Comparison of main simulators

Robotic simulators software help to program robots offline. These simulators enable to test some programs or robot movements without stopping production or cause damage. This section aims at introducing and comparing main robotic simulators.

A - Introduction of main robotic simulators

Gazebo

Gazebo is one of the most popular multi-robot simulators, firstly developed in 2004, fully open-source and supporting a wide range of sensors and objects. It runs on Linux (even if protected versions for Windows are available). It is designed to accurately reproduce the dynamics of the complex environments a robot could encounter. It is well integrated with ROS, flexible, provides accurate simulation with four different physical engines (ODE, Bullet, Simbody and DART) and benefits from a large and active community. Thanks to OGRE (Object-oriented Graphics Rendering Engine), the software provides realistic rendering of environments, for instance high-quality lighting, shadows and textures. The software can also generate sensor data, from different imported sensors or cameras. Besides the large range of robots, any robot can be imported using SDF format. Finally, robots, sensors and environment can be controlled through custom plugins.

Many experts consider it as the best robotic simulator.

RoboDK

RoboDK is an offline programming and simulation software mainly used for industrial robots. It runs on either Windows, Linux, Mac OS, Raspberry or Android. It is available for free (trial version) and purchase at RoboDK website. It has a wide range of CAD model library based on more than 500 professional industrial robots and tools. It offers an intuitive interface that do not require high programming skills. It is then easy to visualize root behavior for a specific movement. One of the main interests of the software is the possibility to export directly programs to the actual robot thanks to RoboDK Post Processors. Besides a module designed to calibrate robot is available, increasing accuracy of the simulation.

Webots

Webots robot simulator was developed at the Swiss Federal Institute of Technology in 1996 that can be downloaded from Cyberbotics company website. It provides a complete development environment (indoor or outdoor) for modeling, programming and simulating robots and can be interfaced with third-party applications through TCP/IP. Its simple and friendly interface enables to add and remove objects, robots, and evaluating them in a scenario, with short development time. In addition, the simulator provides a wide range of existing robots, components such as actuators, sensors, objects, furniture or materials... It also includes a compiler (C++) to test and control algorithms but the software is versatile with open-sources APIs, which are very useful for those who are familiar with a specific programming language (Python, Java, Matlab or ROS) or for the use of a specific library (i.e. OpenCV). It uses the ODE (Open Dynamics Engine) physics engine.

Finally, Webots proposes an exhaustive documentation (through tutorials, examples or user guide) and benefits from an active community.

CoppeliaSim

CoppeliaSim (formerly called V-REP) was first released in 2010 and is closed-source with a free educational license. It offers a distributed control framework solution with advanced functionalities for testing and debugging complex robotic systems. Each object/model can be individually controlled via child scripts, writing plugins, ROS node, and external client application with a remote API. It runs on either Windows or Linux. If the embedded scripts are written in LUA, CoppeliaSim provides plugins for Matlab, C++, Python and Java programming.

The three main elements of CoppeliaSim are consisted of scene objects (such as joints, shape, sensors, paths, etc...), calculation modules (such as inverse kinematics or collision detection) and control mechanism (scripts, plugin, sockets).

CoppeliaSim benefits from a large wide of robots, objects and sensors. Furthermore, models in CoppeliaSim are flexible, portable and scalable. Thus, they can be modified, copied or resized from one scene to another. In addition, even if it is not very intuitive, building a custom robot remains possible. Tutorials and existing models are very helpful for his purpose. In addition, CoppeliaSim provides four different physical engines (ODE, Bullet, Vortex Dynamics and Newton). Compared with Gazebo, it is more stable with easier setup and running.

OpenRave

OpenRave was firstly developed in 2006 at the Carnegie Mellon University Robotics Institute. It aims at analyzing for testing, developing and deploying motion planning algorithms in real-world robotics applications, mostly for industrial purpose. It is cross-platform (Linux, Windows and Mac OS). However, it is not yet available for Ubuntu 20.04. It can be integrated into actual robotics system through command line tools and interfaces.

Unity

Unity is a cross-platform (Linux, Windows and Mac OS) game engine developed by Unity Technologies and released in June 2005. Initially developed to develop 3D-games (and especially popular for iOS and Android mobile games) as it is easy to use for beginner developers, it has been extended in 2010s to create 3D simulations in fields such as automotive and engineering, mainly through the development of its dedicated physics engine Nvidia PhysX.

B - Comparison of main features

In this section, you find two tables comparing a list of non-exhaustive relevant features for a robotic simulator. These tables should help you to choose the most relevant simulators regarding to your needs.

This first table is focusing on features related to general simulators such as programming language or supported OS.

	Gazebo	RoboDK	Webots	CoppeliaSim
Logo				
General Info	Open Source Robotics Foundation	RoboDK	Cyberbotics Ltd (Switzerland)	Coppelia Robotics
Website	gazebosim.org	robodk.com	cyberbotics.com	coppeliarobotics.com
Supported OS	GNU/Linux (Ubuntu)	Linux, Mac OS, Windows, Android	GNU/Linux (Ubuntu) Mac OS Windows	GNU/Linux (Ubuntu) Mac OS Windows
Last Release	11.0.0 (2019-01-30)	5.2.2 (2021-04-26)	R2021a (2020-12-15)	4.2.0 (2021-04-06)
Programming language	C++	Python	C++	Lua
API support	C++	C, C++, Python, Matlab	C, C++, Python, Java, Matlab	C, C++, Python, Java, Urbi, Matlab, Octave

	Gazebo	RoboDK	Webots	CoppeliaSim
Physics Engine	ODE, Bullet, Simbody, DART	None	Proprietary based on ODE	ODE, Bullet, Vortex, Newton
CAD files support	SDF/URDF, OBJ, STL, Collada	STEP, IGES, STL, WRML	WBT, VRML, X3D	OBJ, STL, DXF, 3DS, Collada, URDF
ROS support	ROS1 & ROS2	No	ROS1 & ROS2	ROS1 & ROS2
Licenses	Open-source (hosted by ROS)	Free trial Version (1 month) Pro version for purchase	Open-source (Apache License 2.0) Free and 3 levels of commercial license depending on user support	Free educational (students & research) version Pro version for purchase
Multithreading enabled?	Yes	No	Yes	No

This second table is focusing on features related to robots such as actuators, already existing robots, etc...

	Gazebo	RoboDK	Webots	CoppeliaSim	OpenRave
Family of robots (mobile, humanoid, industrial...)	Mobile, Humanoid, Industrial	Industrial robots (commercial robots)	Mobile, Humanoid, Industrial	Mobile, Humanoid, Industrial	Mobile, Humanoid, Industrial
Supported actuators	Revolute, Prismatic, Screw and Spherical Joints	Possibility to create rotated and linear axis	Brake, Connector, Display, Emitter, Linear Motor, Muscle, Pen, Propeller, Rotational Motor, Speaker, Track (Conveyor Belt or tank robots)	Revolute (and some variants), Prismatic and Spherical Motors	Revolute and linear Joints
Supported Tools	Grippers	Grippers, Weld tools, Spindle, Finishing tools (Grinding, polishing...), tool changer	Gripper	Pens, Paint Gun, Welding Torch, Grippers	Grippers

	Gazebo	RoboDK	Webots	CoppeliaSim	OpenRave
Supported sensors	Camera Sensor, Depth camera sensor, Distance and Proximity Sensors, Laser, Force Sensors	Lasers, Cameras, Laser Tracker	Accelerometer, Camera, Compass, Distance Sensor, GPS, Gyro, Lidar, Position Sensor, Receiver, Touch Sensor	Vision Sensor, Force Sensor, Proximity Sensor, Accelerometers Gyro, Lasers, Lidars	Cameras, Ray-casting Laser

For further information

- L. Pitonakava, M. Giuliani, A. Pipe and A. Winfield (2018). Feature and performance comparison of the V-REP, Gazebo and ARGoS robot simulators. DO: 10.1007/978-3-319-96728-8_30
- A. Ayala, F. Cruz, D. Campos, R. Rubio, B. Fernandes, R. Dazeley (2020). A Comparison of Humanoid Robot Simulators: A Quantitative Approach
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- Serena Ivaldi, Jan Peters, Vincent Padois, Francesco Nori. Tools for simulating humanoid robotdynamics: a survey based on user feedback. IEEE-RAS International Conference on Humanoid Robots (Humanoids), 2014, Madrid, Spain. hal-01116148

Useful links

- https://gazebosim.org - website of Gazebo
- https://robodk.com - website of RoboDK
- https://cyberbotics.com - website-hosting Webots
- https://coppeliarobotics.com - website of CoppeliaSim
- http://openrave.org - website of OpenRave
- https://unity.com/fr/solutions/automotive-transportation-manufacturing/robotics - website of Unity

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Need help ?

Ask your question on the ROS user forum .

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