

CloudSim: Robotics simulation in the cloud

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Introduction

CloudSim is an open source web application that launches pre-configured machines designed to run many of the most common open source robotic tools, especially the open source robotics simulator Gazebo.¹ We are developing CloudSim to support the DARPA Robotics Challenge, in which competitors are designing, programming, and testing robots to perform disaster response tasks. In particular, CloudSim and Gazebo will be used heavily in the upcoming Virtual Robotics Challenge, wherein approximately 100 teams from around the world will perform interactive, real-time simulation tasks in parallel. The cloud provides access to the necessary computing resources for this one time event in a flexible manner. In general, cloud-based simulation tasks can be conducted in parallel, for multiple purposes, such as:

- validating design decisions;
- optimizing designs;
- predicting performance;
- training users;
- hosting competitions; and
- improving robotics education and sharing research.

While there are hourly costs associated with computing resources in a cloud environment, there is no upfront cost and little administrative effort. CloudSim should make possible simulation campaigns that would otherwise take too long to run on a single computer, or be too costly to run at all because of the equipment required.

Overview

CloudSim captures a collection of curated simulator configurations. It deploys machines in groups called constellations that are geared towards specific robotics simulation needs:

- remote simulation workstation;
- real time teleoperation, with human operators in the loop; and
- algorithm testing.

¹For installation instructions and an extensive set of tutorials, see: <http://gazebosim.org/wiki/CloudSim>.

Each of these configurations provides machines types, network topologies, software configurations, keys, and scripts to access the machines over the Internet. Constellation configurations also address security concerns that could prevent teams from using the cloud for simulation. The list of available configurations should grow as CloudSim matures. For example, in cases where real-time simulation is not required, CloudSim could use computing resources that are more cost-effective than the relatively expensive machines used now. In the case of non-interactive simulations, CloudSim could also leverage a lower-cost market of excess server capacity available for limited periods of time.

At the time of writing, the latest version of CloudSim is 1.2.0. This version can spawn individual simulator machines with the latest Gazebo simulator engine and Boston Dynamics Atlas robot model. It can also launch multi-machine constellations inside a virtual private network. The Virtual Robotics Challenge requires a specific multi-machine constellation that includes a router to measure and also manipulate network traffic between the user and the cloud machines.

CloudSim has been created in close relationship with Gazebo. However, its design is flexible enough to be decoupled from any specific program. CloudSim allows the creation of alternative configurations with other popular tools present in the open source robotics ecosystem. An example of an alternative configuration for a cloud constellation might be a set of ROS nodes running CPU-intensive algorithms.

Limitations

The security and performance requirements of the DARPA Robotics Challenge led us to base CloudSim on the Amazon Web Services. At the time of CloudSim's inception, Amazon Web Services were the only providers of on-demand high-end machines equipped with GPUs, which are required for sensor generation in simulation (and eventually may be used for other simulation tasks, such as collision detection). These machines are relatively expensive (at the time of writing, \$2.10/hour). For security, CloudSim relies on Amazon's Virtual Private Cloud service. Unlike common lightweight cloud machines dedicated to serving the web, the GPU-equipped machines are only available in a single data center, which creates latency problems for certain users. Unlike running simulations on a pre-configured workstation, the process of provisioning CloudSim machines takes a non-trivial amount of time. Provisioning a GPU-equipped machine to run Gazebo from scratch can take up to 20 minutes.

Future

In the near future, CloudSim will be able to process a list of consecutive simulation tasks inside a simulator node, with pre-simulation and post-simulation operations. These operations could be used to ensure simulator health before a simulation run, or to collect and process important log files afterwards. Automated build systems (with slave nodes) and map-reduce architectures should serve as guidelines for CloudSim's future high level architecture.

In future versions of CloudSim, we would like to address the need to store existing constellations for sharing and rapid deployment. The ability to quickly provision and share a working simulation environment could be useful to spread knowledge across teams, or within academic environments where the students change. CloudSim constellations could be linked to publications to provide a method for confirming published results.

Conclusion

CloudSim provides a sophisticated ready-to-use simulation capability. We hope that it will be popular among robotists worldwide. We aim to remove the hurdles of configuring a complex software stack and provide near-infinite computing to simulation users without any upfront costs. Teams that rely on simulation in their workflows can create as many simulations as they want, without worrying about tying up hardware.