Omniverse Base Workshop 1

KUKA X IPI

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- 2x 4h Course with examples to
  - Learn the Basics in Omniverse, USD & Isaac Sim
  - Enable you to do Robotic model preparation & Simulation
  - Introduction to IsaacLab

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Trainer Introduction

Fabian Fichtl

Julian Zürn

Institut für Produktion und Informatik

Technologietransferzentrum der Hochschule Kempten

- anwendungsorientierte Forschungseinrichtung
- F&E-Projekte im Kontext Digitalisierung in der Produktion
- Seit 2021 mit 30 Mitarbeitern
- Technologietransfer und Startup Inkubator
- VIBN und Industrial Metaverse in der Lehre

HIGHTECH Agenda Bayern

Introduction round

Please tell a few sentences about yourself, what you expect from this workshop and what you want to use Omniverse for

Agenda Tag 1:

- Introduction Metaverse
- Omniverse basics:
  Nucleus | Data Formats | PhysX| extensions | Stage
- 5 min Pause
- Hands on: Scene manipulation, Kinematics and Assets
  - UI Manipulation Navigation, Manipulation (property window)
  - Mass & Mesh manipulation
  - First Robot
- 10 min Pause
- Import and Tune a Robot
- 5 min Pause
- First Robot Control (LULA test widget)
  - Adding Sensors and Kameras

Agenda Tag 2:

- Debugging Tools:
  - Console, VS Code, UI
- Scene Architecture
  - Build your Scenario: Robot, Gripper, Controller, Environment, Handle Object
- Pick & Place
- Information Channels | Further Courses

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Introduction to Omniverse

Concept: Industrial Metaverse

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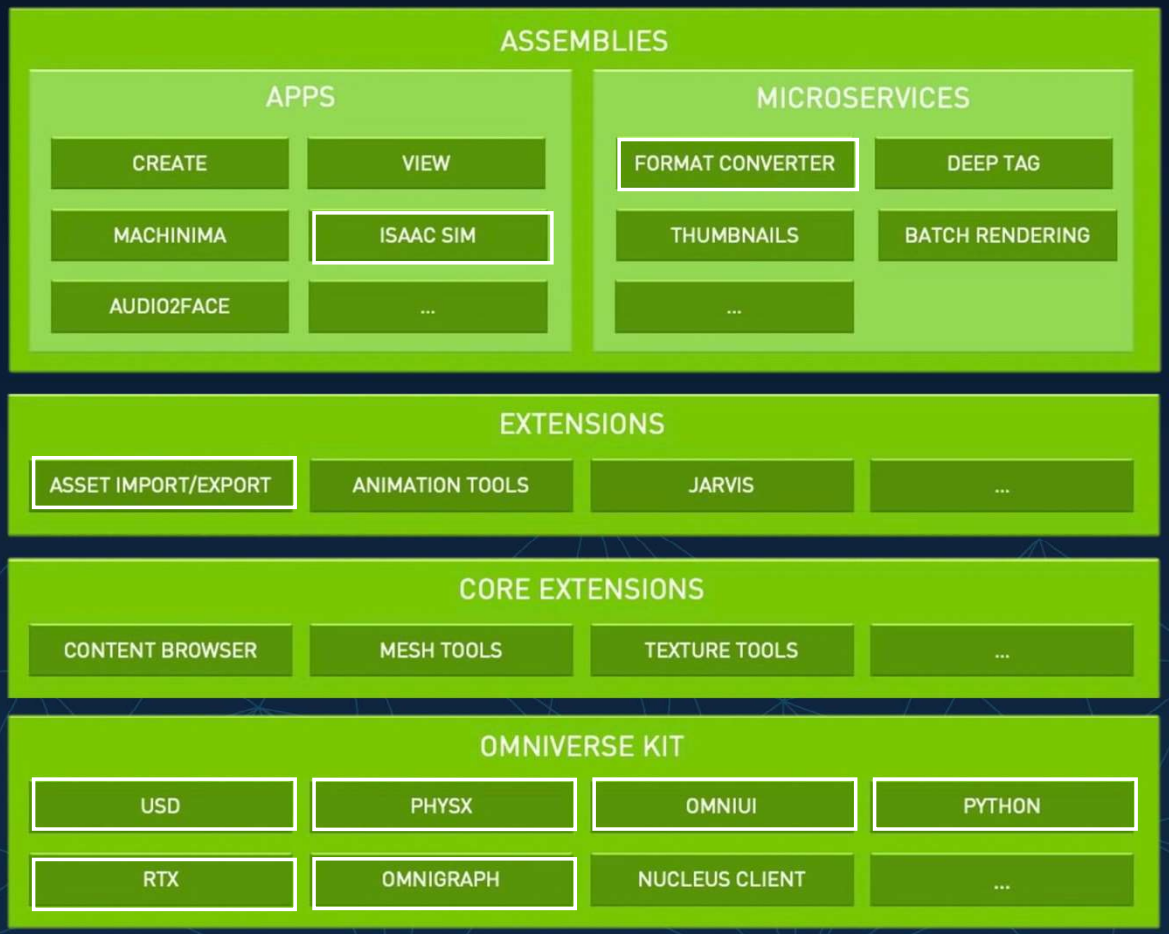
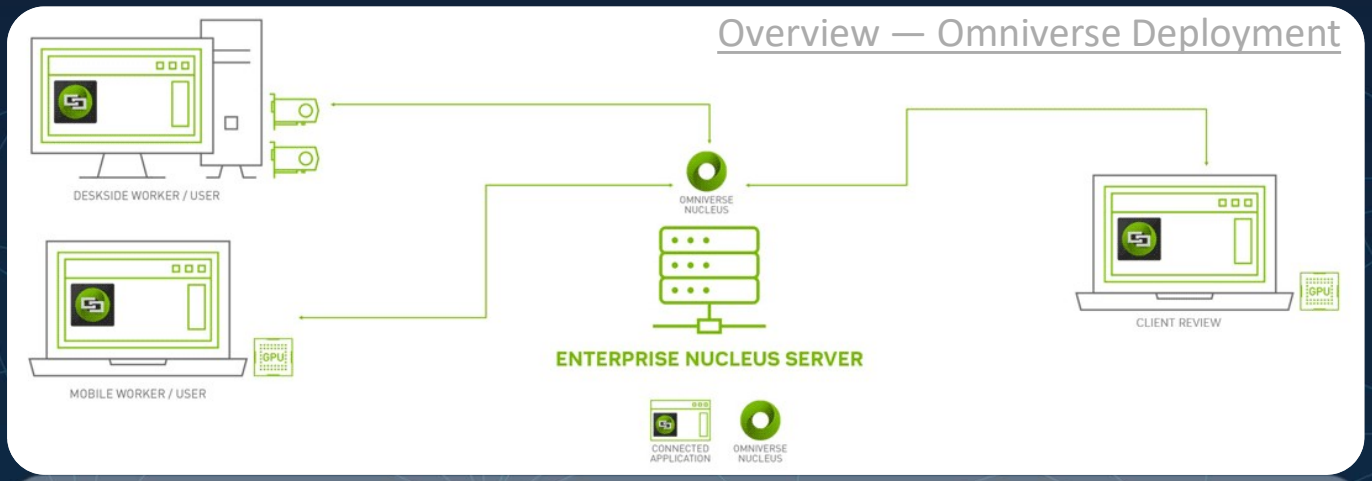
- Virtual Environment
- Real-time Interaction and Collaboration
- Purpose can span the Design, Simulation, Observation or Replay of arbitrary Objects and Processes in any Industry
- The *NVIDIA Omniverse* platform is optimized to run 3D physics Simulations in real-time on *NVIDIA RTX* Hardware

Omniverse Architecture

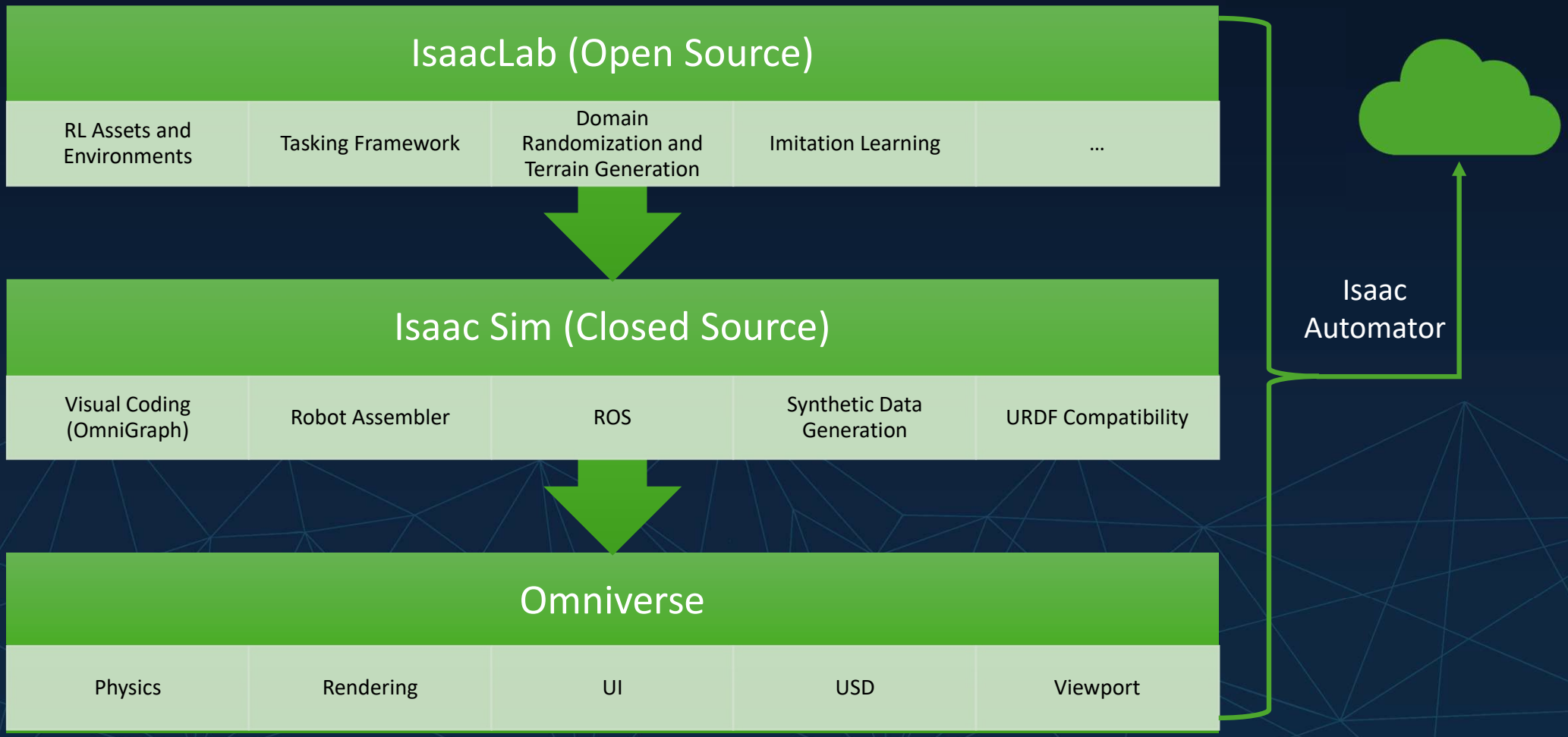


Nucleus – The Omniverse Database

- Enables Real-time Collaboration
- Comprehensive User/Permission Management
- Caching Mechanism for large Assets
- Wide API and Script Integration
- Enterprise Scalability



NVIDIA Isaac Ecosystem



Universal scene description

Interacting with USD (in Omniverse scene)

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- UI Main Capabilities
  - Viewport:
    - Scene
  - Property Window:
    - Prim* Properties
  - Omnigraph:
    - Process Logic
    - ROS Controller
  - Various extensions

- API Main Capabilities
  - Python interface
  - Robot Controllers
  - URDF import
  - Create the scene for IsaacLab
  - Configure the policy
  - Start training

*Nodes in the USD-scene tree are called Primitives or Prims

Robot Data formats

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	URDF	SRDF	XRDF
Description Language	XML	XML	YAML
Purpose	Define Geometries and Kinematic Joints	Complements URDF Data with Semantic Grouping	Complements URDF Data with Kinematic Description
Collision Handling	Simple Shapes and Meshes	Collision Matrix (specifies handling for link pairs)	Collision Spheres along Robot Links
Joint Representation	Varying Types and Parameters	Defines Groups for Motion Planning	Advanced Configuration including Acceleration and Jerk Limits
Handling	Core Format in ROS and converted to USD upon import in Isaac Sim	ROS Moveit Assistant to generate Motion Plans	NVIDA CuMotion and Lula to generate Motion Plans

Manual Modelling Phases Robot Simulation

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1. Import URDF and convert to USD
2. Config Joint drives -> Test
3. Add Gripper/ Cameras
4. Add details to the stage of:
    1. URDF for ROS and RL
    2. SRDF for Moveit
    3. XRDF for Cumotion and LULA / RMPflow

NVIDIA PhysX

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- The PhysX world comprises a collection of Scenes, each containing objects called Actors;
- Each Scene defines its own reference frame encompassing all of space and time;
- Actors in different Scenes do not interact with each other;
- Characters and vehicles are complex specialized objects made from Actors;
- Actors have a physical state: position and orientation, velocity or momentum, energy, etc;
- Actor physical state may evolve over time due to applied forces, constraints such as joints or contacts, and interactions between Actors.

Omniverse Stage

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Until now:

- We reviewed necessary Omniverse Basics and Resources

5 min Break

To be continued:

- Practical session:
  - Extensions installation
  - Scene Manipulation
  - Robot import + tuning

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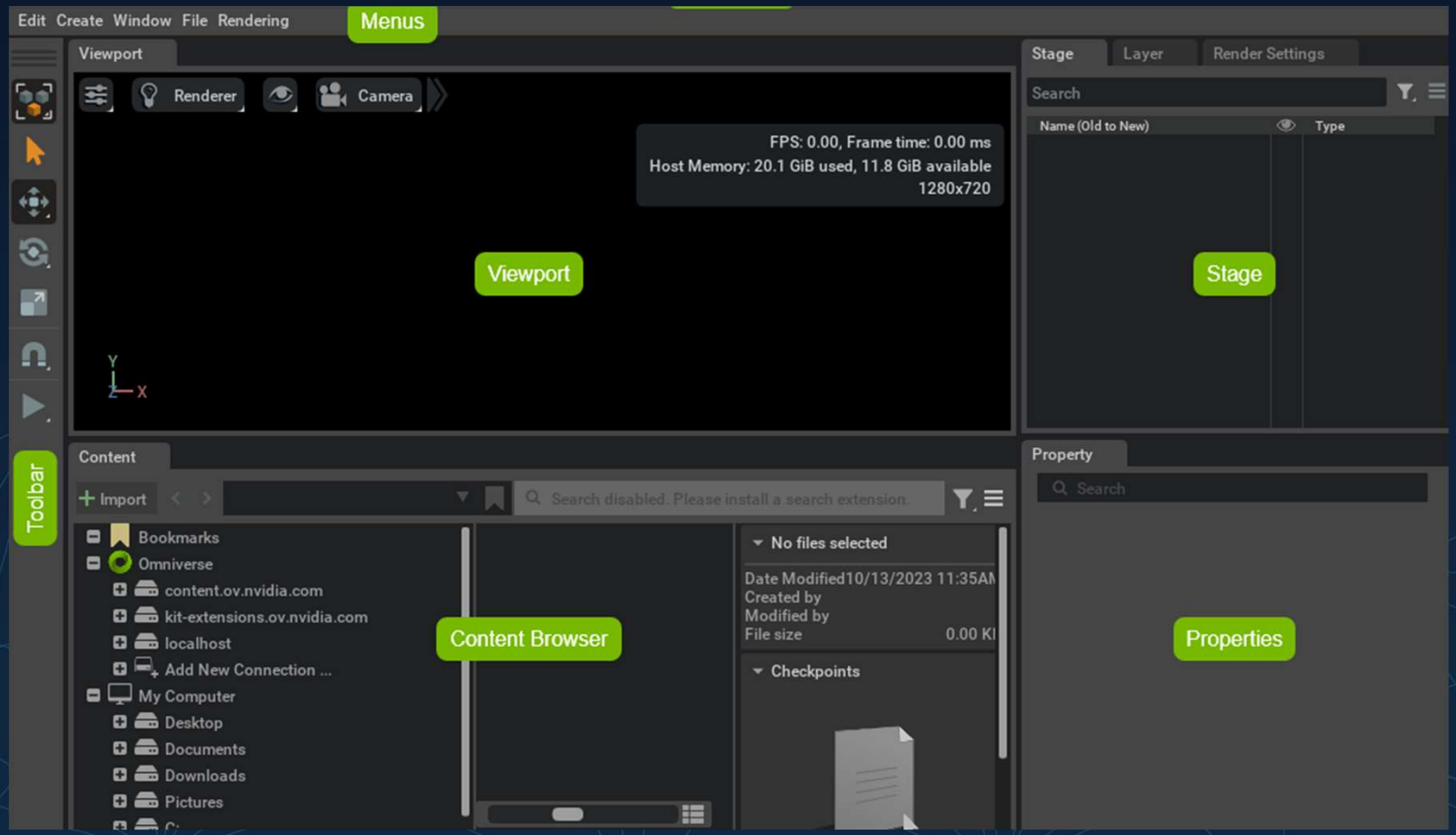
Hands on!

Getting started:

- Start Omniverse Isaac Sim on the Machine
  - Please give feedback if your application is loaded

Standard Layout



How-to: Viewport Navigation

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- Orbit: Left mouse btn. + ALT
- Look: Right mouse btn. (RMB)
- Fly/ Walk: Hold RMB; *WASD* / Q up / E down
- Adjust Speed Hold RMB; Scroll
- Jump to Selection: F

Scene Prep tools (extensions)

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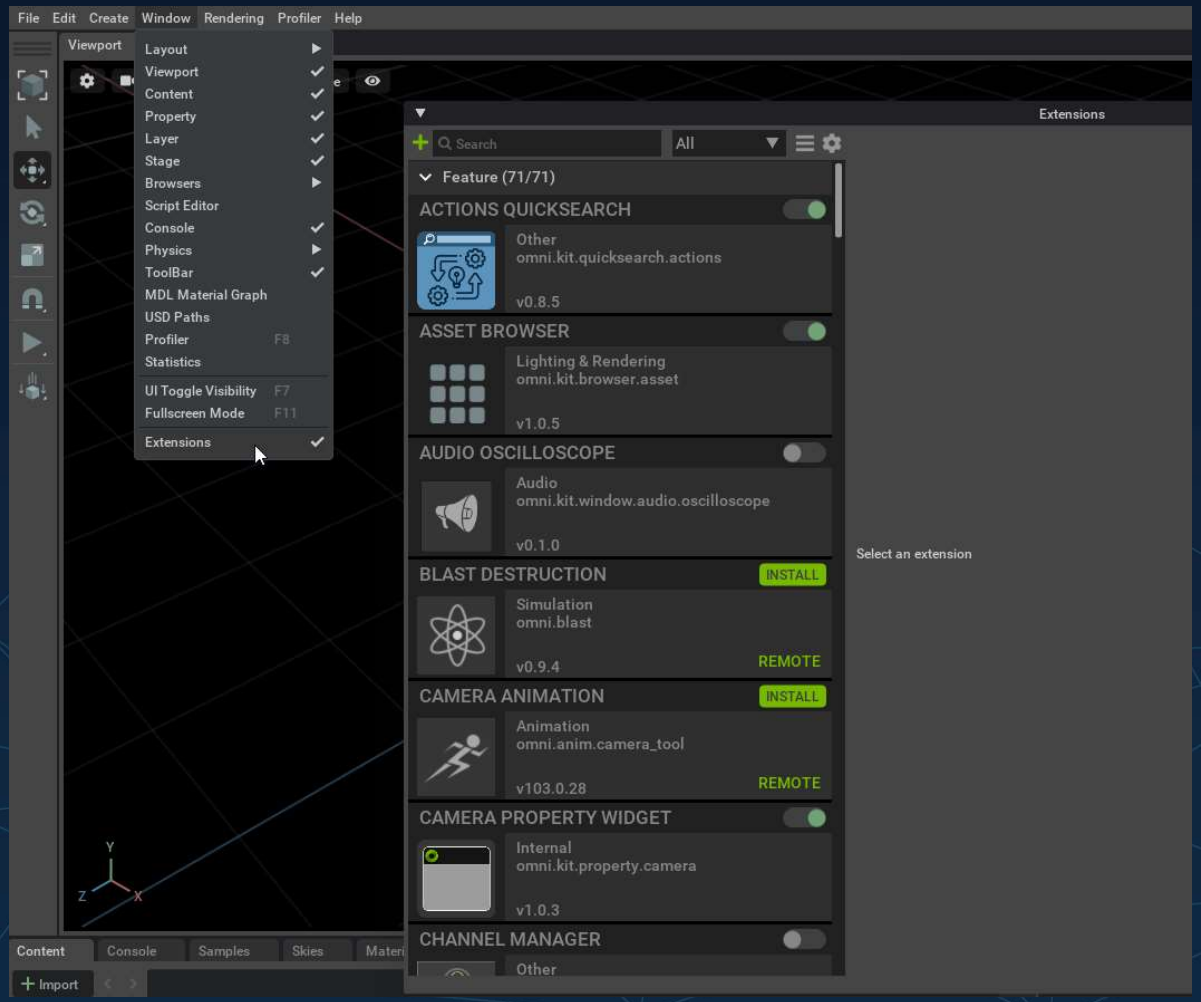
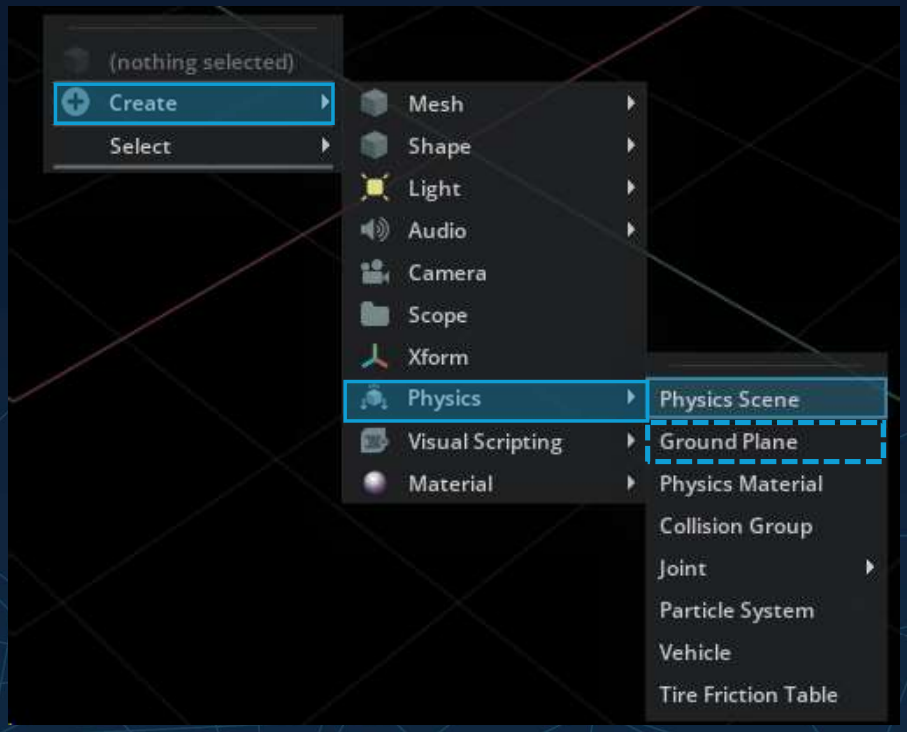
- Check for extensions:
  - Action Graph
  - URDF importer



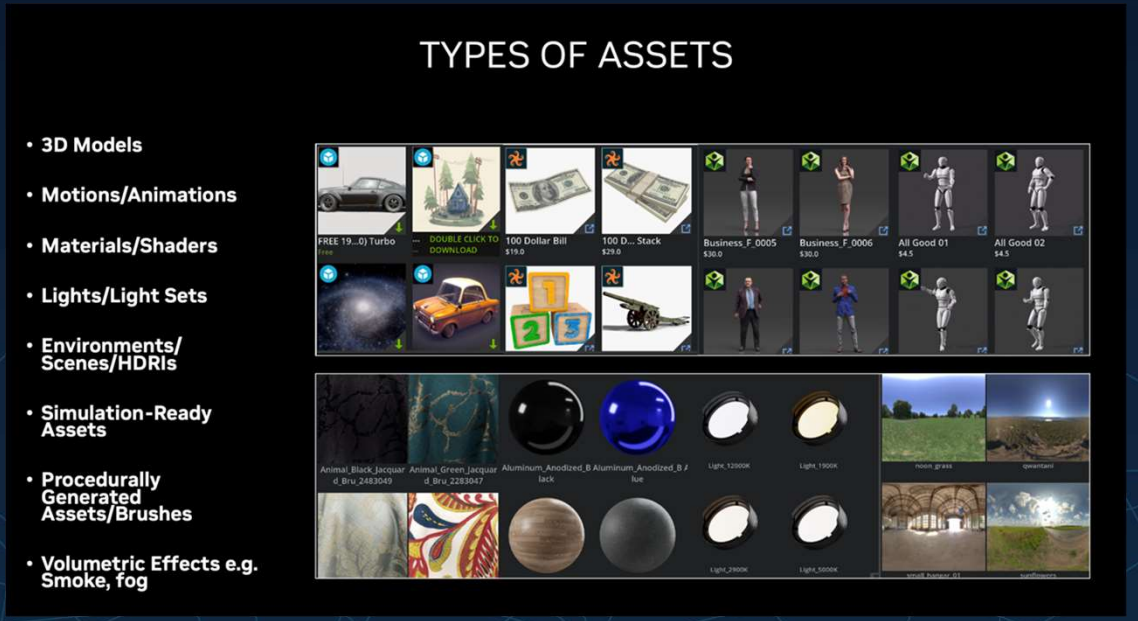
How-to: Add Physics Scene

- Create a Physics Scene
- Create a ground plane



Asset Store

- Import a Box
  - Move above ground plane
  - Adjust the size
  - Add (Rigid Body and and Collider)
  - Press *Play* to start the Simulation



How-to↓

How-to: Use Asset Store

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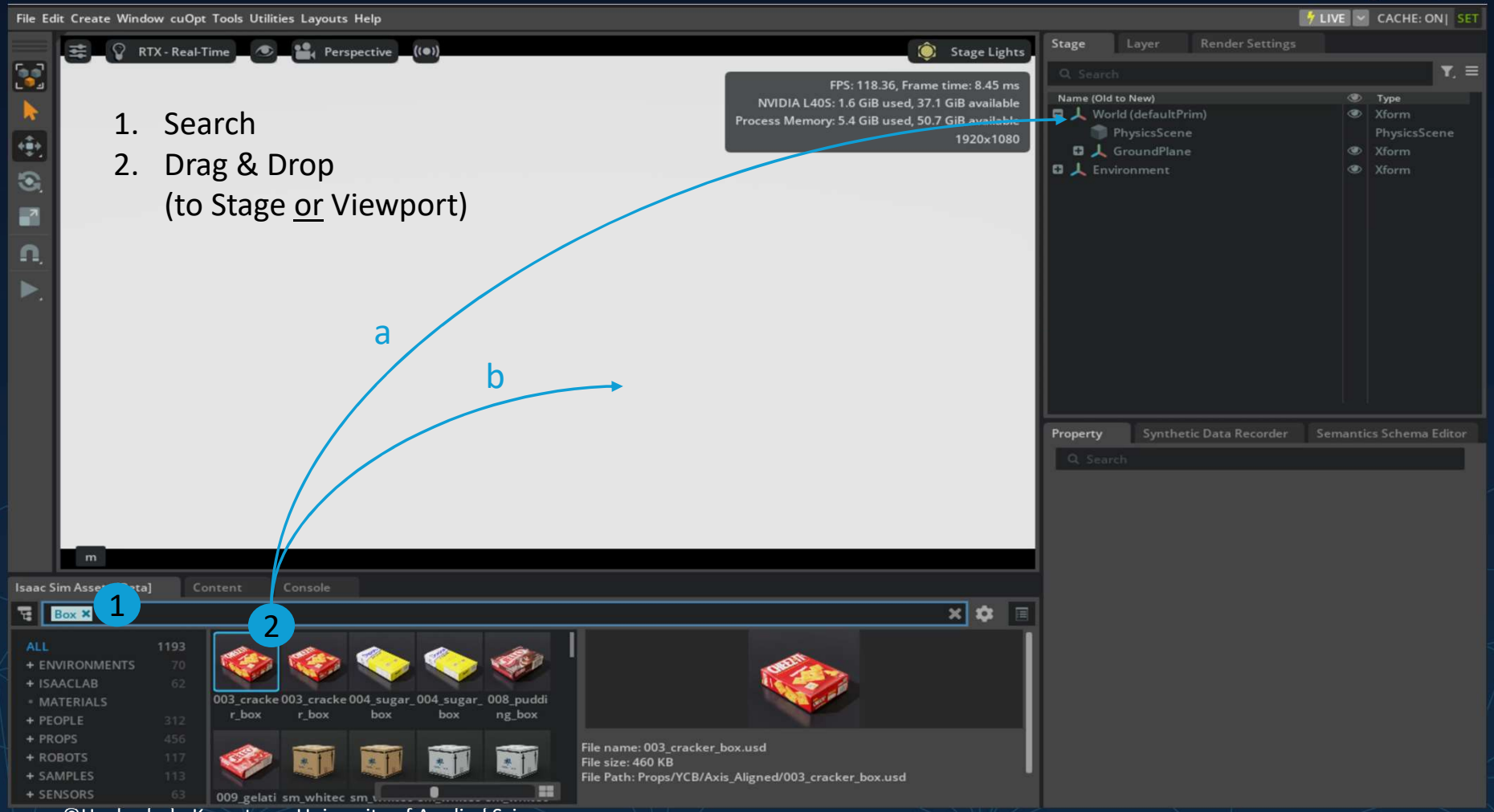

How-to: Manipulation in Viewport

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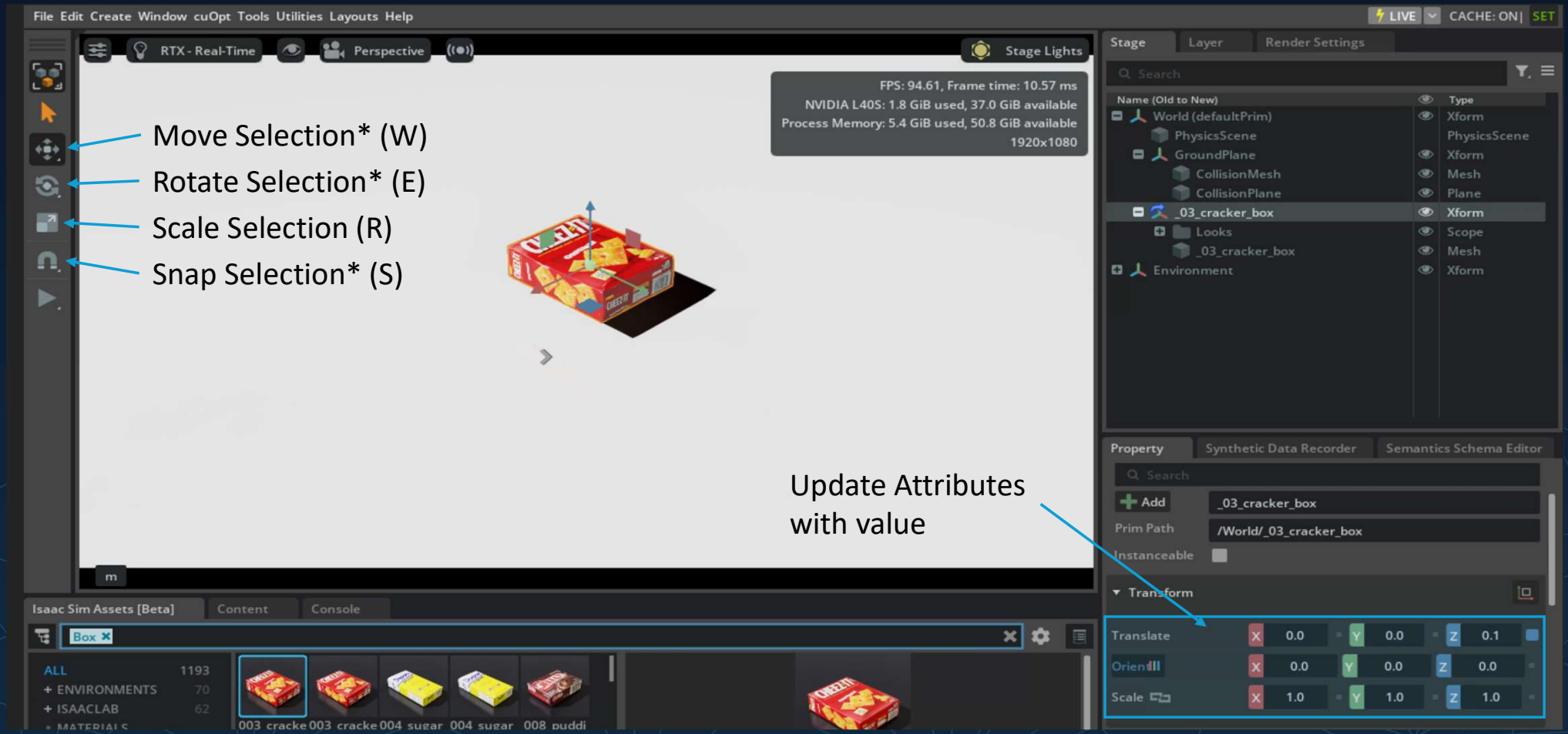

*RMB on icon shows further options

How-to: Add Rigid-body & Collider

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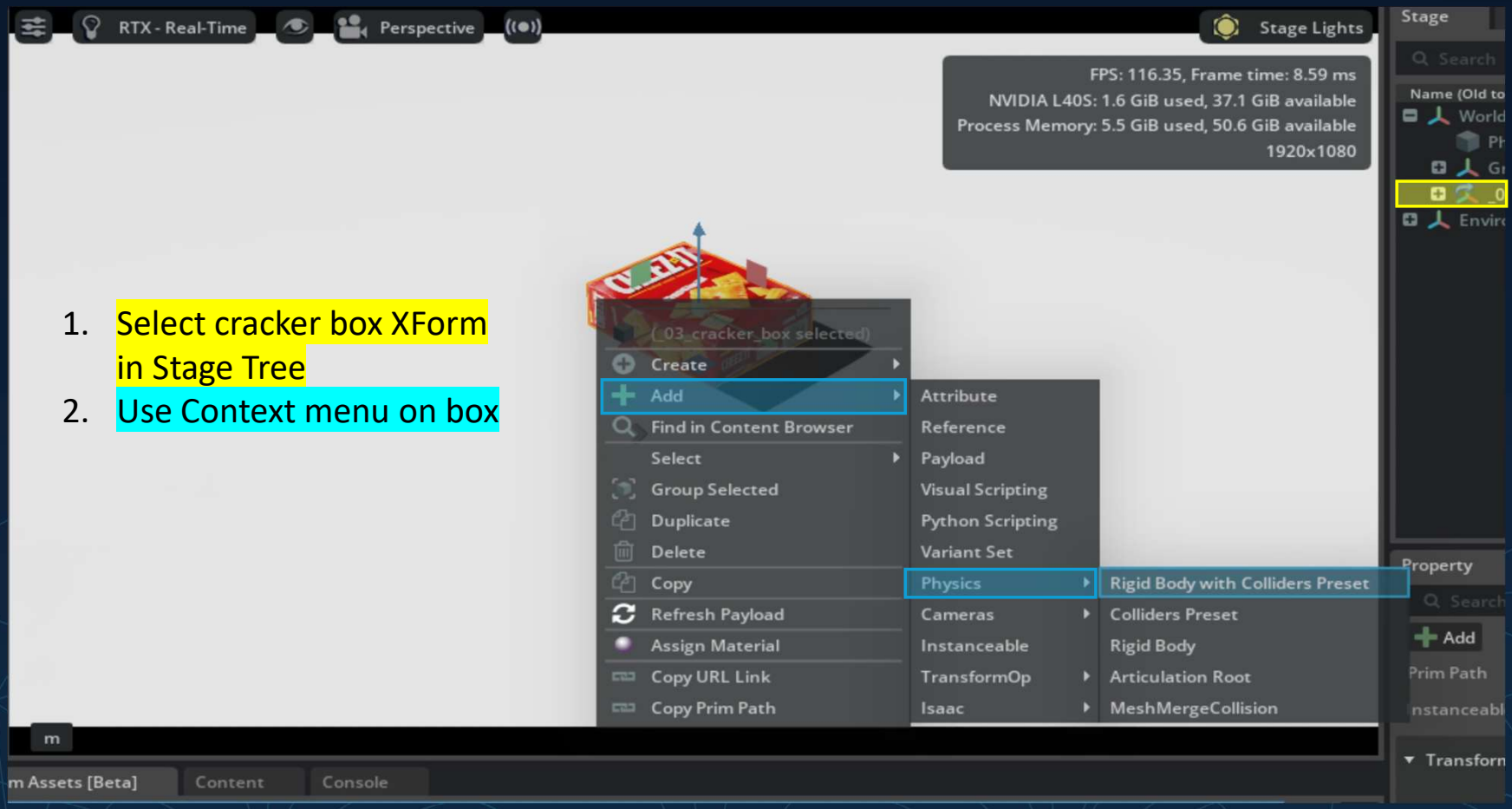
1. Select cracker box XForm in Stage Tree
2. Use Context menu on box



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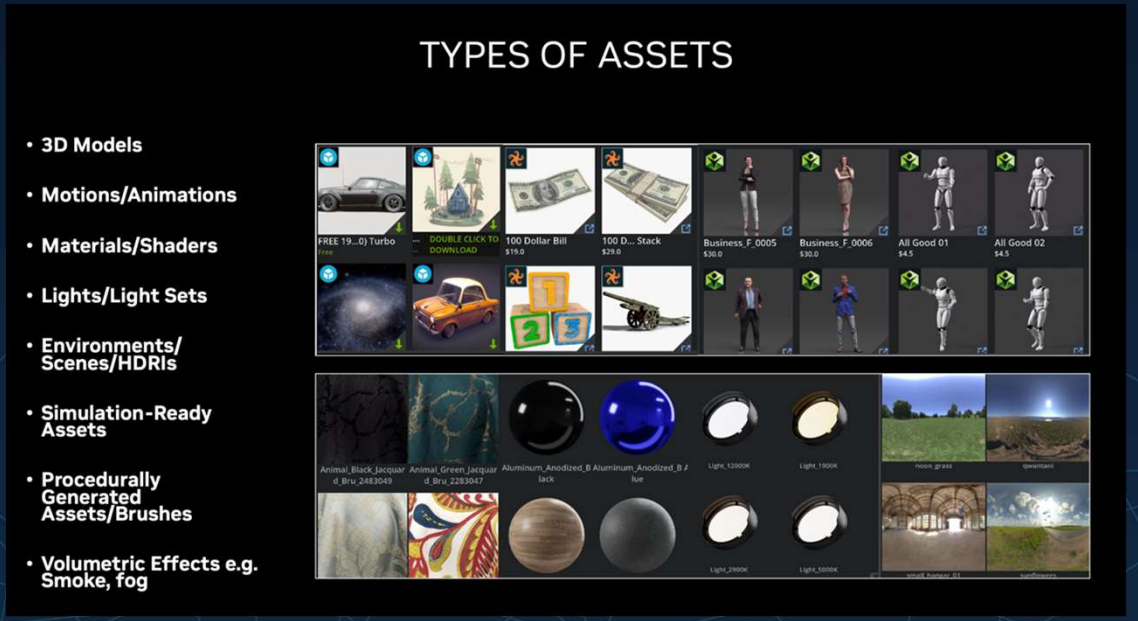
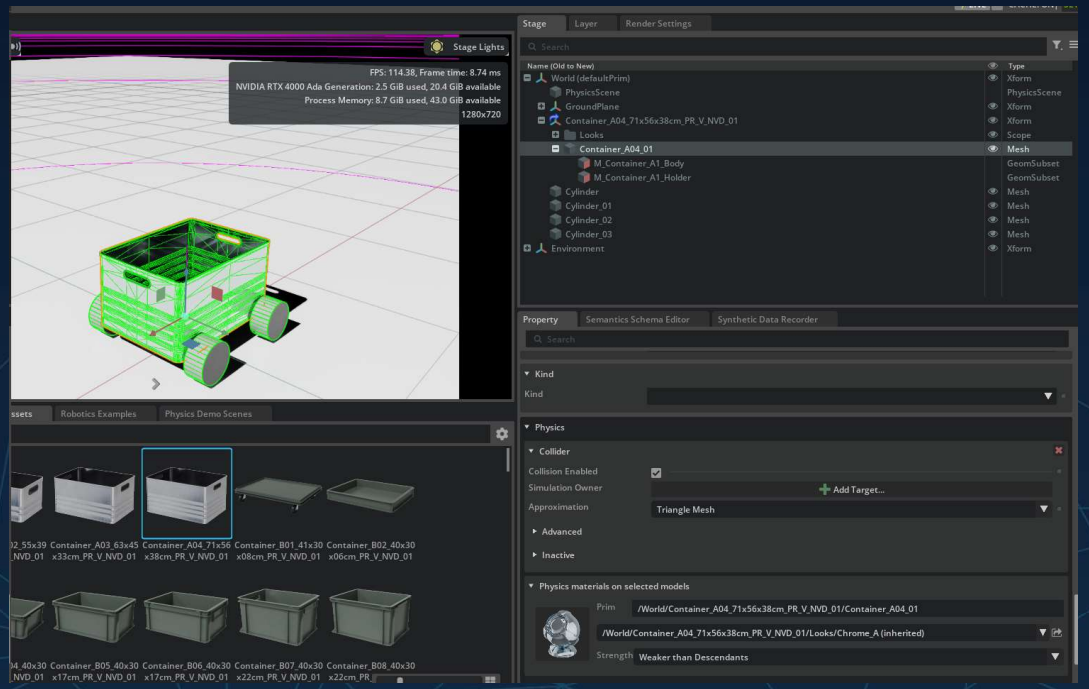


Assemble the first self-built Robot

- Stop the Simulation
- Create Cylinders
  - Move/ orient to the side
  - Create a revolute joint
  - Add Angular drive
  - Modify target velocity + stiffness
- Start the Simulation



How-to

How-to: Add Cylinder

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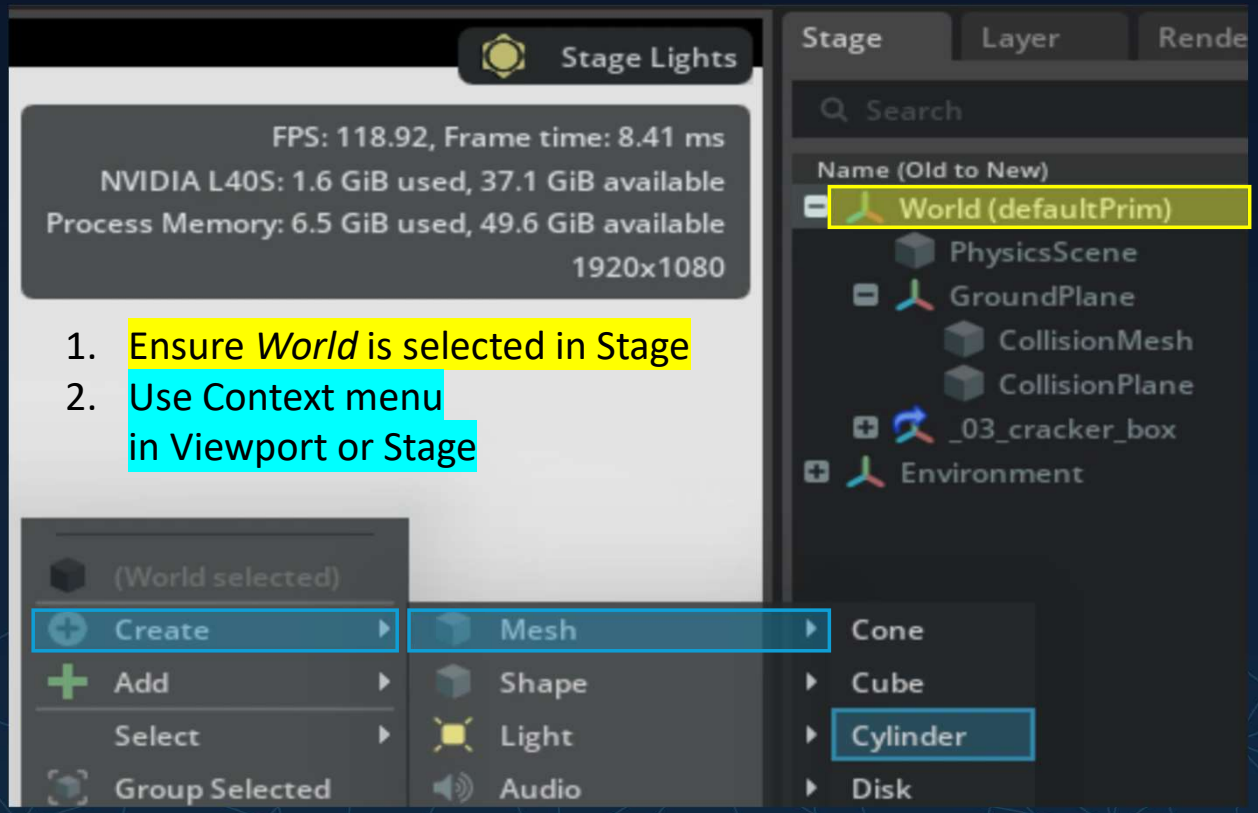

3. Adjust scaling and orientation to represent a wheel
4. Add *Rigid Body & Collider*
5. Use *Ctrl+C* and *Ctrl+V* to replicate the wheel
6. Move the wheels to reasonable positions around the box

How-to: Add Joint

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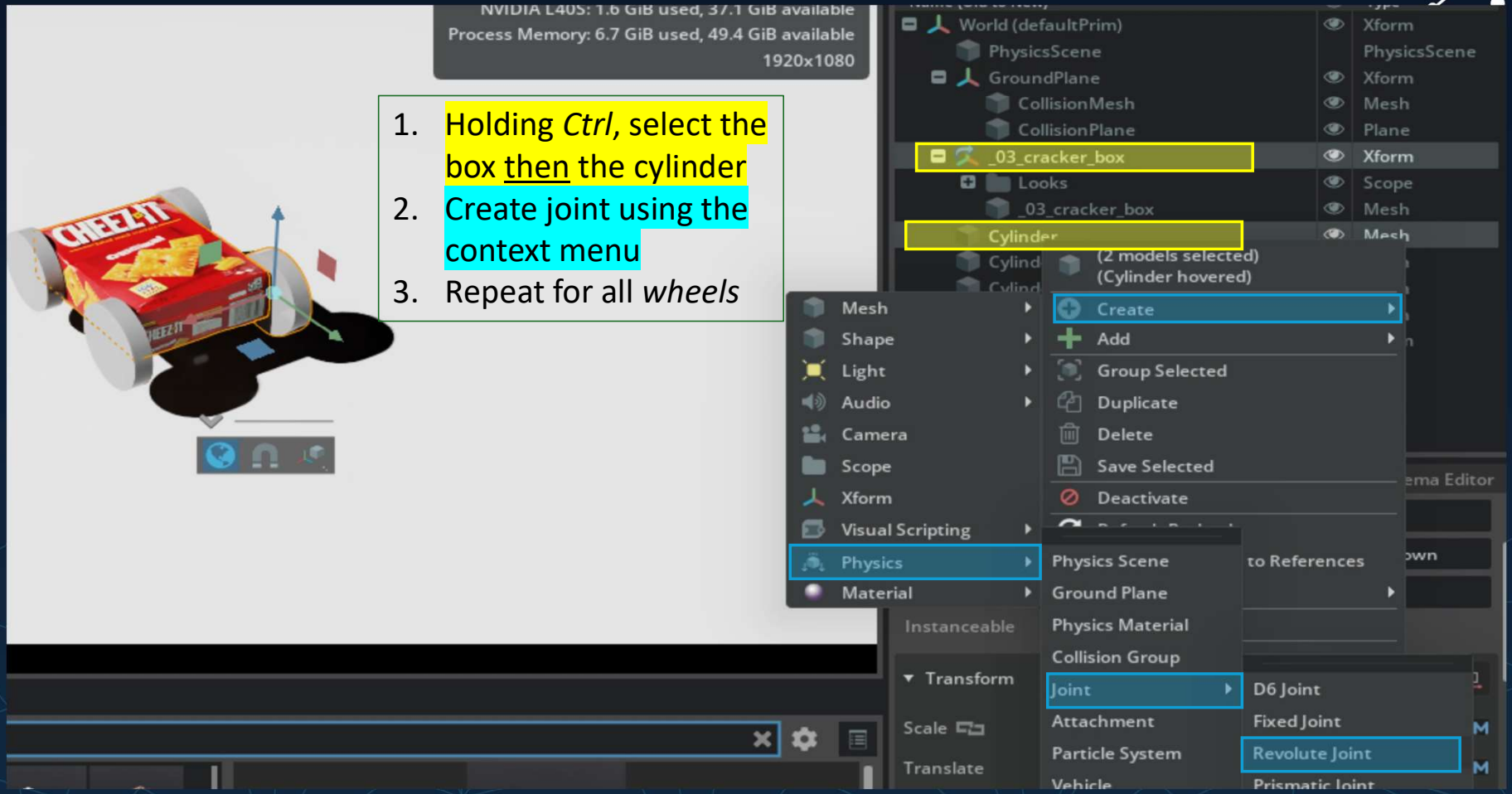

How-to: Adjust Joint and Add Drive

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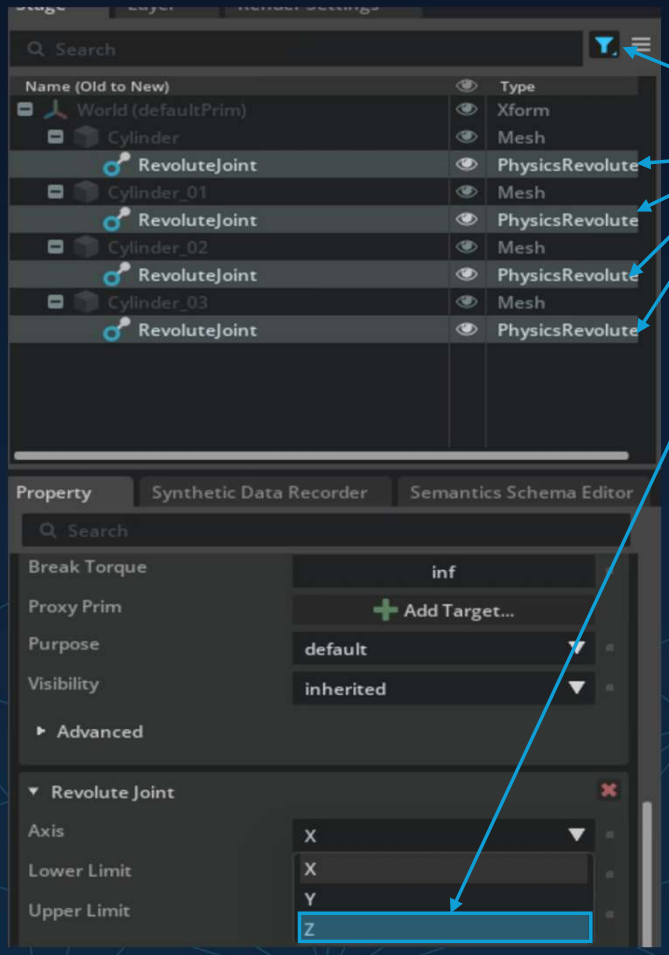
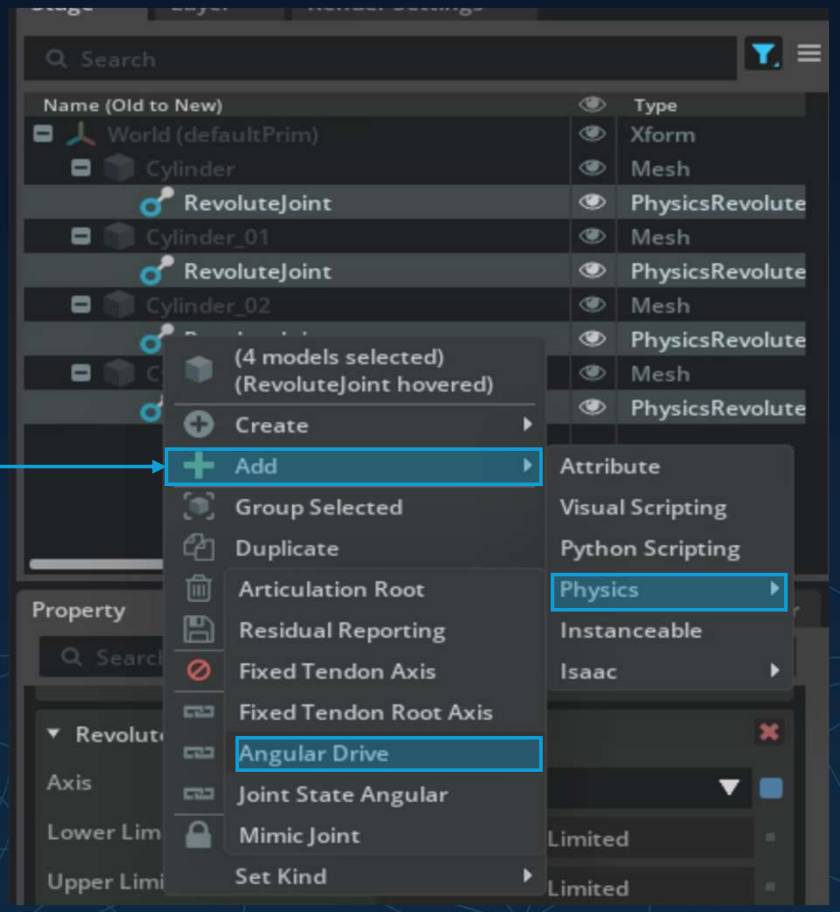


1. Filter for Joints
2. Select all joints (via *Shift* or *Ctrl*)
3. Adjust joint rotation
4. Add Drives to joints (via Context menu)



How-to: Adjust Drive

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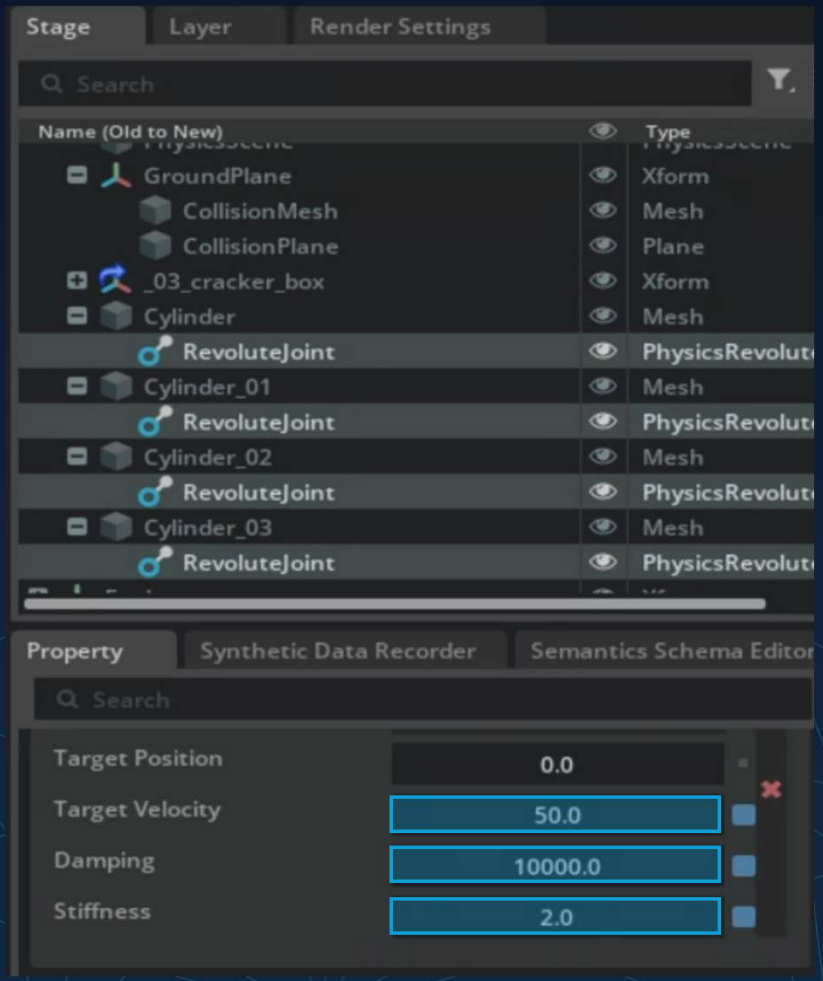

1. Set a Velocity(~20-100)
2. Iterate:
   1. Set Damping & Stiffness Values
   2. Restart Simulation for Testing*

*Not restarting the simulation leads to misleading results due to the forces that already applied before the update

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Assemble the first self-built Robot

- Stop the Simulation
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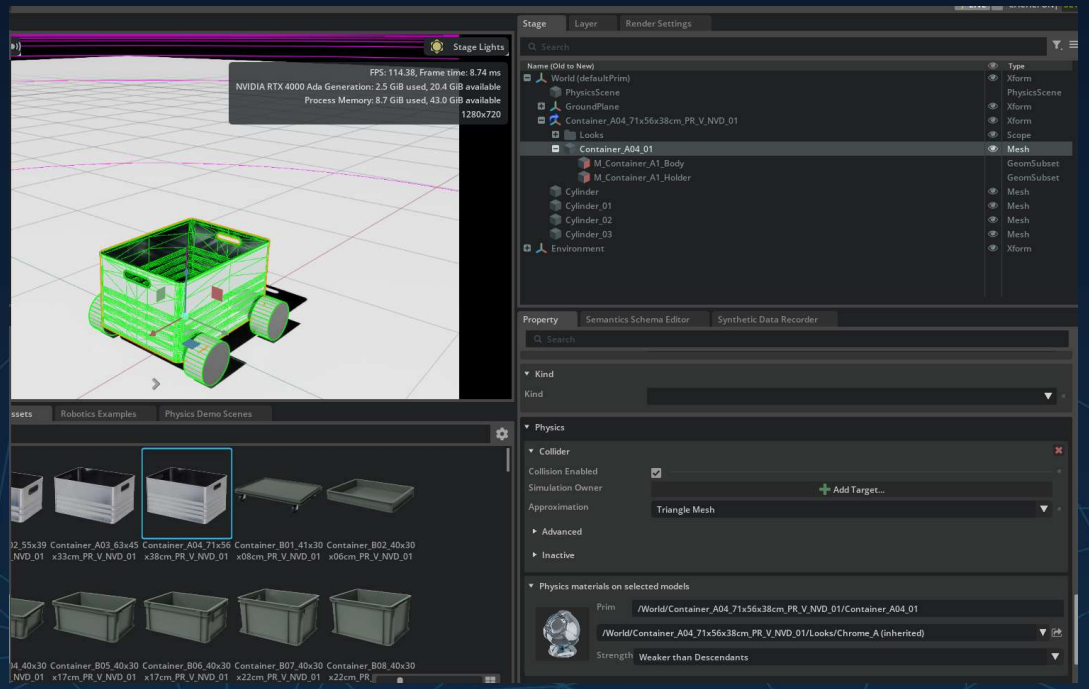
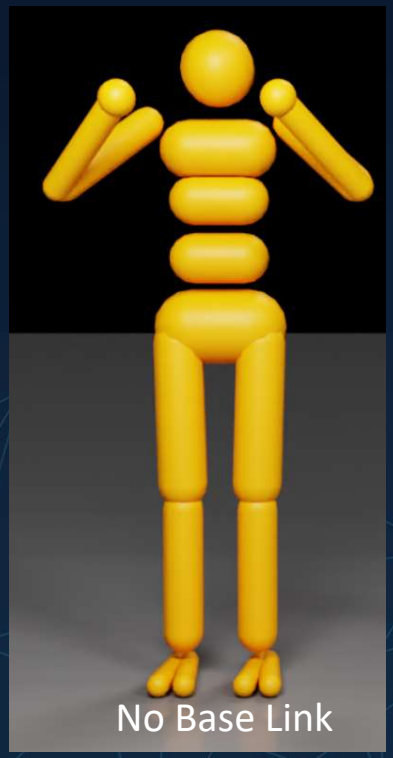
  - Move/ orient to the side
  - Create a revolute joint
  - Add Angular drive
  - Modify target velocity + stiffness
- Start the Simulation



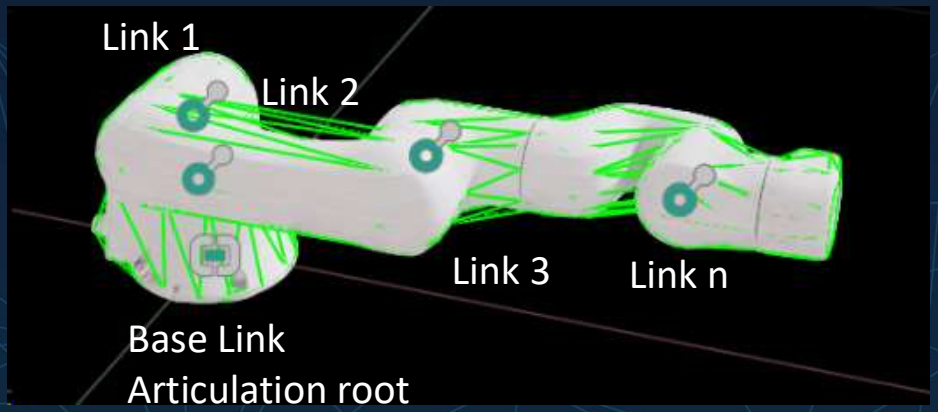
Rigid Bodies and Colliders

- Simpler approximation = faster Simulation

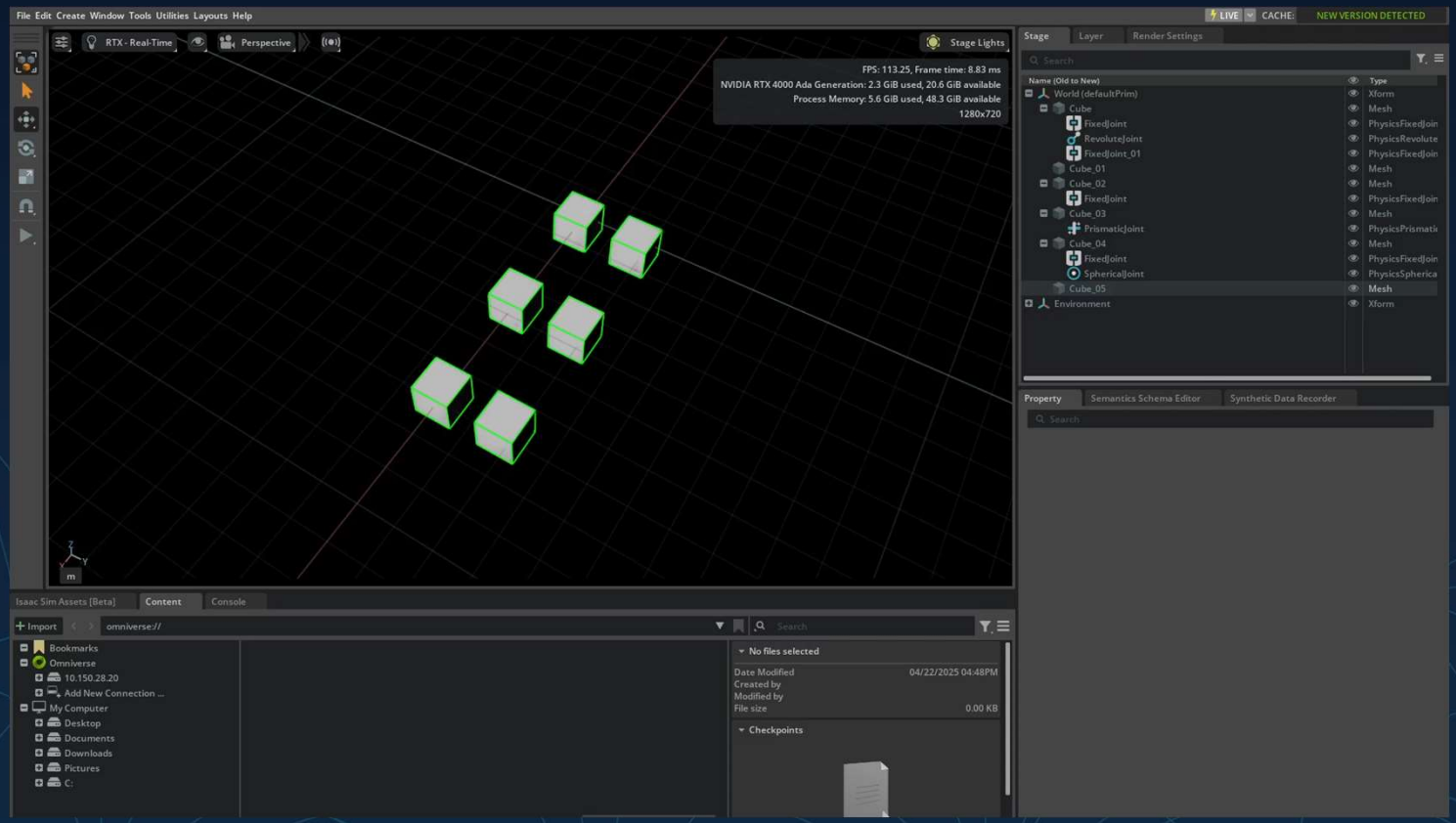
Robot assembly



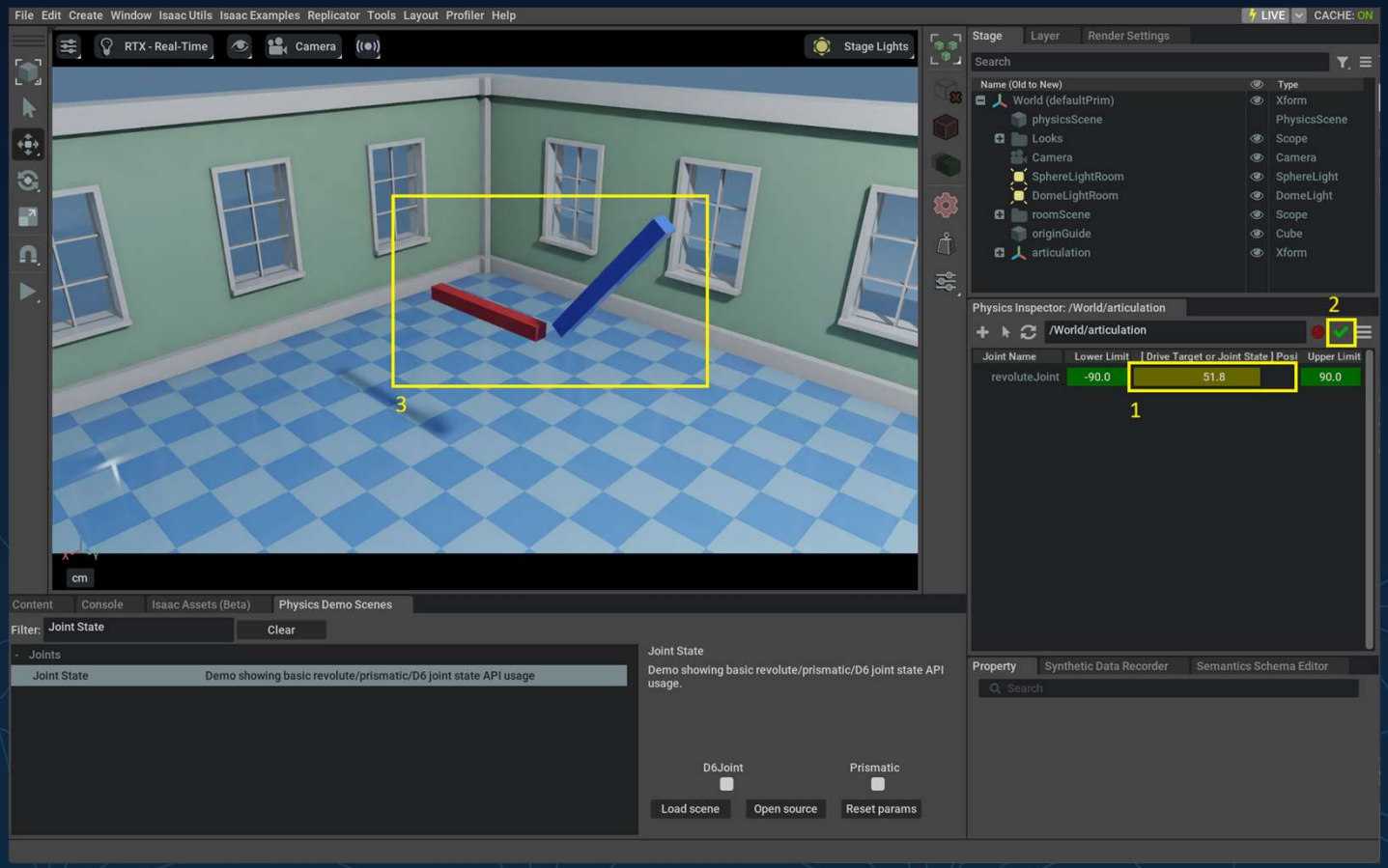
- Structure of mobile / static robot
  - Articulation chain
  - root link free / fixed



Joint types and properties



Joints



Joint types and properties

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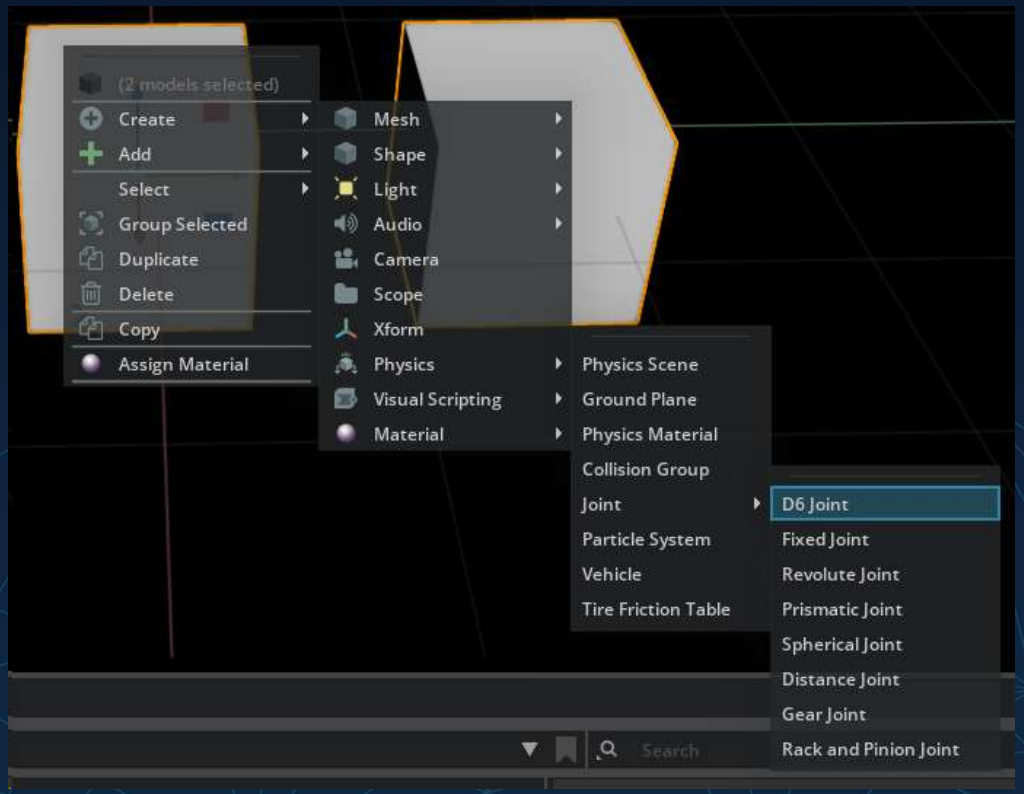

Joint drives are internally simulated with PD-Controllers
- *Stiffness* property <-> Proportional coefficient
- *Damping* property <-> Derivative coefficient

⚠ This can lead to unexpected behavior at low simulation frequencies

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Until now:

- We reviewed necessary Omniverse Basics and Resources
- Practical session:
  - Extensions installation
  - Scene Manipulation

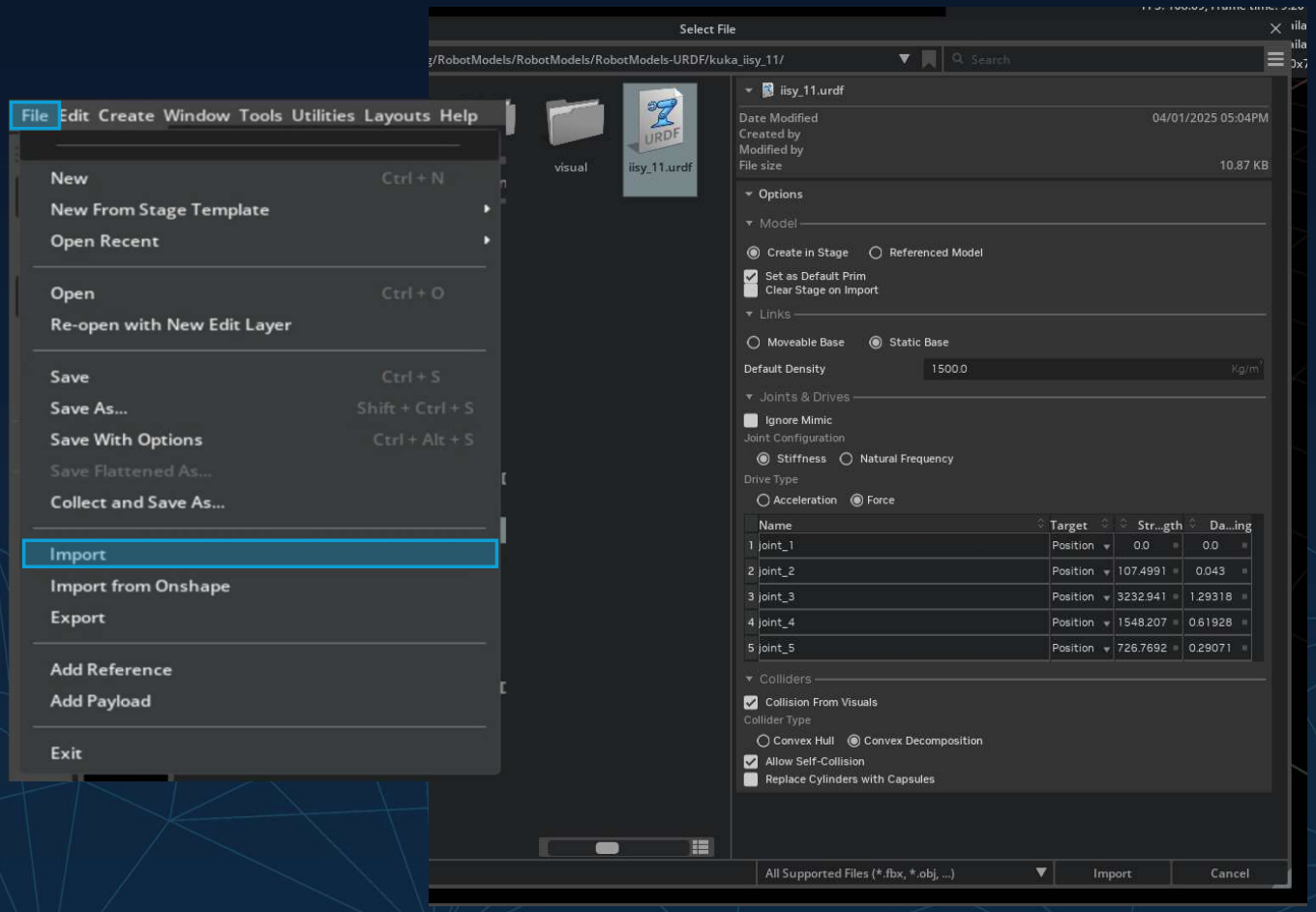
10 min Break

To be continued:

- Practical session:
  - Robot import + tuning

How-to: Starting with a real Robot

- Open *File->import*
- Navigate to a URDF File
- Modify the Options
  - Verify *Model* and *Links*
  - Adjust *Joints & Drives*
  - Verify *Colliders*
- Click *Import*



Robot import Tools

- LULA URDF Import Tool:
  - Import Robot URDF
  - Start scene -> look at joint drives
- Physics Inspector Tool:
  - Activate scene
  - Choose IISY to inspect-> control joint limits/ direction
- Gain tuner:
  - Adjust Stiffness & Damping and test the parameters
- Preparation of self and external collision shape:
  - Sphere approximation Collider tool for RMP

Robot Description Editor

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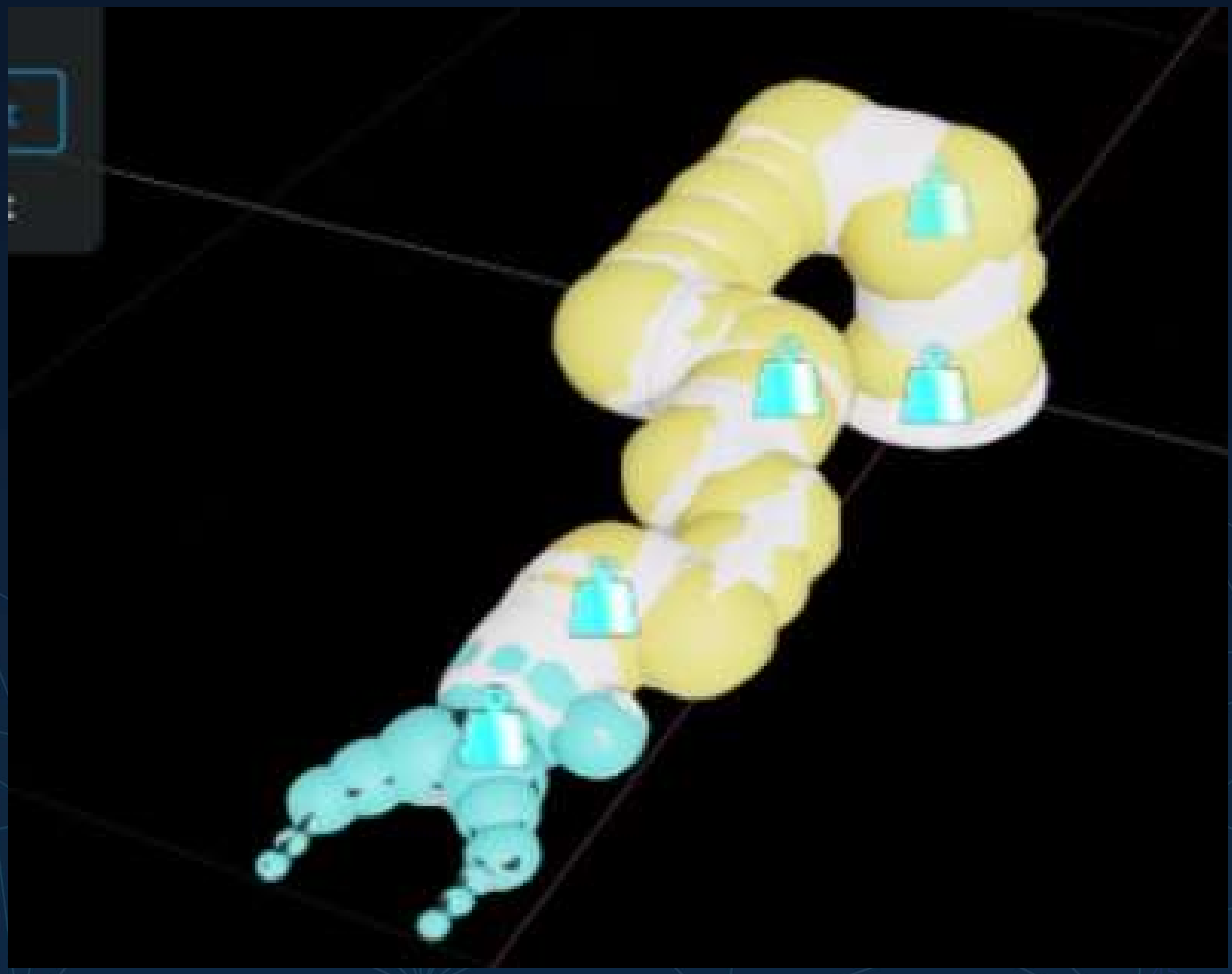
Sphere Approximation Result



Lula Test Widget

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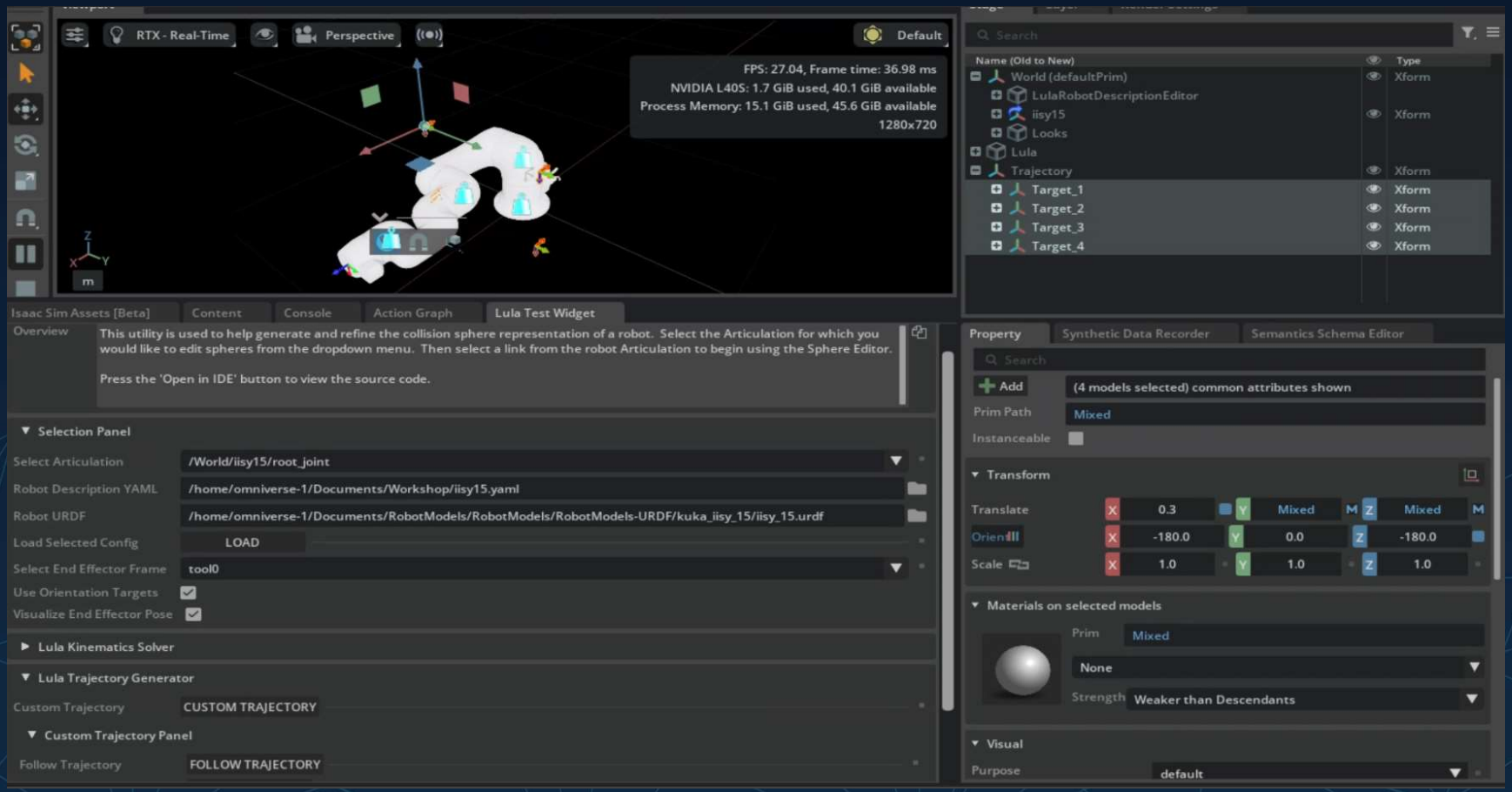

Lula Test Widget

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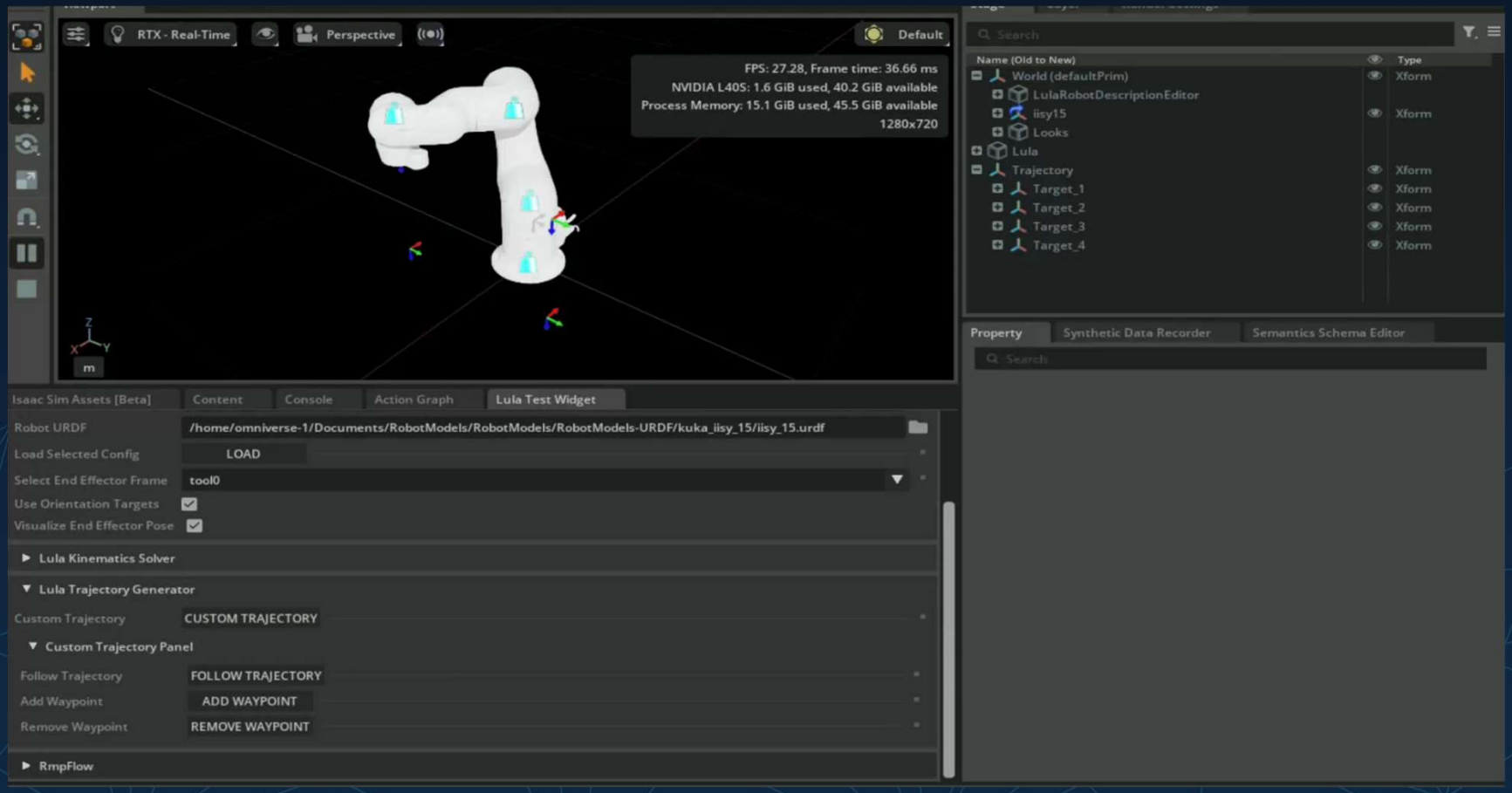

Sensors

- Adding a Wrist Camera to the Robot
  - Tune the Camera

End of Day 1

Please provide some Feedback
Verbal or via:

For further questions mail us:
fabian.fichtl@hs-kempten.de
julian.zuern@hs-kempten.de

Omniverse Base Workshop 1

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- 2x 4h Course with examples to
  - Learn the Basics in Omniverse, USD & Isaac Sim
  - Enable you to do Robotic model preparation & Simulation
  - Introduction to IsaacLab

Review of Day 1

- We reviewed necessary Omniverse Basics and Resources
- Practical session:
  - Extensions installation
  - Scene Manipulation
  - Robot import + tuning

Agenda Tag 2:

- Scene Architecture
  - Build your Scenario: Robot, Gripper, Controller, Environment
- Debugging Tools:
  - Console, VS Code, UI
- Materials
- Motion Planning & Motion Learning
- Practical Session: Pick & Place
- Information Channels | Further Courses

Interacting with USD (in Omniverse scene)

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- UI Main Capabilities
  - Viewport:
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- API Main Capabilities
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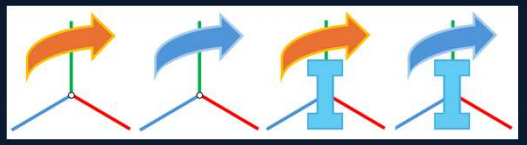
  - Start training

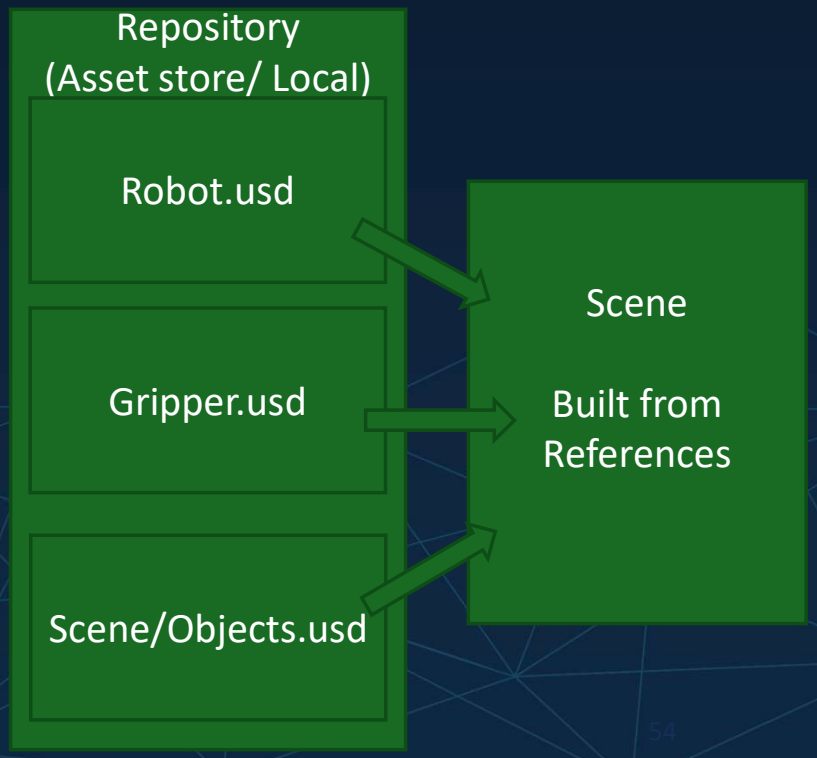
*Nodes in the USD-scene tree are called Primitives or Prims

Scene Assembly

- Payload: blue ↔ Reference: orange
  - The user can choose to not load a payload
  - References always get loaded
  - 𝕀 = Instancing active



- How to build a reference scene architecture
  - To test different robots/ grippers
  - Test Script of Robot Assembly



Assemble Your Scene

TODO click-anleitungen

- Open environment template & inspect it ✓
- Drag robot into Viewport or Stage ✓
- Add ROS Controller ✓
- Inspect ROS2 subscriber ActionGraph
- Run scene
- Execute ROS2 script (from VS code) -> ToBeCreated

How-to: Add the Environment

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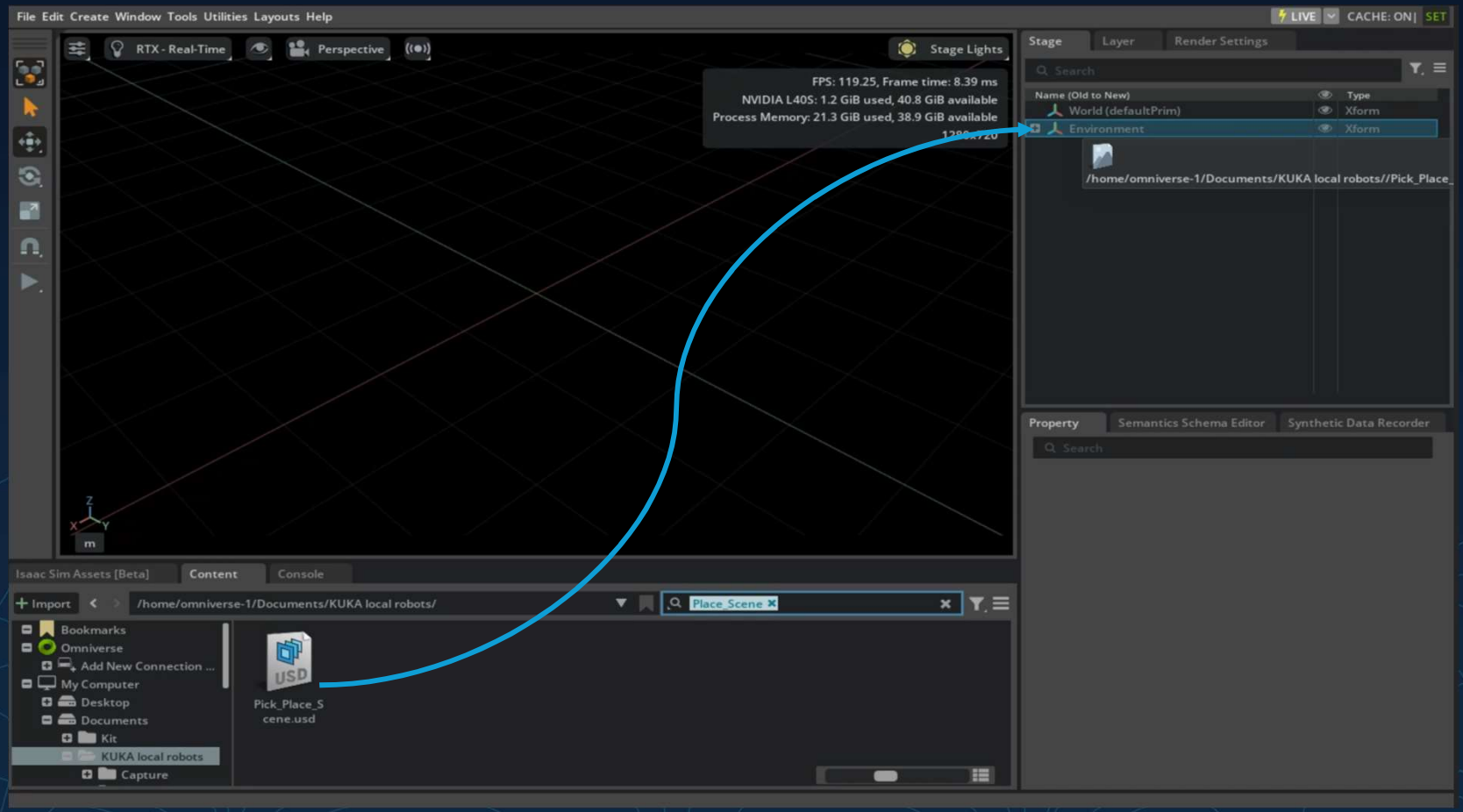

1. Drag USD scene from content browser onto Stage tree

How-to: Add the Robot

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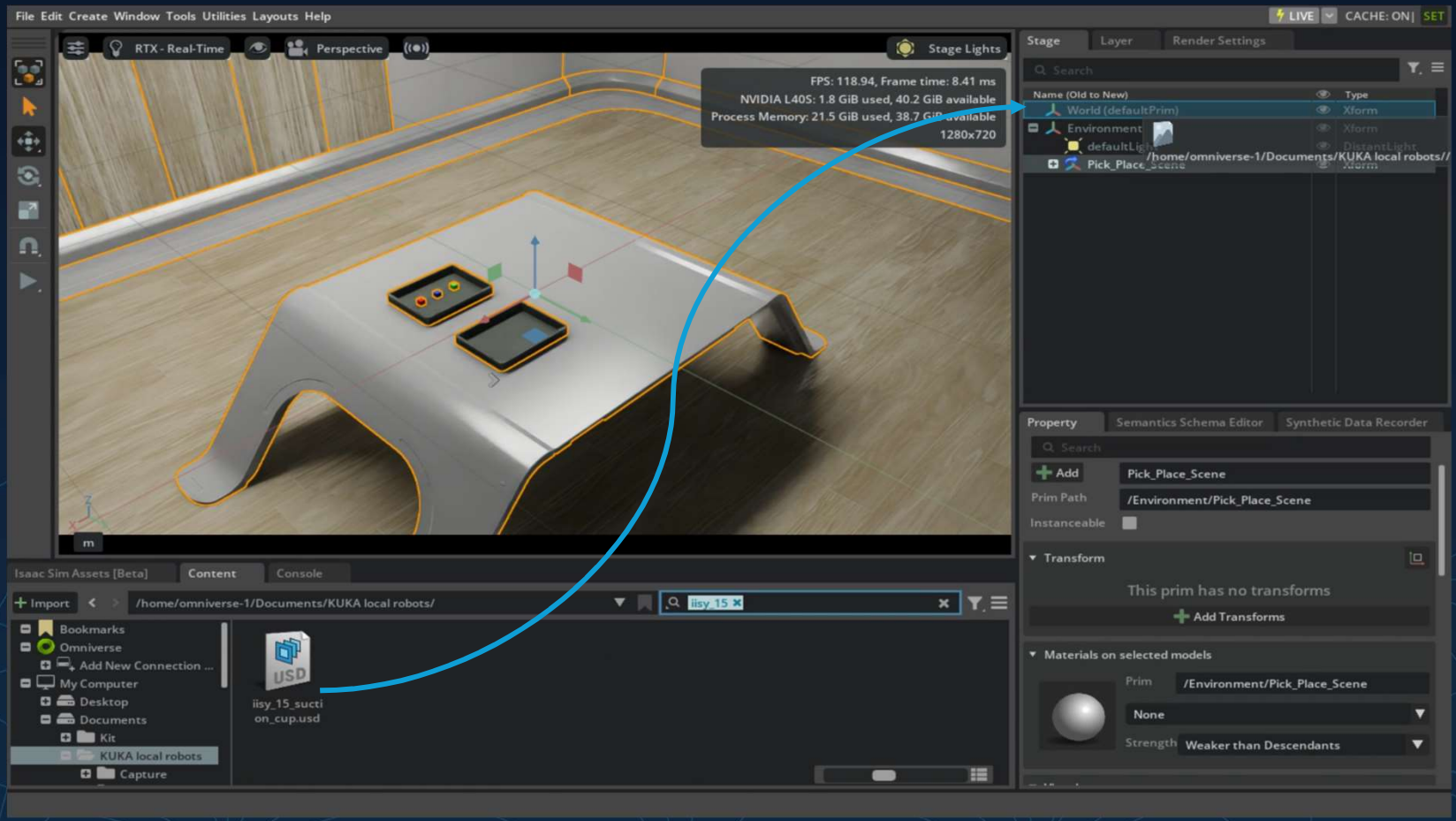
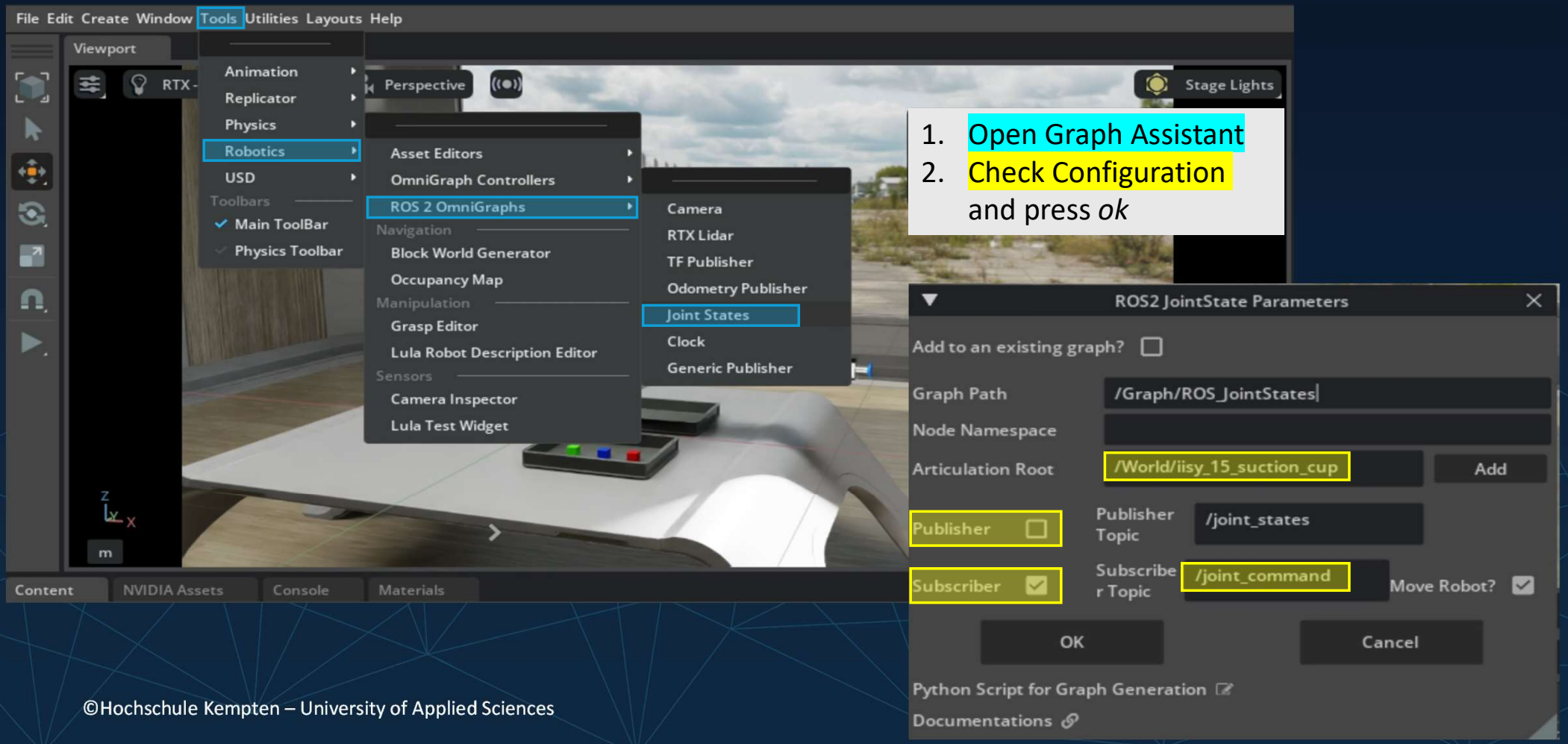


1. Drag robot from content browser onto Stage tree

How-to: Add the Controller

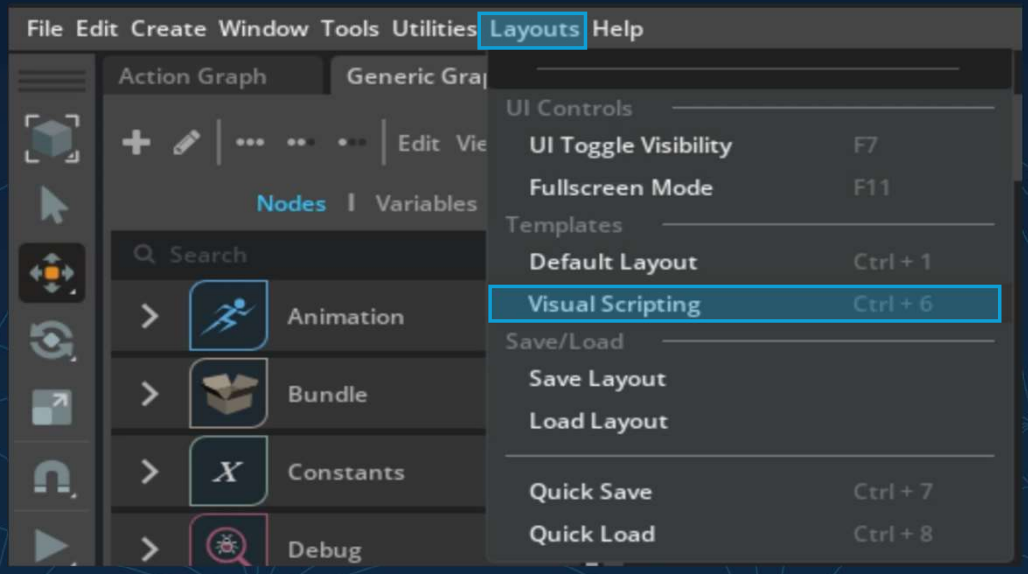


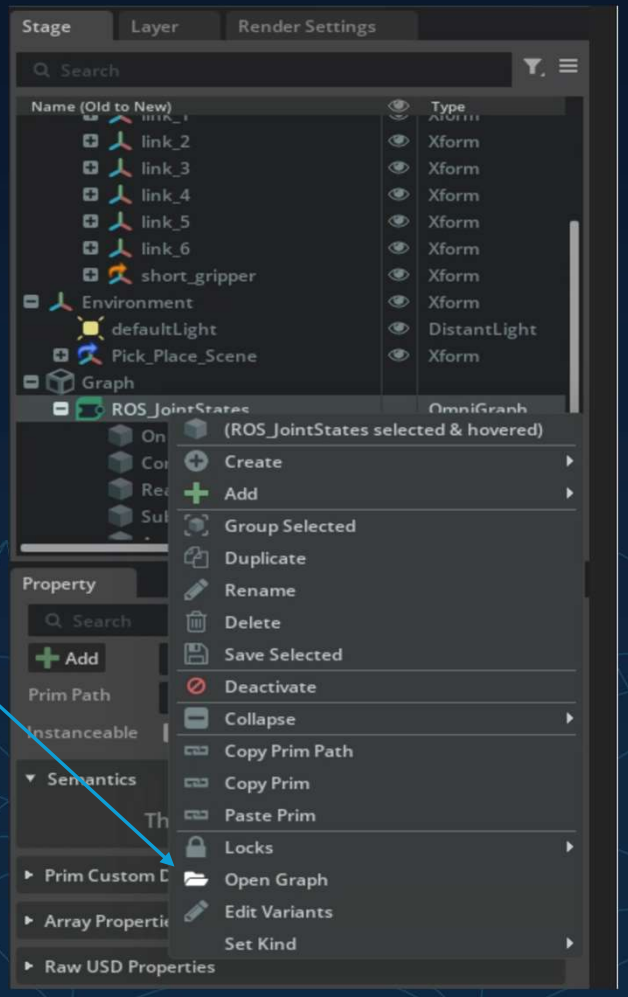
How-to: View the Controller

- Use Context menu in Stage

or

- Use *Visual Scripting* Layout (*Ctrl+6 -> 'Edit Graph'*)





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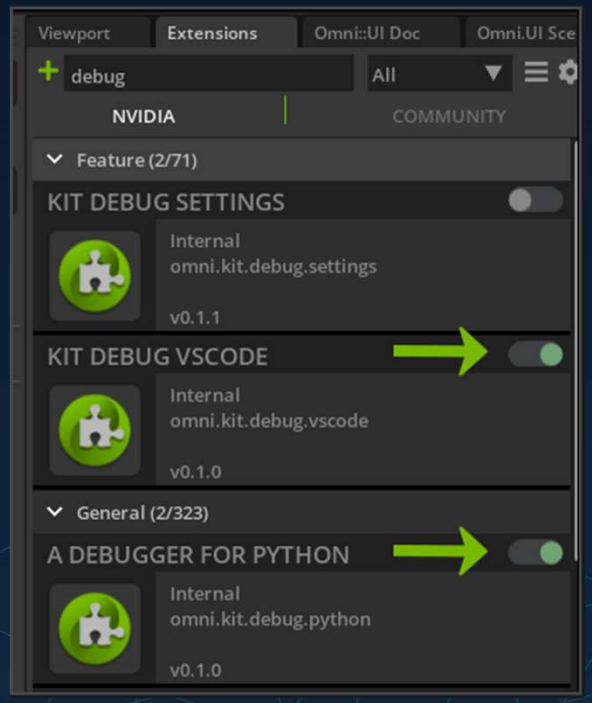
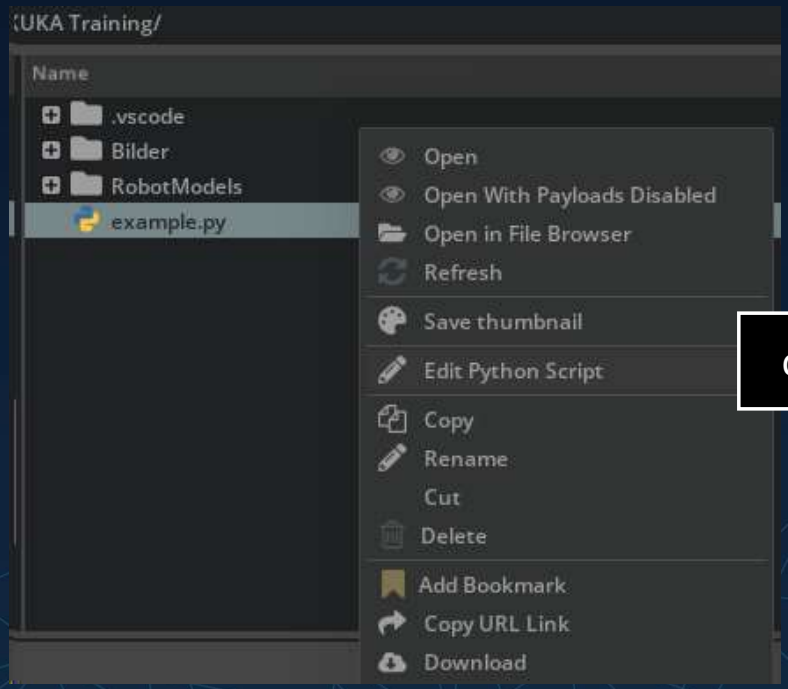
Assemble Your Scene

Save Scene

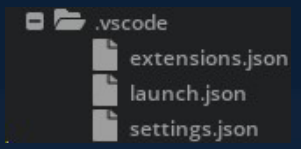
- Use the USDA format
- Inspect the structure and *payloads*

Debugging Tools





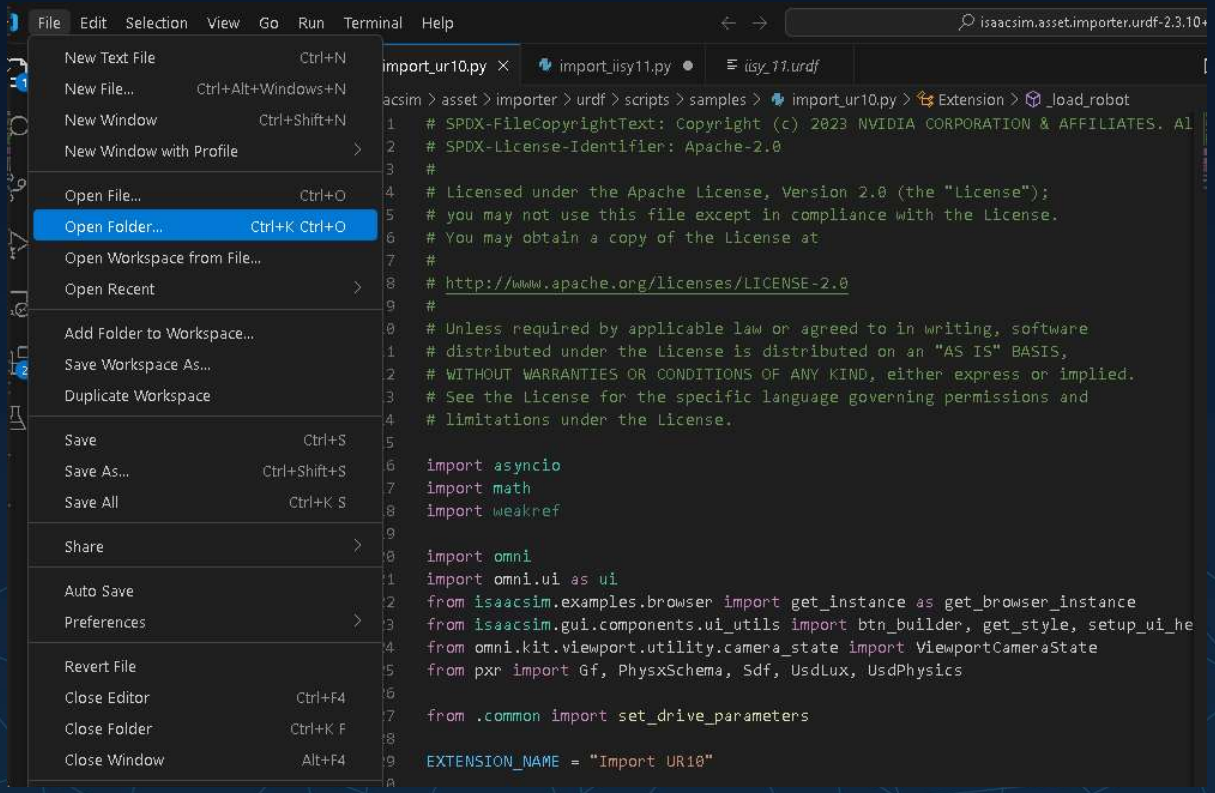
creates

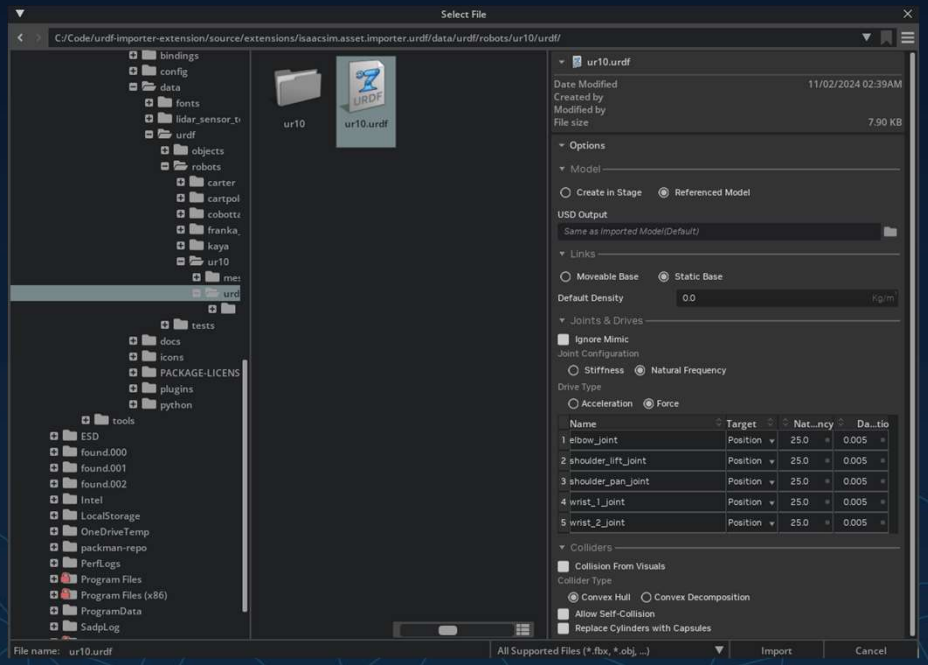


https://docs.omniverse.nvidia.com/extensions/latest/ext_vs-code-link.html

If you open .py in OV, the VS Code Link dependencies are created automatically
-> Enables hot reload of code

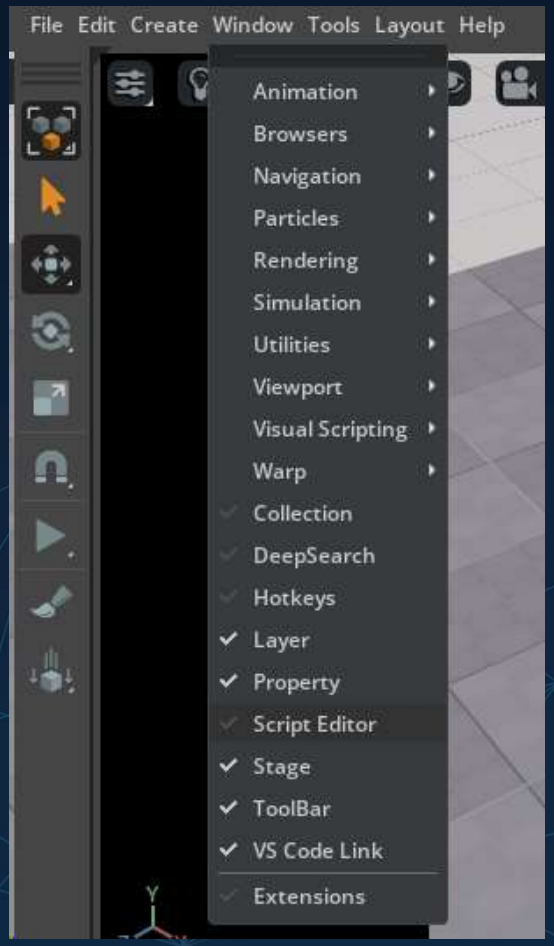
Debugging Tools

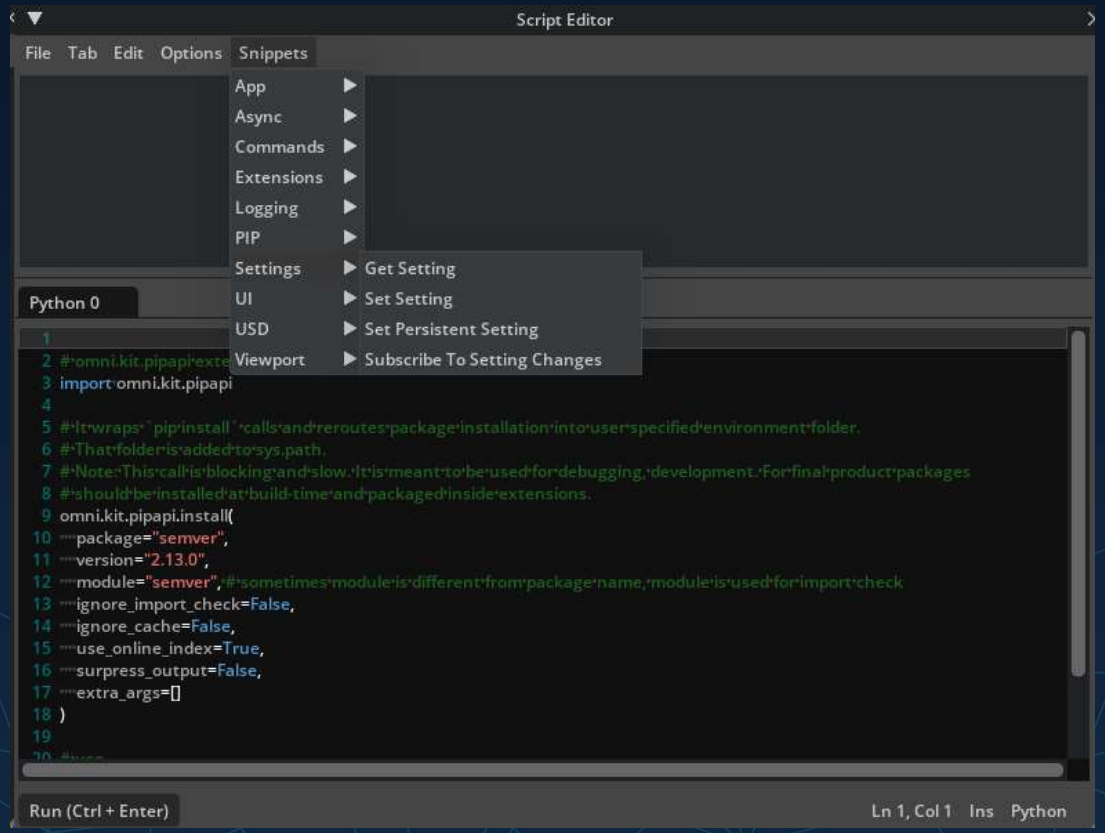




Helpful to reuse example code or look into USDA file

Debugging Tools





Script Editor

Manipulate the Scene by Python API

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```
import omni.usd
import omni.kit.commands from pxr
import Gf
# Get current stage
stage = omni.usd.get_context().get_stage()
# Create cube with specified parameters
result, prim_path = omni.kit.commands.execute(
            "CreateMeshPrim",
            prim_type="Cube",
            prim_path="/World/Cube",
            object_origin=Gf.Vec3f(0, 0, 0),
            half_scale=50.0,
            u_verts_scale=1,
            v_verts_scale=1,
            w_verts_scale=1 )
```

- Open the Script Editor
  - Open the file *scene_Manipulation.py*.
  - Run it
  - Try to create another prim for example a cone:

```
# Create cone with specified parameters
result, prim_path = omni.kit.commands.execute(
            "CreateMeshPrim",
            prim_type=" Cone",
            prim_path="/World/Cone",
            object_origin=Gf.Vec3f(0, 0, 0),
            half_scale=50.0,# 1m Height/Diameter (dep. on def.)
            u_verts_scale=1,
            v_verts_scale=1,
            w_verts_scale=1 )
```

Documentation

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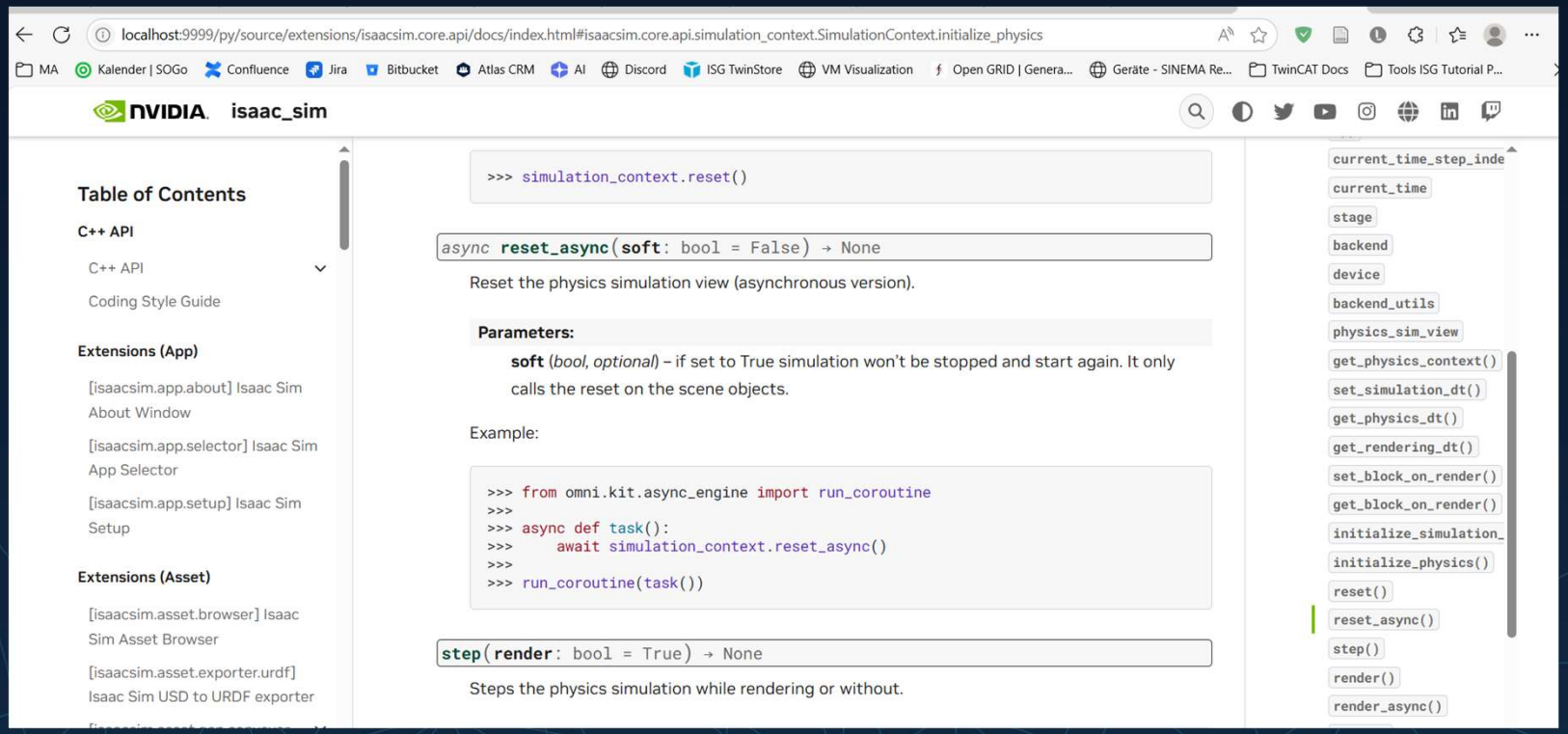

https://docs.isaacsim.omniverse.nvidia.com/4.5.0/py/index.html

Online or Local
(latter might not be available)

$ cd isaacsim/docs
$ python3 -m http.server 9999

Referencing Prims

- Create new scene through GUI
- Open Script Editor
- Open File *assemble_scene.py*
- Analyze Content…
- Run Script

Materials & physics Materials

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Materials:

- Color Map
- Reflectivity
- Absorption
- Many others and mixtures/ Shaders

Physics Materials:

- Static Friction
- Dynamic Friction
- Restitution
- Density

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Until now:

- Scene Architecture
  - Build your Scenario: Robot, Gripper, Controller, Environment
- Debugging Tools:
  - Console, VS Code, UI
- Materials

10 min Break

To be continued:

- Motion Planning & Motion Learning
- Practical Session: Pick & Place

Motion Planning Libraries

- Lula
  - Kinematics Solver (fast-forward and inverse kinematics)
  - Trajectory Generator (using one or more planners)
  - Global Planners (e.g. RRT-Connect, JT-RRT)
  - Local Planners (e.g. RMPflow)
  - CPU-based
- CuMotion
  - Similar capabilities as Lula
  - Supports real-time control
  - Builds upon CuRobo (CUDA-accelerated)

⚠ Lula algorithms require a *robot_description.yaml.* It contains active and fixed joints, default joint positions, collision spheres and more. This format will be superseded by the XRDF-format.

RRT…Randomly-Exploring Random Tree
RMP… Riemannian Motion Policies

Prerequisites for CuMotion with RMP

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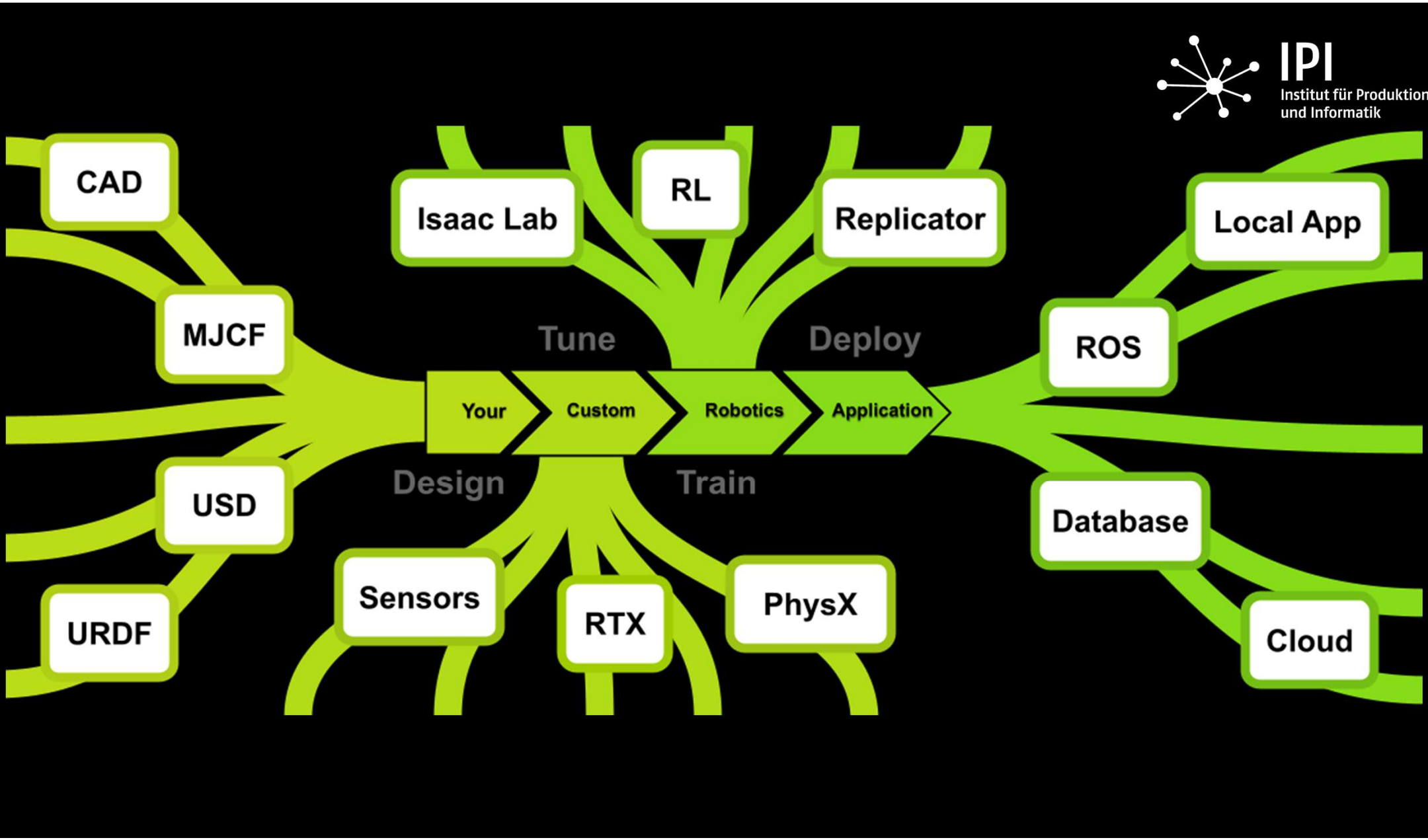
- An URDF file, used for specifying robot kinematics as well as joint and link names. Position limits for each joint are also required.
- An (X)RDF file which can be generated using the Lula Robot Description Editor UI tool. (configure drives, robot density and collision meshes)
- A RMPflow configuration file in YAML format, containing parameters for all enabled RMPs.*

*For algorithms other than RMPflow different configurations and are required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CAD
MJCF
USD
URDF
Isaac Lab
RL
Replicator
Tune
Deploy
Your
Custom
Robotics
Application
Design
Train
Sensors
RTX
PhysX
Local App
ROS
Database
Cloud

IsaacLab Workflow – High Level

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Design & Tune Robot

- Isaac Sim
- Import URDF/ Run Script
- Optimize Kinematics
- Generate Synthetic Data

Train Robot

- Isaac Lab
- Define Task Workflow
- Support for 4 RL Libraries:
  RL-Games, RSL RL, SKRL, SB3

Deploy Robot

- Isaac Sim
- e.g. Running on ROS

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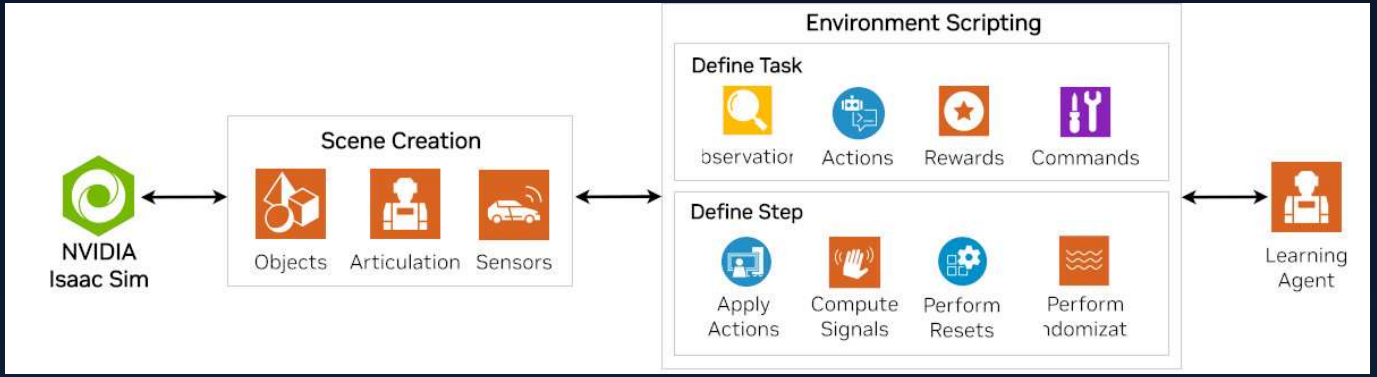
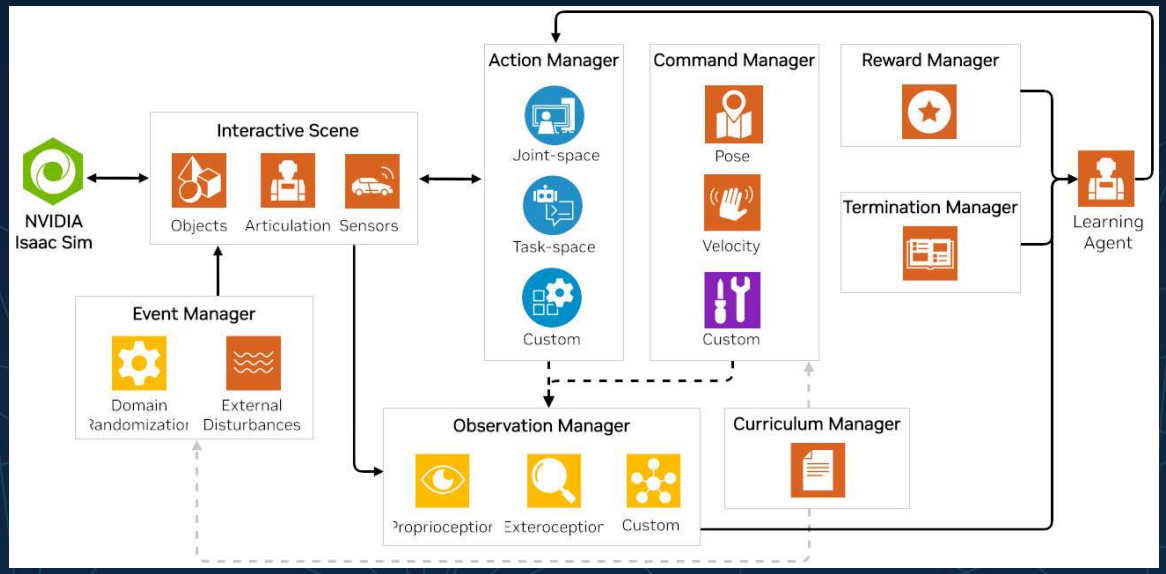
Task Workflows in IsaacLab

Direct RL Workflow



Manager-based RL Workflow



Integrating ML Models

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- Training models on synthetic data generated in Isaac Sim or COSMOS
- Foundation model as perception or reasoning module within the Isaac Lab workflow
- Isaac Lab RL policy optimization

- Groot N1:
  - Requires Trajectory Data, Video
  - https://github.com/NVIDIA/Isaac-GR00T/blob/main/media/model-architecture.png
- π0.5
  - Sensory Data
  - https://pi.website/blog/pi05
- OCTO
  - Generalist Robotic Policy
  - Octo: An Open-Source Generalist Robot Policy

How to generate Trajectory Data

- Classic: Real Robot „imitation learning“
- Trajectory generators
- Applied RL policies
- Teaching sim. Robot with imitation learning

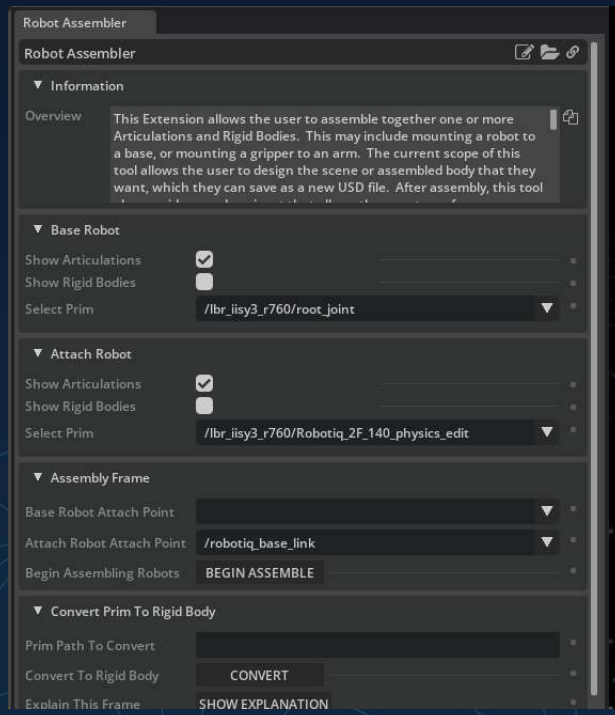
Assemble a gripper to your robot

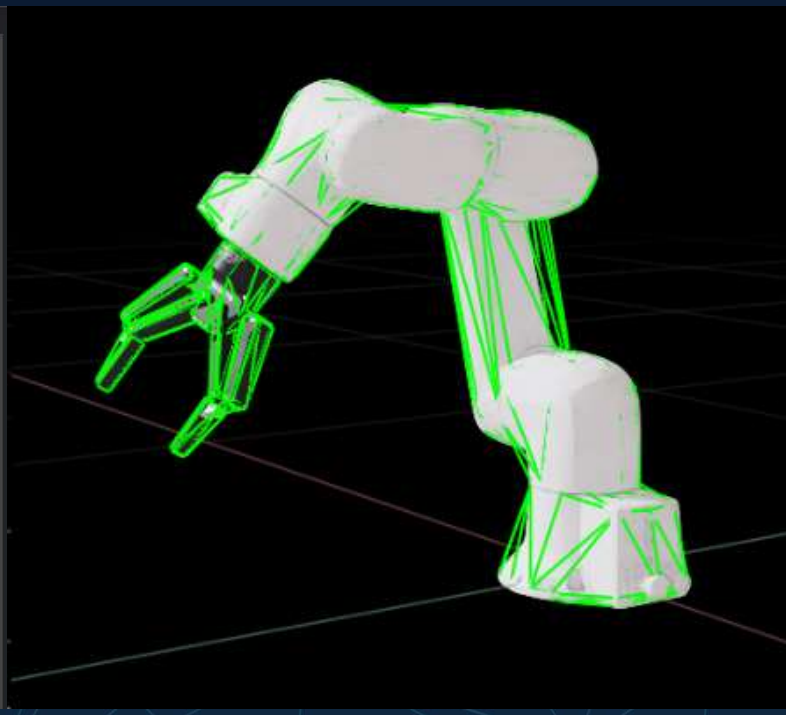
1. UI:

   The Tool joins two articulation trees to one.
   Guides you how

2. Python API

   Code is created automatically from the UI. This can be reused for later automatically create a stage + assembly





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Until now:

- Scene Architecture
- Build your Scenario: Robot, Gripper, Controller, Environment
- Debugging Tools:
  - Console, VS Code, UI
- Materials
- Motion Planning & Motion Learning

5 min Break

To be continued:

- Practical Session: Pick & Place
- Movie Capture

Pick & Place Setup

1. Create new Scene
2. Add a robot from the workshop material:
   - Content -> Workshop -> Robots -> IISY 15_Suction
3. Add graph logic/controller
4. Start script *assemble_pick_place.py*

-> Start the scene by hitting play

https://docs.omniverse.nvidia.com/isaacsim/latest/advanced_tutorials/tutorial_advanced_omnigraph_pickplace_controller.html

Pick & Place Phases

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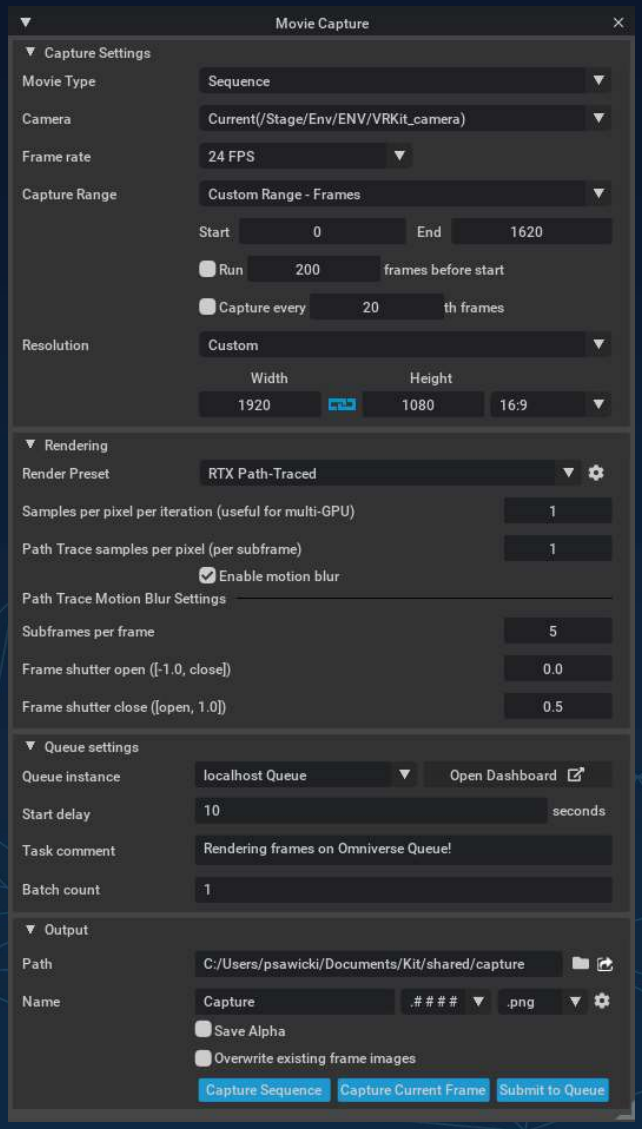
ee... end_effector

- Phase 0: Move above the cube center at the ‘end_effector_initial_height’.
- Phase 1: Move *ee* down to encircle the target cube
- Phase 2: Wait for Robot’s inertia to settle.
- Phase 3: Close grip.
- Phase 4: Move *ee* up again, keeping the grip tight (lifting the block).
- Phase 5: Move the *ee* toward the goal xy, keeping the height constant.
- Phase 6: Move *ee* vertically toward goal height at the ‘end_effector_initial_height’.
- Phase 7: Loosen the grip.
- Phase 8: Move *ee* up again at the ‘end_effector_initial_height’
- Phase 9: Move *ee* towards the old xy position.

Movie Capture Tool

- Navigate to Window -> Extensions Manager using the top-level menu
- Search *Movie Capture* in the text field, to reveal the *omni.kit.window.movie_maker*.
- Click the toggle to enable the extension.

- Open the extension in rendering -> Movie Capture



Movie Capture + simple Animation

Feedback Workshop

For further questions mail us:
fabian.fichtl@hs-kempten.de
julian.zuern@hs-kempten.de

Ressources & further Courses

Omniverse Glossary

- Omniverse Glossary of Terms — Omniverse Developer Workstations

USD

Payload vs Reference:
https://forums.developer.nvidia.com/t/usd-payload-vs-reference-vs/252658

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Joints

- https://nvidia-omniverse.github.io/PhysX/physx/5.3.0/_downloads/6acf3afb8f69452757e0e766b5a22978/implicitDrives.pdf

URDF Import

- https://docs.isaacsim.omniverse.nvidia.com/4.5.0/robot_setup/ext_isaacsim_asset_importer_urdf.html

Gripper

- https://docs.isaacsim.omniverse.nvidia.com/latest/robot_setup/assemble_robots.html
- https://docs.isaacsim.omniverse.nvidia.com/latest/robot_simulation/ext_isaacsim_robot_surface_gripper.html

- cobotta demo und anschließend mit iisy
- https://docs.isaacsim.omniverse.nvidia.com/latest/robot_setup/import_manipulator.html
- https://docs.isaacsim.omniverse.nvidia.com/latest/manipulators/manipulators_configure_rmpflow_denso.html#isaac-sim-app-tutorial-configure-rmpflow-denso

https://docs.isaacsim.omniverse.nvidia.com/latest/robot_setup/grasp_editor.html

Roboter konfiguration

- https://docs.omniverse.nvidia.com/isaacsim/latest/advanced_tutorials/tutorial_configure_rmpflow_denso.html

- Articulation Root
  -> Mobil oder stationär
- https://docs.omniverse.nvidia.com/extensions/latest/ext_physics/articulations.html

Inverse Kinematics solver

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

MoveIt

- https://moveit.picknik.ai/main/index.html
- https://moveit.picknik.ai/main/doc/concepts/concepts.html

Cumotion

- https://nvidia-isaac-ros.github.io/concepts/manipulation/index.html#nvidia-cumotion
- Isaac Manipulator consists of a set of components and reference workflows for advanced perception-driven manipulation. These components include state-of-the-art packages for object detection and object pose estimation, as well as obstacle-aware motion generation.

Task Space Controller

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

Self paced Courses:

- https://learn.nvidia.com/courses/course?course_id=course-v1:DLI+S-OV-31+V1&unit=block-v1:DLI+S-OV-31+V1+type@vertical+block@bd7da7c3339a42c69f073ca845778391
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-31+V1
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-15+V1
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-27+V1
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-29+V1
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-20+V1
- https://learn.nvidia.com/courses/course-detail?course_id=course-v1:DLI+S-OV-28+V1
- https://academy.nvidia.com/en/course/nvidia-ai-enterprise-administration/?cm=55144