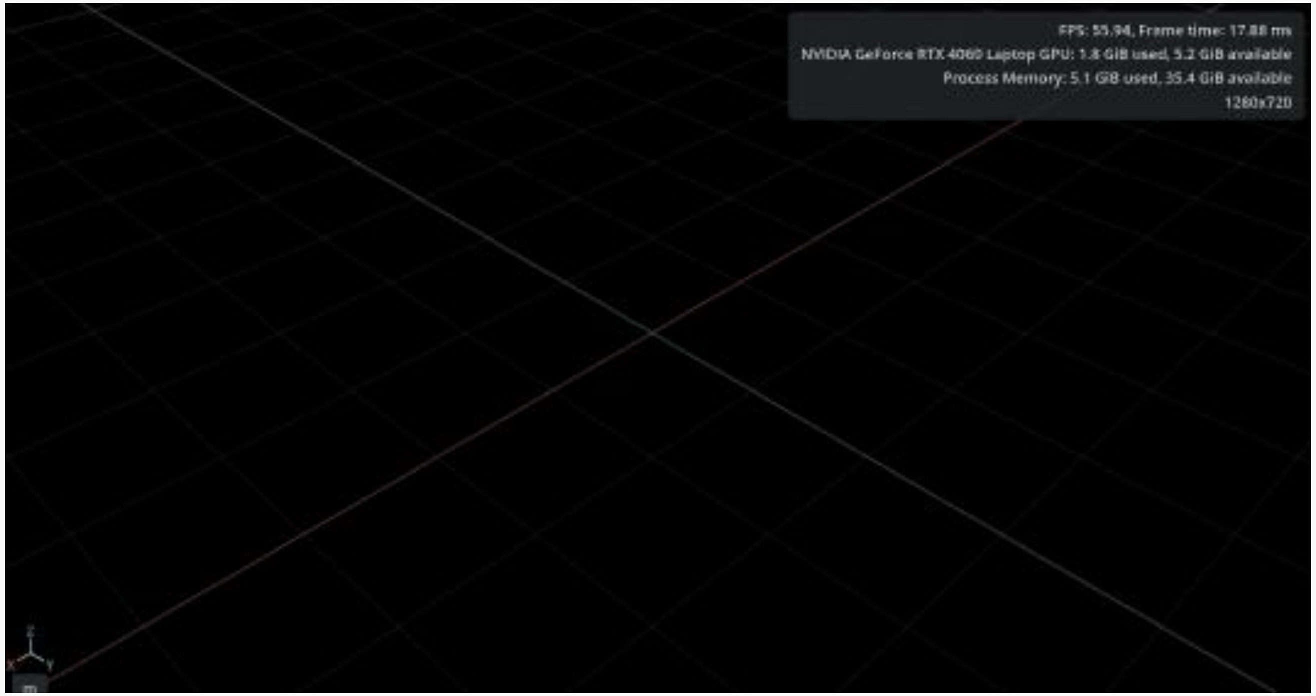

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Step 1 — Defining the Scene Structure with Configuration

```
@configclass
class TableTopSceneCfg(InteractiveSceneCfg):
    ground = AssetBaseCfg(
        prim_path="/World/defaultGroundPlane",
        spawn=sim_utils.GroundPlaneCfg(),
        init_state=AssetBaseCfg.InitialStateCfg(pos=(0.0, 0.0, -1.05)),
    )

    dome_light = AssetBaseCfg(
        prim_path="/World/Light",
        spawn=sim_utils.DomeLightCfg(intensity=3000.0, color=(0.75, 0.75, 0.75)),
    )

    table = AssetBaseCfg(
        prim_path="{ENV_REGEX_NS}/Table",
        spawn=sim_utils.UsdFileCfg(
            usd_path=f"{ISAAC_NUCLEUS_DIR}/Props/Mounts/Stand/stand_instanceable.usd",
            scale=(2.0, 2.0, 2.0),
        ),
    )
```

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Step 2 — Selecting and Instantiating Robot Assets (in TableTopSceneConfig)

```
from isaaclab_assets import FRANKA_PANDA_HIGH_PD_CFG, UR10_CFG

if args_cli.robot == "franka_panda":
    robot = FRANKA_PANDA_HIGH_PD_CFG.replace(prim_path="{ENV_REGEX_NS}/Robot")
elif args_cli.robot == "ur10":
    robot = UR10_CFG.replace(prim_path="{ENV_REGEX_NS}/Robot")
else:
    raise ValueError("Unsupported robot")
```

We define all the assets (ground, light, table and robot) in **TableTopSceneConfig.**

We don’t need to define config for each environment separately.

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Step 3 — Creating the Simulation Context and Scene

```
sim_cfg = sim_utils.SimulationCfg(dt=0.01, device=args_cli.device)
sim = sim_utils.SimulationContext(sim_cfg)

sim.set_camera_view([2.5, 2.5, 2.5], [0.0, 0.0, 0.0])

scene_cfg = TableTopSceneCfg(num_envs=args_cli.num_envs, env_spacing=2.0)
scene = InteractiveScene(scene_cfg)

sim.reset()
```

We feed the **TableTopSceneConfig** to InteractiveScene, and create the simulation context.

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Step 4 — Accessing Scene Entities and Creating Controllers

```
robot = scene["robot"]


from isaaclab.controllers import DifferentialIKController, DifferentialIKControllerCfg
diff_ik_cfg = DifferentialIKControllerCfg(command_type="pose", use_relative_mode=False, ik_method
diff_ik_controller = DifferentialIKController(diff_ik_cfg, num_envs=scene.num_envs, device=sim.de
```

Isaac Sim has already implemented some IK algorithms, we can use them with **DifferentialIKControllerCFG** and **DifferentialIKController.** Please check the specific API in their document.

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Step 5 — Defining Batched Goals for Parallel Environments

```
ee_goals = torch.tensor([
    [0.5, 0.5, 0.7, 0.707, 0, 0.707, 0],
    [0.5, -0.4, 0.6, 0.707, 0.707, 0.0, 0.0],
    [0.5, 0, 0.5, 0.0, 1.0, 0.0, 0.0],
], device=sim.device)

current_goal_idx = 0
ik_commands = torch.zeros(scene.num_envs, diff_ik_controller.action_dim, device=robot.device)
ik_commands[:] = ee_goals[current_goal_idx]
```

The input of the environments is batched. Depends on our requirements, we can control them separately or synchronously.

The goals are the quaternions and coordinates of 3 fingertips.

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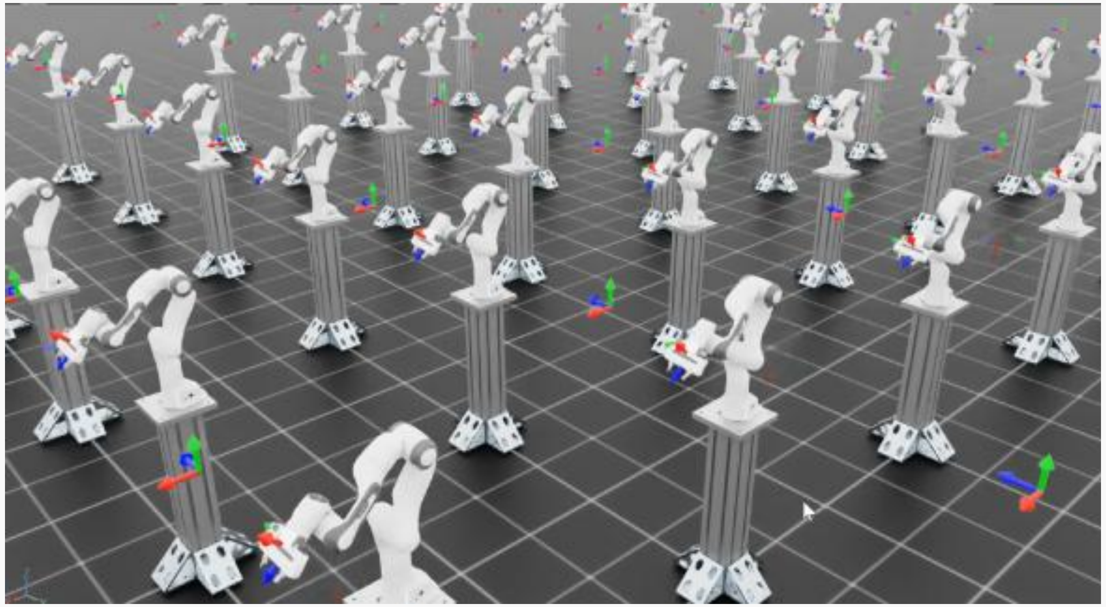

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Step 6 — Simulation Loop: Reset

```
if count % 150 == 0:
    joint_pos = robot.data.default_joint_pos.clone()
    joint_vel = robot.data.default_joint_vel.clone()
    robot.write_joint_state_to_sim(joint_pos, joint_vel)
    robot.reset()

    ik_commands[:] = ee_goals[current_goal_idx]
    joint_pos_des = joint_pos[:, robot_entity_cfg.joint_ids].clone()

    diff_ik_controller.reset()
    diff_ik_controller.set_command(ik_commands)

    current_goal_idx = (current_goal_idx + 1) % len(ee_goals)
```

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Step 6 — Simulation Loop: Observe

```
jacobian = robot.root_physx_view.get_jacobians()[:, ee_jacobi_idx, :, robot_entity_cfg.joint_ids]
ee_pose_w = robot.data.body_pose_w[:, robot_entity_cfg.body_ids[0]]
root_pose_w = robot.data.root_pose_w
joint_pos = robot.data.joint_pos[:, robot_entity_cfg.joint_ids]
```

The design of observation is important based on your task. You can get both the joint state and rendered images with Issac Gym.

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Step 6 — Simulation Loop: Compute

```
ee_pos_b, ee_quat_b = subtract_frame_transforms(
    root_pose_w[:, 0:3], root_pose_w[:, 3:7],
    ee_pose_w[:, 0:3], ee_pose_w[:, 3:7],
)

joint_pos_des = diff_ik_controller.compute(ee_pos_b, ee_quat_b, jacobian, joint_pos)
```

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Step 6 — Simulation Loop: Act

```
robot.set_joint_position_target(joint_pos_des, joint_ids=robot_entity_cfg.joint_ids)
scene.write_data_to_sim()

sim.step()

scene.update(sim_dt)
count += 1
```

Interactively apply the Inverse Kinematic, we can move the end-effector to the desired position.

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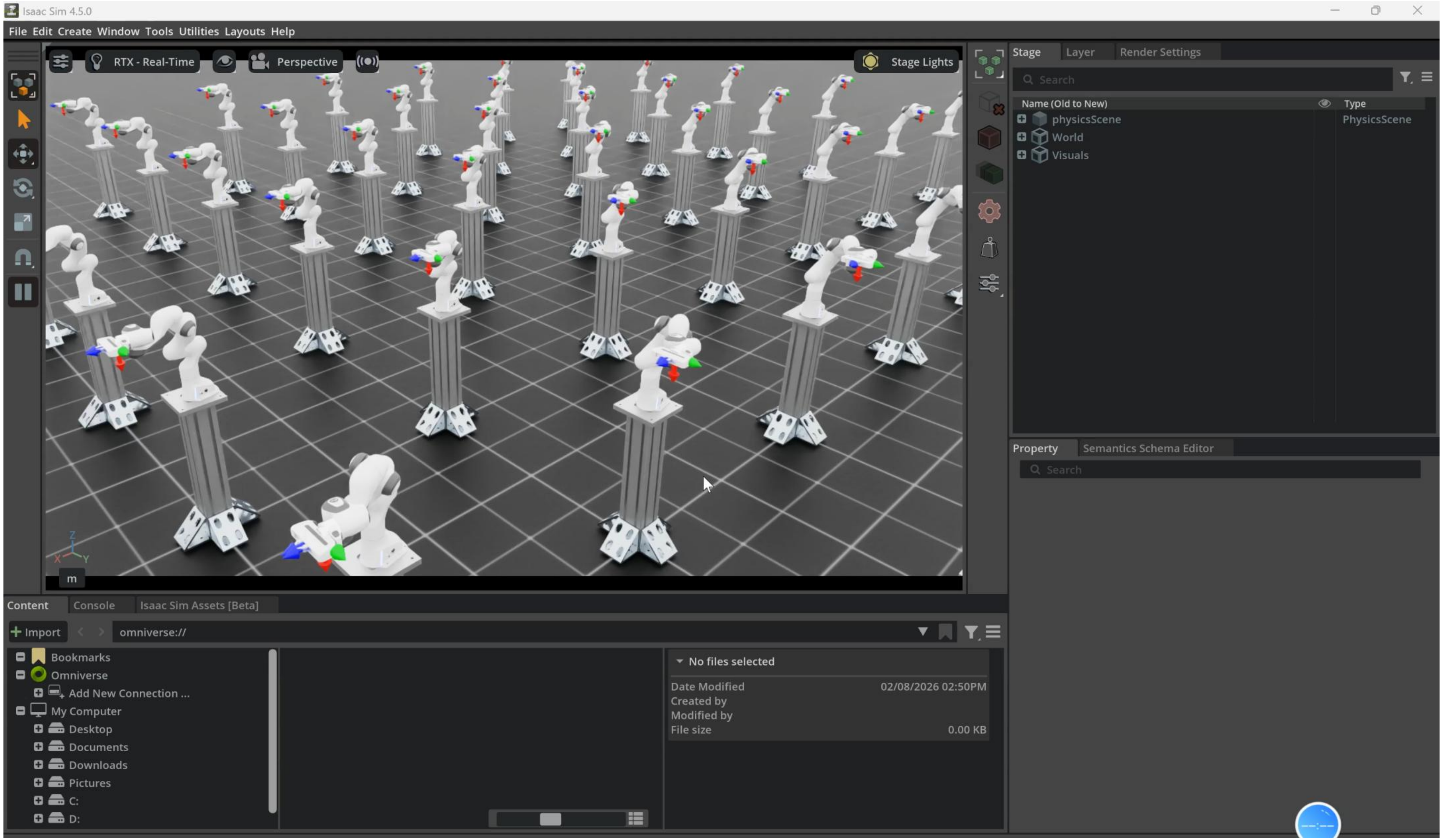

Q&A