The Robotic Edge

The Role of the Cloud
In the Future of Robotics

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AWS RoboMaker
a cloud service to build, test, deploy, and manage robotics applications at cloud scale

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Cloud-based simulation

Test and verify

Design and develop

Deploy and update

ROS & AWS integrations

Fleet management
Design and Develop
robotics applications and functionality

Agile development of robotics application requires software reuse and iterative development
Design and Develop

ROS and ROS packages for AWS integrations

- 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
Amazon Kinesis Video Streams

Ingests, stores, and indexes video streams from millions of cameras

Welcome to Amazon Go and the world’s most advanced shopping technology. No lines, no checkout—just grab and go!
Woodside Intelligent Asset – 20 mins

• What we have done (8 / 4)
  • Surveillance Intelligent Asset with site trials
  • Task autonomy with manipulation
  • Integration
  • Digital Twin or Workspace – Fuse Demo
Test & 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
Pre-built virtual 3D worlds provided out of 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
Test & Verify

Able to run thousands of concurrent simulations
iRobot accelerates robot regression testing

**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)
It’s Working

Within 3 months!

5,000 missions a month
Gating submissions
Catching issues
Higher quality mainline
Docker for local runs
Developers want more

Credit: Chris Kruger, iRobot
Simulate multiple robots within the same environment

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

Simulate inter-robot interactions or missions across robots
Problem statement

Bastian Solutions enables orchestration of a fleet of robots
Software testing currently requires physical robots; practical limitation of 8–10 robots in test lab

Use of AWS RoboMaker

AWS enabled simulation of a multi-robot environment with 35+ robots, thus enabling testing without physical robots
AWS services used: AWS RoboMaker, AWS IoT Greengrass, AWS Lambda

Business benefits

Bastian Solutions easily able to test application for larger environments without having to stand up physical devices
Launch (n) number of AWS RoboMaker Simulation Jobs, with various environment variables.

**AWS RoboMaker**

**Multiple Robots in Simulation**

**Application Architecture**

- **AWS RoboMaker Simulation Job**
  - Consolidated Robot Data
  - Cloud Connected ROS Extensions

- **AWS IoT Communication Layer**
  - Device Shadow
  - Raw Location Data over MQTT

- **Robot spawner and mover**
  - Cloud Connected ROS Extensions
  - Client Application ROS Extensions

- **Robot N**

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**AWS Lambda**

Launch (n) number of AWS RoboMaker Simulation Jobs, with various environment variables.
Simulation for Model Training

- Rapidly generate trial data in simulation to train reinforcement learning model
- Train reinforcement learning model natively in the simulation or in AWS SageMaker
- Run concurrent simulations to speed up training of a single model
SageMaker training
Simulation environment
Actions
Observation
Trained model
RL agent
Model updates
Training data
Deploy model
Fleet management deployment

Trained model → Deploy model

Model updates

SageMaker training

RL agent
Simulation environment

Observation
Action
Reward

Training data

Observation action reward
Persistent Emergency Detecting Drones built on AWS RoboMaker

**Application Architecture**

**DJI M600 Pro Drone**

- **ROS Application**
  - **ROS Node with ML Libraries**
  - **AWS RoboMaker ROS Extensions**

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- **Trained ML Model**

- **Amazon SageMaker**

- **Download New Models**

- **Training**

- **Amazon CloudWatch**

- **Amazon Kinesis Video Streams**

- **AWS Greengrass Core Device**

- **AWS RoboMaker Fleet Management**

- **AWS RoboMaker**
  - **Development Environment**
  - **Simulation Environment**

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- **Video Recordings Captured for Retraining**

- **More...**

- **Iterative, Test-driven Development**

- **Reliable Over-the-Air (OTA) Deployments**

- **Trigger Deployments**

- **Trigger New Model Training**

- **AWS Amplify React Website**

  - **Dashboard User Interaction**

- **Remote Monitoring Drone**
Deploy and Update
at cloud scale

- Ability to control deployments
- Visibility to robot health
- Deploy across multiple robot brands

Enterprises need greater command and control over robot assets
Problem statement
Enterprise customers are unable to easily manage a fleet of multiple AMR brands
Inability to orchestrate across AMR brands
Inability to share map information across robots

AWS RoboMaker and AWS cloud services
Enable a unified interface to orchestrate robots and share maps across multiple brands
AWS services used: AWS RoboMaker, AWS Lambda, AWS Step Functions, AWS DynamoDB

Business benefits
Ability to plan a mission across robot brands and robot types
Deploy and Update

- Register robots with RoboMaker fleet management and organize them into fleets
- Deploy a robotics application into a robot fleet securely through just a few clicks
- Conditional over-the-air updates
- Fleet monitoring and alerting*
- Fleet deployment rollback*

* Coming soon
Role of the Cloud

1. Intelligent cloud services can enhance local processing on the robot and improve performance over time.

2. Simulation can be used to test application correctness, and ensure performance across a range of conditions.

3. Simulation, combined with reinforcement learning, can be used to program robot actuation.

4. Cloud services enable developers to build applications for their business, end-to-end, that include robotics.
Our team was busy in 2019!

- Accelerated build/bundle time by 80%
- ROS Melodic support
- Gazebo 9 simulation engine
- Offline CloudWatch cloud extension
- Log-Based simulation
- Launched in NRT, FRA, CMH, SIN regions
- Event driven simulation termination
- Conditional OTA updates
Roadmap

- Automatic Rollback for OTA Update
- Batch API for Simulation
- ROS 2 Enhancements
- Full GA Support for ROS 2 in AWS RoboMaker
- Optional GUI Tools (20% cost reduction)
- GPU Enabled Simulation
- Realistic Rendering in Gazebo
Roadmap

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- Realistic Rendering in Gazebo
- Develop on your own machine, containers
AWS Contributions to ROS2

- Quality of Service (QoS) features for topics
- Cross-compilation tools
- ROS2 launch sandboxing extension
- Secure-ROS2 (SROS2) improvements
- Runtime analysis tools address & thread sanitizers (Asan/Tsan)
- Created and maintain rcpputils core package

https://github.com/aws-robotics
Quality of Service / Deadline

Node 1
- Send msg1

Node 2
- Receive msg1

msg1 Deadline
- Success! Message is received before deadline.

Node 1
- Send msg2

Node 2
- Receive msg2

msg2 Deadline
- Failure! Message has not been received on time.
Quality of Service / Lifespan

Node 1
- Send msg1

Node 2
- Receive msg1
  - Success! Message delivered before expiry date

Node 1
- Send msg2

Node 2
- Drop msg2
  - Failure! Message delivered after expiry date
Quality of Service / Liveliness

Node

- Heartbeat
- Heartbeat
- Heartbeat
- Heartbeat

Node is considered alive

Node

- Heartbeat
- Heartbeat

Node is not considered alive
In ROS 2 D, we solved:

- 4 memory leaks impacting production
- 17 memory leaks impacting tests
- 2 data races impacting Fast RTPS

Fixed 89% of ASan detected defects.

Nightly run of GCC sanitizers (ASan/TSan) to detect:

- Lock Order Inversion (deadlocks)
- Data Races
- Unsafe Signal Handling
- Invalid Memory Access
- Memory Leaks

ROS 2 Threat Model
RoboMaker in Education

- Arizona State University
- Cal Poly
- Fresno State
- University of Washington
- RMIT University
- University of Cambridge
- University of Central Florida
- The University of Texas at Austin
- Dartmouth University
- Rutgers University
- University of Waterloo
- Northeastern University
RoboMaker in Education

Individual Student & Educator Accounts:
Individual students and educators can register for AWS Educate starter accounts on AWS Educate. Enrolled users will receive a lump sum of AWS Credits.

AWS RoboMaker Classroom:
Virtual environment for students to use AWS RoboMaker in projects and assignments.
AWS JPL OSS Rover Challenge

GLOBAL VIRTUAL COMPETITION
DEC - FEB 2ND - 21ST

$20,000 USD IN CASH PRIZES
Call to Action

- **Have requirements for fleet management?**  Let’s talk! We are currently preparing the ‘working backwards’ document for what we will build in 2020.

- **Do you have ROS tutorials and/or curriculum?**  Let’s talk! Over 7,000 students have used AWS RoboMaker to learn ROS and Robotics. Let’s pull together tutorials and resources that any learner can use to get started on their robotics journey!

- **It’s still Day 1 for robotics and automation.**  I would like to crowd source whitepapers on topics that CTOs, CIOs, and COOs will need to successfully navigate this space:
  - Why ROS?
  - What is ROS2?
  - What is ROS Industrial?
  - Examples of successfully deploying robots, lessons learned, considerations to get started.
  - Available Resources.
Try AWS RoboMaker Today!

I welcome your feedback!

- 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
Questions?