



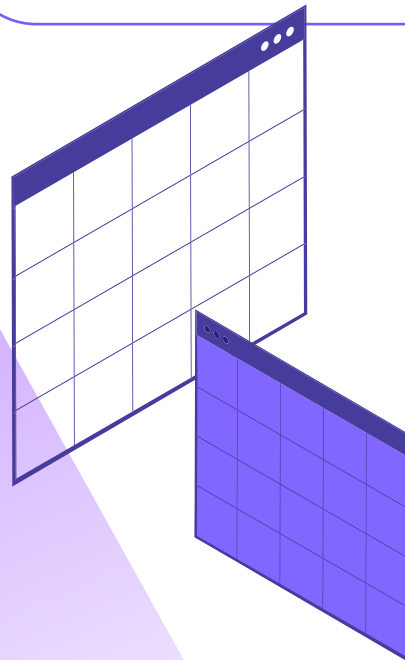
How to Choose your simulator:

Expert Rankings → and Criteria

... This guide will help you choose the right robotics simulator by covering key criteria like physics, rendering, hardware requirements, and ROS 2 integration. Featuring expert rankings and clear comparisons of top simulators such as Gazebo, NVIDIA Omniverse Isaac Sim™, MuJoCo, O3DE, and MVSIM, it provides practical guidance to select the best fit for your project and avoid costly mistakes.



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Simulator Decision Matrix

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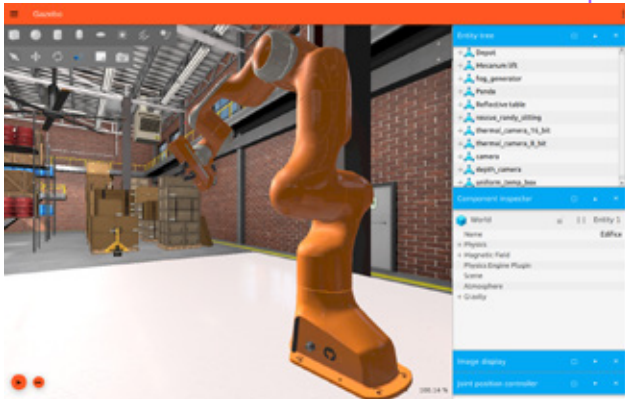
Simulations are a powerful tool for developing robotics applications, offering scalability, safety, and rapid iteration. Many different simulators can accomplish the task, but to maximize these benefits, it is crucial to choose the one that best suits your specific use case and needs.

In this chapter, we will explore various leading simulator options, contrasting their pros and cons to help you find the most suitable fit. For the majority of robotic applications, general-purpose simulators serve as an effective starting point, typically offering user-friendly interfaces, sufficient physics accuracy, and commendable performance. Adhering to these guidelines, we will examine Gazebo, a widely adopted simulator; NVIDIA's Isaac Sim, the most photorealistic alternative; MuJoCo, more geared towards reinforcement learning and precise physics simulations; O3DE, a balanced option between performance and rendering fidelity; and MVSIM, a 2.5D lightweight simulator optimized for high-performance multi-robot and navigation testing. Numerous other options exist, some specializing in particular simulation types, such as aerial, fluid, particle, or autonomous vehicle simulations.



Simulator Overview

Next, we'll highlight the aforementioned options.



- **GAZEBO:**

Gazebo stands as the open-source standard simulator within the ROS community. It's a modular platform offering a balanced feature set, straightforward ROS 2 integration, and diverse physics engine options. Gazebo has been the pioneer in general-purpose robotics simulators, and its large community is a consequence of this.

Robotic arm simulated in Gazebo, available in the GazeboSim organization repository on GitHub.



- **MUJOCO:**

MuJoCo is primarily a physics engine, with additional features to serve as a simulator. It's renowned for its speed and accuracy, especially in complex contact and articulation dynamics. It is a favorite in the research community for RL and advanced control algorithms development.

*Boston Dynamics Spot quadruped in the MuJoCo simulator
Image sourced from the MuJoCo Menagerie model gallery.*



*Image sourced from the Hugging Face website.
Author: NVIDIA Corporation
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- **NVIDIA OMNIVERSE ISAAC SIM™:**

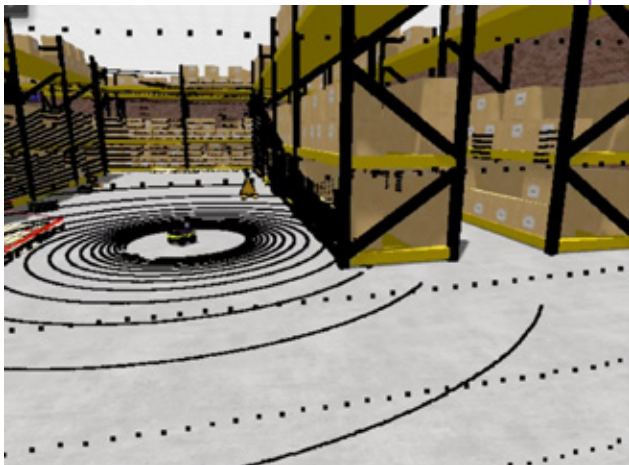
Built on top of the Omniverse ecosystem, this photorealistic simulator leverages RTX technology for high-fidelity sensor simulation and synthetic data generation. It's the go-to choice for training and validating vision-based AI models. Has seamless integration with ROS 2 and has recently become open-source with its latest release. Additionally, extending its functionality is straightforward, enabling Python scripting for rapid prototyping.



Frame captured from the Robotized Fulfillment Center demo video on the O3DE website.

- **O3DE:**

A full-featured, open-source game engine (a successor to Amazon Lumberyard) with several extensions to be suitable for robotics simulation. Its dedicated "ROS 2 Gem" allows easy and native integration with ROS. Its rendering engine (Atom) supports modern rendering techniques, which combine well with several robotics scenarios; however, its strong point is its design for creating massive, dynamic worlds, making it suitable for large-scale autonomy simulations.



- **MVSIM:**

MVSim: A **lightweight, open-source 2.5D simulator**. It integrates directly with ROS 2 and is highly efficient for testing navigation stacks, fleet management systems, and SLAM algorithms, providing a simple 3D rendering of the environment while keeping the physics and vehicle dynamics simple to enhance performance.

This image was taken from the mvsim repository and is a frame captured from their warehouse demo video.

How to Choose

Next, we show a comparative table outlining the primary characteristics of general purpose simulators. While this table aims to give an overview of the capabilities of different options, it's important to note that many of the presented tools are oriented towards a specific type of application.



CRITERIA	GAZEBO	NVIDIA OMNIVERSE ISAAC SIM™	MUJOCO	O3DE	MVSIM
Physics	★★★★	★★★★★	★★★★★★	★★★★★	★★
Rendering	★★★★	★★★★★★	★★	★★★★★	★
ROS 2 integration	★★★★★★	★★★★★★	★	★★★★★	★★★★★
Hardware Requirements	★★★★★★	★★	★★★★★★	★★★★★	★★★★★★
Sensors support	★★★★★★	★★★★★★	★★	★★★★★★	★★★★
Community	★★★★★★	★★★★★	★★★★★	★★	★★

Understanding the ratings

- **PHYSICS:**

MuJoCo earns the highest rating for specializing in fast and highly accurate contact and articulation dynamics, making it a top choice for reinforcement learning and complex manipulation tasks. Gazebo, Isaac Sim, and O3DE offer robust, general-purpose physics engines (like PhysX or DART) that are more than capable for a wide range of mobile robot and manipulator applications. MVSIM offers a simplified physics engine that offers good enough features for the use cases it aims to simulate.



- **RENDERING:**

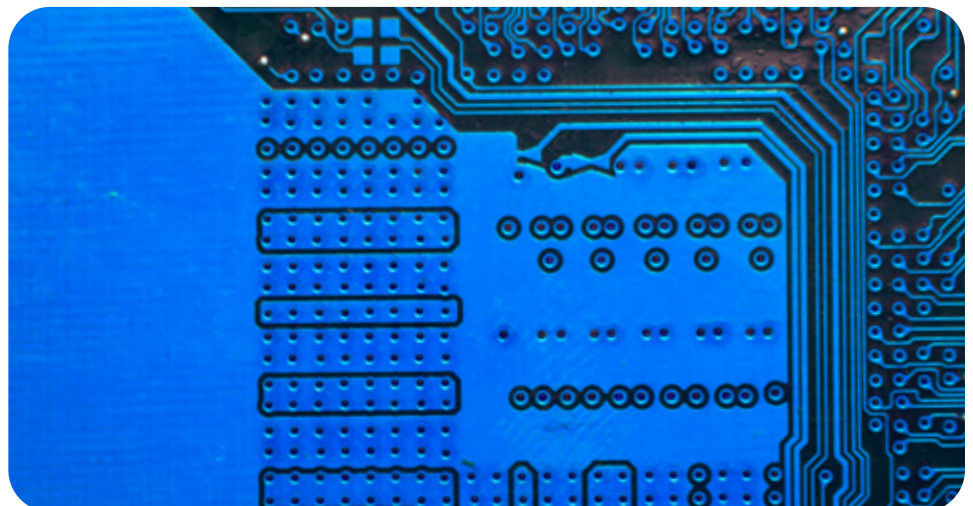
NVIDIA Isaac Sim, built on the Omniverse platform, leads in rendering with real-time RTX ray tracing for photorealistic results. O3DE, a modern game engine, also provides high-fidelity visuals that, while not photorealistic, offer a better performance than its direct competitor. Gazebo's functional and improved rendering suits most non-vision-critical tasks. MuJoCo and MV Sim provide only basic visualization, as rendering is not their primary focus.

- **ROS 2 INTEGRATION:**

Gazebo is the standard-bearer in the ROS community, offering seamless, native integration, as does Isaac Sim with its Omnigraphs, while O3DE is not far behind with dedicated, officially supported tools for robust ROS 2 connectivity. MVSIM provides excellent support for ROS 2, making it very easy to integrate with standard navigation and robotics stacks. In contrast, MuJoCo presents the most integration challenges, relying on community-driven bridges.

- **HARDWARE REQUIREMENTS:**

Gazebo, MuJoCo, and MVSIM do not require any specific hardware. While O3DE recommends any dedicated GPU, Nvidia Isaac Sim demands at least an RTX 3070. While all these simulators can run on the cloud and be used for CI, their costs are directly proportional to their hardware requirements.





- **SENSORS SUPPORT:**

Gazebo, Isaac Sim, and O3DE provide support for a vast list of common robotics sensors, such as Lidar 2D/3D, RGB+D / segmentation / bounding box cameras, IMU, GPS, etc, even though O3DE might depend on the ROS 2 GEM to use them. MuJoCo, as a physics engine, focuses on accurately sensing the interaction forces and internal states of the robots, providing support for IMU and force/torque sensors. It does not, however, come with built-in LiDARs or cameras. On the other hand, MVSIM's limited list of sensors is composed of RGB+D cameras, Lidar 2D/3D, IMU, and GPS, which is more than enough for the use case the simulator aims to.

- **COMMUNITY:**

Gazebo has the biggest community among all its competitors, mostly as a result of its long trajectory. Isaac Sim and MuJoCo, while not at the same level as Gazebo, have active and growing communities.

The criteria to select a simulator are almost entirely dependent on the scope of the project; however, there are some high-level questions you can start answering that can define what tool to choose. Ultimately, your project requirements define priorities, and trade-offs must be made to achieve those focal points.

Robotic system

- **NUMBER OF ROBOTS:**

- Simulators like MVSIM are a great tool to simulate fleets of robots due to their low computational cost

- **ROBOT TYPE**

- **Arm Manipulators**
 - Often require accurate physics for joint control and grasping
- **Ground Mobile Robots**
 - Need a good balance of physics and rendering for navigation and interaction.
- **Autonomous Vehicles/Aerial/Maritime**
 - Although these often have specialized simulators, Gazebo, Isaac Sim and O3DE would allow simulating the forces involved, being an alternative with a little steeper ramp-up, but more flexibility in the long run.



Environment

IS YOUR SCENARIO OUTDOOR OR INDOOR?

- Outdoors scenes may require more advanced rendering capabilities for realistic lighting and good performance optimization options for large environments.

DOES YOUR SCENARIO REQUIRE HAVING AUTONOMOUS ACTORS (SUCH AS PEDESTRIANS)?

- O3DE and Isaac Sim provide useful tools to simulate autonomous actors, enhancing their already powerful photorealistic features. While Gazebo also supports actors, their capabilities are much more limited.

Physics requirements

IS PHYSICS ACCURACY A PIVOTAL POINT FOR YOUR PROJECT?

- MuJoCo provides the most accurate physics model among the proposed options. Simulators like NVIDIA Isaac Sim and O3DE use the PhysX engine, which provides a flexible and performant alternative. On the other hand, Gazebo allows for different physics engines to be selected.

Rendering requirements

IS PHOTOREALISM IMPORTANT FOR THE PROJECT?

- NVIDIA Isaac Sim and O3DE, provide excellent, photorealistic environments, ideal for vision system simulations.
 - Isaac Sim outperforms its competitors in terms of photorealism, while O3DE is close, with a little lower hardware requirements.

DOES YOUR ROBOT REQUIRE RUNNING WITH A VISION STACK?

- Then the scale turns in favor of either Isaac Sim, or O3DE. Another controversial but important option to consider is splitting physics and rendering between two different simulators, to allow each team to concentrate on what they care about the most.

IS THE USE CASE ORIENTED TOWARDS DOMAIN RANDOMIZATION?

- Then Isaac Sim offers some tooling for quick prototyping and an extensive API for scene randomization.

* All these simulators struggle in terms of performance the more cameras your robot has. Take that into account!



Communication

requirements

HOW IS THE STACK EXPECTED TO BE CONNECTED TO THE SIMULATION?

- If ROS 2 is required, then Gazebo, Isaac Sim, O3DE, and MVSIM are more than capable of satisfying that requirement.
- If, on the other hand, there's a need to connect to a custom communication stack, then the options diverge between:
 - Creating a bridge to communicate with ROS, and using one of the options mentioned above. This is not the optimal solution, but it might allow quick prototyping.
 - Taking advantage of the ease of extending Isaac Sim or Gazebo capabilities through their extensions/plugins system to implement your stack natively.

Hidden Costs to Watch

HARDWARE & INFRASTRUCTURE:

The need for powerful GPUs can be a significant expense to consider.

LEARNING CURVE FOR NEW TOOLS:

A new simulator requires learning new APIs, workflows, and scripting languages. This training time is a direct project cost. This learning curve can be considerably reduced by readily available documentation and an active user community.

ASSET CREATION AND MANAGEMENT:

While high-fidelity worlds and assets are nice to have, they require high-quality 3D models. Sourcing or creating these assets requires time and potentially a specialized, skilled artist.



Making the Right Choice

Selecting the right simulator is a critical decision that can significantly impact the efficiency and success of your robotics project. As we've explored, there is no one-size-fits-all solution. The ideal choice depends on a careful evaluation of your specific requirements—balancing trade-offs between physical accuracy, rendering fidelity, performance, and integration capabilities. Ultimately, the best simulator is the one that truly fits your project's needs. By applying the expert criteria and comparisons in this ebook, you can move beyond generic choices and select a tool that accelerates development, minimizes bottlenecks, and supports the creation of robust, capable robotic systems.

If you're feeling overwhelmed or need expert support from a team that works with simulation every day, don't hesitate to reach out to us: **contact@ekumenlabs.com**.



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