PRESENTATION //

Building a Legged Robot with ROS

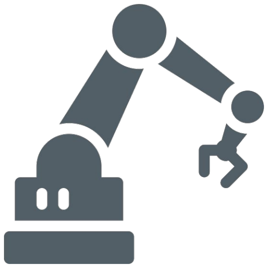
Case Study by ANYbotics

March 5, 2021

Maximilian Wulf, Harmish Khambhaita

ANYbotics

Robots Change the Way We Work



1980

Manufacturing

Stationary manipulation

2010

Logistics

Mobility in structured environments

2020

The New World

Mobile interaction in industrial, urban and natural environments

Let Robots Go Anywhere!

THE CHALLENGE //

Safety, Data Quantity and Quality Are the Main Cost Drivers for Inspection

From Research to Industrial Applications

2009	2012	2015	2017	2018	2019	2021
ALoF	StarlETH	ANYmal Alph	ANYmal Beth	ANYmal B	ANYmal C	

RESEARCH

DEMONSTRATOR

APPLICATION

ETH zürich

Maturity, Autonomy, Performance, Robustness

ANYbotics

VIDEO //

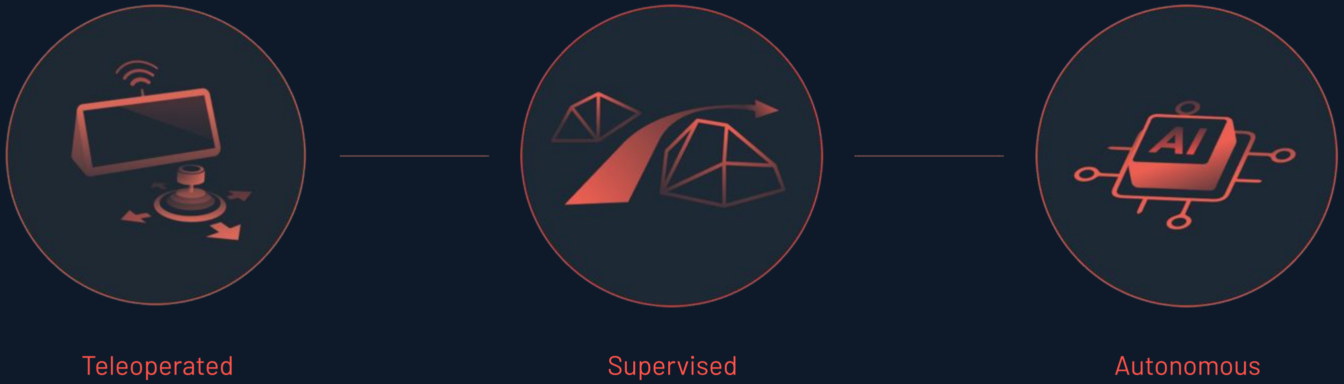
ANYmal C Legged Robot – The Next Step in Robotic Industrial Inspection

ANYmal C's Legs Provide Extreme Mobility in Challenging Environments

- **SPEED** [1 M/S]
- **OMNI-DIRECTIONAL**
- **SLOPE** [20°]
- **STAIRS** [45°]
- **STEP** [35 CM]
- **OBSTACLE** [20 CM]
- **OVERHANGING** [50 CM]
- **GAP** [25 CM]
- **PASSAGES** [60 CM]

OPERATING MODES //

Fully Autonomous Operation and Seamless Switching to Supervised or Manual Control



ADVANCED SENSING //

All-around Depth Cameras for Obstacle Detection

360° OBSTACLE DETECTION
4x DEPTH CAMERAS

360° Environment Scanning

360° OBSTACLE DETECTION
4x DEPTH CAMERAS

ENVIRONMENT SCANNING
LIDAR

Front and Back Cameras for Teleoperation

360° OBSTACLE DETECTION
4x DEPTH CAMERAS

ENVIRONMENT SCANNING
LIDAR

WIDE ANGLE CAMERAS

ADVANCED SENSING //

GPS (RTK) Based Navigation for Outdoor Environments

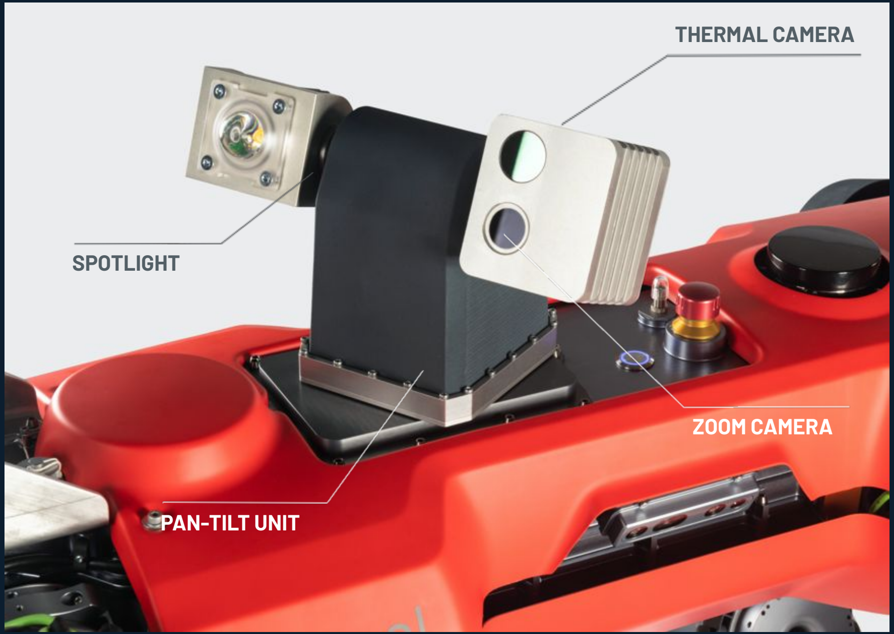
360° OBSTACLE DETECTION
4x DEPTH CAMERAS

ENVIRONMENT SCANNING
LIDAR

WIDE ANGLE CAMERAS

GPS (OPTIONAL)

Expandable Platform to Tackle a Wide Range of Applications



Example inspection payload

10 KG

Carry a payload with up to 10 kg

CPU

Dedicated onboard computer for custom applications

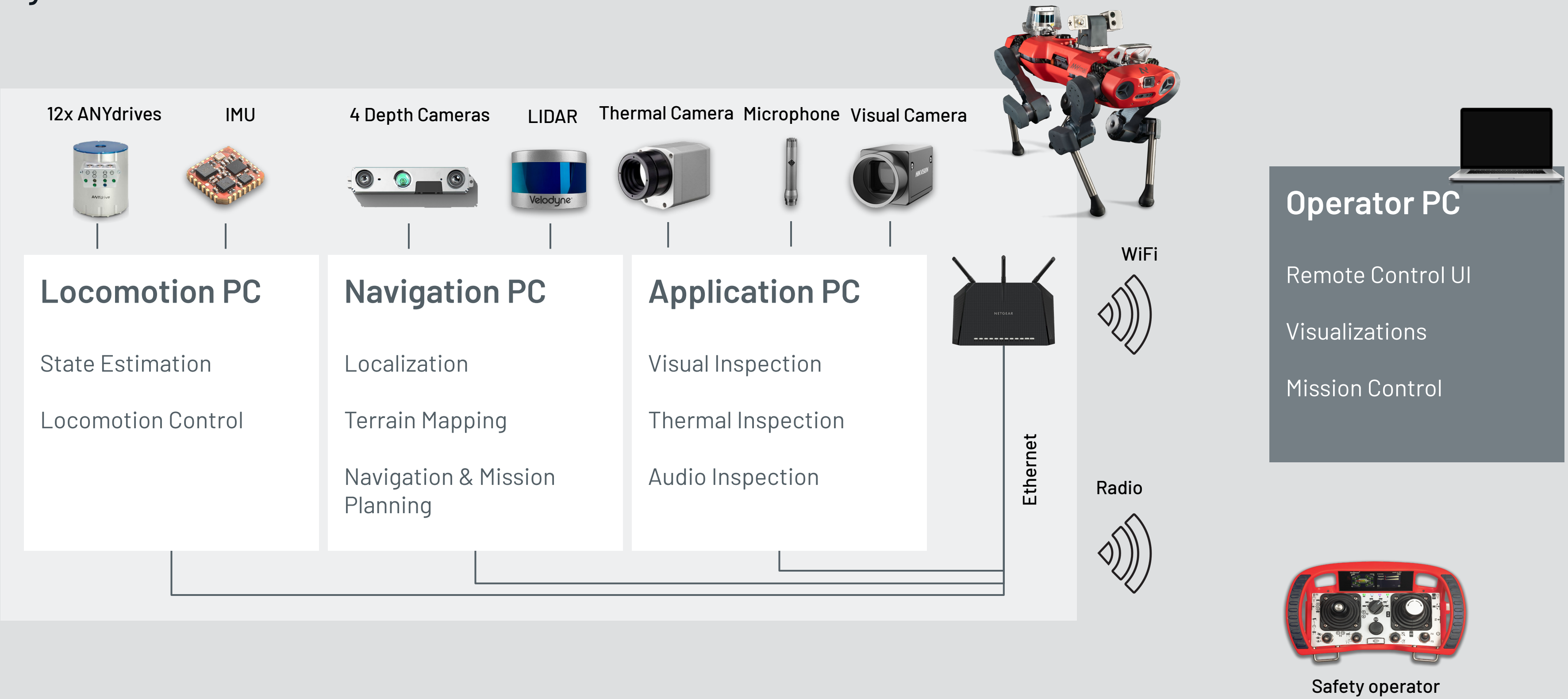
Access to USB, Ethernet, and power sockets

ROS

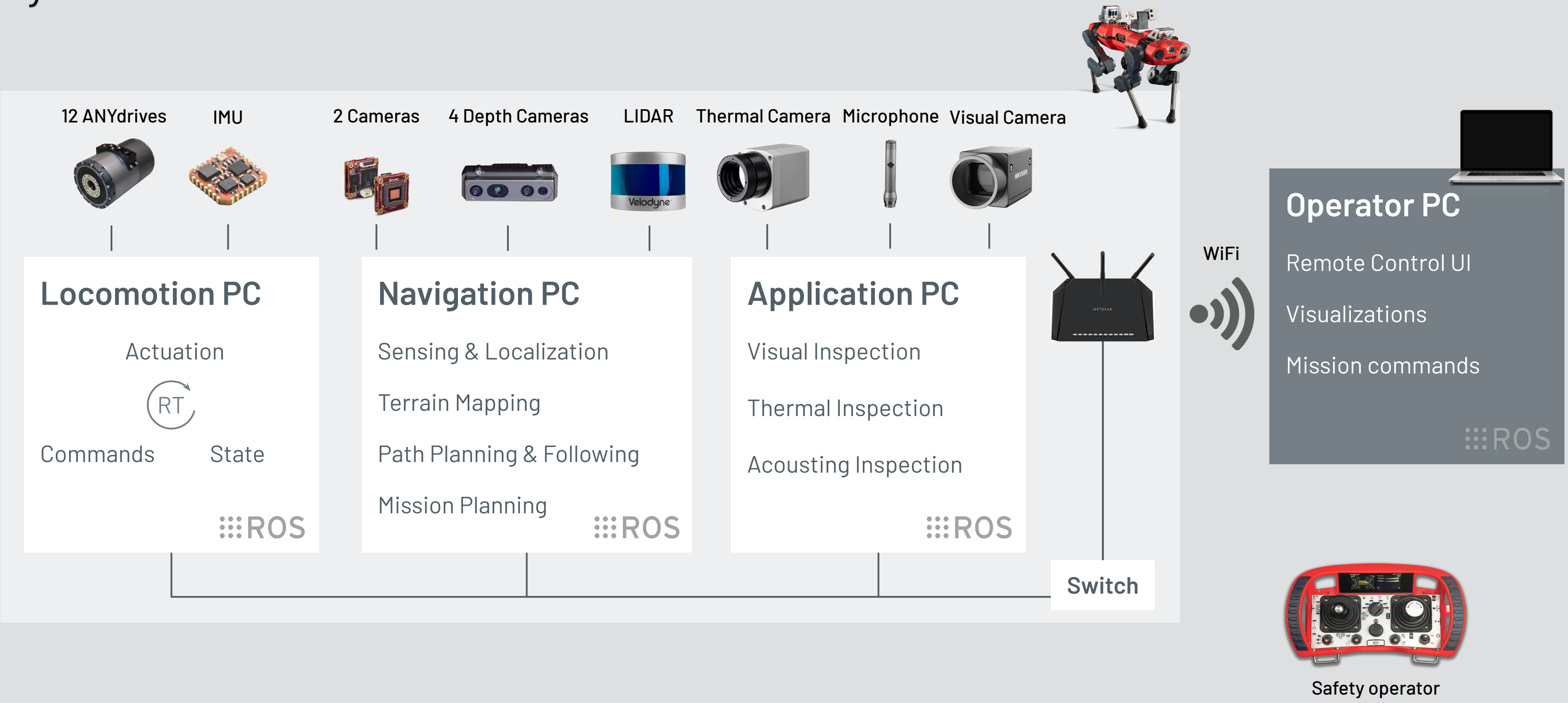
Interface via ROS APIs

ROS For ANYmal

System Overview

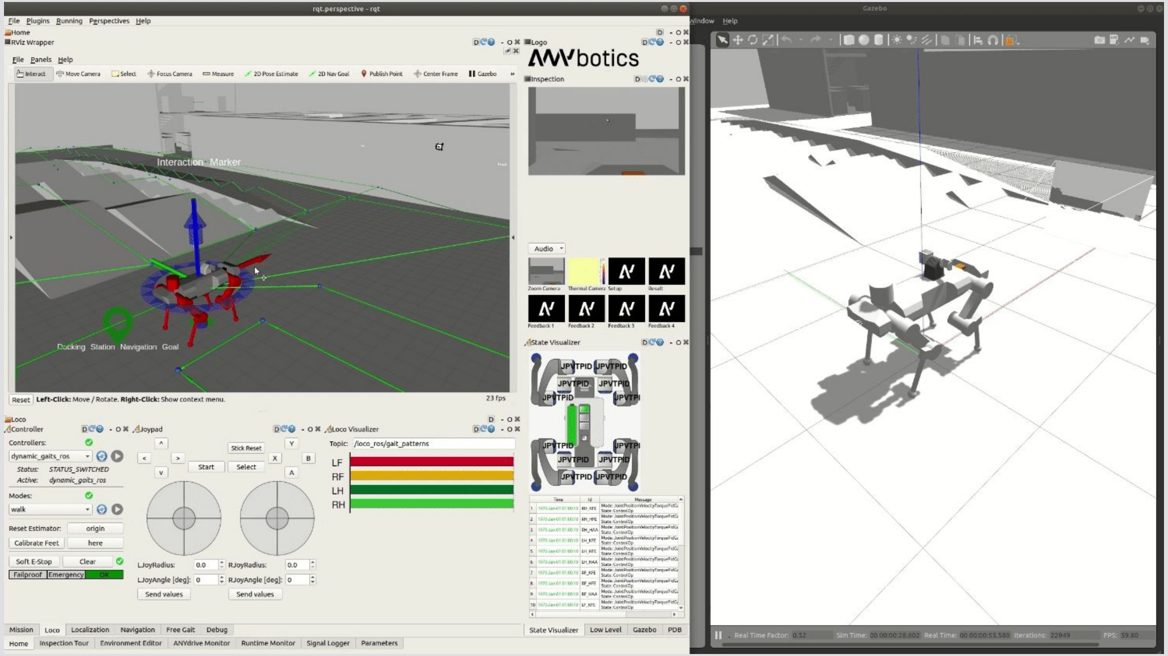


System Overview



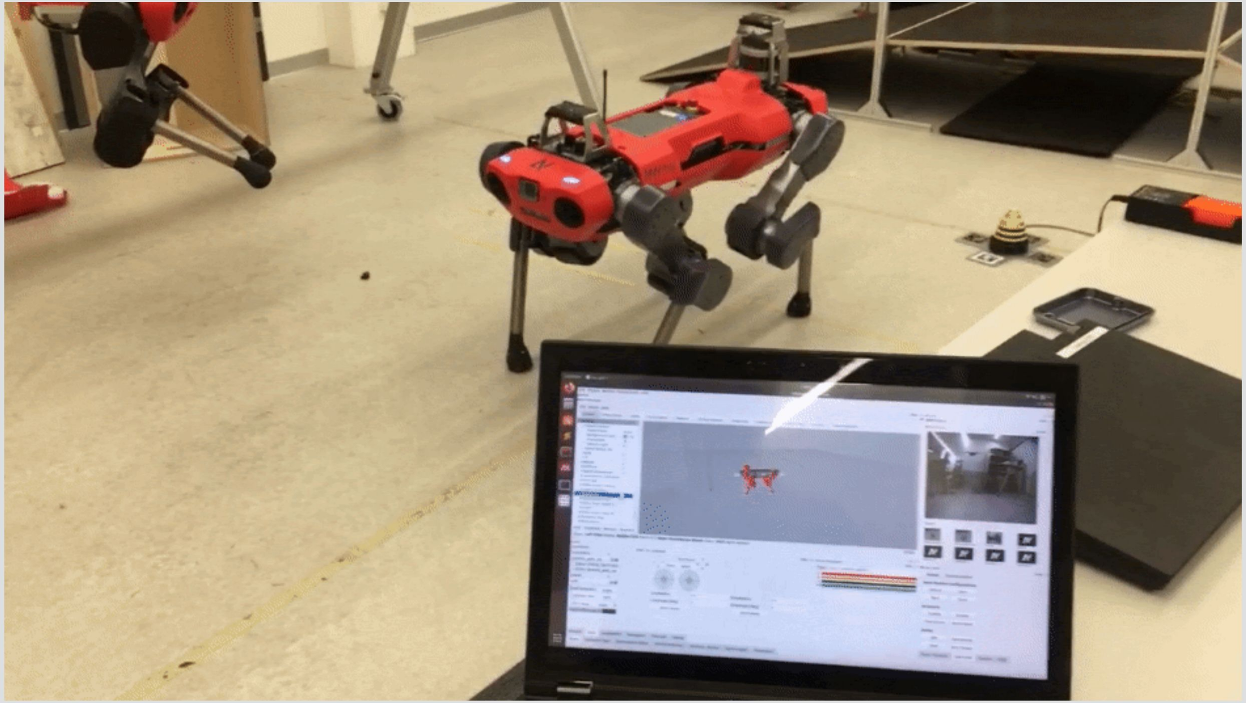
Robot State Simulation, Visualization and Interaction

- **RVIZ**
  Visualizes off the shelf and custom ROS topics.
- **RQT**
  Combines different control and supervision elements into one GUI.
- **Gazebo**
  Simulating the physical world around ANYmal.



Interaction with Real Robot

- **RVIZ**
  Visualizes off the shelf and custom ROS topics.
- **RQT**
  Combines different control and supervision elements into one GUI.
- **Real Robot**
  Real physics guide the motion of ANYmal.

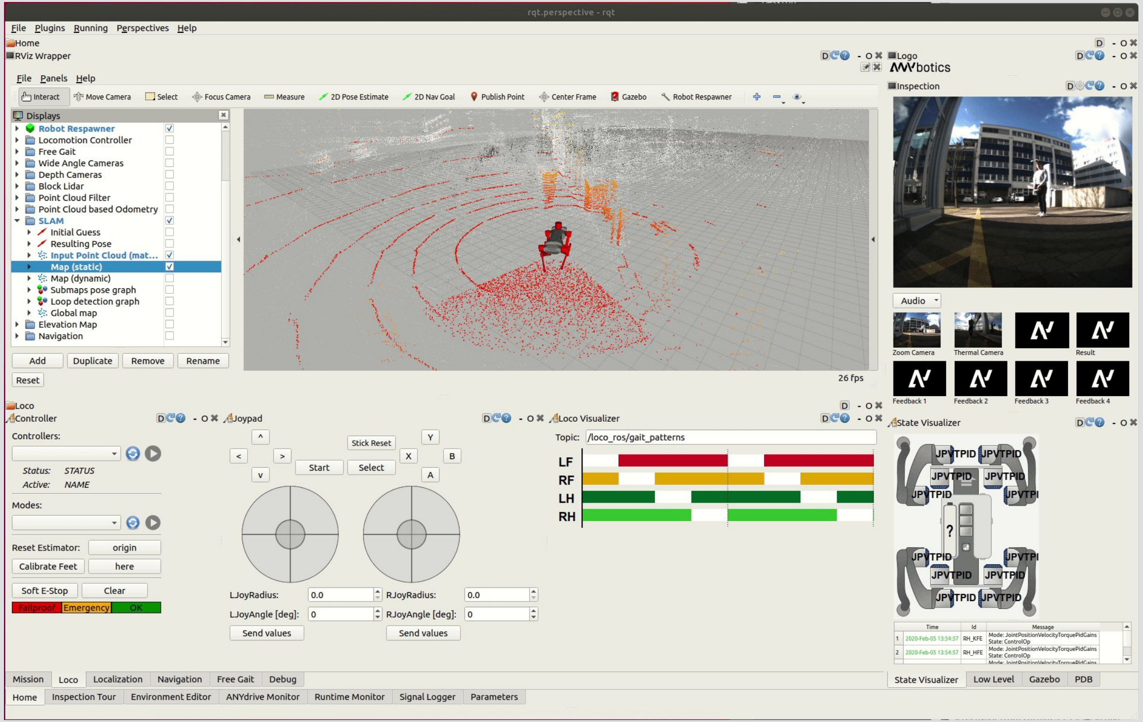


ROS Bags

- **Recording**
  Record topics on the robot while performing any task and save them to a ROS bag.

- **Replaying**
  Replay the ROS bag on a local computer, run the corresponding algorithms on it and visualize the results in RVIZ.

- **Debugging and Tuning**
  Increase of code reusability and more lightweight using and testing of the library. Simple setup of distributed systems.

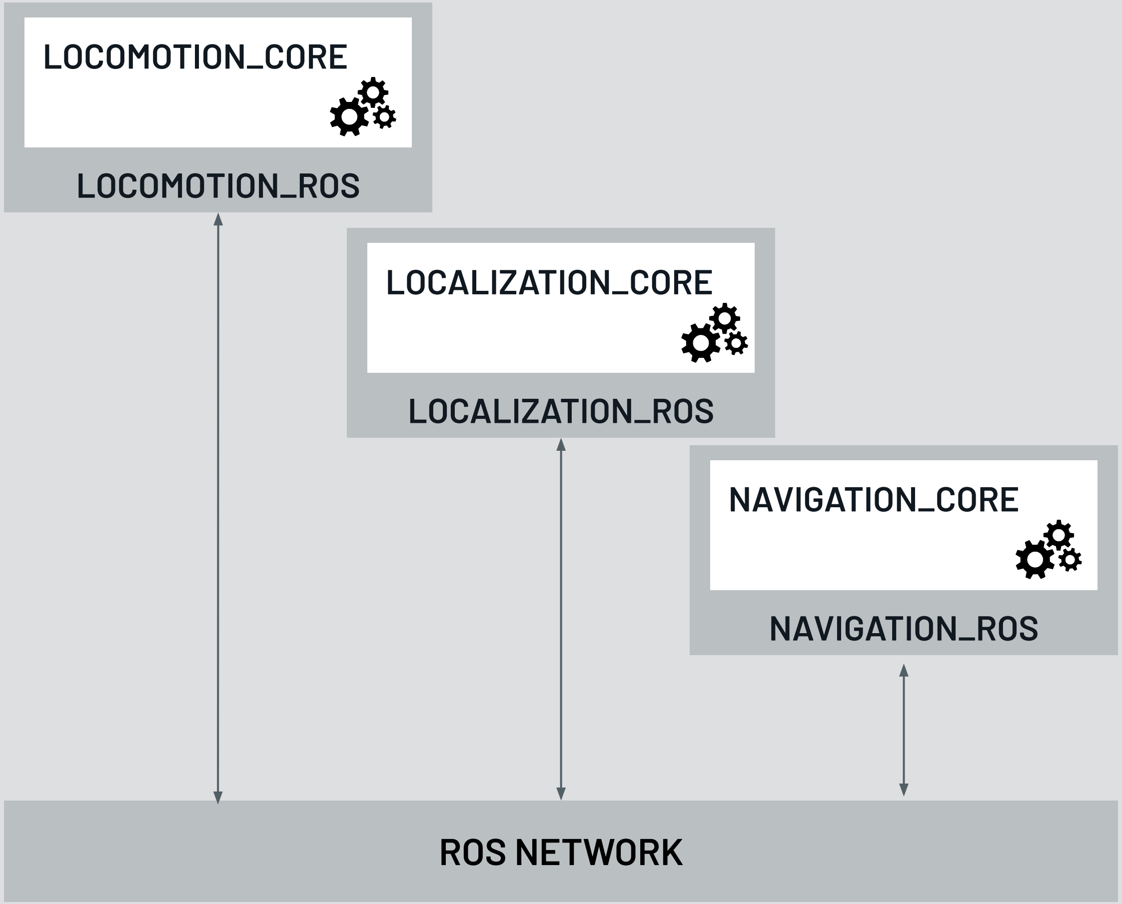


ROS Agnostic Design

Modularity
Separate core algorithms (_CORE) from ROS interface nodes (_ROS). Plugins allow injection of ROS dependent code.

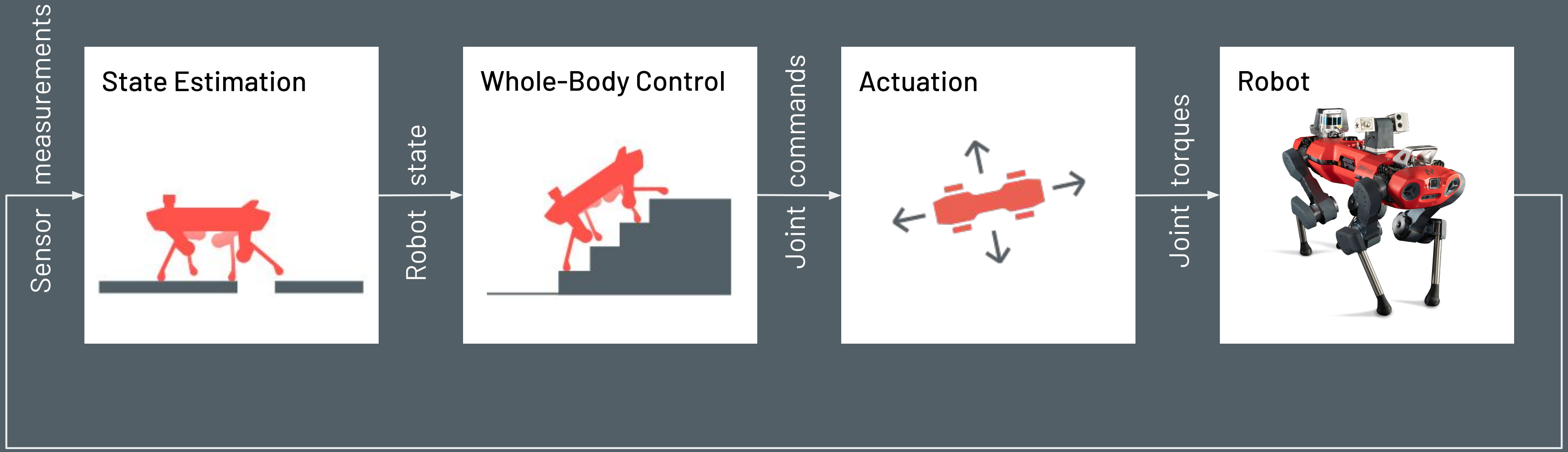
Independence
Usable in environment without ROS and minimal effort to update to new ROS versions

Scalability
Increase of code reusability and more lightweight using and testing of the library. Simple setup of distributed systems.



ROS Inside ANYmal

Sense-Think-Act

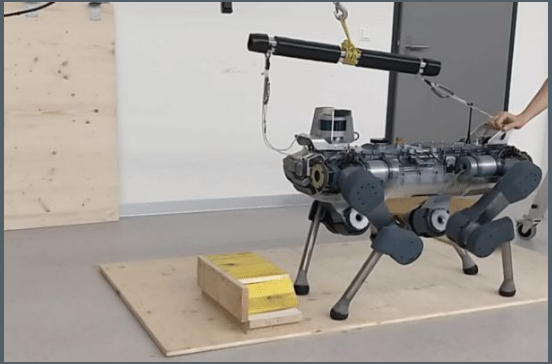


Perceptive Locomotion

Stair Climbing

Terrain Perception

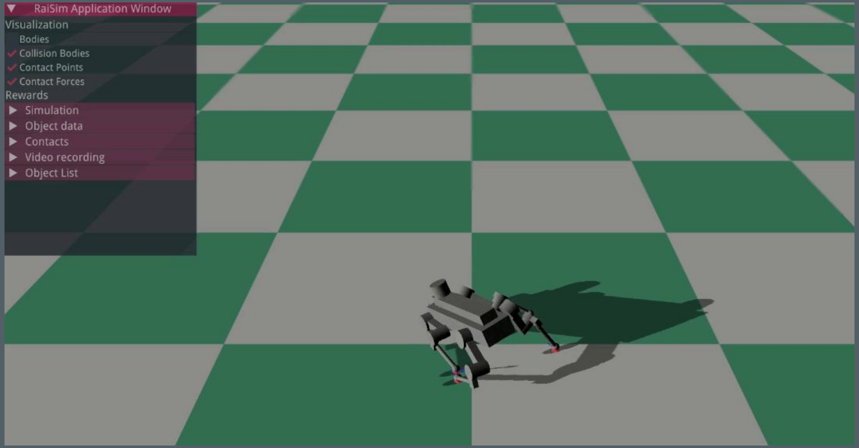
Obstacle Avoidance



Learning Locomotion Skills

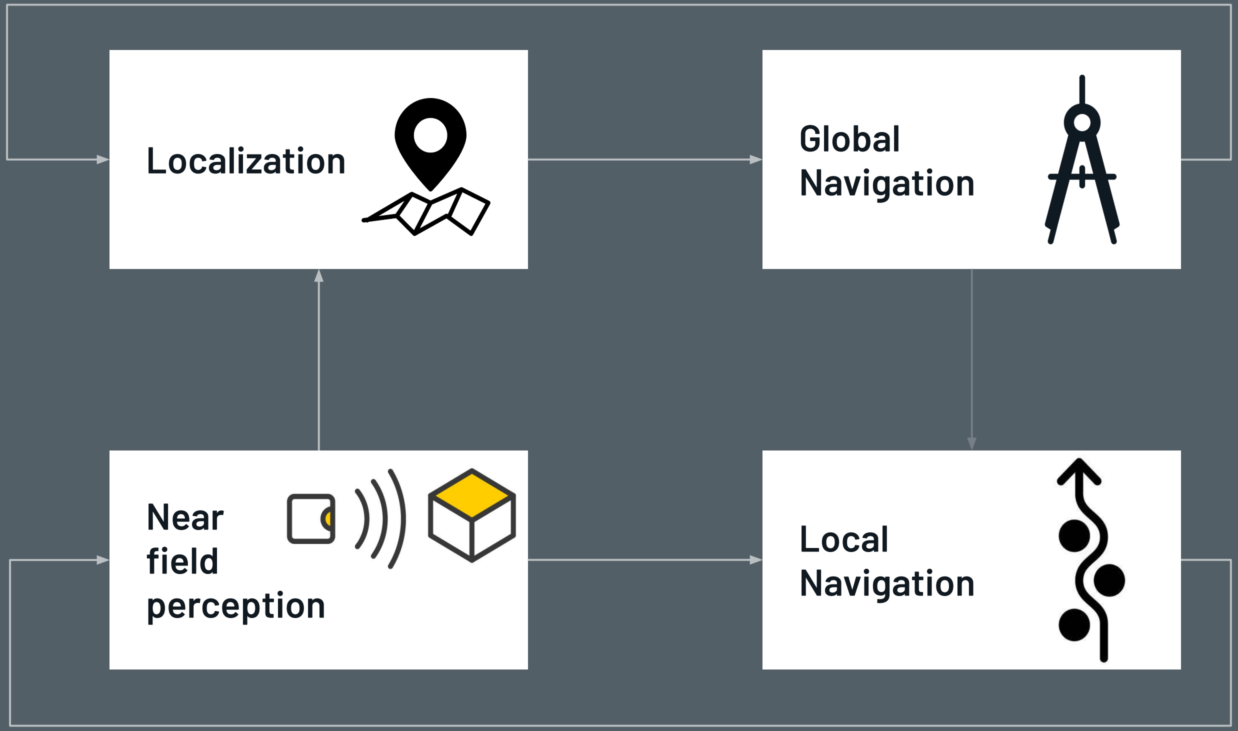
Simulation
Using reinforcement learning in a simulator to learn specific motions and maneuvers.

Real Robot
With Sim-to-Real transfer the learned model is applied on the real robots. One specifically learned capability is fall recovery.



RSL Robotic Systems Lab

More Sense-Think-Act



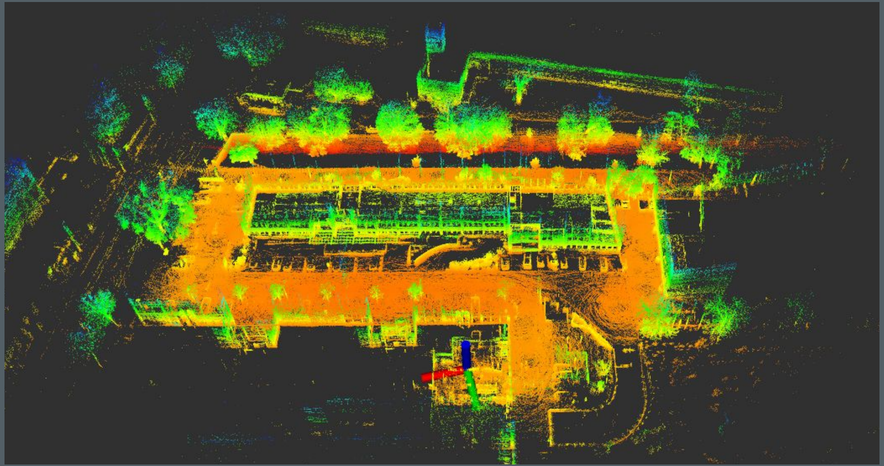
Simultaneous Localization & Mapping

Point Cloud based SLAM

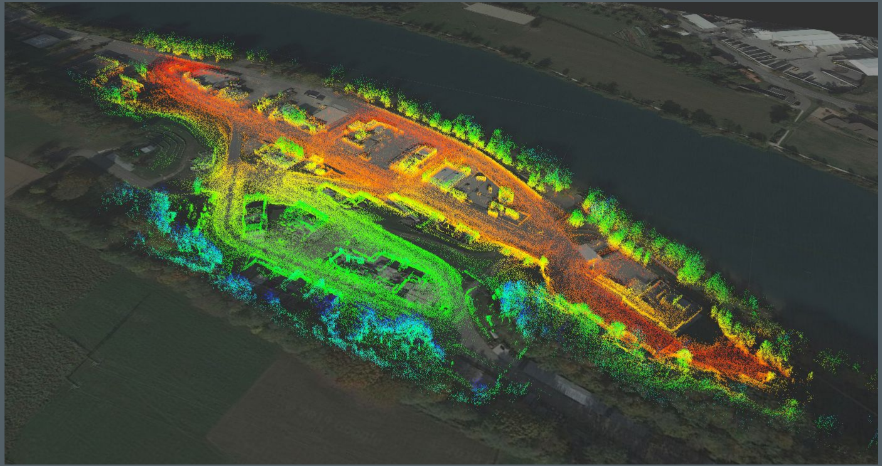
LIDAR and depth sensors are used to generate a map and localize within the map.

Scalable

A localization accuracy of less than 10 cm is achieved while being scalable to large industrial environments.



Hagenholz, Oerlikon



Wangen an der Aare

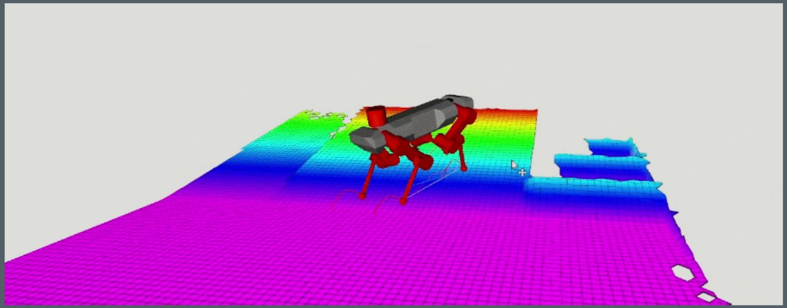
Terrain Mapping

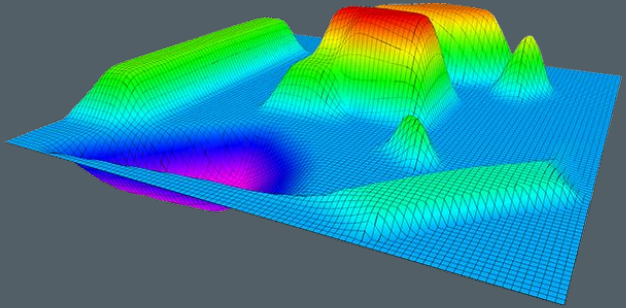
Elevation Mapping

Robo-centric height maps are generated based on the surrounding depth data.

Grid Map

Dedicated data structure created for height maps and shared with the ROS community. Tight integration into RVIZ with a custom visualization plugin.





Open Source
www.github.com/anybotics

Path Planning & Following

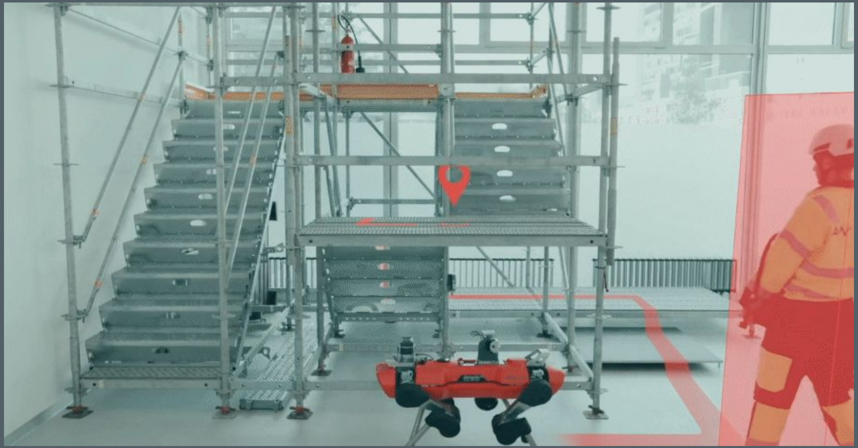
Calculation

Given a point cloud based map, the software finds the shortest path from A to B in a graph. Based on the task it can switch between different controllers.

Execution

Given a path the module outputs velocity commands to the locomotion controller. With the help of perception it can also avoid obstacles.

Path Planner



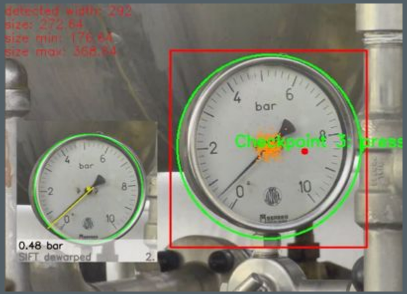
Path Follower

Regularly Collect and Interpret Physical Properties of Equipment and Environment

Reading Instruments

GAUGES VALVES COUNTERS

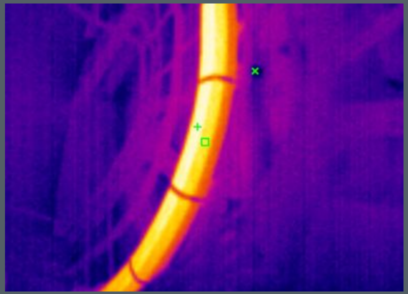
PHOTO



Detecting Events

THERMOGRAPHY ACOUSTIC LABELS

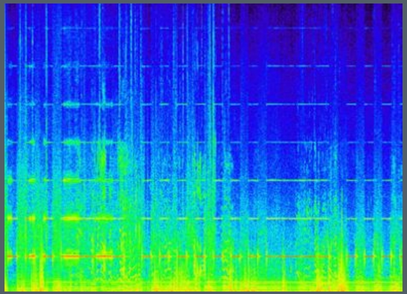
LEAKAGES MISSING PARTS



Checking Health of Equipment

HOTSPOTS GASES ALARMS

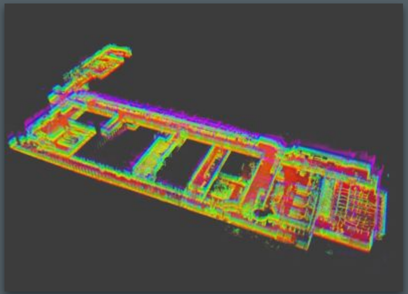
TEMPERATURES



Monitoring Environments

REALITY CAPTURE ESCAPE ROUTES

EQUIPMENT HUMANS



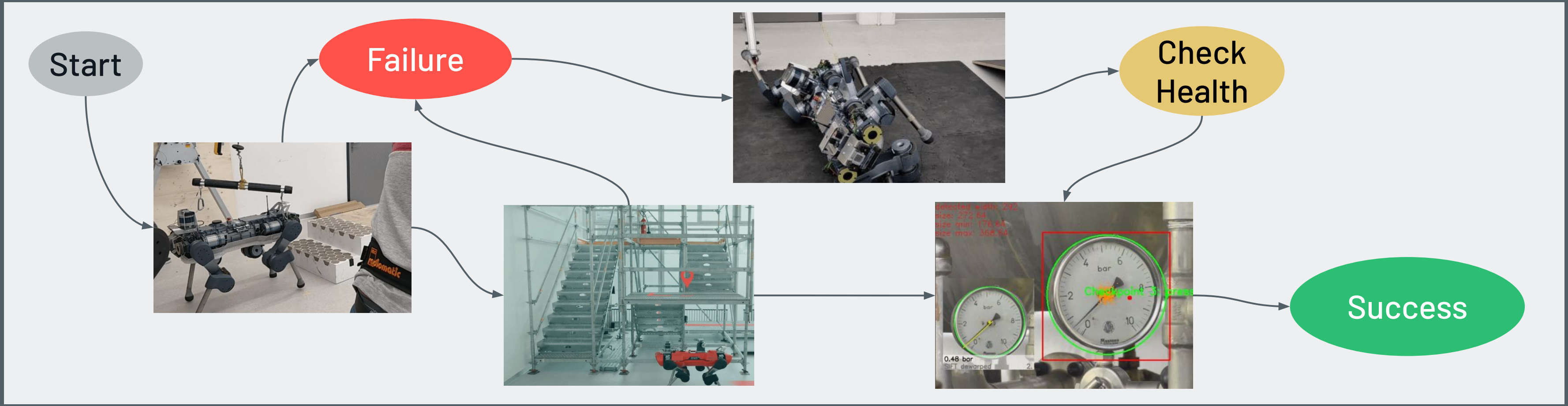
Factory Automation

Monitoring

The health of the system is constantly monitored. In case of a failure or undefined behavior a rescue behavior can be performed or a remote operator can be contacted.

Repeat

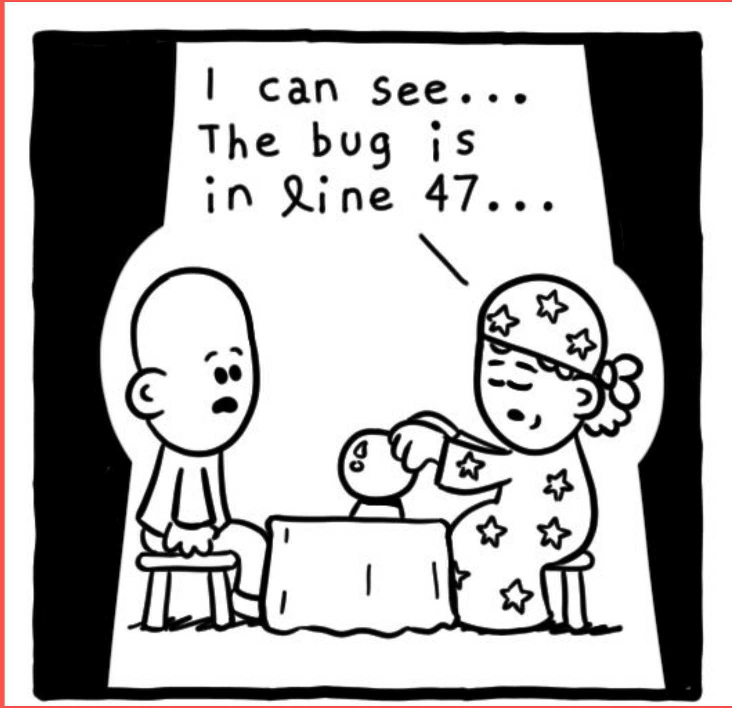
Teach once, repeat forever. Navigation and inspection tasks can be scheduled. Each customer gets an easy-to-use interface to create custom missions.



Automated Docking

- **Find docking station**
  Perception based detection system.
- **Dock**
  Autonomous maneuver.
- **Rest**
  Switch on power saving mode.
- **Repeat**
  Continue once fully charged.

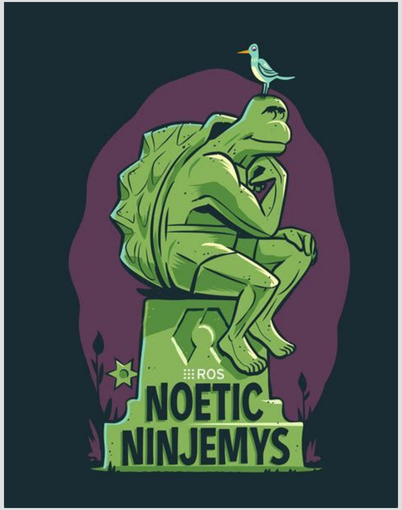
How We Keep Things Smooth



Computer Setup

Consistency

All developers and all robots have the same setup. The computers run Ubuntu 20.04 LTS with ROS Noetic.



Code Sharing

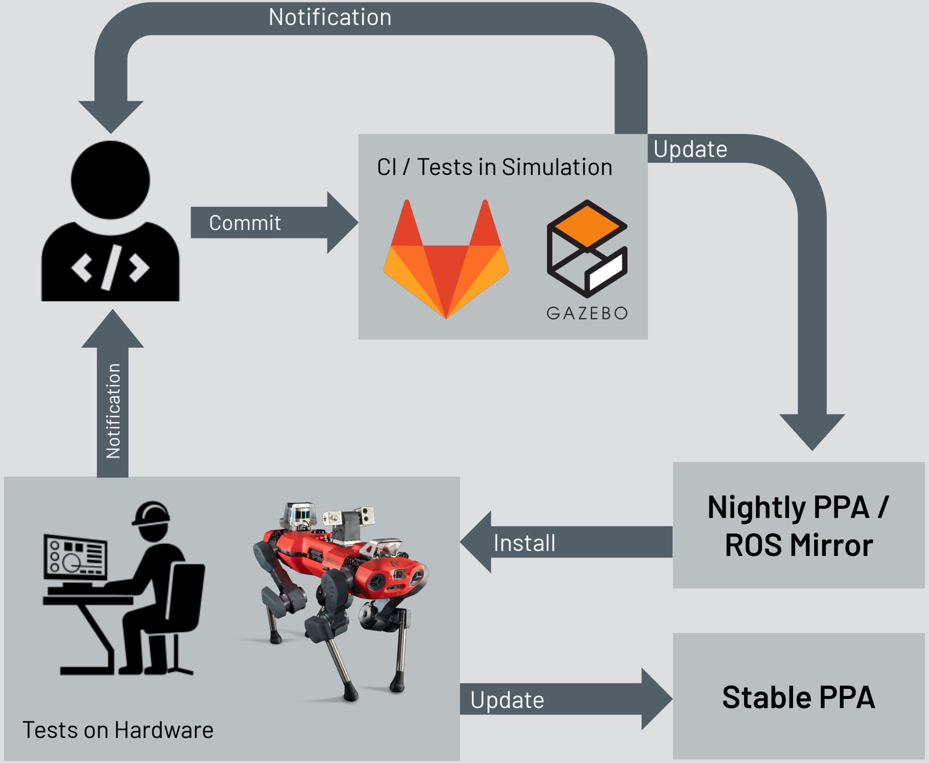
Software version is controlled with Git. Gitlab acts as host and ANYbotics employs a monorepo structure. Open-source packages are maintained on GitHub.

GitLab

GitHub

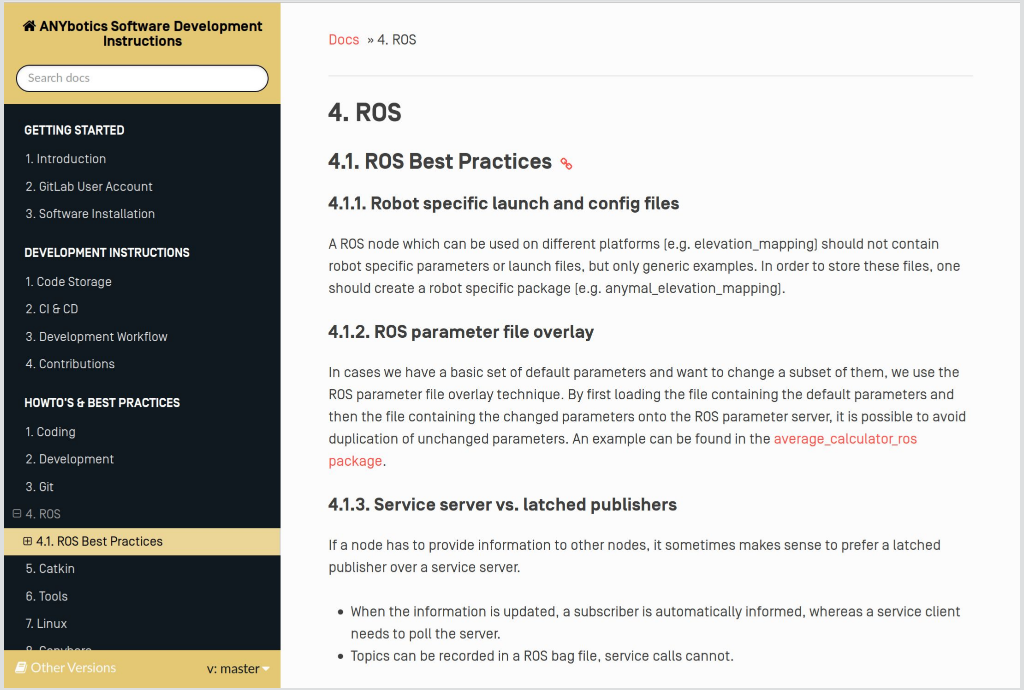
Quality Assurance

- **GitLab CI**
  Runs on pushed commit.
- **Unit tests**
  Runs on every merge request.
- **ROS integration tests**
  Runs every night.
- **Hardware in the loop test**
  Once every week.
- **Debians**
  Tested binaries are released frequently for customers.



Rules for the Developers

- Software Development Instructions
  → ROS and catkin best practices
  → C++ style guide
  → Development workflow
- Documentation
  → API documentation using Doxygen
  → User manual using Sphinx


ANYbotics Software Development Instructions

Search docs

GETTING STARTED
1. Introduction
2. GitLab User Account
3. Software Installation

DEVELOPMENT INSTRUCTIONS
1. Code Storage
2. CI & CD
3. Development Workflow
4. Contributions

HOWTO'S & BEST PRACTICES
1. Coding
2. Development
3. Git
4. ROS
4.1. ROS Best Practices
5. Catkin
6. Tools
7. Linux

Other Versions v: master

Docs » 4. ROS

4. ROS

4.1. ROS Best Practices

4.1.1. Robot specific launch and config files

A ROS node which can be used on different platforms (e.g. elevation_mapping) should not contain robot specific parameters or launch files, but only generic examples. In order to store these files, one should create a robot specific package (e.g. anymal_elevation_mapping).

4.1.2. ROS parameter file overlay

In cases we have a basic set of default parameters and want to change a subset of them, we use the ROS parameter file overlay technique. By first loading the file containing the default parameters and then the file containing the changed parameters onto the ROS parameter server, it is possible to avoid duplication of unchanged parameters. An example can be found in the average_calculator_ros package.

4.1.3. Service server vs. latched publishers

If a node has to provide information to other nodes, it sometimes makes sense to prefer a latched publisher over a service server.

- When the information is updated, a subscriber is automatically informed, whereas a service client needs to poll the server.
- Topics can be recorded in a ROS bag file, service calls cannot.

Partners Around the World

ANYbotics
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THE UNIVERSITY of EDINBURGH
UNIVERSITY OF OXFORD
TECHNISCHE UNIVERSITÄT DARMSTADT
POLITECHNIKA POZNAŃSKA
NVIDIA
USI/SUPSI Istituto Dalle Molle di studi sull'intelligenza artificiale IDSIA
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intel
idiap RESEARCH INSTITUTE
LAAS CNRS
University of Nevada, Reno
UNIVERSITY OF MICHIGAN
UNIVERSITÀ DI PISA
UNIVERSITY OF TWENTE.
TNO innovation for life
DUBAI FUTURE ACCELERATORS

Community
Share your ideas, tell us about your work, and get community support if you have any questions.
→ Visit Discourse

Videos
Watch and share the results that have been achieved by ANYmal Researchers.
→ Watch on YouTube

Papers
Read and share papers that have been published by ANYmal Researchers.
→ Visit ResearchGate Project

Documentation
ANYmal and the ANYmal Simulation are fully documented to get you started quickly.
→ See Documentation

Research Agreement
An agreement makes sure that you can freely publish your results while respecting the intellectual property of other researchers.

Attribution
ANYmal Researchers attribute all partners that their work builds on including their affiliation with ANYmal Research.

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