

ROS in der vernetzten Produktion (15 June 2021)

ROS in Robotics at Bosch

Dr. Ralph Lange

Bosch Corporate Research

Introducing Myself

Dr. Ralph Lange

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github.com/ralph-lange



- ▶ Senior project manager for robotics systems and software engineering at Bosch Corporate Research
- ▶ Following and contributing to development of ROS 2
- ▶ Supporting Bosch business units on use of ROS
- ▶ Principal investigator in EU-funded project on micro-ROS

Robotics Products: Consumer

Indego

- ▶ Only robotic mower with intelligent navigation
- ▶ Market entry 2014



Roxxter

- ▶ SLAM-enabled vacuum robot
- ▶ Persistent mapping, annotations via App
- ▶ Telepresence
- ▶ Market entry 2019



eStroller

- ▶ Force-assisted baby stroller
- ▶ Emmaljunga NXT90e
- ▶ Market entry 2021



Mykie

- ▶ CES 2017
- ▶ Countertop kitchen robot. Smart home hub
- ▶ Concept



Robotics Products: Manipulation

APAS

- ▶ Collaborative robot
- ▶ Safety-certified contact-free person detection
- ▶ Fanuc, KUKA inside
- ▶ Since 2015



Smart Flex Effector

- ▶ Sensor-supported compliance module in 6 dofs
- ▶ Very accurate and sensitive manipulation e.g., peg-in-hole tasks
- ▶ Market entry 2021



Smart Item Picker

- ▶ Model-free manipulation for order picking and placing
- ▶ Building kit: choose arm, sensor, gripper, etc.
- ▶ Market entry 2022



Robotics Products: Service

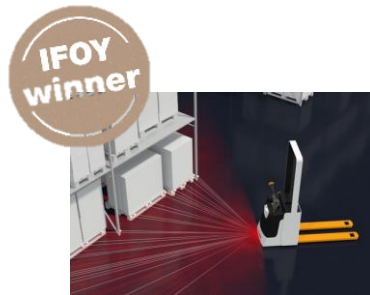
ActiveShuttle

- ▶ SLAM-enabled intralogistics transportation platform for stacks of boxes
- ▶ Comes in fleets
- ▶ Since 2020



Locator

- ▶ Award-winning cm-accurate SLAM-based localization SW
- ▶ For intralogistics, manufacturing
- ▶ Since 2019



Container AGV

- ▶ Container port AGV
- ▶ Robust, life-long SLAM for 24/7 year-round operation
- ▶ cm-accuracy
- ▶ Concept



People Mover

- ▶ Mobility services with fleets of autonomous shuttles
- ▶ L5 in restricted areas
- ▶ Concept



Robotics Excellence – Selection of Recent Publications

ICRA 2020

- ▶ *Accurate Detection And 3D Localization Of Humans Using A Novel Yolo-based RGB-D Fusion Approach And Synthetic Training Data*, T Linder, KY Pfeiffer, N Vaskevicius, R Schirmer, KO Arras
- ▶ *An NMPC Approach Using Convex Inner Approximations For Online Motion Planning With Guaranteed Collision Avoidance*, T Schoels, L Palmieri, KO Arras, M Diehl

IROS 2020

- ▶ *Plug-and-Play SLAM: A Unified SLAM Architecture for Modularity and Ease of Use*, M Colosi, I Aloise, T Guadagnino, D Schlegel, B Della Corte, KO Arras, G Grisetti
- ▶ *Learning and Sequencing of Object-Centric Manipulation Skills for Industrial Assembly Tasks*, L Rozo, M Guo, AG Kupcsik, M Todescato, P Schillinger, M Gifftthaler, M Ochs, M Spies, N Waniek, P Kesper, M Buerger
- ▶ *Sample-Efficient Learning for Industrial Assembly using Qgraph-bounded DDPG*, S Hoppe, M Gifftthaler, R Krug, M Toussaint

IEEE RA Letters 2020

- ▶ *THÖR: Human-robot Navigation Data Collection And Accurate Motion Trajectories Dataset*, A Rudenko, TP Kucner, CS Swaminathan, RT Chadalavada, KO Arras, AJ Lilienthal, 5(2)

IEEE Transactions 2020

- ▶ *MeTRAbs: Metric-Scale Truncation-Robust Heatmaps for Absolute 3D Human Pose Estimation*, I Sárándi, T Linder, KO Arras, B Leibe, IEEE Transactions on Biometrics, Behavior, and Identity Science, 3(1)

NeurIPS 2020

- ▶ *High-Dimensional Bayesian Optimization via Nested Riemannian Manifolds*, N Jaquier, L Rozo

CVPR 2020

- ▶ *Multi-path learning for object pose estimation across domains*, M Sundermeyer, M Durner, EY Puang, ZC Marton, N Vaskevicius, KO Arras, R Triebel

IJRR 2020

- ▶ *Human Motion Trajectory Prediction: A Survey*, A Rudenko, L Palmieri, M Herman, KM Kitani, DM Gavrila, KO Arras, 39(8)
- ▶ *Geometry-aware manipulability learning, tracking, and transfer*, N Jaquier, L Rozo, DG Caldwell, S Calinon, 40(2)

CORL 2020

- ▶ *Action-Conditional Recurrent Kalman Networks For Forward and Inverse Dynamics Learning*, V Shaj, P Becker, D Buchler, H Pandya, N van Duijkeren, CJ Taylor, M Hanheide, G Neumann

FG 2020

- ▶ *Metric-scale truncation-robust heatmaps for 3D human pose estimation*, I Sárándi, T Linder, KO Arras, B Leibe

IFAC 2020

- ▶ *CIAO*: MPC-based Safe Motion Planning in Predictable Dynamic Environments*, T Schoels, P Rutquist, L Palmieri, A Zanelli, KO Arras, M Diehl

Classes of Use of ROS

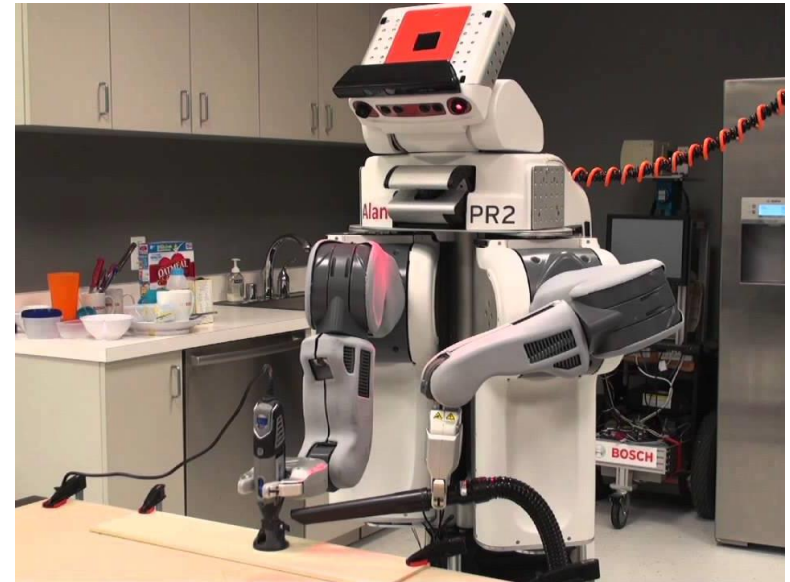
Research and
advance development

Development
tool and environment

Middleware and
framework in
product software

ROS in Research and Advance Development

- ▶ Bosch has long history with ROS
 - ▶ ... as the only industrial participant in PR2 beta program
- ▶ First use in fundamental research in service robotics and autonomous driving
- ▶ Classic ROS offers hundreds of open-source packages for all aspects of robotics, but of varying quality

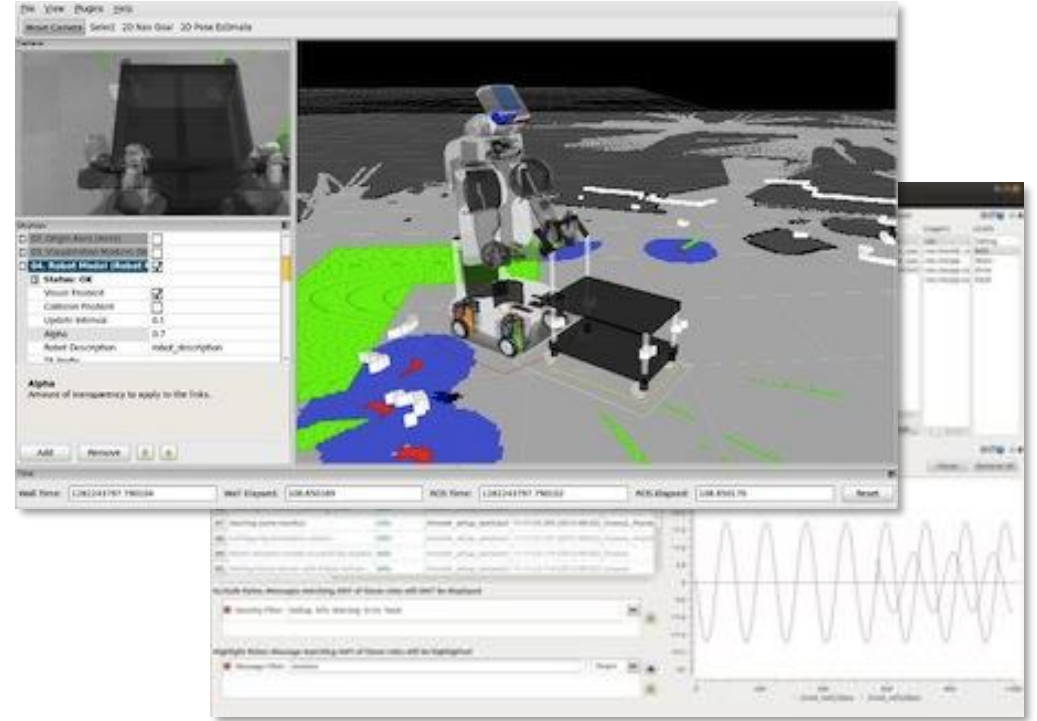


<https://spectrum.ieee.org/automaton/robotics/robotics-software/the-origin-story-of-ros-the-linux-of-robotics>

ROS software ecosystem and tools accelerate prototyping significantly

ROS as Development Tool and Environment

- ▶ ROS comes with several tools for data recording and visualization
 - ▶ Open-source and commercial solutions for large-scale data storage and management
- ▶ De-facto standardized message types ensure long-term compatibility
- ▶ ROS used in various projects for system testing
 - ▶ ... including control of test setup and measurement system

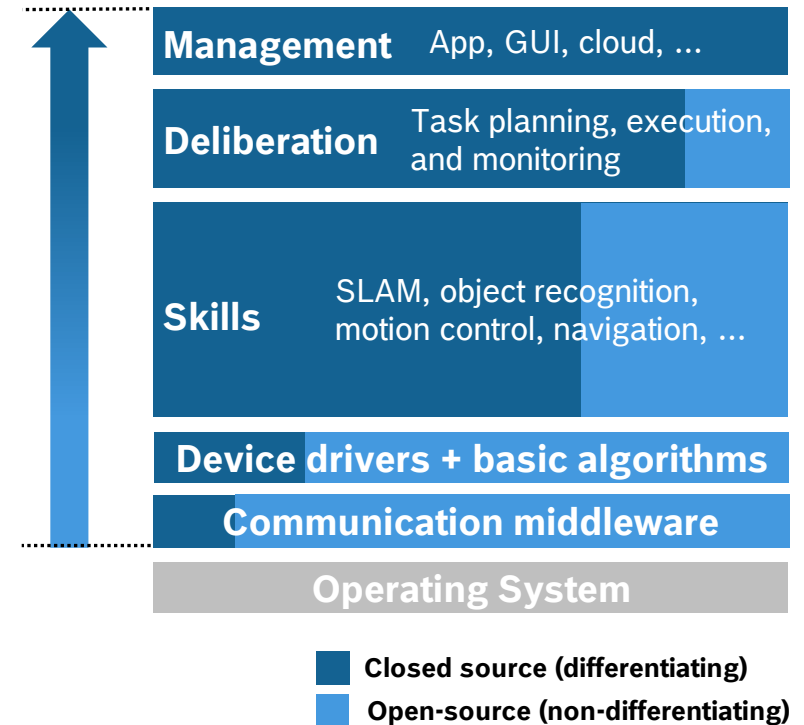


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ROS tools facilitate system testing and data analysis

ROS as Middleware and Framework in Product Software

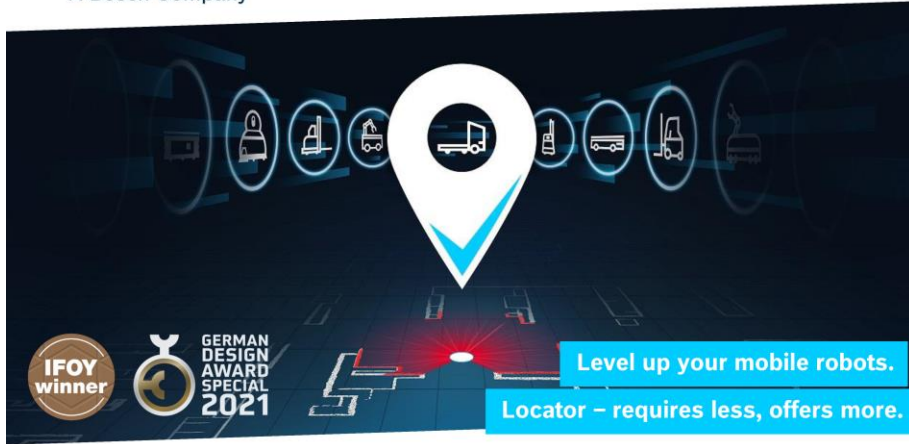
- ▶ ROS 2 has paved the way for professional use
 - ▶ Proven middleware standard DDS with security
 - ▶ Well-defined quality assurance, cf. [REP-2004](#)
 - ▶ Application-level stacks for mobile robotics ([Navigation2](#)) and manipulation ([MoveIt](#)) available
- ▶ Great technical foundation for internal SW reuse
- ▶ Of course, there are also shady sides
 - ▶ Transition to ROS 2 is slow – industry goes ahead
 - ▶ Open issues in execution management
 - ▶ Pure open-source ROS stack is not safety certified



ROS increases development efficiency and fosters SW reuse

ROS as Middleware and Framework in Product Software

rexroth
A Bosch Company



ROS interface to the Rexroth ROKIT Locator
at github.com/boschglobal/locator_ros_bridge



www.ctrlx-automation.com

ROS 2 control and other ROS packages on
ctrlX CORE using snap container technology

ROS compatibility attracts new customers

Contributions by Bosch to ROS



Bosch participates in PR2 beta program



Founding member of ROS-I Europe



Bosch sponsors development of ROS 2



Founding member of ROS TSC

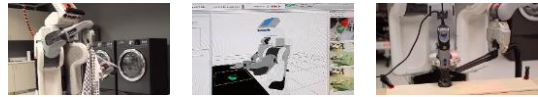


EU project micro-ROS

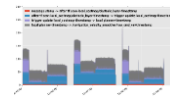


EU ITP MROS

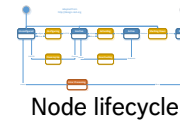
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021



Tools and basic algorithms from PR2 beta program



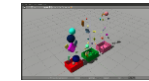
Tracepoints



Node lifecycle



rosbag tool



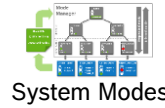
pcg_gazebo



ros2_control



Client library for C



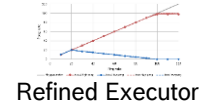
System Modes



Middleware adapter



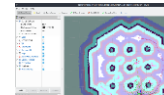
fmi_adapter



Refined Executor



UUV simulator

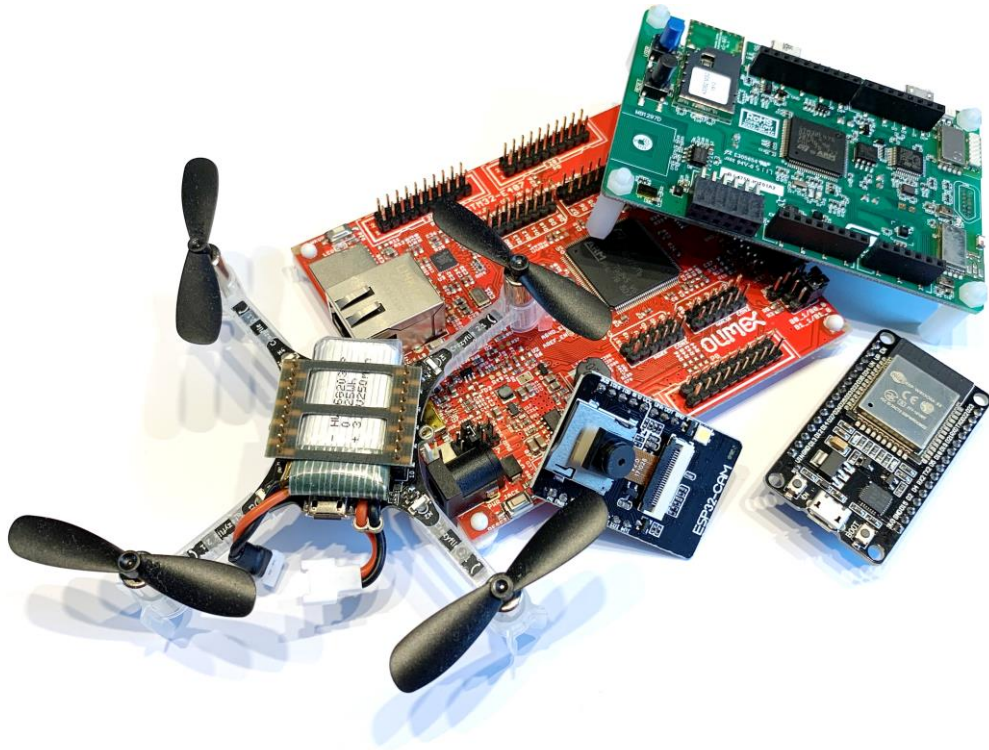


rviz2

+ dozens of talks, tutorials, and exhibitions
+ regular sponsoring of developer conferences

Give-and-take basis • Helped to shape the core architecture

Microcontrollers in Robotics



- ▶ **Hardware access**
- ▶ **Hard, low-latency real-time**
- ▶ **Power saving**
- ▶ **Safety**

“micro-ROS puts ROS 2 onto microcontrollers”

EU-funded project OFERA bridges the gap between microcontrollers and larger processors by

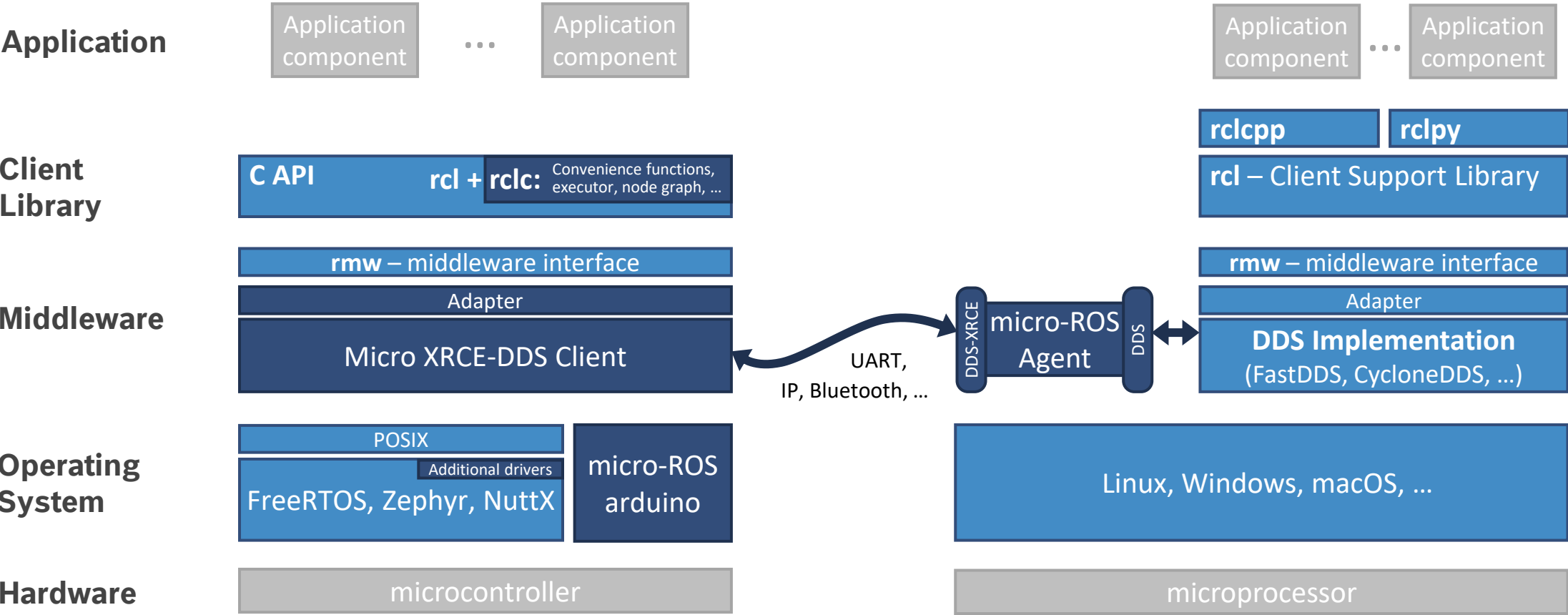


- ▶ Seamless integration of μ Cs with ROS 2
- ▶ Ease portability of ROS 2 code to μ Cs
- ▶ Ensure long-term maintenance of micro-ROS stack



The OFERA project is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 780785

micro-ROS Architecture




micro-ROS | ROS 2 for microc... X

https://micro.ros.org

micro-ROS Overview Concepts Tutorials API Blog


Search via Lunr.js

»micro-ROS puts ROS 2 onto microcontrollers«



Mission

Bridging the gap between resource-constrained microcontrollers and larger processors in robotic applications that are based on the Robot Operating Systems.




Key Features

- ✓ Microcontroller-optimized client API supporting all major ROS concepts
- ✓ Seamless integration with ROS 2
- ✓ Extremely resource-constrained but flexible middleware
- ✓ Multi-RTOS support with generic build system
- ✓ Permissive license
- ✓ Vibrant community and ecosystem
- ✓ Long-term maintainability and interoperability

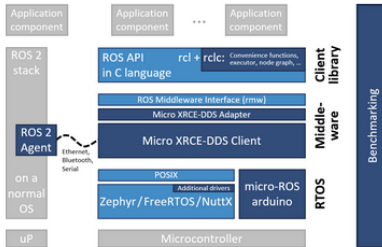
Getting Started

Our [tutorials](#) and [demos](#) give you a quick start with micro-ROS. The [basic tutorials](#) can even be completed without a microcontroller.



Architecture

The [architecture of the micro-ROS stack](#) follows the ROS 2 architecture. Dark blue components are developed specifically for micro-ROS. Light blue components are taken from the standard ROS 2 stack.



Why Microcontrollers?

Microcontrollers are used in almost every robotic product. Typical reasons are:

- Hardware access
- Hard, low-latency real-time
- Power saving

Another important reason is safety, but note that micro-ROS is not developed according to any safety standard.

Source Code

Source code can be found at github.com/micro-ROS. It comes under the permissive license Apache 2.0 just as the standard ROS 2 stack.

The primary repository is `micro_ros_setup`, which provides command line scripts for creating your first micro-ROS application.

Developed an new feature or found a bug? We answer both pull requests and tickets.

News Questions

Looking forward to your questions!

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