PRESENTATION //

Building a Legged Robot with ROS

Case Study by ANYbotics

February 28, 2020

Maximilian Wulf, Harmish Khambhaita

ANYbotics


FRA
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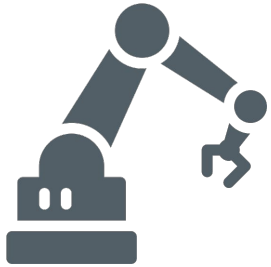
CRO

Robots Change the Way We Work



1980

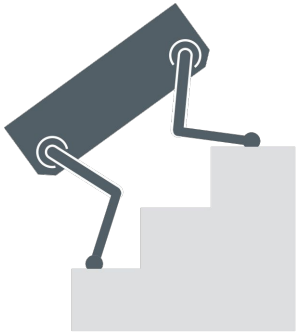
Manufacturing

Stationary manipulation

2010

Logistics

Mobility in structured environments



2020

The New World

Mobile interaction in industrial, urban and natural environments

Let Robots Go Anywhere!

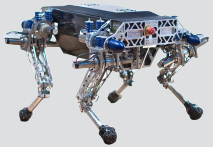
THE CHALLENGE //

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


ANYmal
North Sea
September 2018
ANYbotics

From Research to Industrial Applications

2009
ALoF



2012
StarlETH

2015
ANYmal Alph

2017
ANYmal Beth

2018
ANYmal B

2019
ANYmal C

RESEARCH

DEMONSTRATOR

APPLICATION

ETH zürich

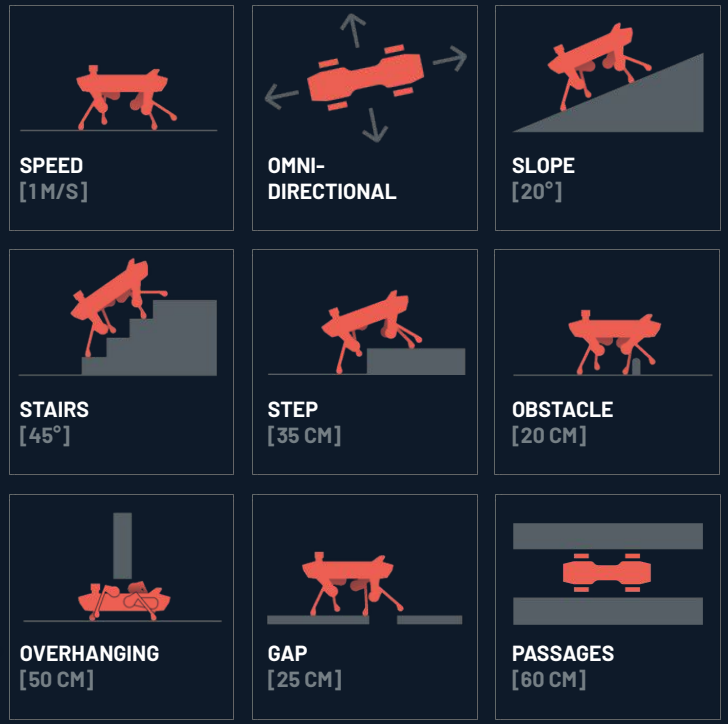
Maturity, Autonomy, Performance, Robustness

ANYbotics

VIDEO //

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

ANYmal C's Legs Provide Extreme Mobility in Challenging Environments



Fully Autonomous Operation and Seamless Switching to Supervised or Manual Control

Teleoperated

Supervised

Autonomous

All-around Depth Cameras for Obstacle Detection

360° OBSTACLE DETECTION
4x DEPTH CAMERAS

ADVANCED SENSING //

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

GPS (RTK) Based Navigation for Outdoor Environments

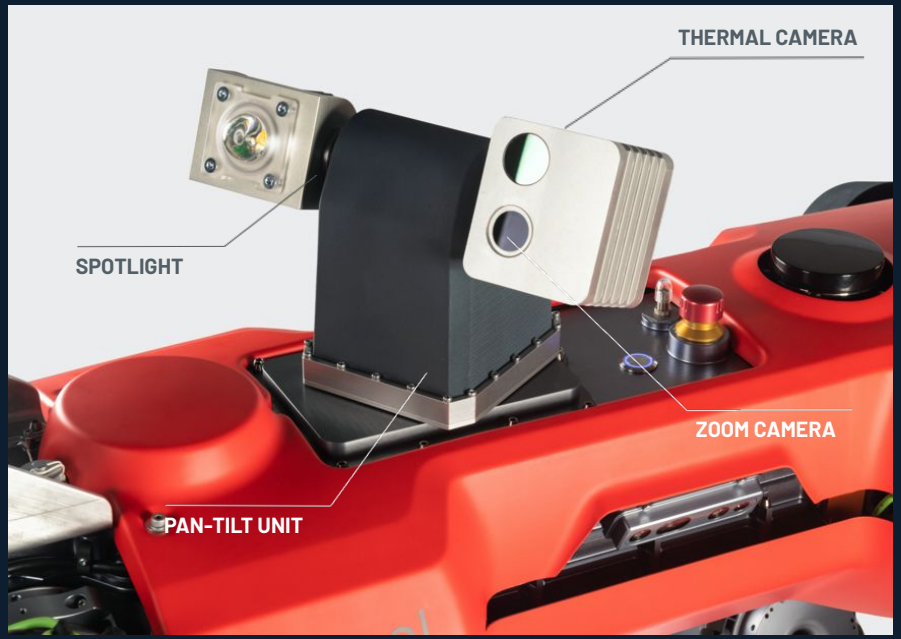
360° OBSTACLE DETECTION
4x DEPTH CAMERAS

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

12x ANYdrives

IMU

4 Depth Cameras

LIDAR

Thermal Camera

Microphone

Visual Camera

Locomotion PC

State Estimation

Locomotion Control

Navigation PC

Localization

Terrain Mapping

Navigation & Mission Planning

Application PC

Visual Inspection

Thermal Inspection

Audio Inspection

WiFi

Ethernet

Radio

Operator PC

Remote Control UI

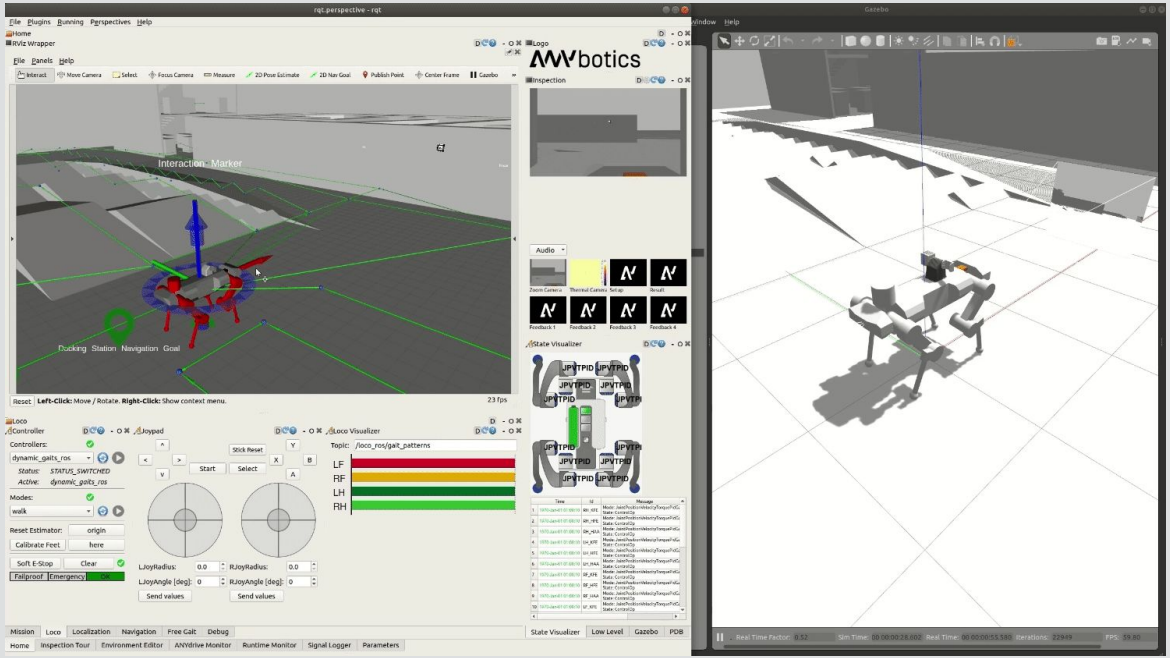
Visualizations

Mission Control

Safety operator

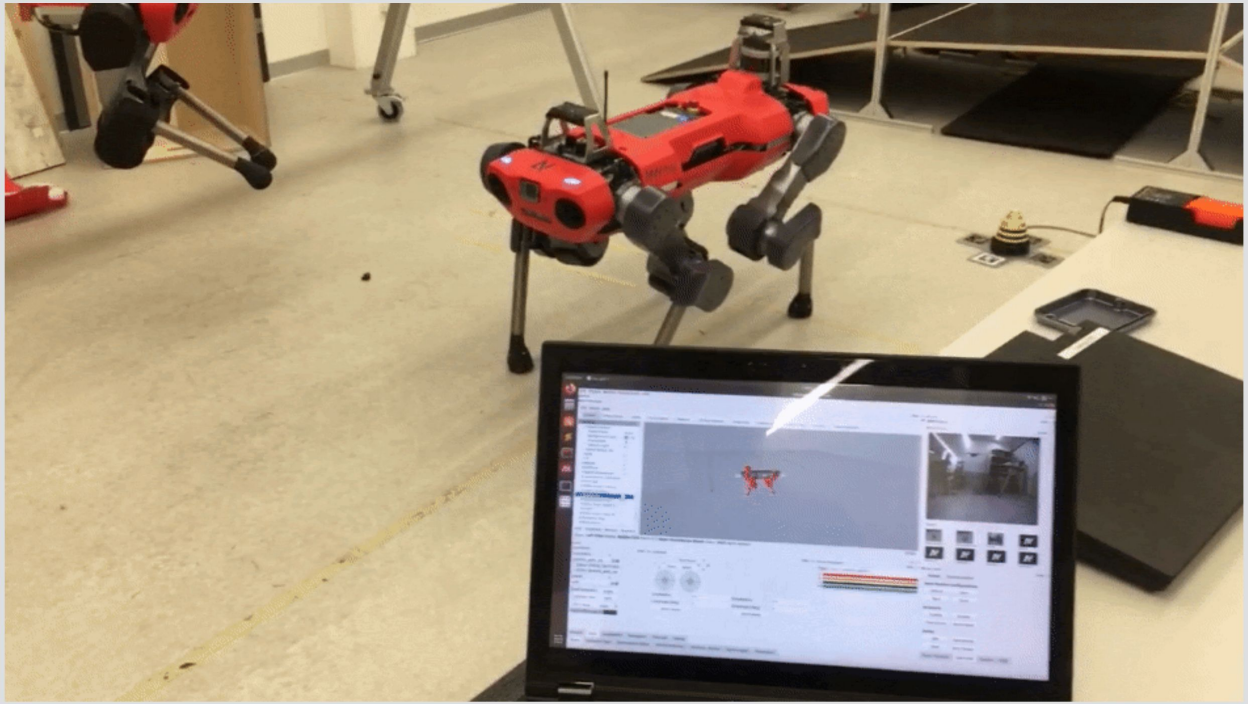
Robot State Simulation, Visualization and Interaction

- **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

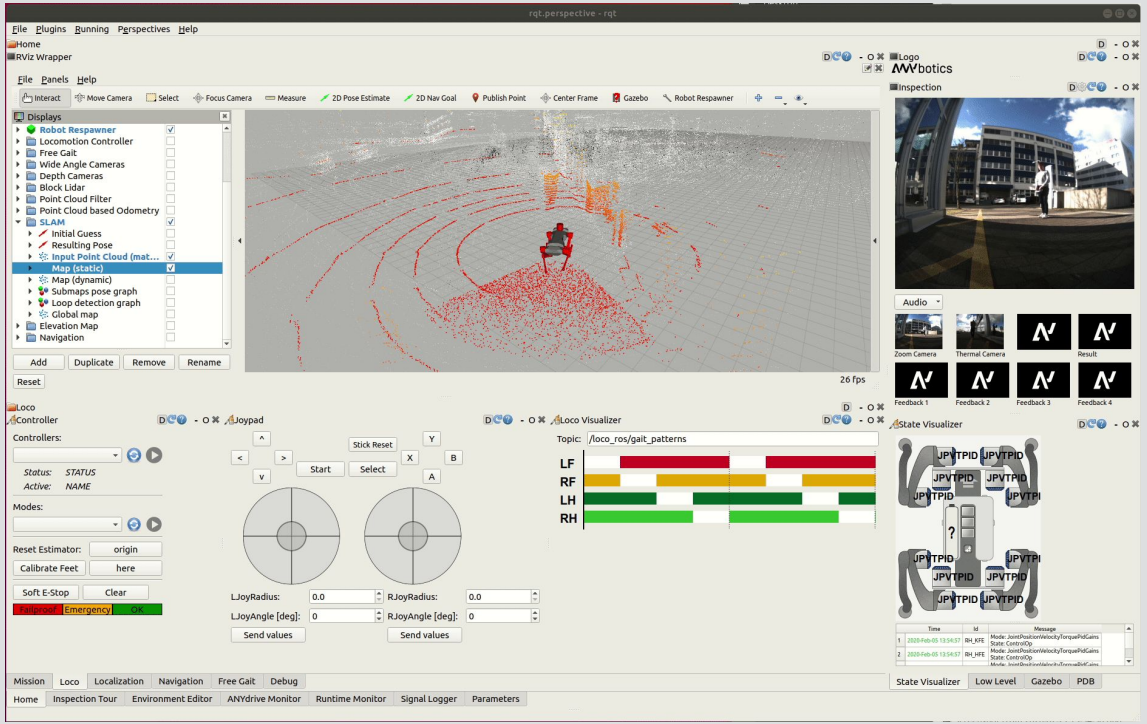
Record topics on the robot while performing any task and save them to a ROS bag.

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.

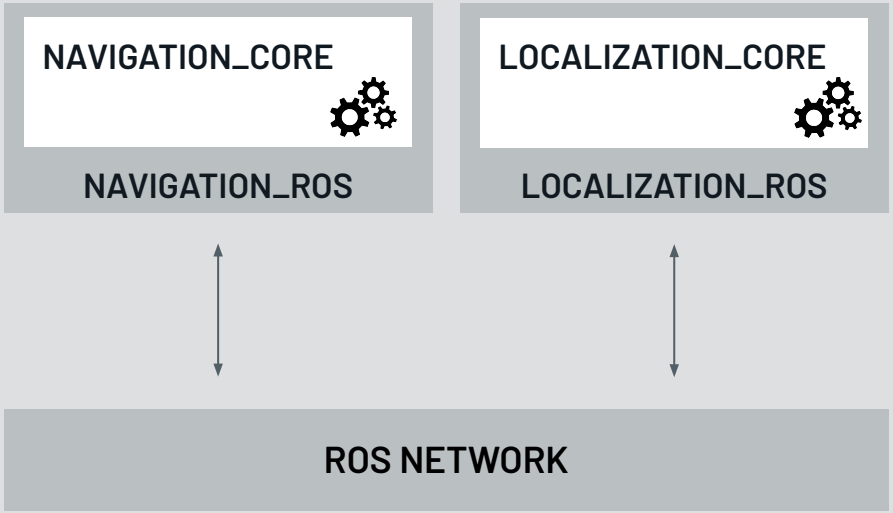


ROS Agnostic Design

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

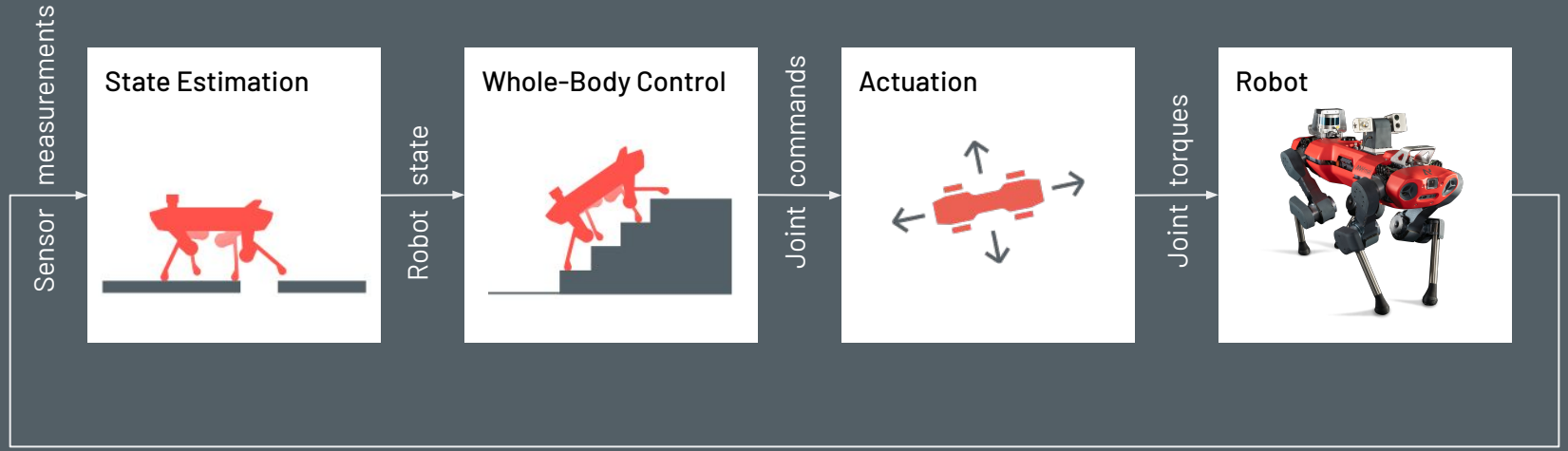
Independence
Usable in environment without ROS and minimal effort to update to new ROS versions

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

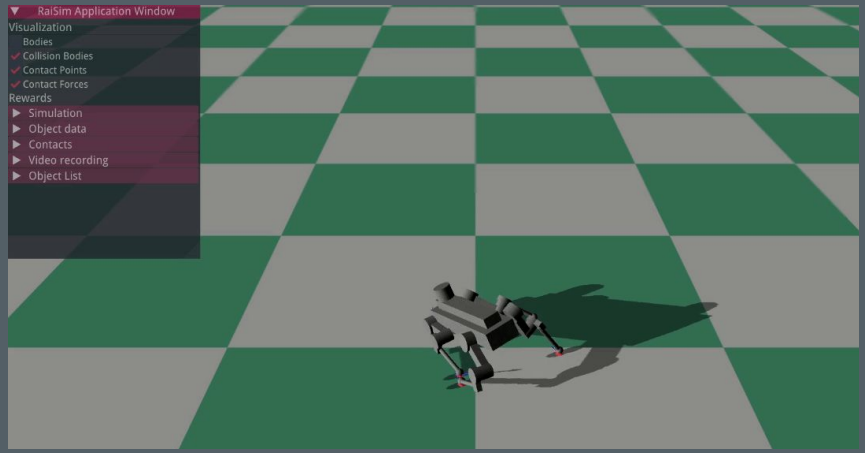
Terrain Perception

Obstacle Avoidance

Learning Locomotion Skills

Simulation

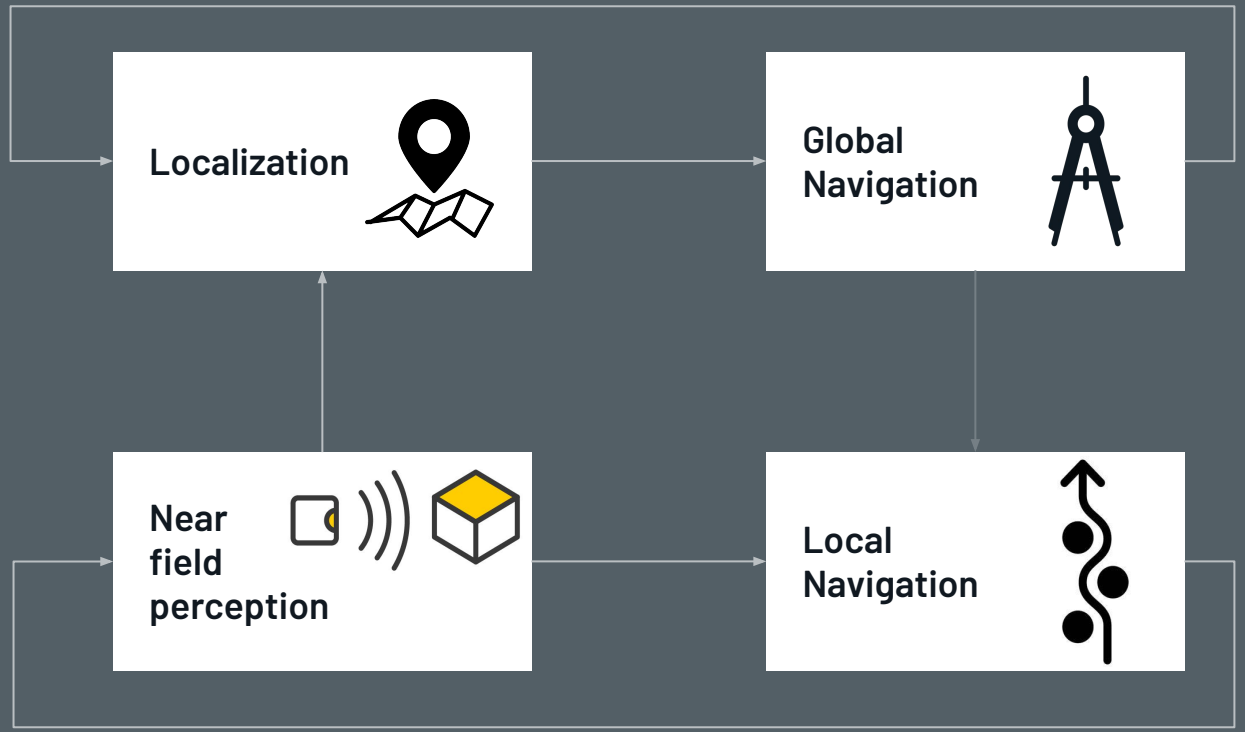
Using reinforcement learning in a simulator to learn specific motions and maneuvers.



Real Robot

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

More Sense-Think-Act



Simultaneous Localization & Mapping

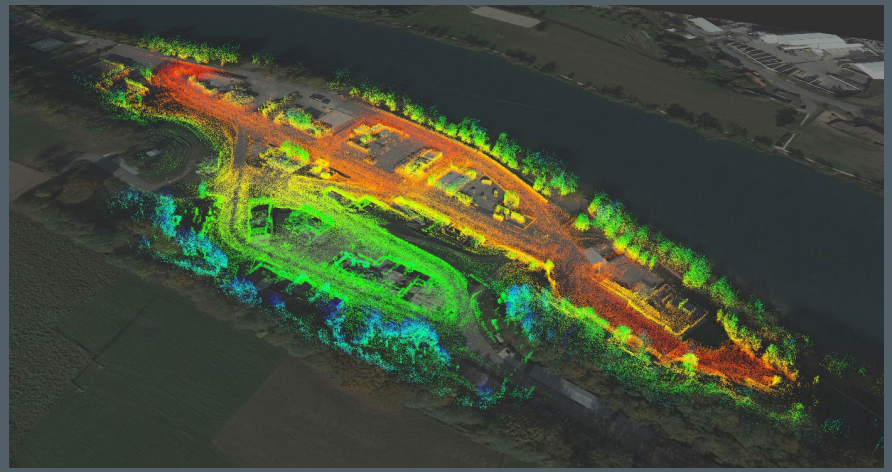
Point Cloud based SLAM

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

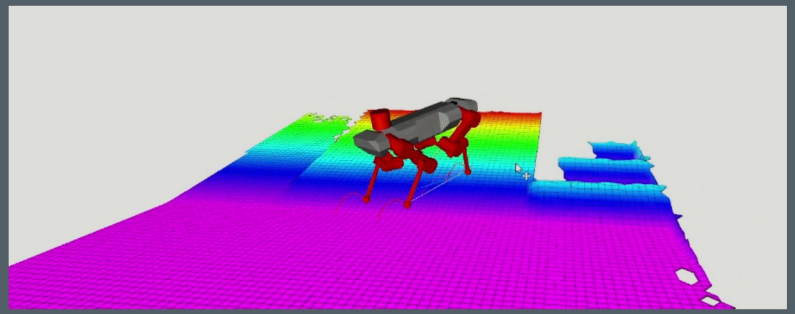


Wangen an der Aare

Terrain Mapping

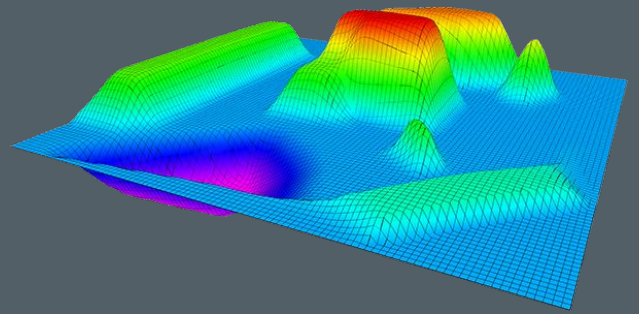
Elevation Mapping

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.

Path Planner

Execution

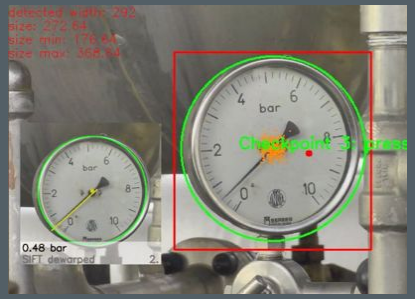
Given a path the module outputs velocity commands to the locomotion controller. With the help of perception it can also avoid obstacles.

Path Follower

Regularly Collect and Interpret Physical Properties of Equipment and Environment

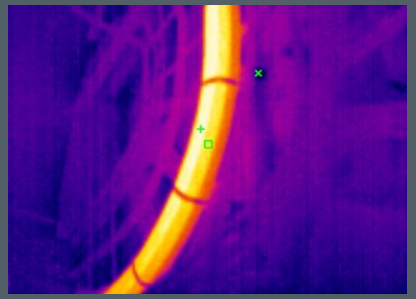
Reading Instruments

GAUGES VALVES COUNTERS PHOTO



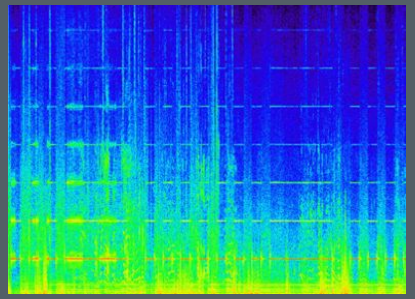
Detecting Events

THERMOGRAPHY ACOUSTIC LABELS LEAKAGES MISSING PARTS



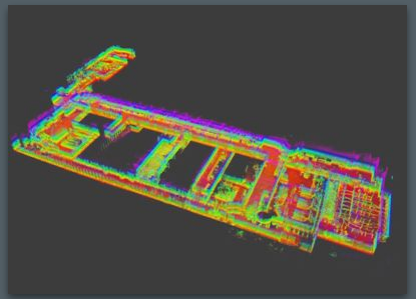
Checking Health of Equipment

HOTSPOTS GASES ALARMS TEMPERATURES



Monitoring Environments

3D MAPPING ESCAPE ROUTES EQUIPMENT HUMANS



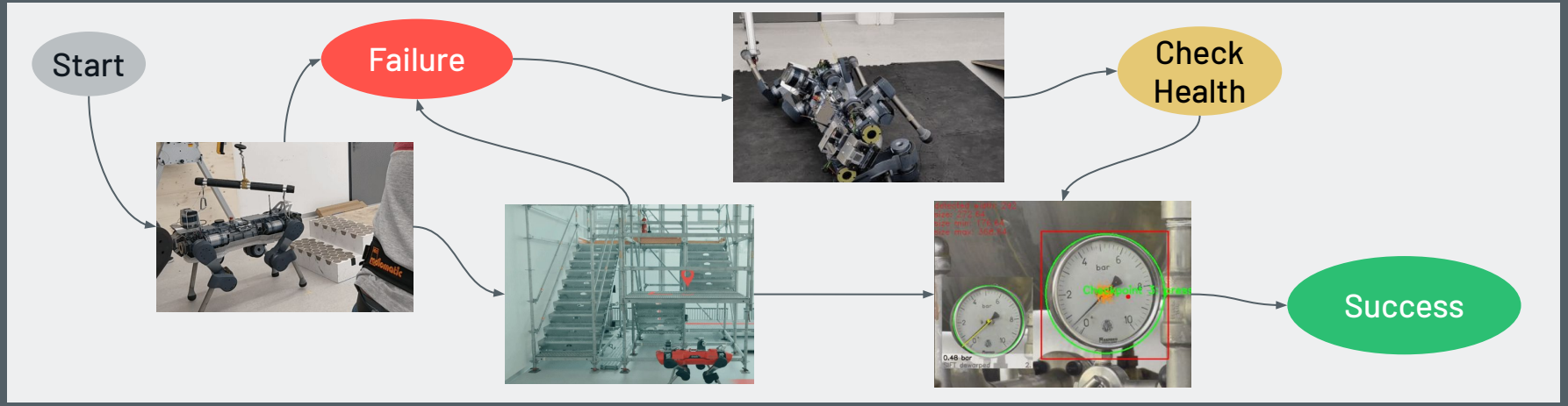
Factory Automation

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

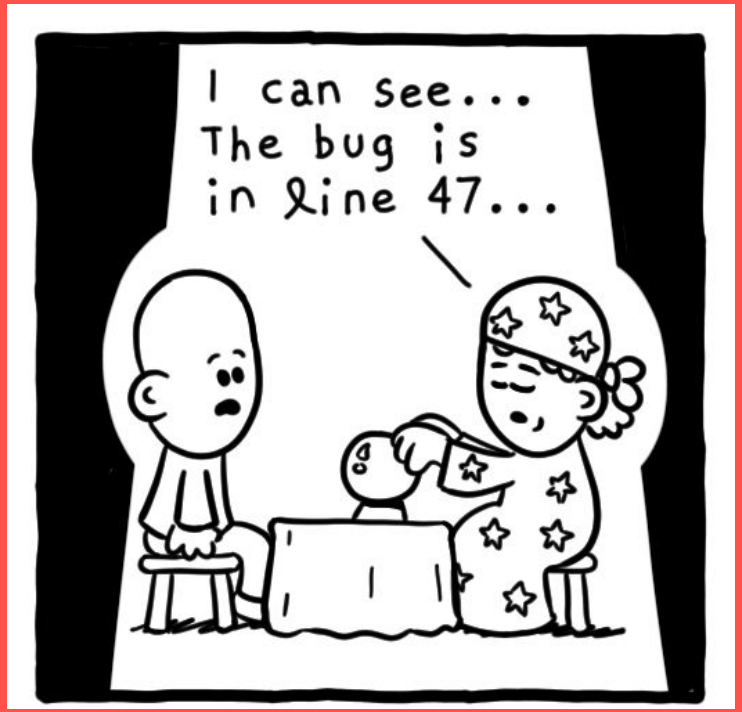
Teach once, repeat forever. Navigation and inspection tasks can be scheduled. Each customer gets an easy-to-use interface to create custom missions.



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

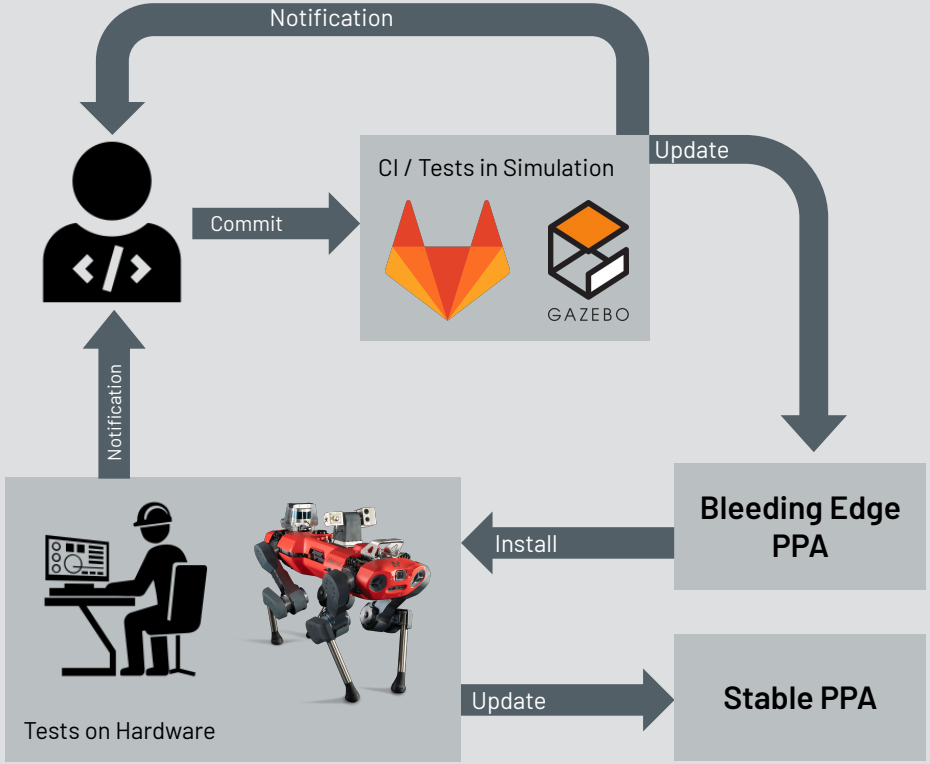
All developers and all robots have the same setup. The computers run Ubuntu 18.04 LTS with ROS Melodic.

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.

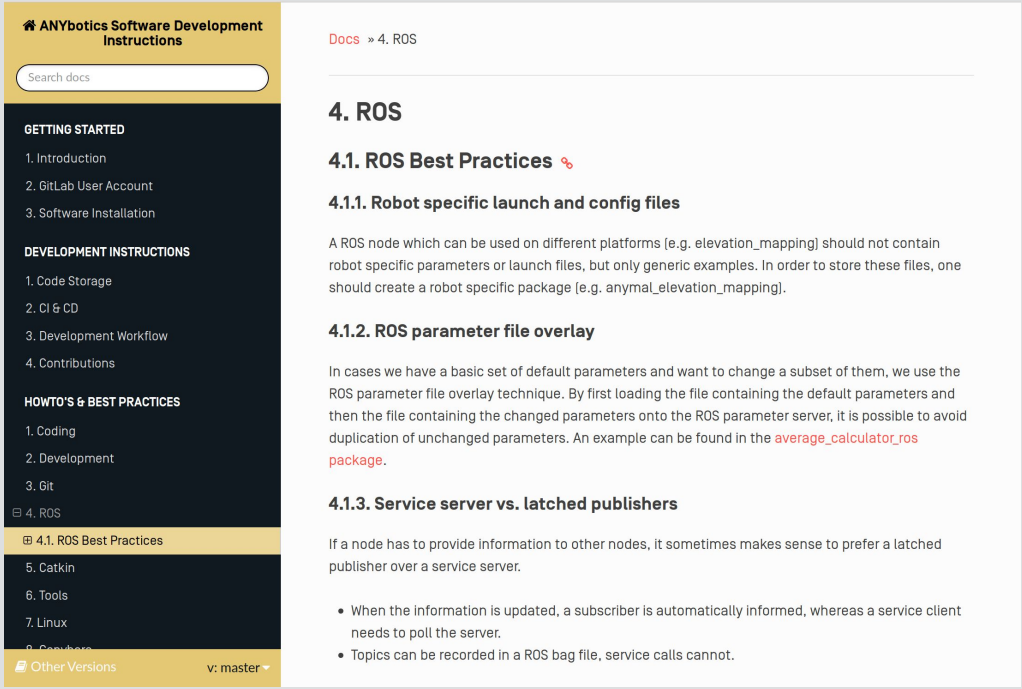
Quality Assurance

- **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



Partners Around the World

ANYbotics
ETH zürich
THE UNIVERSITY of EDINBURGH
UNIVERSITY OF OXFORD
TECHNISCHE UNIVERSITÄT DARMSTADT
POLITECHNIKA POZNAŃSKA
NVIDIA
USI/SUPSI Istituto Dalle Molle di studi sull'intelligenza artificiale IDSIA
UNIVERSITY OF LEEDS
intel
idiap RESEARCH INSTITUTE
LAAS CNRS
University of Nevada, Reno
UNIVERSITY OF MICHIGAN
UNIVERSITÀ DI PISA
Hide

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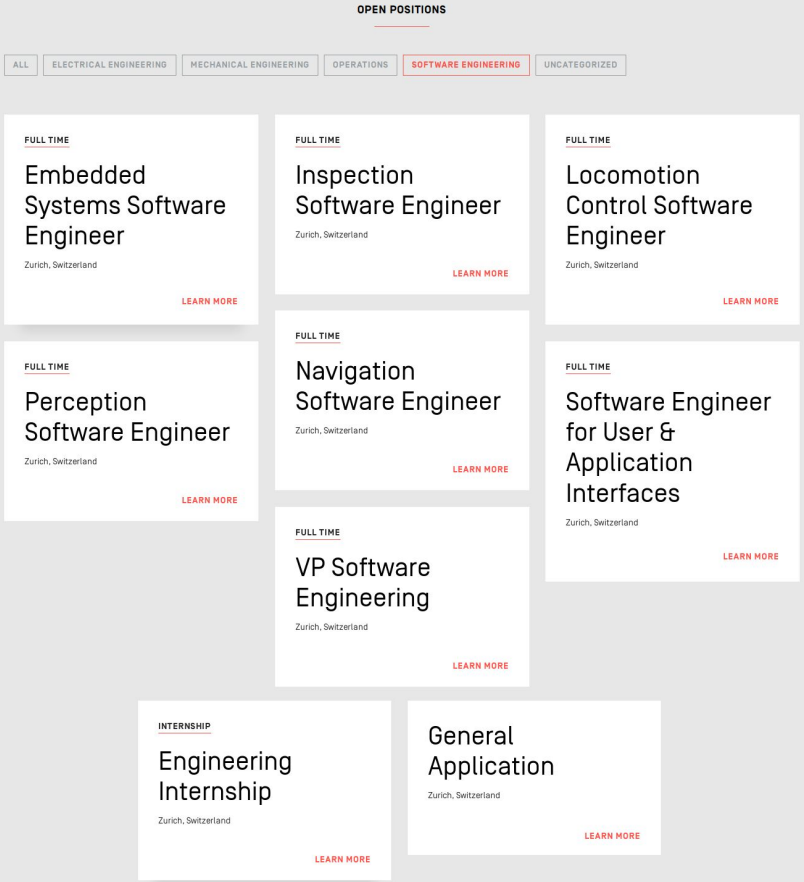

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