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ROS机器人操作系统在工业实时环境的发展应用

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机器人开发面临的问题

- 机器人应用如此广泛, 却如此复杂
  - 串并联机器人/无人机/移动机器人/夹具/导航/视觉/力控
- 创建实体机器人非常困难
  - 机器人学传统属于机械学科,但现在已经成为机械/自动化/计算机的融合学科.
  - 算法和控制在机器人领域所占比重越来越大,却无法摆脱实体机器人的束缚
  - 实体与虚拟世界差异巨大(Gap between reality and simulation)
- MATLAB robotics toolbox提供了一些功能,但远远不够
- 机器人行业已经有大量研发基础,需要整合,进化:传感器,路径规划,视觉,避障
- 行业研发人员需要快速开发,部署原型

设计目标

- 将硬件功能标准化,抽象化,统一驱动接口
- 通过系统快速实现对底层硬件的控制
- 跨进程组件模型及消息传递机制
- 强大的编译环境
- 调试和虚拟仿真验证工具
- 硬件/操作系统的跨平台能力
  - Windows
  - Android
  - QNX

机器人系统软件构成-1

1. 实时环境: Linux/Windows/Sylix/Vxworks
2. 现场总线:EtherCAT/TSN/CCLink/Profinet/RTEX
3. 硬件接口(Hardware API):

   -适配各类传感器(视觉,力控等),

   -提供驱动层接口

   -适配伺服驱动器,通讯端子
4. 运动控制(Motion Control): 符合PLCOpen标准(单轴/轴组)
5. 机器人控制(Robot Control):

   -基于机器人模型的动力学,运动学控制算法,并且可以提供定制化接口
6. 运动规划(Planning):基于视觉等外部传感器的高级规划功能
7. 人工智能(Deep Learning):深度学习/强化学习等框架的调用平台

机器人系统软件构成-2

8. 端云协同:与云计算平台(Aliyun,AWS)结合
9. 机器人语言: 机器人指令集
   -机器人控制
   -支持模块化编程
   -支持解释执行和编译执行
   -支持倒序执行/任意行执行
   -支持指令预取及优化/运动轨迹前瞻
   -IDE开发环境
10. 外部调用接口:ROS Python C/C++ Java
11. 仿真平台:matlab,labview,gazebo
12. 逻辑控制: IEC-61131-3 softPLC
13. 功能安全: IEC61508(主动安全,被动安全)

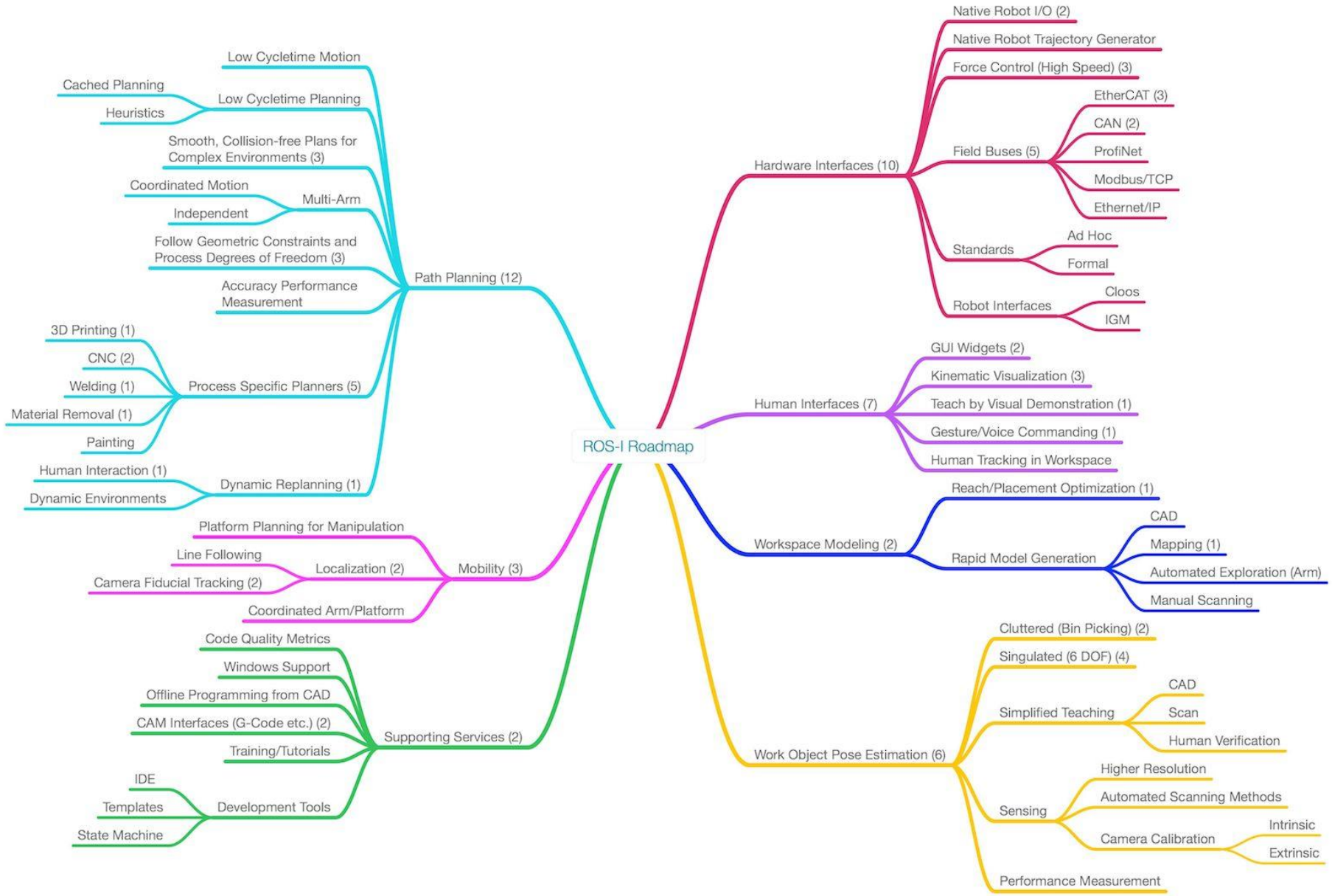
ROS: Robot operation system

- 设计一套开放机器人控制系统成为机器人行业的共同目标.
- 积累较多的商业化公司不愿意做开放平台-既得利益
- 机器人行业没有Google这样的巨头推动
  - 利益不够大,行业太分散
- 学术界先行, 2007年推出ROS系统,在Linux基础上整合众多开源项目,获得了最广泛的支持,成为业界最普及的机器人开发平台
- ROS在开发过程中暴露了越来越多的问题,因此出现ROS2(ROS-Industrial)
- 未来是否可能将商业化软件与ROS/ROS2有机结合? 这是ROS2产业化的先决条件
  - 产业界是利润驱动的,没有利益分享机制,就不会取得商业成功
  - 产业界欢迎开放平台去打破现有利益格局
  - 开放平台对创业公司和零部件公司更有利.

ROS ：高质量的机器人开发平台

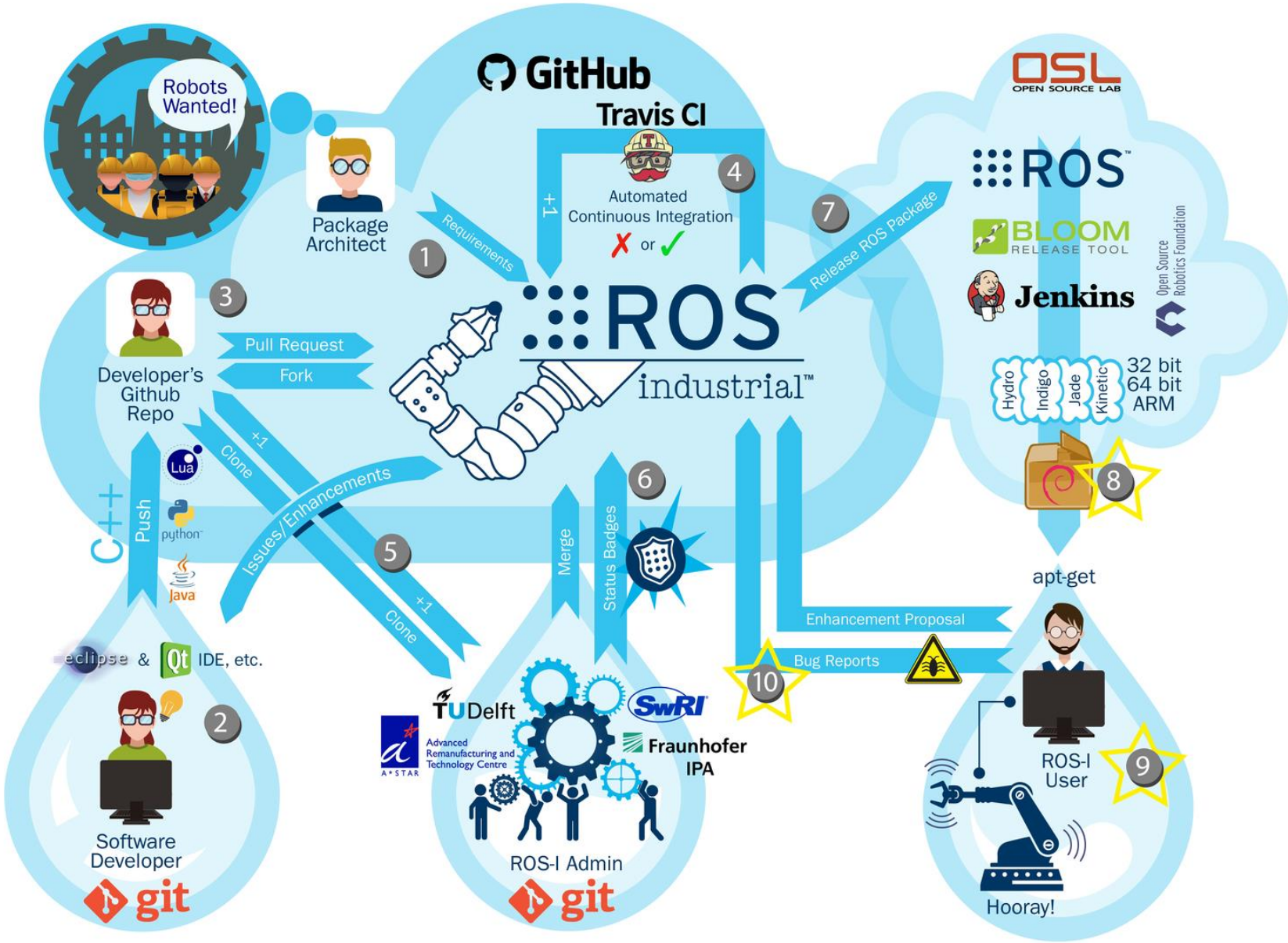
- 很多机器人产品都已经开始支ROS
  - Robotiq’s robot grippers,
  - MARA’s robot arm
  - Robonaut 2 of NASA :laboratory applications, field tests and implementations within the International Space Station.

ROS-I Roadmap



1. **Hardware Interfaces:** new interfaces to other robot contorllers, sensors and actuators
2. **Human Interfaces:** new ways to interact with humans by "traditional" means such as graphical interfaces or non-traditional means such as gesture commanads
3. **Workspace Modeling:** rapid generation of environement models and how to configure the robot within those environments
4. **Work-Object Pose Estimation:** identification and locating known objects in unknown locations (unstructured)
5. **Path Planning:** determining optimal motion plans for a robot manipulator while obeying process constraints
6. **Mobility:** topics unique to mobile platforms including localization and navigation
7. **Support Services:** developer and user support such as training and documentation

ROS-I开发流程


Robots Wanted!
Package Architect
GitHub
Travis CI
Automated Continuous Integration
✗ or ✓
Requirements
+1
1
4
7
Release ROS Package
OSL
OPEN SOURCE LAB
ROS
BLOOM
RELEASE TOOL
Jenkins
Open Source Robotics Foundation
Hydro
Indigo
Jade
Kinetic
32 bit
64 bit
ARM
8
3
Developer's Github Repo
Pull Request
Fork
ROS industrial™
C++
Push
Lua
python
Java
+1
Clone
Issues/Enhancements
5
+1
Clone
Merge
Status Badges
6
apt-get
Enhancement Proposal
Bug Reports
10
eclipse & Qt IDE, etc.
2
Software Developer
git
TUDelft
Advanced Remanufacturing and Technology Centre
A*STAR
SwRI
Fraunhofer IPA
ROS-I Admin
git
ROS-I User
9
Hooray!

ROS-I成员


3M
ABB ROBOTICS
ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE
ADLINK
AEROBOTIX
AFMANTECH
UNITED STATES AIR FORCE
ALIAS ROBOTICS
Robot Cybersecurity
ARC SPECIALTIES
arm
ARM
aws
Advanced Remanufacturing and Technology Centre
ARTC
AmstedRail
Bastian SOLUTIONS
BOEING
BOSCH
BMW
CAT
COGNICEPT
DELTA
FH AACHEN
UNIVERSITY OF APPLIED SCIENCES
Fraunhofer IML
Fraunhofer IPA
Fraunhofer IPK
FZI
Georgia Tech Research Institute
GTRI.gatech.edu
GLIDEWELL LABORATORIES
HARTING
automotive engineering
iav
infineon
INESCTEC
intel
JOANNEUM RESEARCH
JOHN DEERE
Johnson&Johnson
LELY
KEBA
Automation by innovation.
KONICA MINOLTA
KYOCERA
LINCOLN ELECTRIC
AUTOMATION
MAGNA
MathWorks
Microsoft
NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE
NIST
National Institute of Standards and Technology
U.S. Department of Commerce
NOV
NRC·CNRC
THE UNIVERSITY OF TEXAS AT AUSTIN
Nuclear Robotics Group
OMRON
open robotics
THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING
Panasonic
PEPPERL+FUCHS
PICKNIK
PILZ
PLUS ONE ROBOTICS
PPM
PUSHCORP, INC.
DALLAS, TEXAS
Rensselaer
CATS
Center for Automation Technologies and Systems
rethink robotics
part of the HAHNGROUP
REPUBLIC POLYTECHNIC
SAXION
HOGESCHOOL
SEC
SCHAEFFLER
SIAA
SIEMENS
SINGAPORE POLYTECHNIC
SP
SPIRIT AEROSYSTEMS
SURFACE
SwRI
synaptiCAD
TREND MICRO
TARDEC
TDS
TORMACH
traclabs
T··Systems·
Let's power higher performance
TU Delft
ubuntu
Delivered by Canonical
UNIVERSAL ROBOTS
VOLVO
VOLVO GROUP
Woodside
YASKAWA
YOKOGAWA

Path planning library

•MoveIt!: The MoveIt! framework is actually a higher level construct that provides the facilities for various path planning codes.

•OMPL: OMPL is library of sampling-based planners that are the defaults for ROS.

•SBPL: The search-based planning library is a graph search framework.

•OpenRave: OpenRave is a full environment for planning and simulation including a plug-in architecture for other codes.

•CHOMP: Optimization based planners.

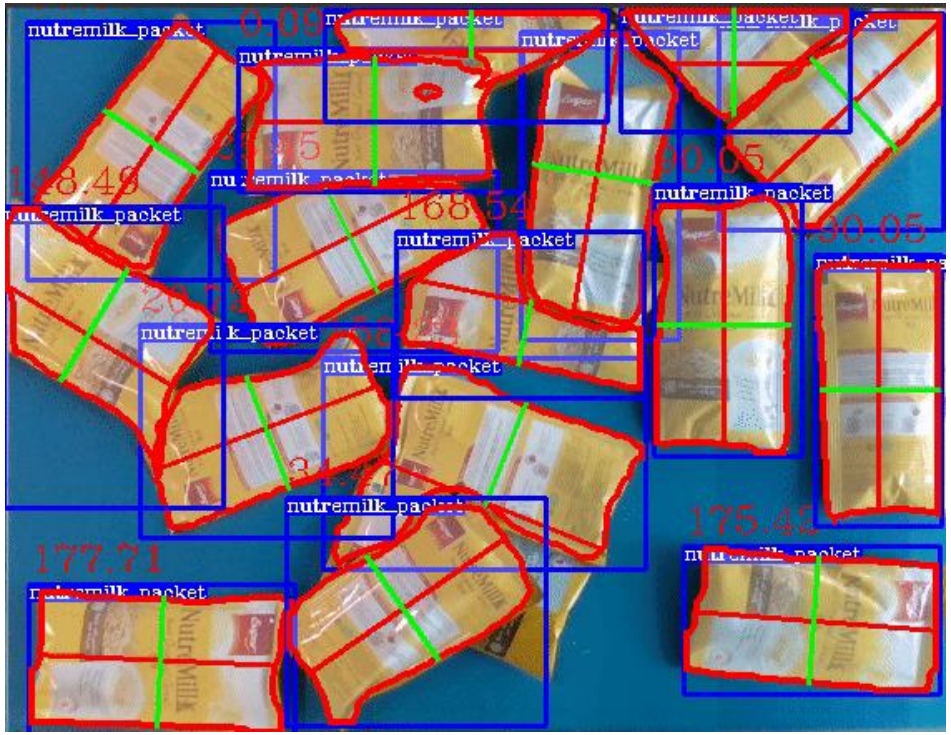
•Orocos/KDL: Orocos is a larger framework for robot control including state estimation and realtime components. KLDL provides kinematics solvers including trajectory planners.

Mobility

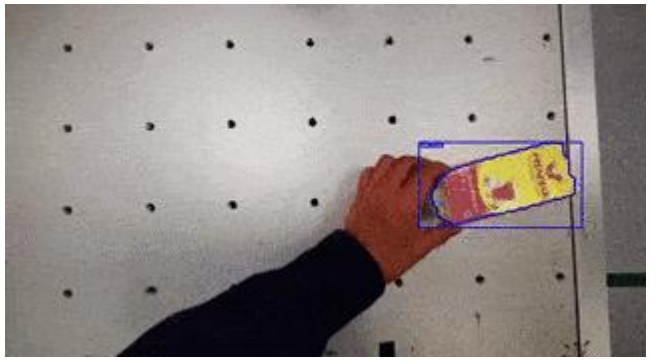
- Gmapping
- Hector SLAM
- RTAB-MAP (RGB-D SLAM)
- RATSLAM

ROS Package: Easy_perception

- GitHub - ros-industrial/easy_perception_deployment:
- 用于CV模型在工业环境快速部署和训练的ROS2软件包



EPD



Goals of ROS 2

Support multi-robot systems
involving unreliable networks

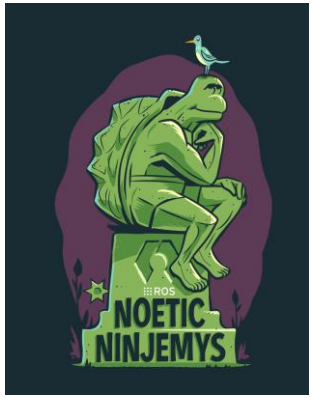
Remove the gap between
prototyping and final products

“Bare-metal”
micro controller

Support for
real-time control

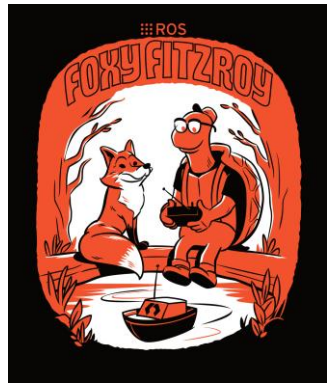
Cross-platform
support

ROS1/ROS2



ROS1

ROS1	ROS2
基于匿名publish-subscribe 模式构建 新硬件接入困难	基于DDS : Data Distribution System 硬件Node可独立开发
没有跨平台,只有ubuntu	跨平台windows/linux/mac
框架过于灵活,没有限制	
缺乏实时性	DDS QoS
稳定性差,距离产品化过于遥远	面向生产环境
PC环境	适用于小型嵌入式环境
要求良好的网络环境	允许网络中断与延时
不支持多机模式	支持多机

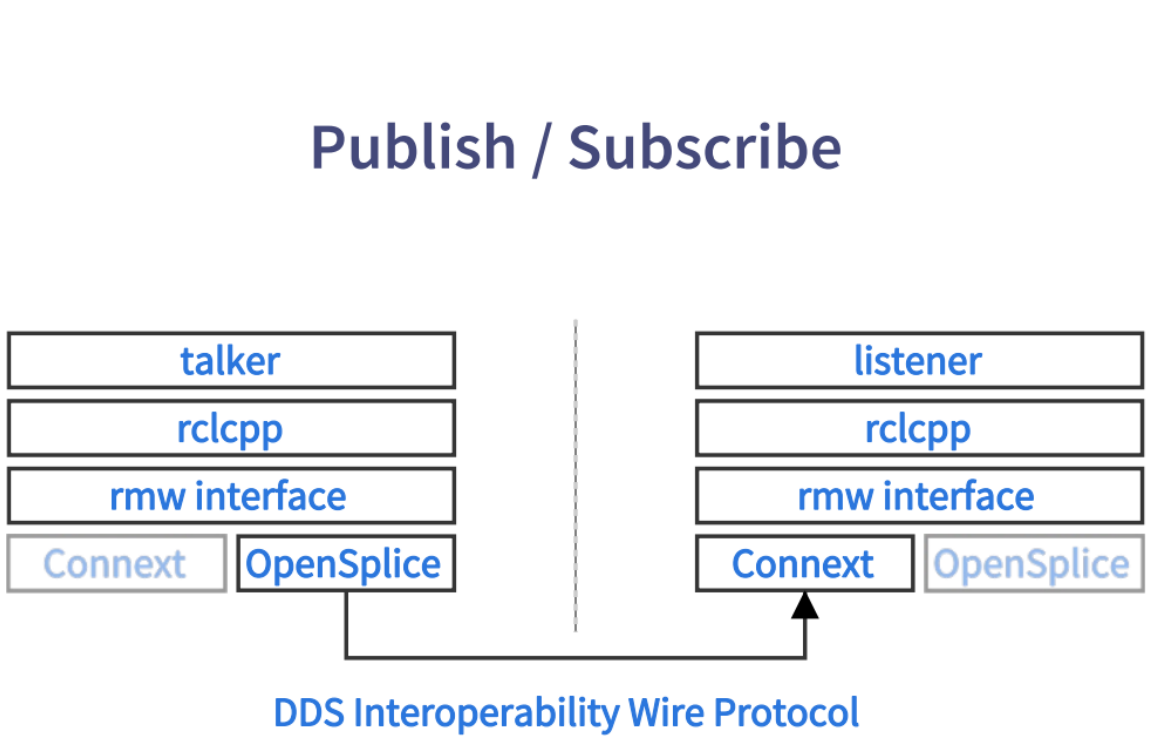


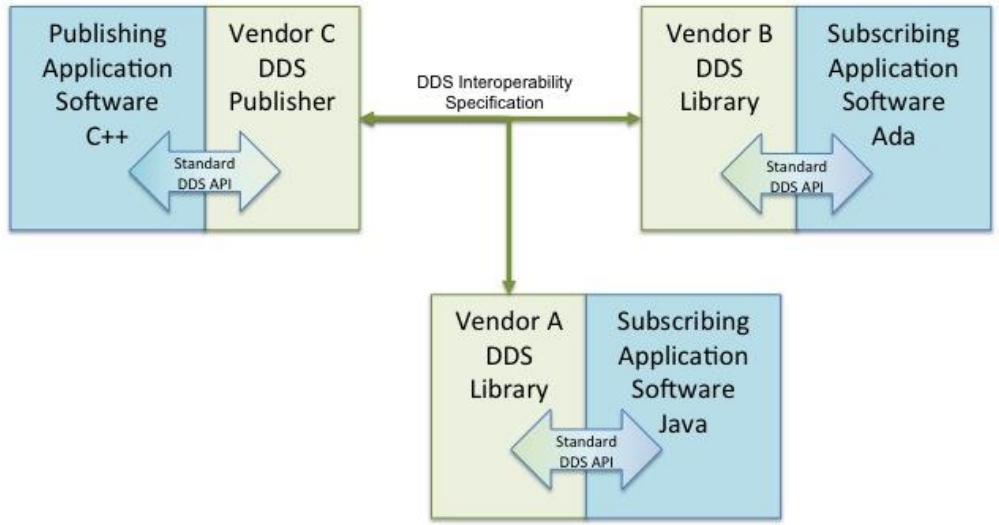
ROS2

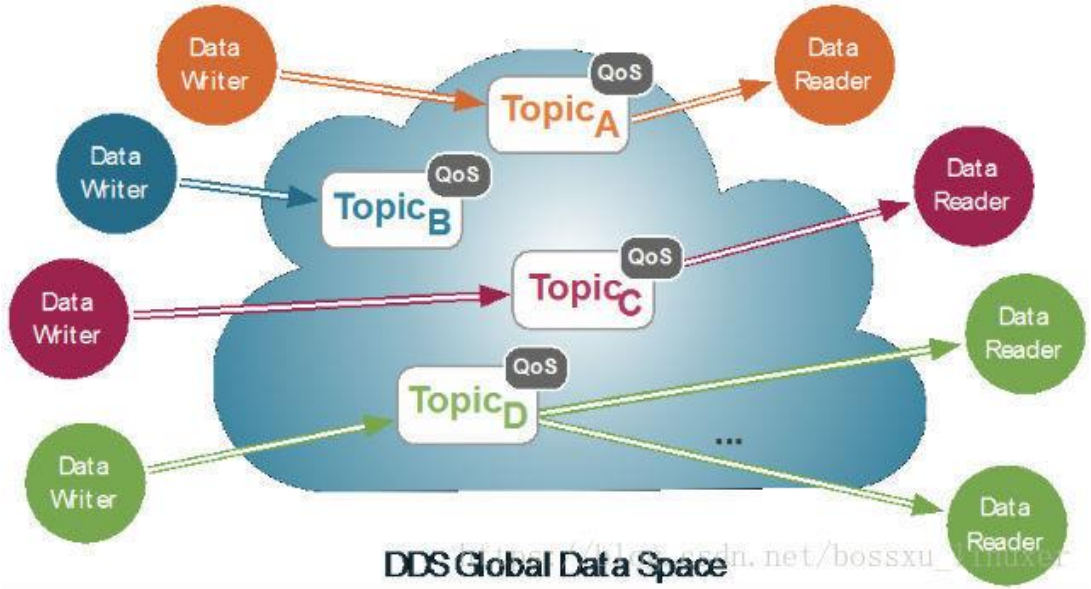
结论: ROS继续用于科研领域　ROS2才有可能解决产品化问题

DDS组件模型介绍

- End to End solution







DDS改变ROS驱动开发模式

ROS

- Master是ROS的中心节点, 消息必须被master转发

- 基于自定义的XML-RPC消息序列化传输机制, 重复封装/解封

- 耦合性太强

ROS2基于DDS,不再需要ros-master做中转;

- 每个node可以独立开发

ROS2- 实时计算环境

- 实时环境几大特性: 在确定的时间完成确定的计算
  - 执行时间可被精确量化与控制(线程/进程/存储调度)
  - Deadline: 实时Task的执行时间窗口
  - Quality of Service: 网络质量.包括bandwith, throughput, availability, jitter, latency, and error rates.

实时系统分类

- 实时系统: 在确定的时间,在确定的周期内执行任务
- 硬实时: 错过deadline视为系统错误
  - airplane sensor and autopilot systems, spacecrafts and planetary rovers.
- 软实时: 错过deadline不认为系统失效
  - audio and video delivery software for entertainment (lag is undesirable but not catastrophic).
- 严格实时(Firm real-time)
  - 错过deadline不认为系统失效,会降低系统QoS,类似软实时
  - Financial forecast systems, robotic assembly lines
- 低时延系统: 实时系统与低时延系统没有关系. 实时系统必须确保在指定时间运行的能力,并在确定时间内完成任务,因此运行时延必须是可测量,可控制的.

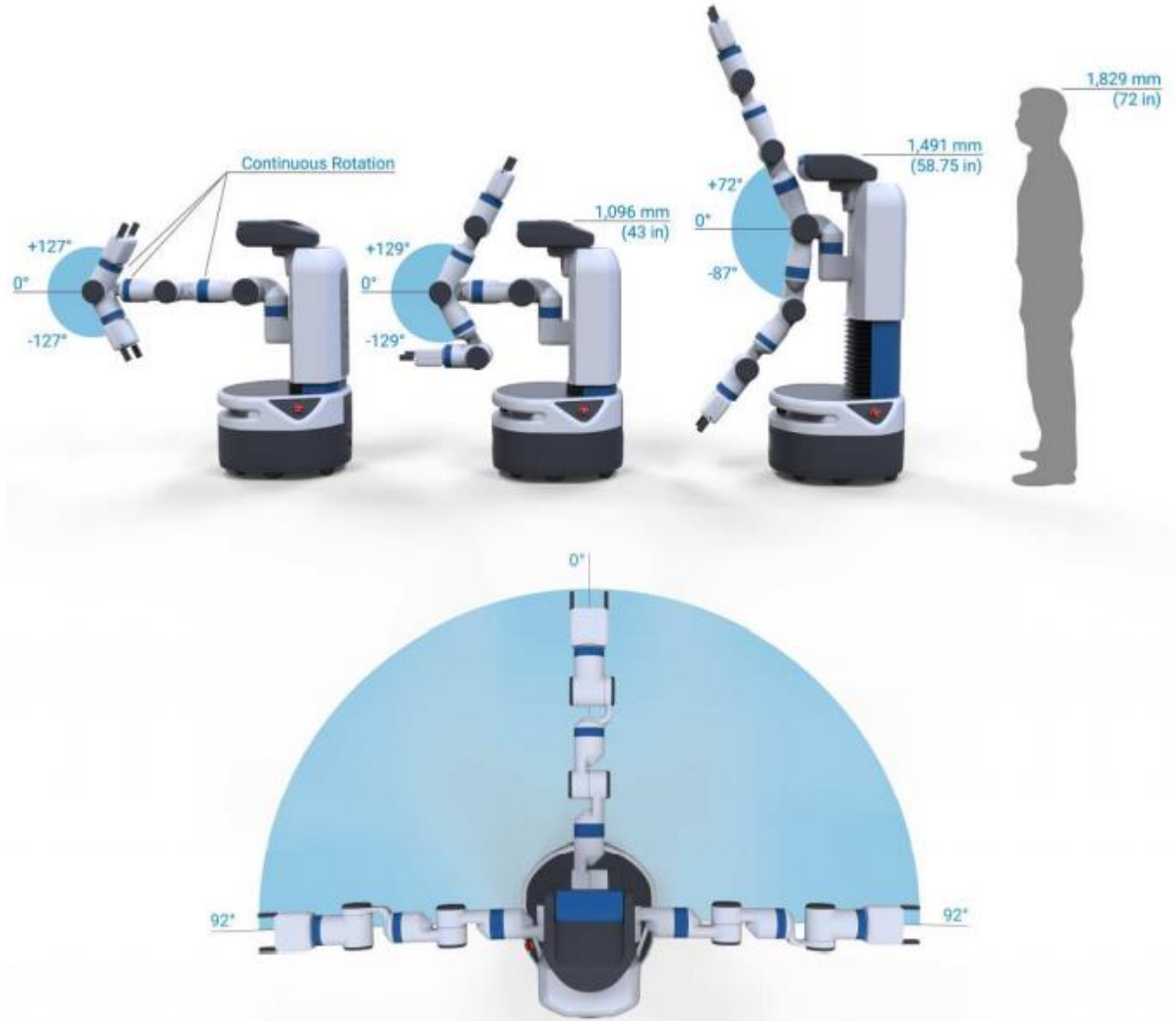
机器人主流实时操作系统

- The RT_PREEMPT Linux kernel patch
- Sylix
- Vxworks
- Xenomai, a POSIX-compliant co-kernel (or hypervisor)
  - The Linux kernel is treated as the idle task of the real-time kernel's scheduler (the lowest priority task).
- RTAI, an alternative co-kernel solution.
- QNX Neutrino, a POSIX-compliant real-time operating system for mission-critical systems
- Windows with RT extension
  - Intime/Ontime…

基于ROS的机器人

- 大部分ROS机器人应用都是移动机器人,无人机等.
- 机械臂厂家只提供ROS接口, 如ABB/UR等, 但控制系统实现并不基于ROS

Fetch Robotics



ADLink ROSCube AMR

Hardware

LiDar
Motor
Camera
Sensor
Arm
.....

Tool

Rviz Nodegraph
RQT TF monitor
Catkin

ROScube BSP

Unified
hardware API

Optimized ROS2 Core

QoS
- History
- Depth
- Reliability
- Durability
- Ownership
- Transport Priority

Event handler improvement

ROS/ROS 2.0

ADLINK Neuron SDK

Simulation

Gazebo
AWS RoboMaker
Microsoft Azure

GAZEBO

Azure

AWS RoboMaker

Library Tool

OpenNI
OpenSLAM
OpenCV
OMPL
PCL
MoveIt
.....

OpenSLAM
Give your algorithm to the community

OpenCV

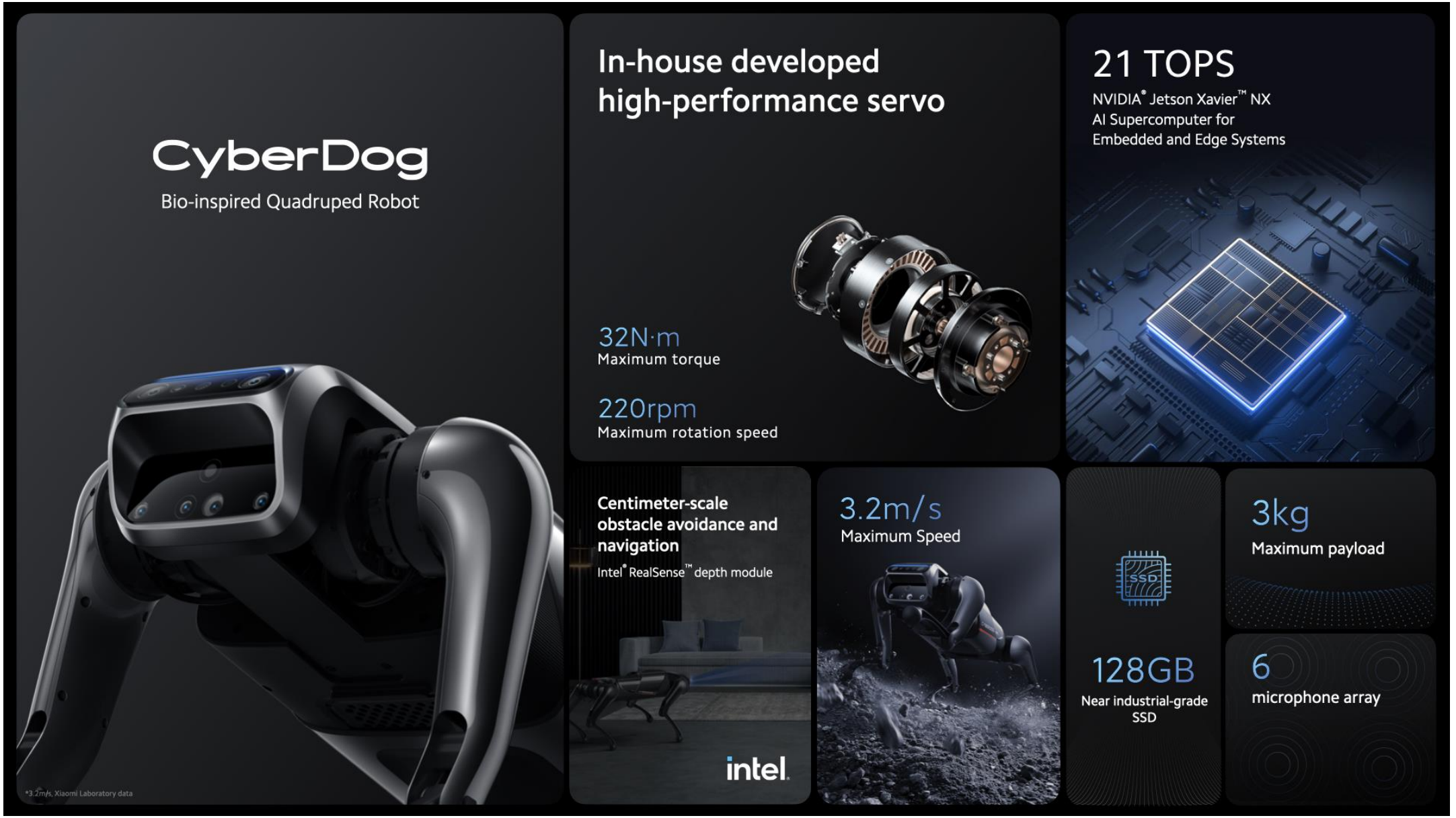
MoveIt!

Advanced DDS Implementation

- Basic DDS Pub-Sub mechanism
- Internal process speed up
- DDS standard QoS
- Compatible with DDSI-RTPS™ Version: 2.2
- Support multicast communication


Private Cloud
ERP/MES/CRM
3rd Party Cloud Services
aws
Microsoft Azure
AI Training Database
ROS 2 Data River
AI Engine
intel
NVIDIA
Development Environment
Neuron SDK
2
ROScube
ROScube-I
Starter Kit
NeuronBot
Flexible Hardware Systems with BSP
Professional
Service Robot
Application

ROS2应用：小米 CyberDog



ROS2应用： Robotis

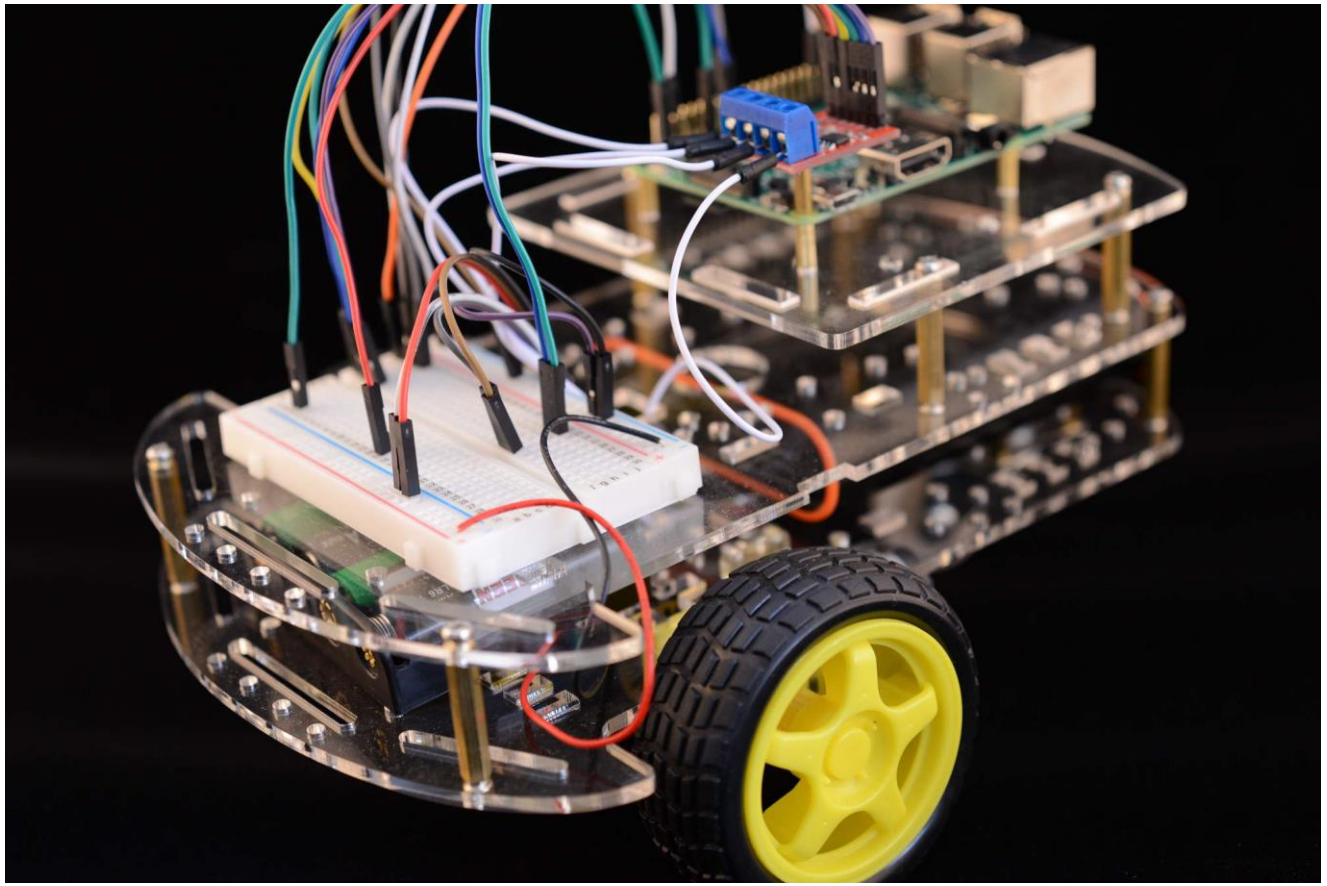
- Turtlebot 3
- Open Manipulator

ROS2应用：Rover Zero, by Rover Robotics

- Same procedure as the previous 2.
- 同时支持ROS 和ROS2

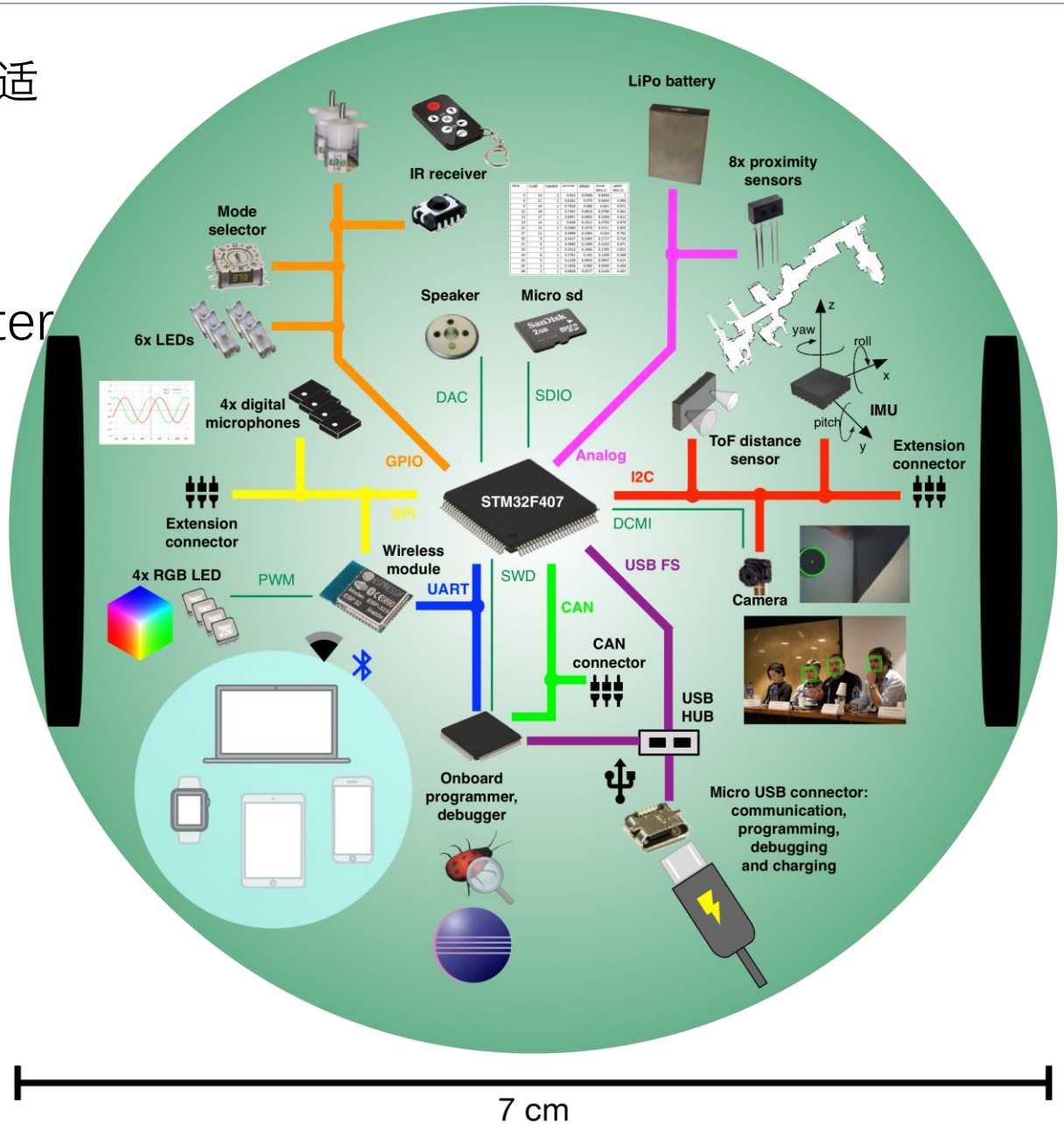
ROS2应用： Hadabot， by Hadabot

- 教学平台



ROS2应用： e-puck 2， by GCTronic.

- Cyberbotics 公司提供了原生的ROS2 驱动,可以适用于各种ROS环境
- 集成了非常多的传感器
- Open software, open hardware. 8 proximity, VGA camera, 3D accelerometer 3 microphones, Bluethooth.

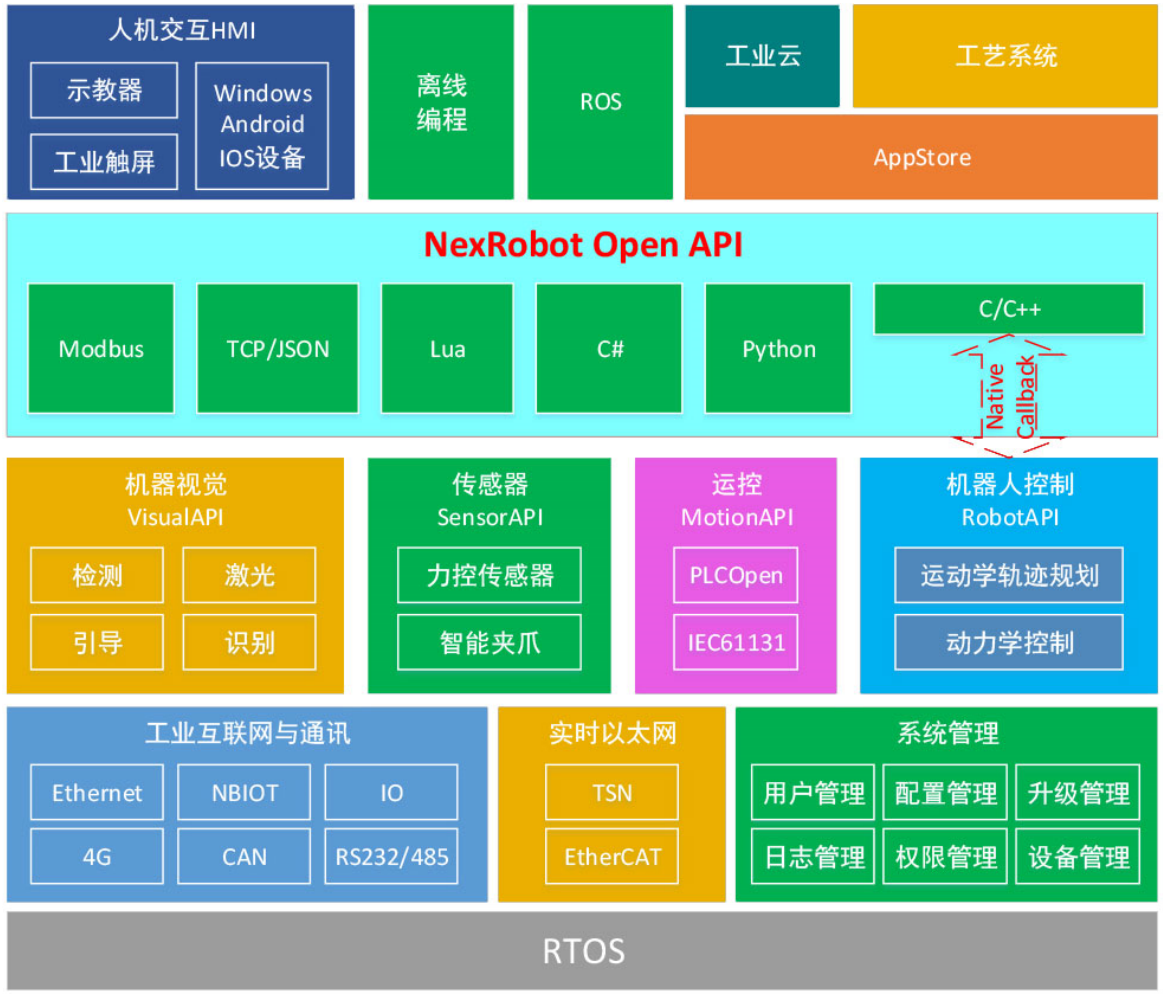


为什么ROS2设备这么少

- ROS1 设备可以通过ROS1_bridge被ROS2兼容
- ROS2还没有真正为工业领域所接受
- ROS2编译复杂

国产机器人生态尝试

- 2021年内:
  - 提供ROS/ROS2 node接口
  - 支持DDS
- 支持多轨迹规划库实现
  - 北航/沈自所/…
  - 纳博特
- 支持多语言
  - NexRobot
  - IEC61131
  - Lua脚本编程
- 打通MABLAB
  - 沈自所
- 多系统支持
  - Sylix
  - Linux
  - Windows



纳博特机器人控制系统（NexDroidOS）

谢 谢!