Robotics Simulation using the Cloud

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Robotics use is accelerating in key industries

Robotics is undergoing fundamental change in collaboration, autonomous mobility, and increasing intelligence

By 2023, it's estimated that mobile autonomous robots will emerge as the standard for logistic and fulfillment processes

By 2030, 70% of all mobile material handling equipment will be autonomous

Source: IDTechEx
Agenda

Traditional Robot Application Development vs Rapid Robot Application Development with Simulation in the Cloud vs ROS & AWS RoboMaker & WorldForge
What is the Customer Need?
What is the **Problem** You Are Trying to Solve?

Make a spaceship app quickly and cheaply
Traditional Robot Application Development

Design a prototype
Traditional Robot Application Development

Manufacture Robot Components
Traditional Robot Application Development

Develop Firmware
Traditional Robot Application Development

Develop Drivers
Traditional Robot Application Development

Integrate and Test
Traditional

Robot Application Development

Develop Application
Traditional

Robot Application Development

Design a prototype → Manufacture Robot Components → Develop Firmware → Develop Drivers → Integrate and Test → Develop Application
Rapid Robot Application Development

Big bag of building block software + Simulation Environment + A few hours
Rapid Robot Application Development

A finished App
Rapid Robot Application Development

- Lacks fine detail
- Recognizable, but not exactly what was asked for
- Easy to modify and extend
Optimization

Take a group of Lego bricks…
…and form a new custom brick
A more specialized common component
<table>
<thead>
<tr>
<th>Traditional</th>
<th>Rapid Development</th>
</tr>
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<tbody>
<tr>
<td>Full custom design</td>
<td>Building bricks assembly</td>
</tr>
<tr>
<td>Months of work</td>
<td>Hours of work</td>
</tr>
<tr>
<td>Custom components may be fragile and need to be</td>
<td>Standard reliable components scale and are</td>
</tr>
<tr>
<td>debugged and integrated</td>
<td>well understood and interoperable</td>
</tr>
<tr>
<td>Too many detailed choices</td>
<td>Need to adjust requirements to fit the</td>
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<tr>
<td></td>
<td>patterns available</td>
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<tr>
<td>Long decision cycles</td>
<td>Constraints tend to reduce debate and</td>
</tr>
<tr>
<td></td>
<td>speed up decisions</td>
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</table>
Robot Operating System (ROS)  
Powering the world’s robots

Most widely used open source software framework for robot application prototyping, development and deployment.

- Over **1000 developers** have contributed to ROS core distros and over **2800 contributors** to released packages since 2008
- Over **264 Million** binary debian packages downloaded in 2019
ROS: Development and Validation Tools

Gazebo
Simulation tool with robust physics engine, 3D graphics and programmatic interfaces

RViz
Visualization

rqt suite
Analysis
Who is using ROS?
The core architectural change between ROS 1 and ROS 2 is the addition of the ROS Middleware (RMW) and Data Distribution Service (DDS). Which support security, reliability and determinism.
Some of **AWS Robotics**

Customer Obsessed Contributions to ROS 2

- Quality of Service (QoS) Features for Topics
- Cross-Compilation Tools
- rosbag2 splitting, compression
- ROS2 Launch Sandboxing Extension
- Nodes and example applications for AWS integration
- Runtime Analysis Tools Address & Thread Sanitizers
ROS2 Technical Steering Committee

- Manage roadmap
- Contribute development efforts for core tools and libraries
- Set developer policies
- Establishes working groups to focus on important topics
  - AWS Robotics leads ROS Tooling Working Group

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Takeaways

• Open Source is a force multiplier, and continues to help grow HW and SW ecosystems: projects, communities, and commercial distributions

• Robotics Strategy must include Open Source to Win

• Robot OEMs should be first ones to adopt ROS 2, since ROS has the software, tools, and packages to support the widest and broader variety of HW compute, sensors and platforms

• Developer usage and adoption, will lead to design wins
Robotics development and deployment challenges

- Multi-domain expertise required to build robots
- Iterative development to get it right
- Configuration management is hard
- Limited robot hardware available for testing
- Deployment and updates need to be managed
AWS RoboMaker: a cloud service to simulate and deploy robotics applications at cloud scale.
Test and verify:
simulations at cloud scale

Simulate your environment
Test alternative scenarios
Drive optimization

Use simulations to replicate your environment, test variations, and optimize usage of robot resources
Test and verify: cloud-based simulations

- Pre-built virtual 3D worlds provided out of the box, or bring your own
- Zero infrastructure to provision, configure, or manage
- Run multiple simulations in parallel
- Auto-scale based on simulation complexity
- Pay-as-you-go simulation resource consumption
Regression testing using either recorded rosbags or with physics-based simulators

Large scale concurrent simulations triggered in a batch using RoboMaker simulation APIs

Integration with CI pipeline with AWS CodePipeline and CodeBuild

Automatically advance successful simulations every night, upon each code update, or upon each software release
AWS RoboMaker

ROS Application CI/CD Workflow

Application Architecture

Git Repository (GitHub or AWS Code Commit)

1. Branch: feature
   - Pull Request
   - Git Hook (Merge)

2. Cloned on
   - Branch: integration

3. AWS CodePipeline
   - AWS CodeBuild
     - Build and Bundle Code in ROS Container
     - Bundles stored in S3
   - AWS Step Functions: Testing
     - AWS Lambda
       - Simulation Launcher
     - AWS RoboMaker
       - Simulation Service
     - AWS Lambda
       - Status Checker

4. Tests Passed

5. Branch: master (release)
   - Cloned on
     - Git Hook (Merge)

6. AWS CodePipeline
   - AWS CodeBuild
     - Build and Bundle Code in ROS Container
   - AWS Step Functions: Physical Testing and Delivery
     - AWS Lambda
       - AWS RoboMaker
         - Deploy Launcher
       - Production Deploy
     - Manual Action

7. Fleet Management
   - Test Fleet
   - Prod Fleet
Need
Test coverage for different floor layouts and scenarios
Improve code release speed

Challenges
Costly and time consuming to test
Limited test cases and coverage
Late bug discovery in the field

Solution
iRobot built a CI/CD pipeline for large-scale and automated testing using RoboMaker’s simulation service
More than 40 automated tests on each code commit and more than 500 automated tests for each release candidate
Much faster testing and release cycle (1 hour versus 3 weeks for testing 70 complex localization scenarios)
How iRobot Uses AWS RoboMaker to Build, Test and Manage Millions of Robots

www.youtube.com/watch?v=LS2k3i-Id4Q
Simulate multiple robots in a fleet

Connect multiple simulations to a central fleet-management software to test multi-robot scenarios

Simulate inter-robot interactions or missions across robots
Multiple Robots in Simulation
Application Architecture
https://github.com/aws-samples/multi-robot-fleet-sample-application

AWS RoboMaker Simulation Job

Consolidated Robot Data
Cloud Connected ROS Extensions

AWS IoT Communication Layer
Device Shadow
Raw Location Data over MQTT

AWS RoboMaker Simulation Job
Robot spawner and mover
Cloud Connected ROS Extensions
Client Application ROS Extensions

Job: 1

AWS Lambda
Launch (n) number of AWS RoboMaker Simulation Jobs, with various environment variables
Support for ROS Kinetic, ROS Melodic, ROS 2 Dashing (beta)

Native ROS packages for AWS services:
- Amazon S3 for secure, scalable storage
- Amazon CloudWatch for logging and metrics
- Amazon Rekognition for image and video recognition
- Amazon Kinesis for video streaming
- Amazon Lex and Amazon Polly for voice recognition and text-speech conversion
Racetrack World
https://github.com/aws-robotics/aws-robomaker-racetrack-world
Open Source Hospital World

https://github.com/aws-robotics/aws-robomaker-hospital-world
Simulation bottleneck: world authoring

Even with good tools and excellent artists, never enough hand-crafted worlds

Need automation to create massive sets of environments for testing
AWS RoboMaker WorldForge Simplifies Creating Simulation Worlds for Robotics
https://www.youtube.com/watch?v=tD-a2WNAsSs
AWS RoboMaker WorldForge

A new AWS RoboMaker capability that automatically generates one or more residential simulation worlds within minutes

- Out-of-the-box 3D assets and world templates
- Generate a world within minutes versus weeks or months
- $1.5 per generated world versus thousands of dollars
- Concurrent world generation up to hundreds of worlds
- Fully integrated with RoboMaker Simulation
AWS RoboMaker WorldForge

• Creating a simulation world is hard **now much easier**
• Creating a simulation world is time-consuming **now much faster**
• Creating a simulation world is costly **now much cheaper**
Try AWS RoboMaker today!

- Pre-configured ROS and ROS 2.0
- Cloud simulation service
- Regression testing via batch simulation and CI/CD pipeline
- Simulate multi-robot environments
- Cloud-based fleet management

aws.amazon.com/robomaker

Resources

- Tutorials
- Developer Guide
- Blog