

PRESENTATION //

Building a Legged Robot with ROS

Case Study by ANYbotics

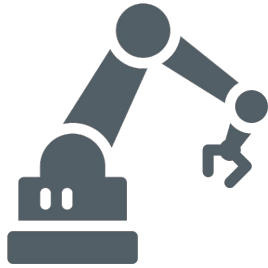
February 28, 2020

Maximilian Wulf, Harmish Khambhaita

FRA 0:0 CRO



Robots Change the Way We Work



1980

Manufacturing

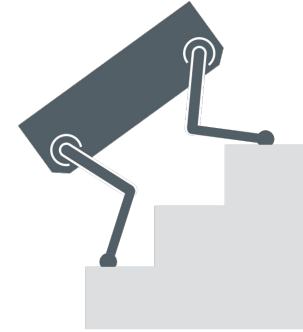
Stationary manipulation



2010

Logistics

Mobility in structured environments



2020

The New World

Mobile interaction in industrial, urban and natural environments

Let Robots Go Anywhere!

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

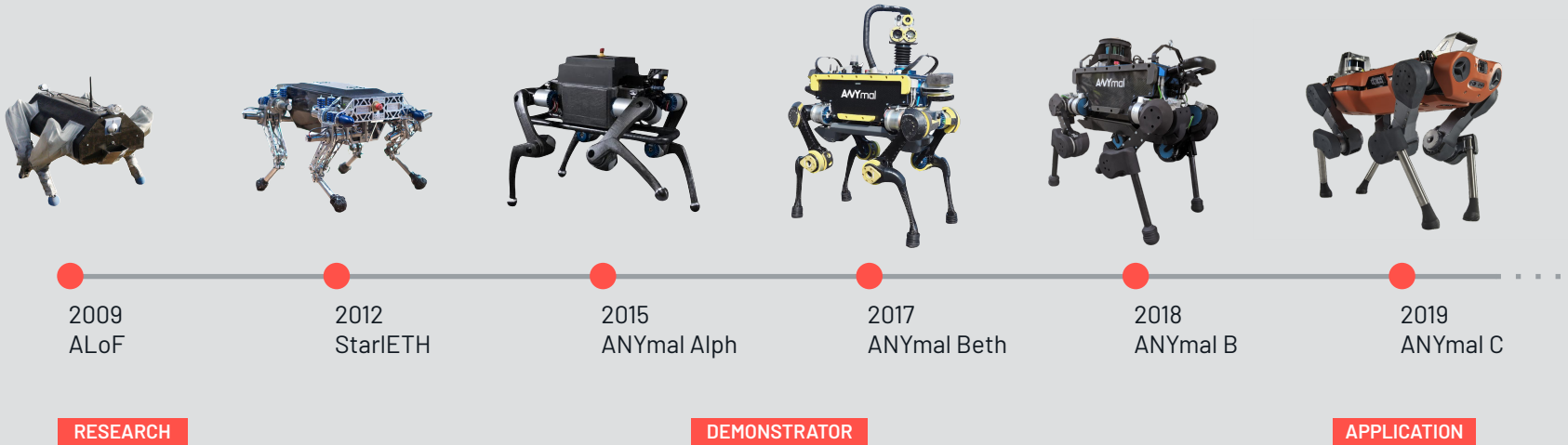




North Sea
September 2018

ANYbotics

From Research to Industrial Applications



ETH zürich

Maturity, Autonomy, Performance, Robustness

ANYbotics



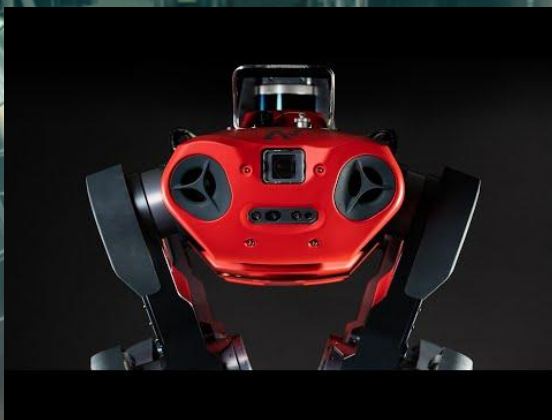
VIDEO //

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

4.6 BAR ✓

WARNING!

Gas leak detected ✗












EMERGENCY
ROUTE FREE ✓



ANYmal C's Legs Provide Extreme Mobility in Challenging Environments



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

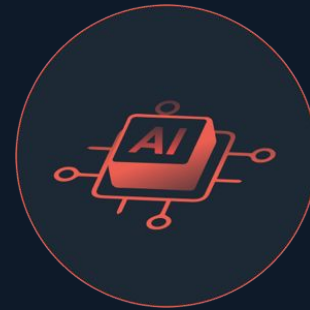
Fully Autonomous Operation and Seamless Switching to Supervised or Manual Control



Teleoperated



Supervised



Autonomous

All-around Depth Cameras for Obstacle Detection



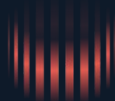
360° OBSTACLE DETECTION
4x DEPTH CAMERAS



360° Environment Scanning



360° OBSTACLE DETECTION
4x DEPTH CAMERAS



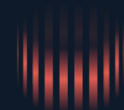
ENVIRONMENT SCANNING
LIDAR



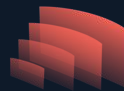
Front and Back Cameras for Teleoperation



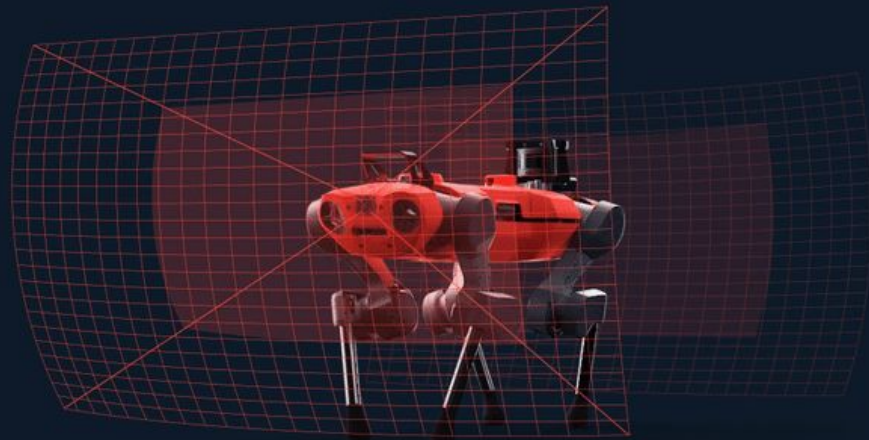
360° OBSTACLE DETECTION
4x DEPTH CAMERAS



ENVIRONMENT SCANNING
LIDAR



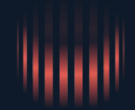
WIDE ANGLE CAMERAS



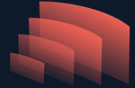
GPS (RTK) Based Navigation for Outdoor Environments



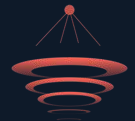
360° OBSTACLE DETECTION
4x DEPTH CAMERAS



ENVIRONMENT SCANNING
LIDAR



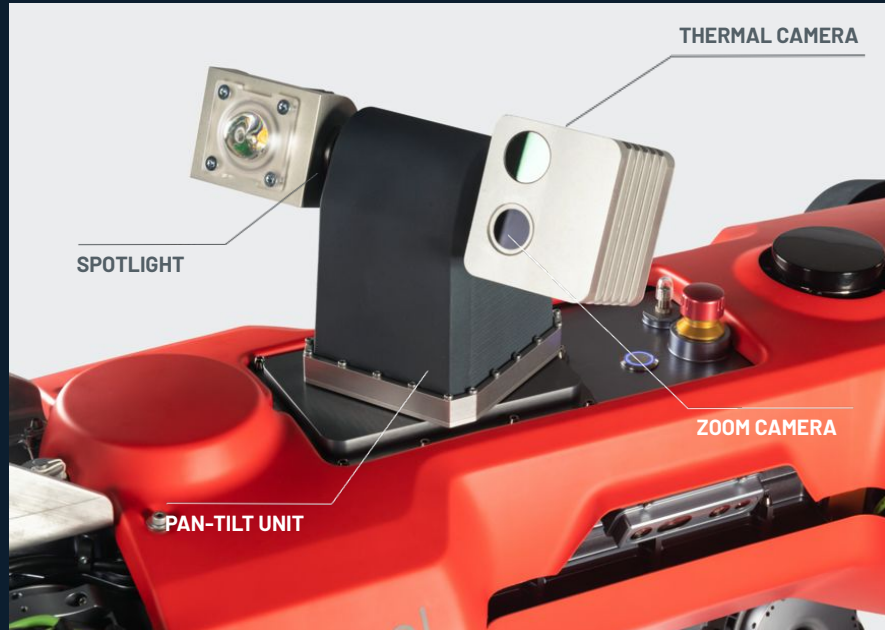
WIDE ANGLE CAMERAS



GPS (OPTIONAL)



Expandable Platform to Tackle a Wide Range of Applications



Example inspection payload



Carry a payload with up to 10 kg



Access to USB, Ethernet, and power sockets

CPU

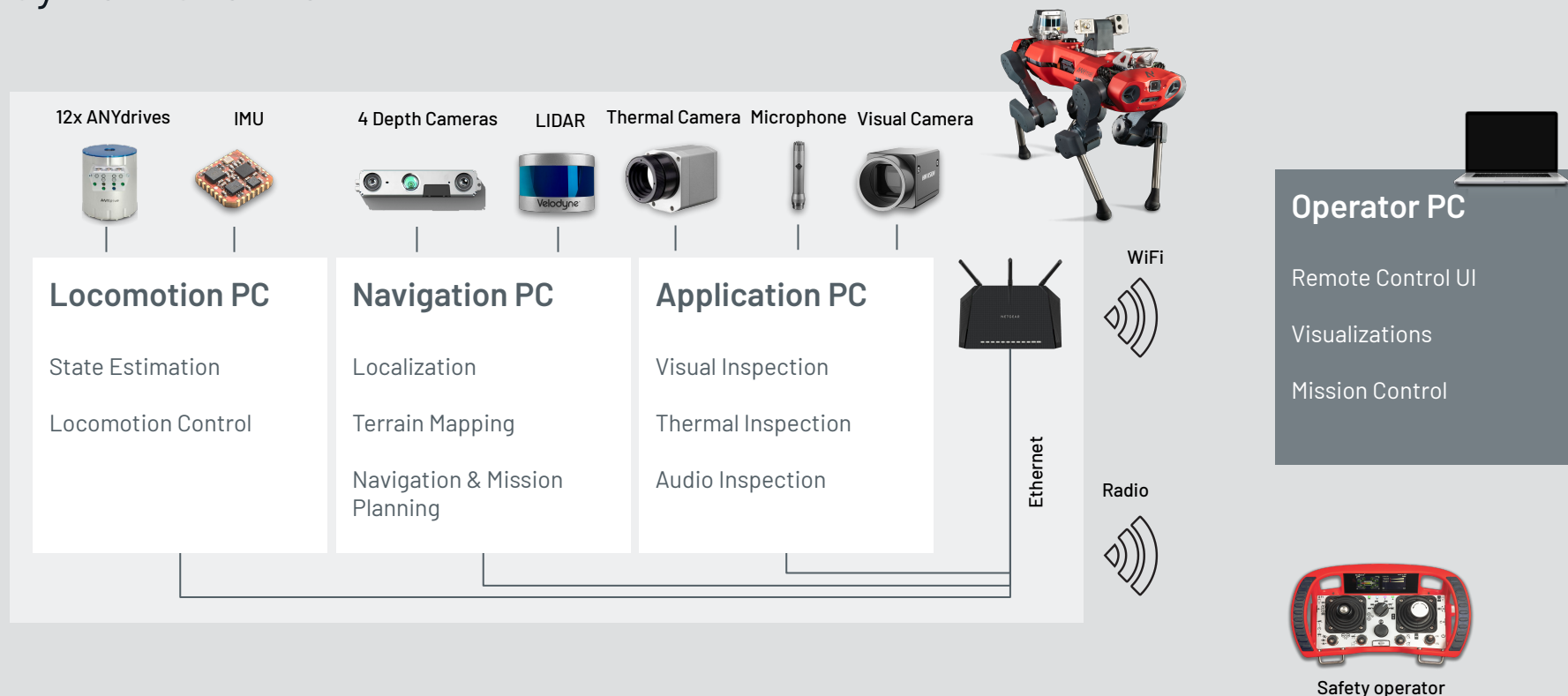
Dedicated onboard computer for custom applications

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

Operator PC

Remote Control UI

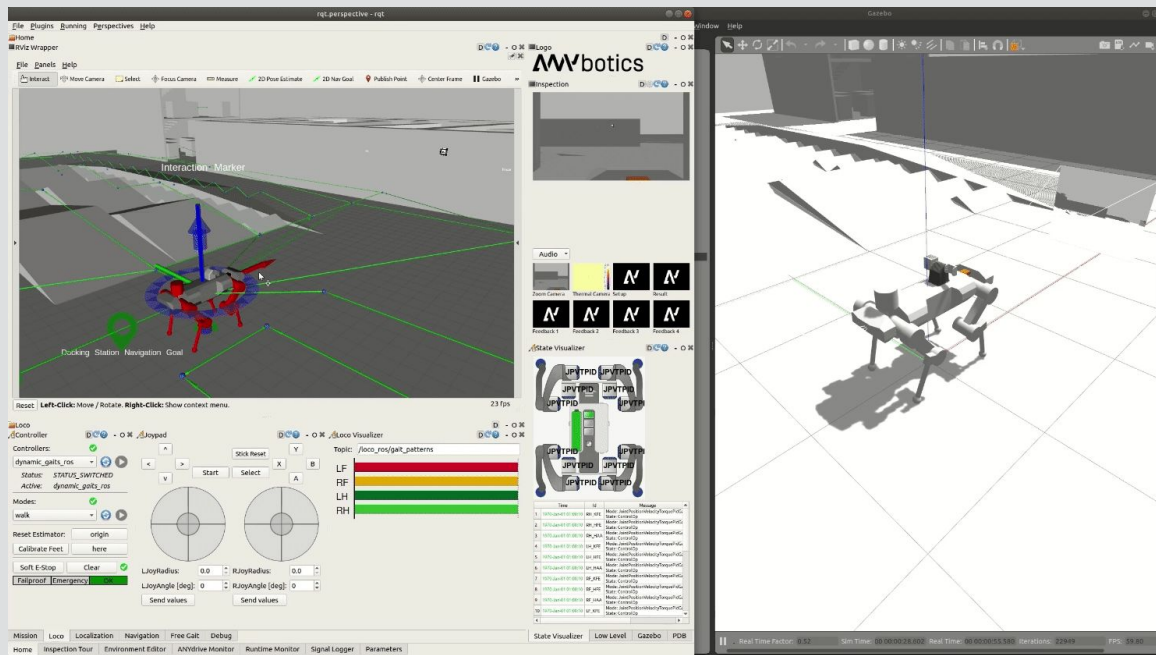
Visualizations

Mission Control

Safety operator

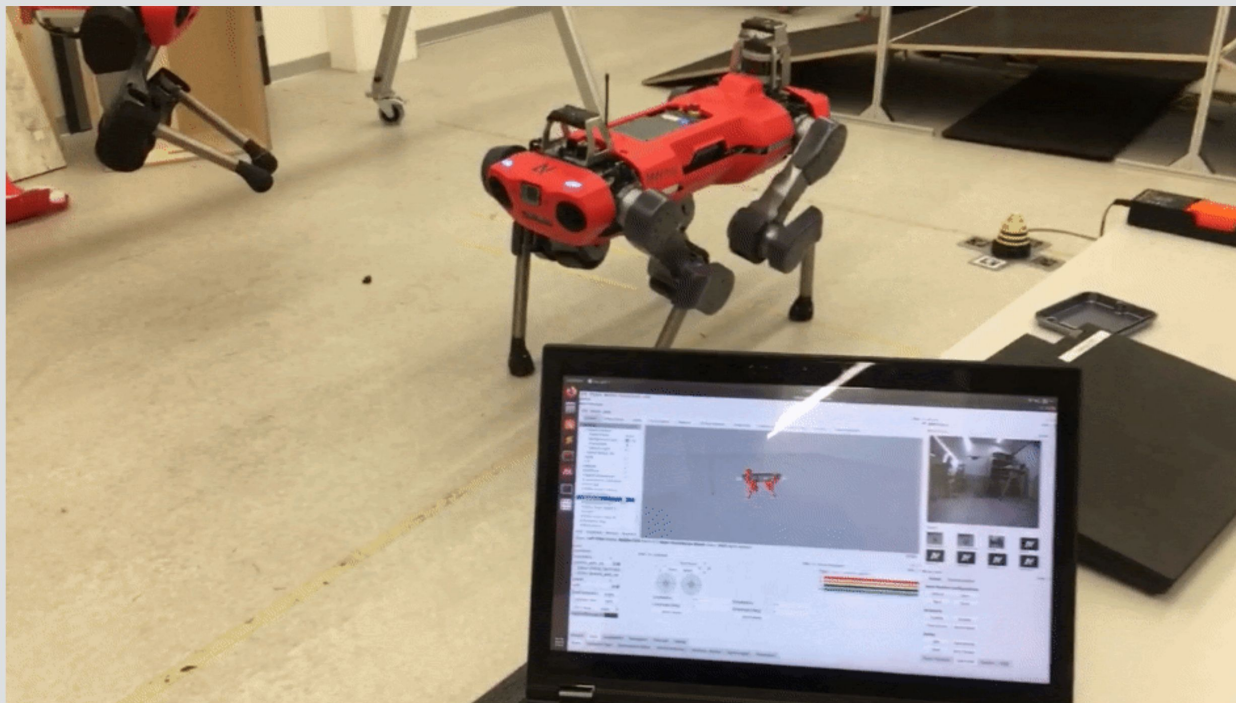
Robot State Simulation, Visualization and Interaction

- ✓ **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

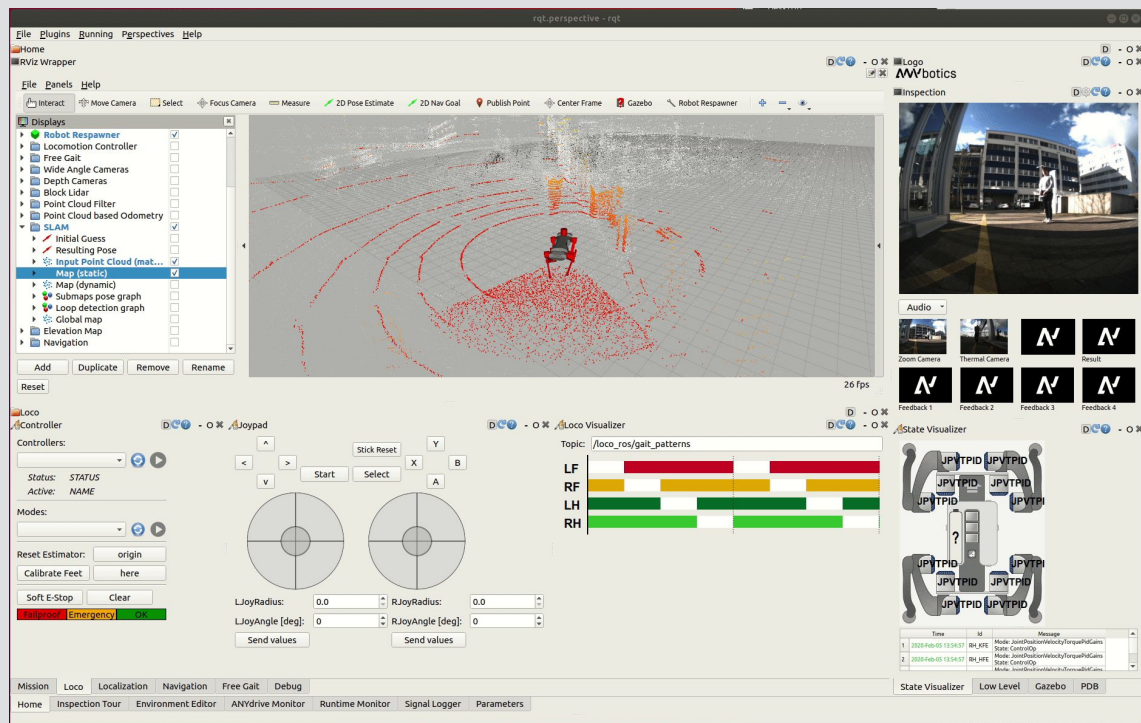
Record topics on the robot while performing any task and save them to a ROS bag.

✓ 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**

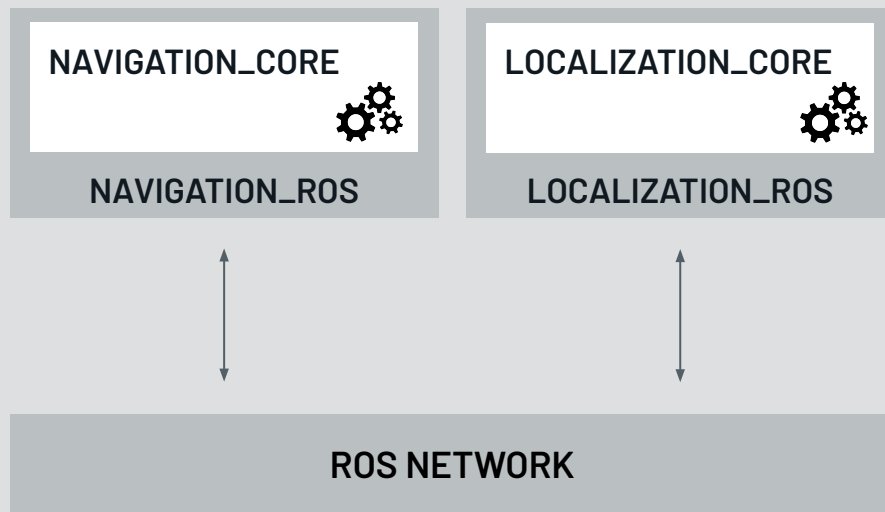
Separate core algorithms (_CORE) from ROS interface nodes (_ROS). Plugins allow injection of ROS dependent code.

✓ **Independence**

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

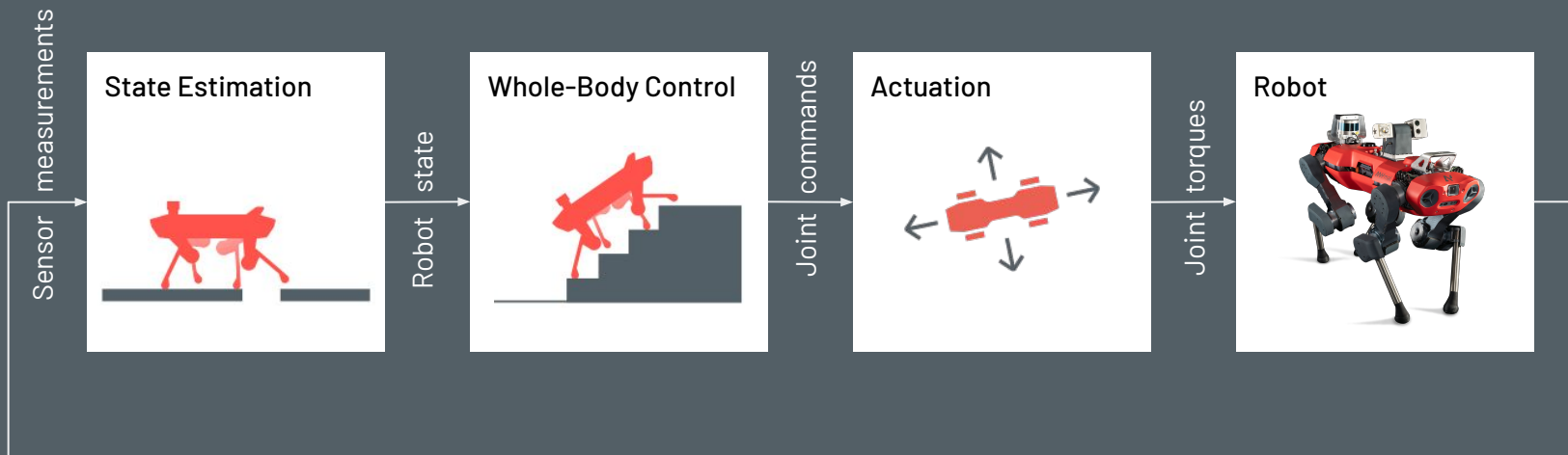
✓ **Scalability**

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

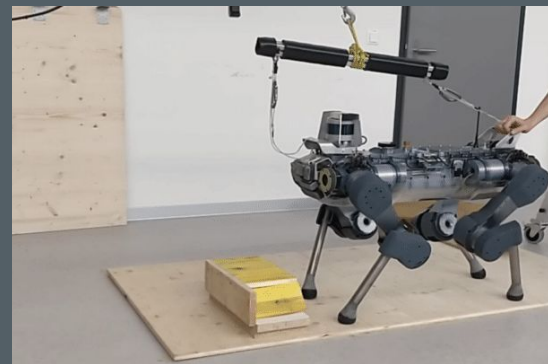
Stair Climbing



Terrain Perception



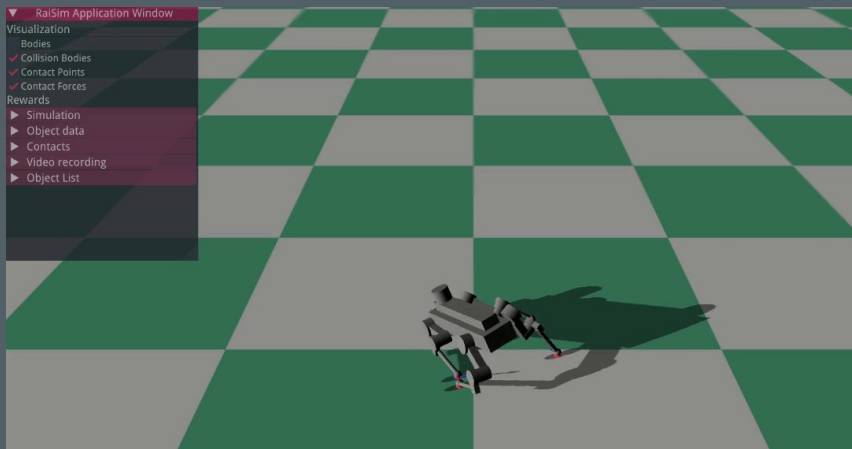
Obstacle Avoidance



Learning Locomotion Skills

✓ Simulation

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

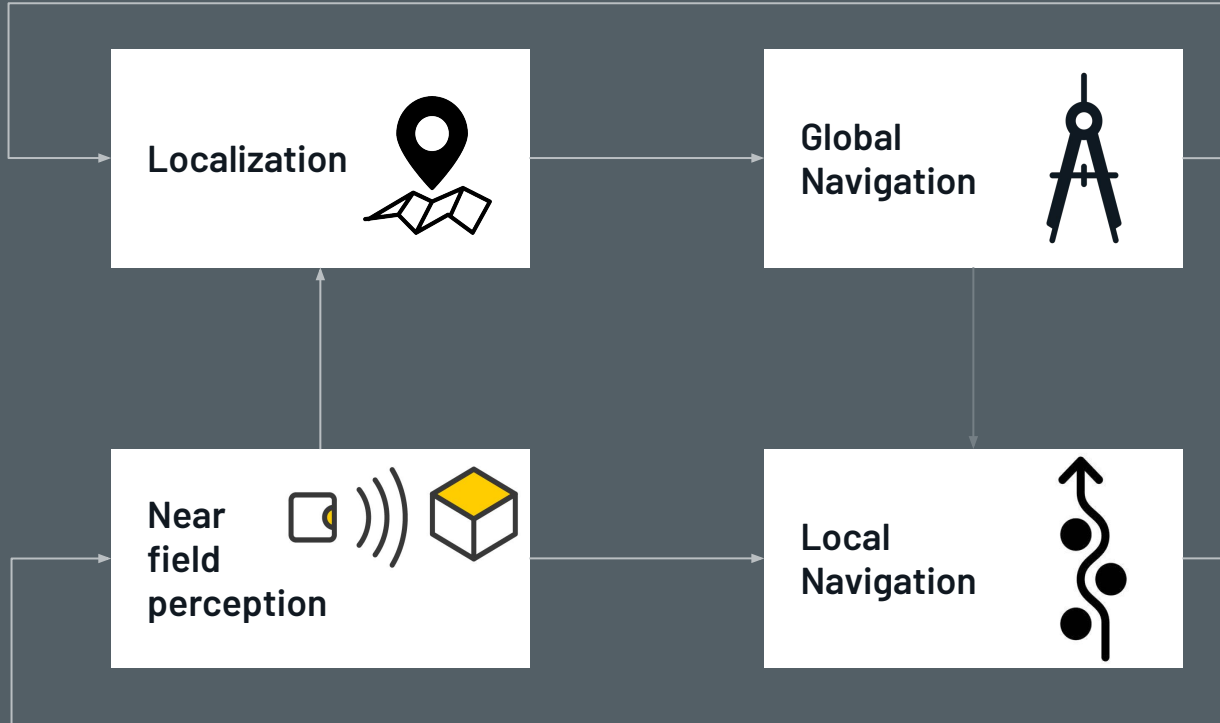


✓ Real Robot

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



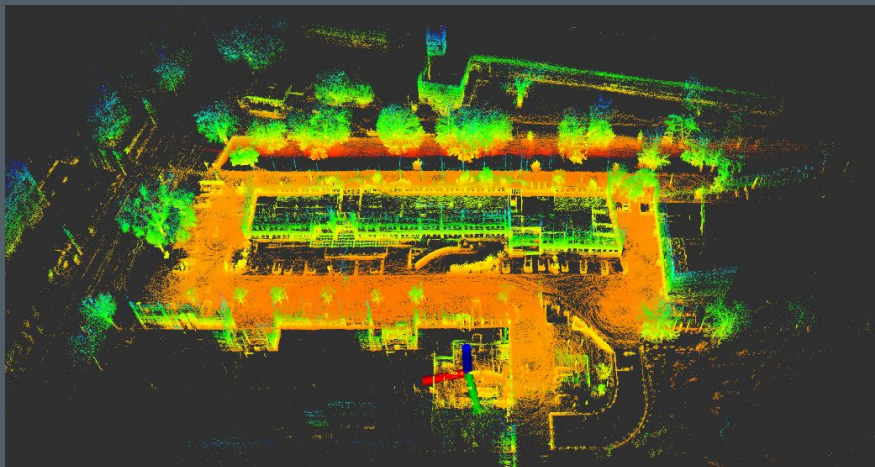
More Sense-Think-Act



Simultaneous Localization & Mapping

✓ Point Cloud based SLAM

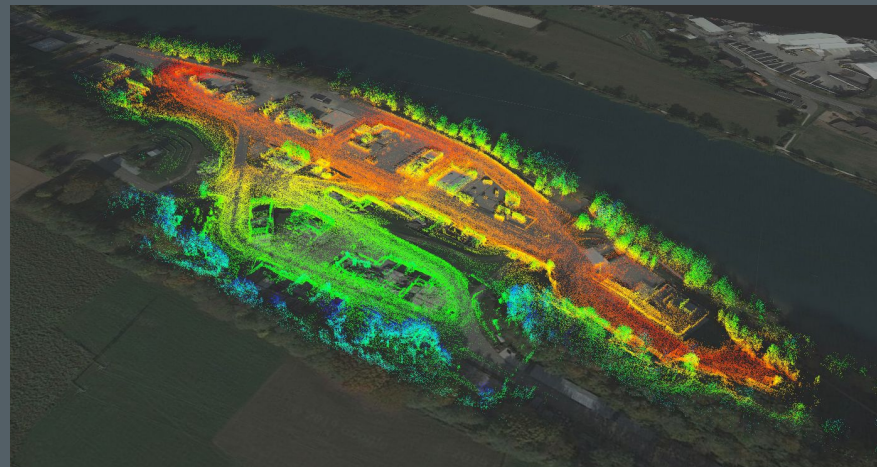
LIDAR and depth sensors are used to generate a map and localize within the map.



Hagenholz, Oerlikon

✓ Scalable

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

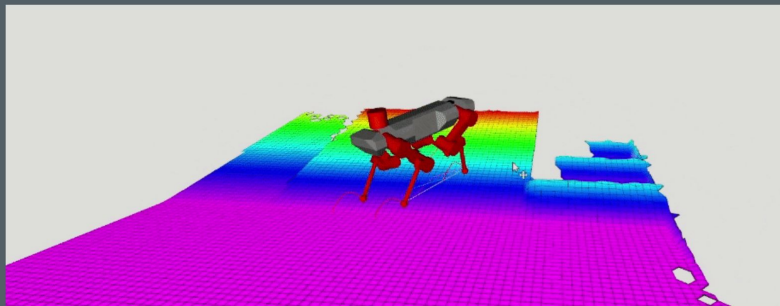


Wangen an der Aare

Terrain Mapping

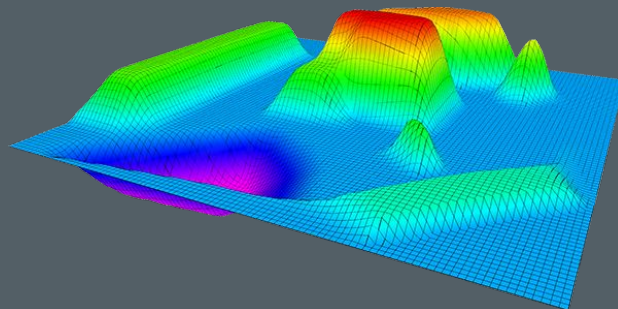
✓ Elevation Mapping

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.

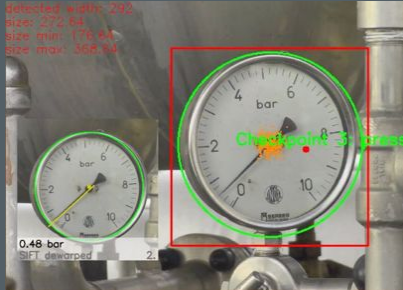


Path Follower

Regularly Collect and Interpret Physical Properties of Equipment and Environment

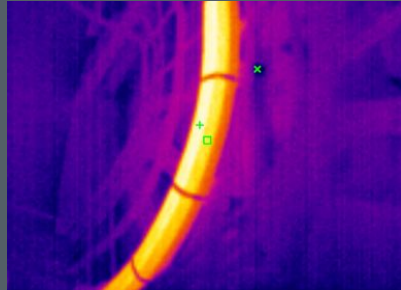
Reading Instruments

GAUGES VALVES COUNTERS
PHOTO



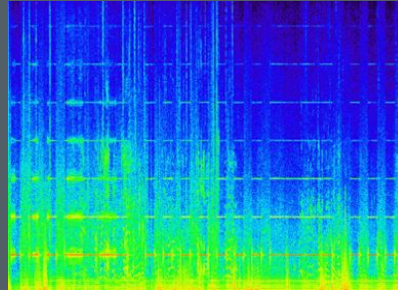
Detecting Events

THERMOGRAPHY ACOUSTIC LABELS
LEAKAGES MISSING PARTS



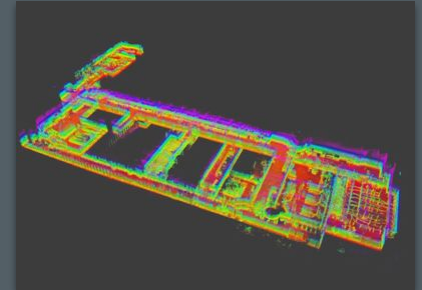
Checking Health of Equipment

HOTSPOTS GASES ALARMS
TEMPERATURES



Monitoring Environments

3D MAPPING ESCAPE ROUTES
EQUIPMENT HUMANS



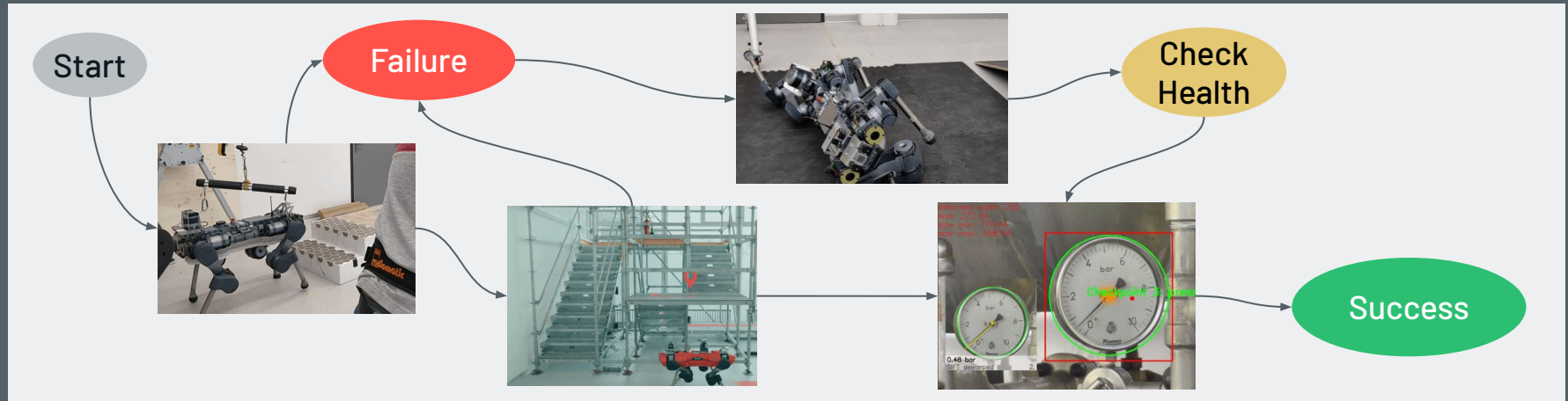
Factory Automation

✓ 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.

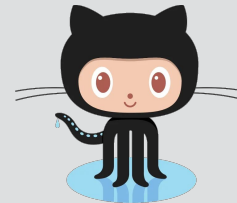


✓ Code Sharing

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



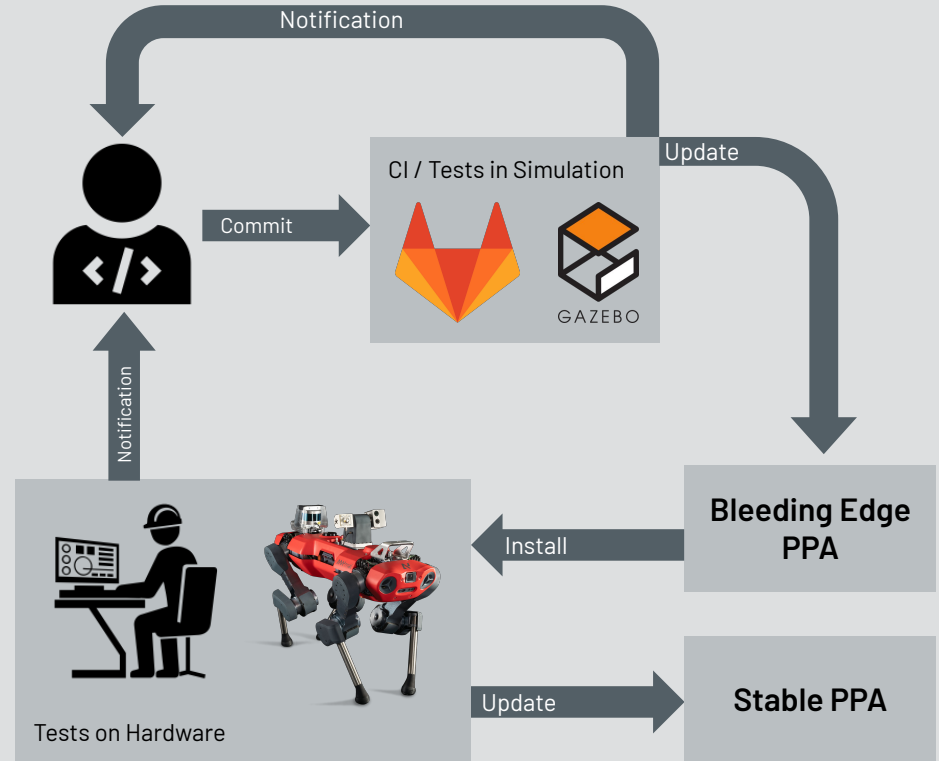
GitLab



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

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
8. Contribute

📄 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

Research From Oxford Dynamic Robot Systems Group appearing at International Conference on Robotics and Automation (ICRA 2020) in Paris



Preprints: <https://ori.ox.ac.uk/labs/drs/drs-publications/>



Hide





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