7th ROS-Industrial Conference
Stuttgart, Germany (EU)
rosindustrial.org/riceu2019

ROS2 Robot Dev Kit Featuring Navigation2 Overview

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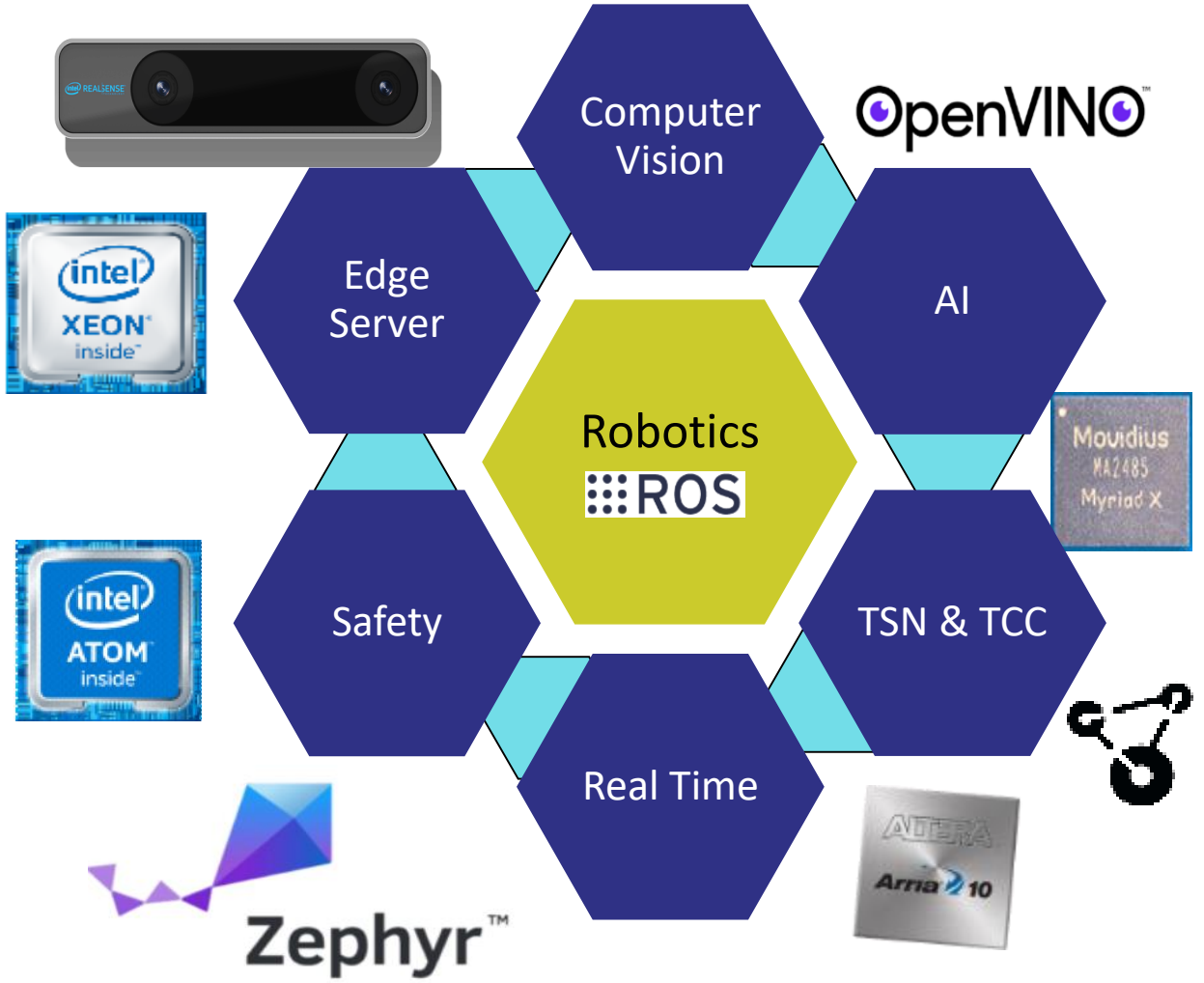
Open Source Robotics
Intel

Intel Open Source Robotics

https://01.org/robotics-autonomous-systems

Robot Development Kit (RDK) for ROS2 is our platform for robotics development

- Make it **simple**
- Make it **performant**
- Make it **open source** with ROS2
- Make it with **Intel® technologies**



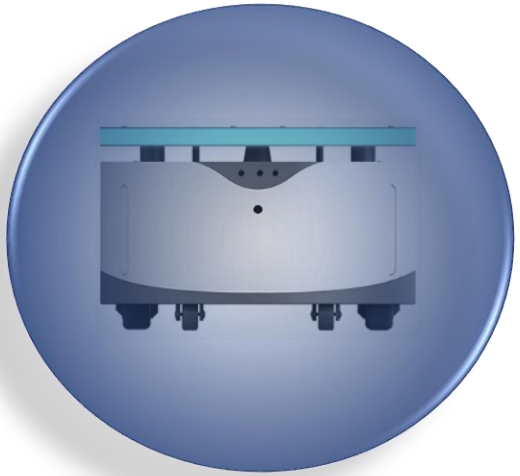
Accelerate industry adoption of ROS2 so you can innovate!

RDK – Intelligence, Performance, Vision

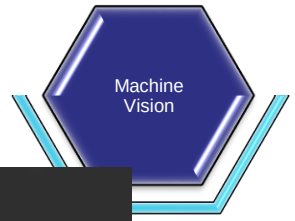
Mapping & Planning

Machine Vision

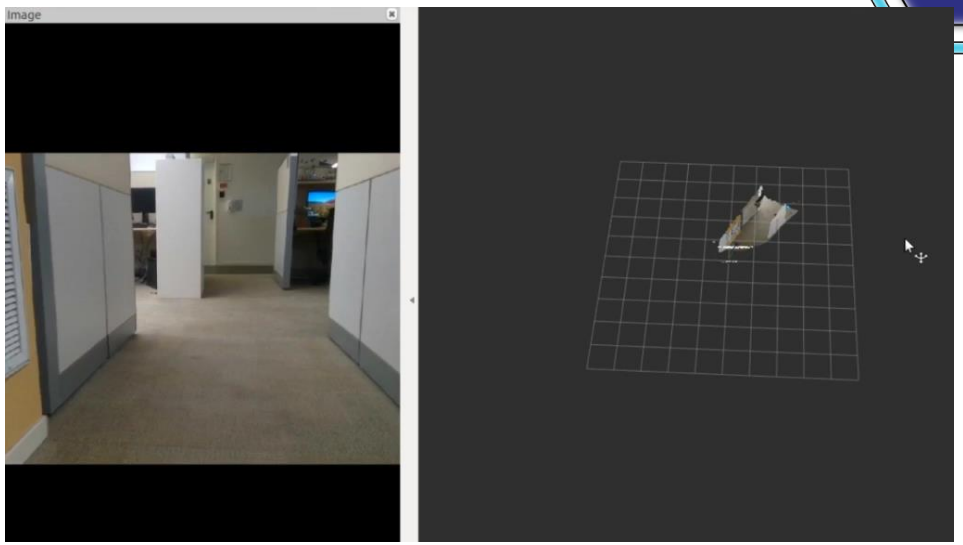
Intelligent Manipulation



ROS2 Machine Vision: ROS2 RealSense™



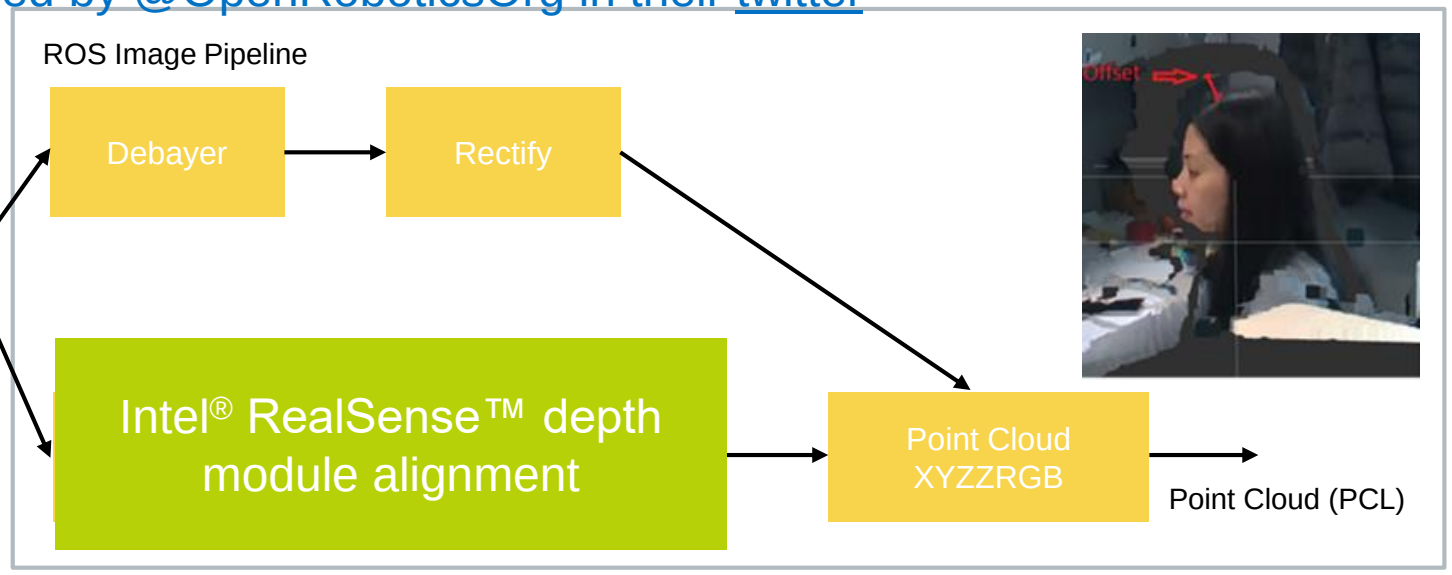
- High Performance Stereo RGBD camera
  - Point cloud generation
  - Mapping & Navigation
  - Object detection
  - Face & gesture detection
- https://github.com/intel/ros2_intel_realsense
  Also announced by @OpenRoboticsOrg in their twitter

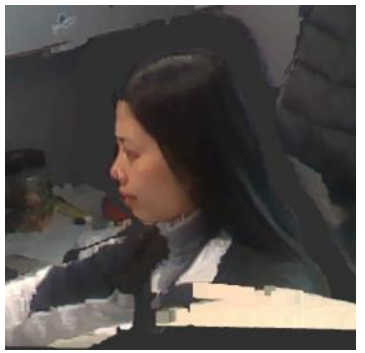


Color image

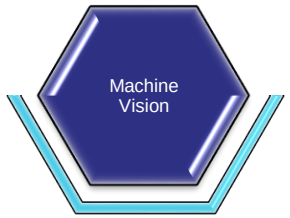
ROS Camera Driver

Depth image





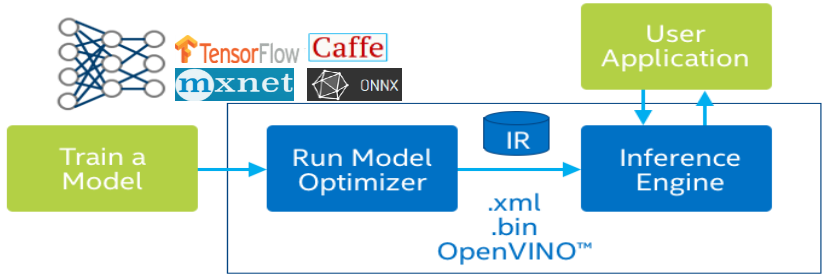
ROS2 Machine Vision: OpenVINO™ toolkit

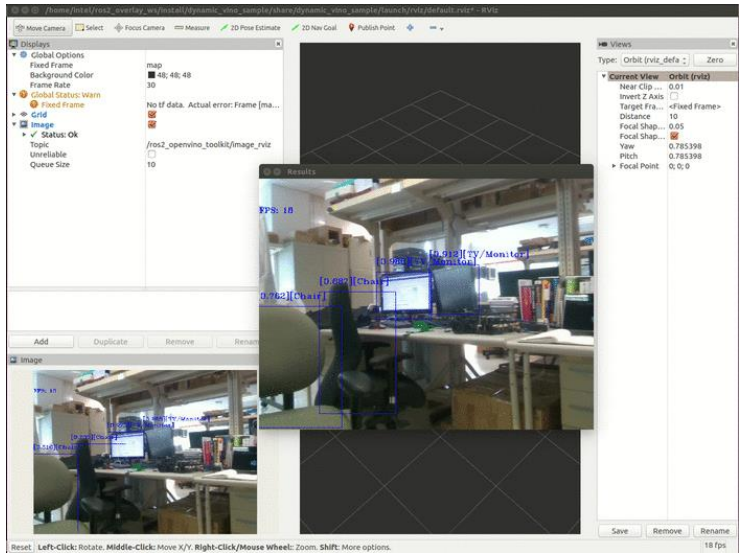


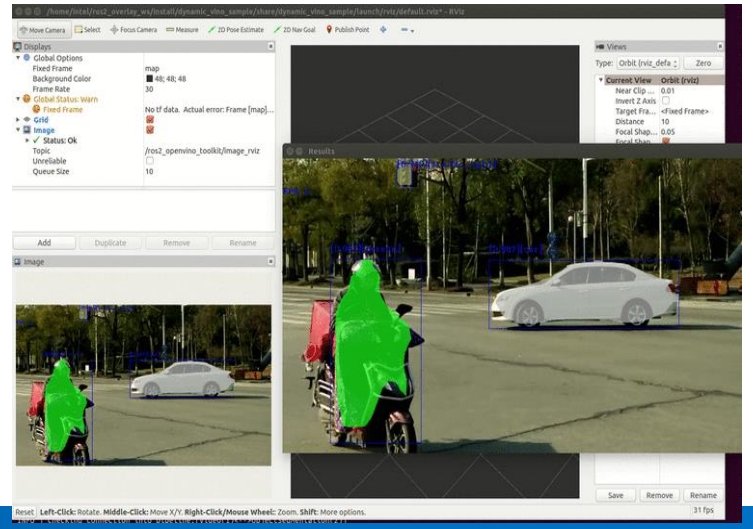
- Intel® Open Visual Inference & Neural network Optimization Toolkit
- CNN inference with Intel® OpenVINO™ optimization and acceleration
- Deployment on various devices – using common APIs
  - CPU, GPU, Movidius™ VPU, FPGA
- ROS2 interfaces for

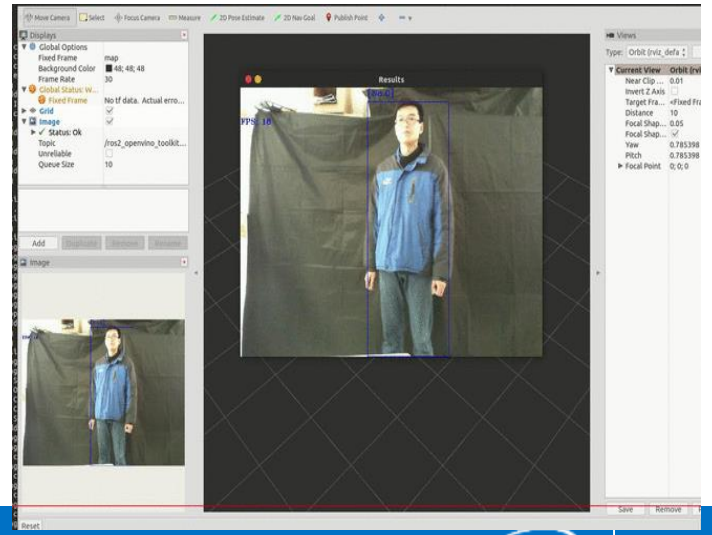
Object Detection	Face/Emotion/Age/ Gender
Object Segmentation	Person Re-identification

https://github.com/opencv/dldt
https://github.com/intel/ros2_openvino_toolkit



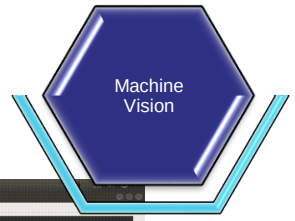






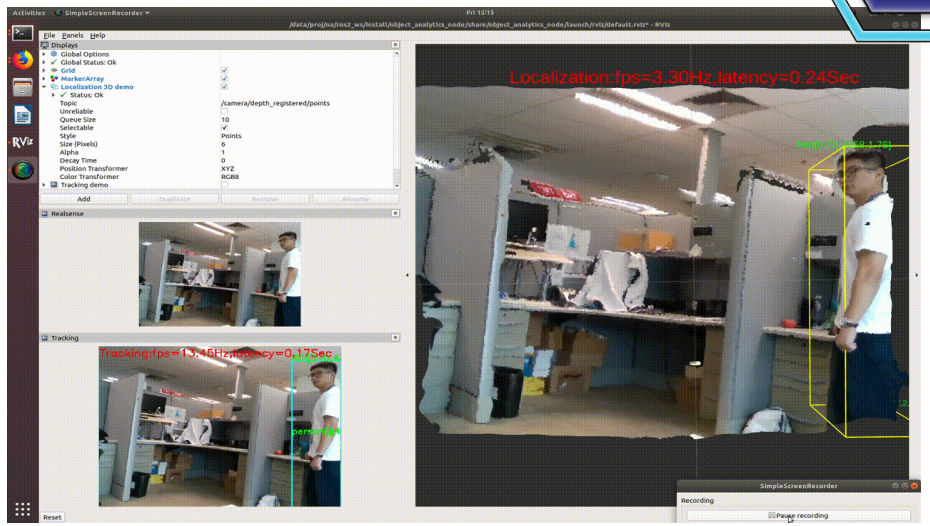
*Other names and brands may be claimed as the property of others.

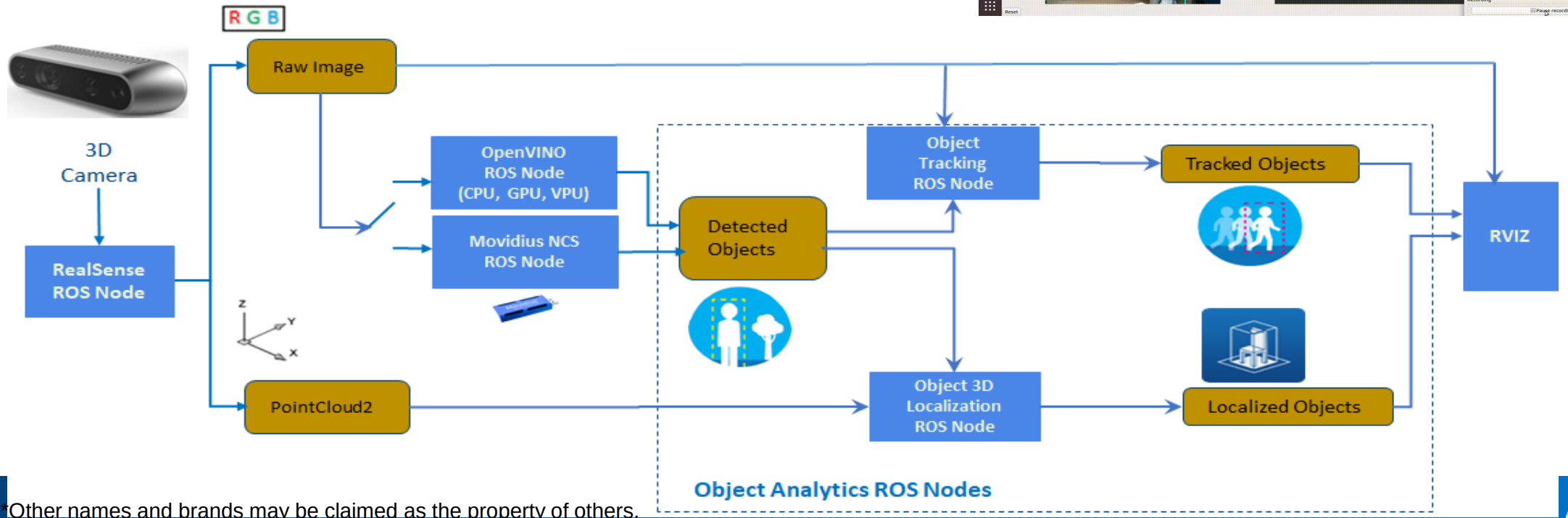
ROS2 Machine Vision: Object Analytics



- Real-time object detection, tracking, localization

https://github.com/intel/ros2_object_analytics





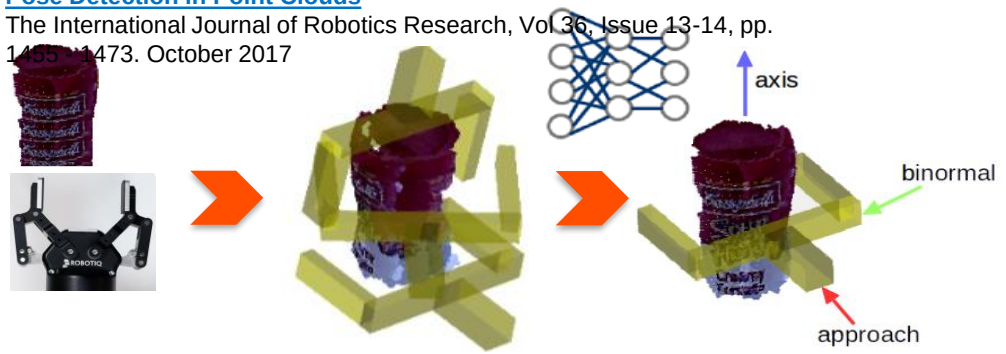
ROS2 Intelligent Manipulation: Grasp detection

Intelligent Manipulation

- Convolutional Neural Networks (CNN)-based grasp detection
  - Dex-Net*
  - Grasp Pose Detection (GPD)
  - OpenVINO™ Inference acceleration
- Grasp planning
- Works with MoveIt* interfaces

https://github.com/intel/ros2_grasp_library

Andreas ten Pas, Marcus Gualtieri, Kate Saenko, and Robert Platt. Grasp Pose Detection in Point Clouds
The International Journal of Robotics Research, Vol 36, Issue 13-14, pp. 1455 - 1473. October 2017



Point Cloud Library (PCL) or Depth
Hand Geometry

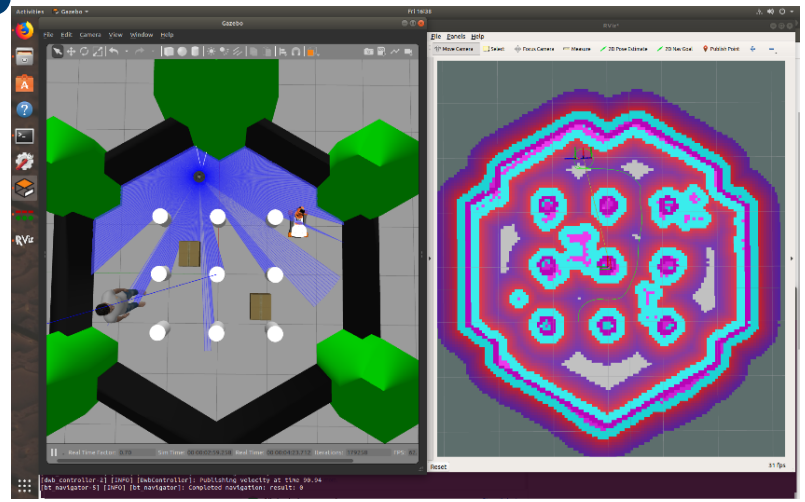
Grasp Candidates

Grasp Classification

Robotiq gripper photo: https://robotiq.com/products/2f85-140-adaptive-robot-gripper

*Other names and brands may be claimed as the property of others.

ROS2 Mapping & Planning: Navigation2



ROS Navigation -http://wiki.ros.org/navigation

- One of the key and most used packages of ROS
- Autonomous movement for a robot in a 2D map
  - Given a ‘current pose’ and a ‘goal ‘pose’
  - Path is planned, robot drives itself to the goal
- Key to accelerating ROS2 development and adoption across the community and industry
  - As of Spring 2018 - no one had committed to porting Navigation to ROS2
  - We gathered input from the ROS community; changes and improvements they wanted in ROS2 Navigation
  - Proactively with support from OSRF, our team assumed ownership of ROS2 Navigation
  - Ported, refactored, and made architectural improvements from ROS
- https://github.com/ros-planning/navigation2

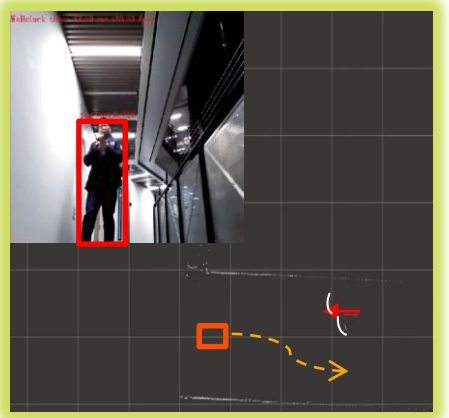
Product Example: Yunji Deli Platform w/ ROS2 + RDK

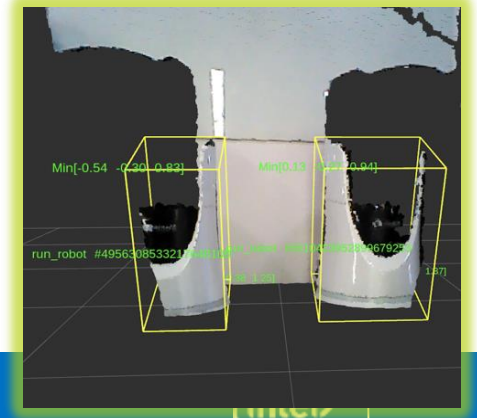
Hardware:

- Intel Core i7 processor (ADLink neuron board for robotics)
- Intel Realsense RGB-D camera
- Laser radar sensor, bidirection ranging
- Ultrasonic distance measuring sensor
- IMU 6 axis sensor
- 6 wheels (2 driving + 4 universal wheels) differential driving
- Net weight: 50kg; Loading capacity: 80kg

Software:

- Ubuntu Linux 18.04
- ROS2
- Semantic Mapping, multi-storey support
- Navigation2
- Intelligent collision avoidance with pedestrian detection and path prejudgment**
- Real-time object detection, localization and tracking**
- Cloud multi robot scheduling
- Elevator IoT communication





Navigation2 Goals

We asked the community for input and some recurring themes emerged:

- **Customizable** logic –ability to customize behavior, less need to fork the code
- **Modularity** –ability to more easily replace planners and control algorithms
- **Extensibility** – ability to use Python or other languages to write planners and control

In addition, the development team wanted to ensure other properties such as:

- **Reliability** – the system should be able to perform in a consistent way
- **Quality** – the code submitted should be validated before merging
- **Maintainability** – the workflow should prevent regressions in the above

The navigation2 project is an attempt to meet these goals

Navigation2 Overview

Improvements:

- **Customizability**: Behavior Trees
- **Extensibility / Modularity:**
  - Planners and Recovery behaviors as ROS2 Actions with plugins
- **Reliability**: Lifecycle nodes
- **Quality**: System tests
- **Maintainability:** Continuous Integration

https://github.com/ros-planning/navigation2

ROS2 Navigation Enabling on Commercial Mobile Robot

Comparison – ROS Navigation vs Navigation2

amcl and map_server – **ported** from ROS Navigation with refactoring

move_base – **replaced by behavior tree** based navigation node called ‘bt_navigator’

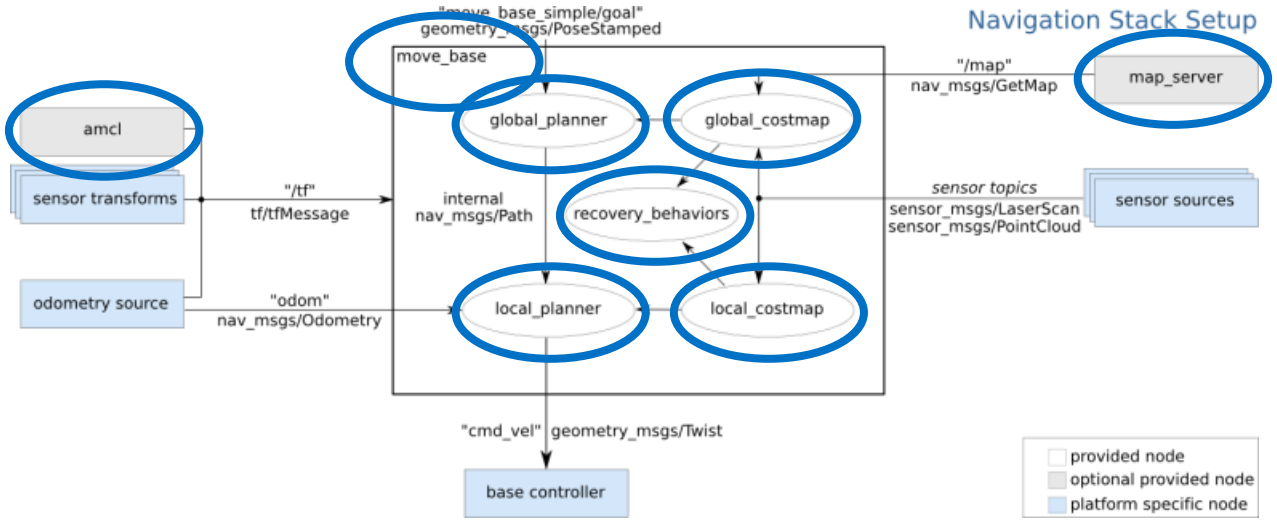
recovery_behaviors – now **actions** within the behavior tree(s)

global_planner – **navfn ported** as a global planner called navfn_planner

local_planner – ‘dwb’ local planner **ported** from the robot_navigation project as dwb_planner

global_costmap and local_costmap - contained within the global and local planners respectively

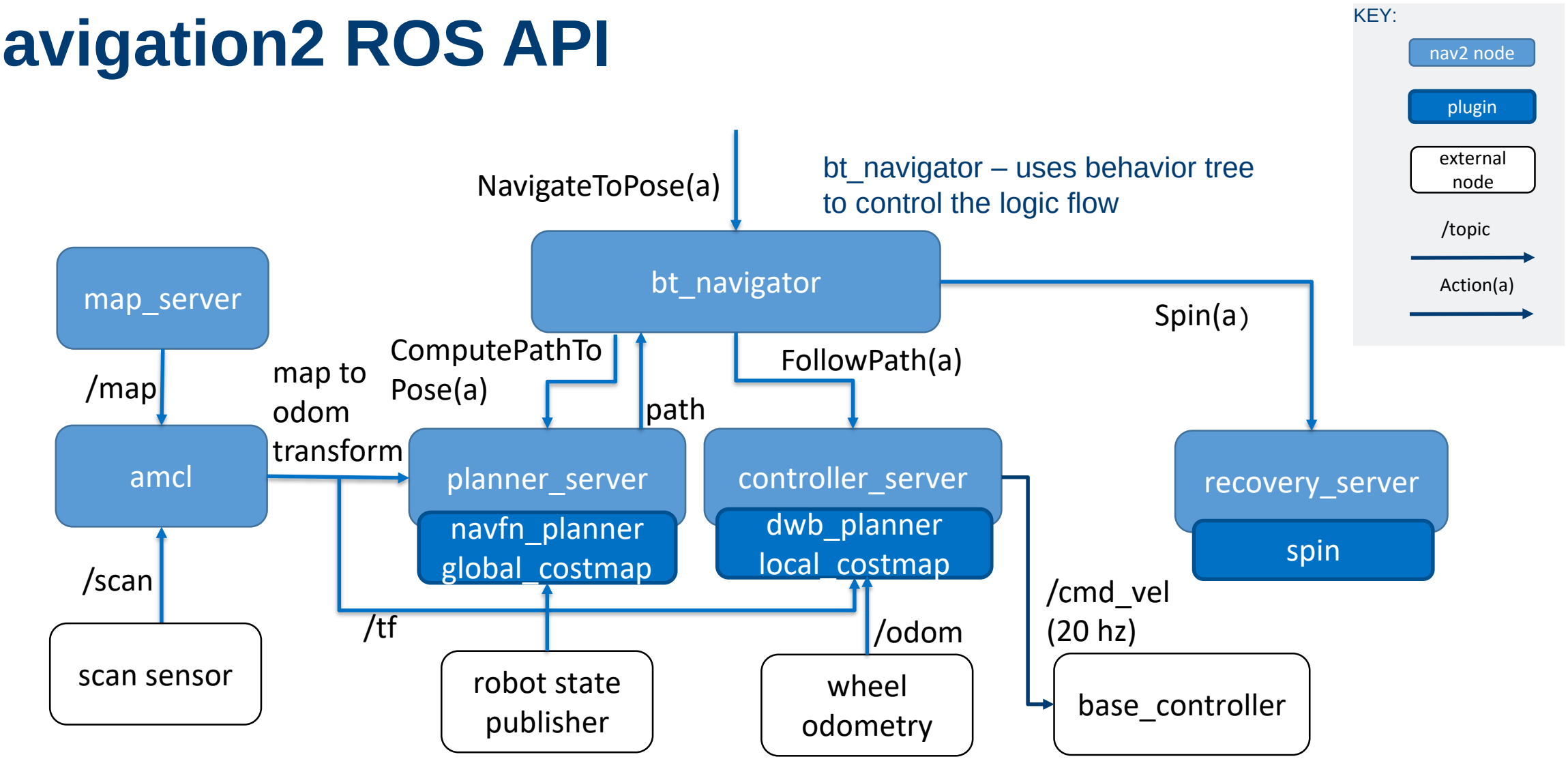
planner_server and controller_server **(NEW)** - ROS2 action servers (ComputePathToPose) and (FollowPath)



http://wiki.ros.org/navigation/Tutorials/RobotSetup

We blew up move_base and planted a behavior tree in it’s place

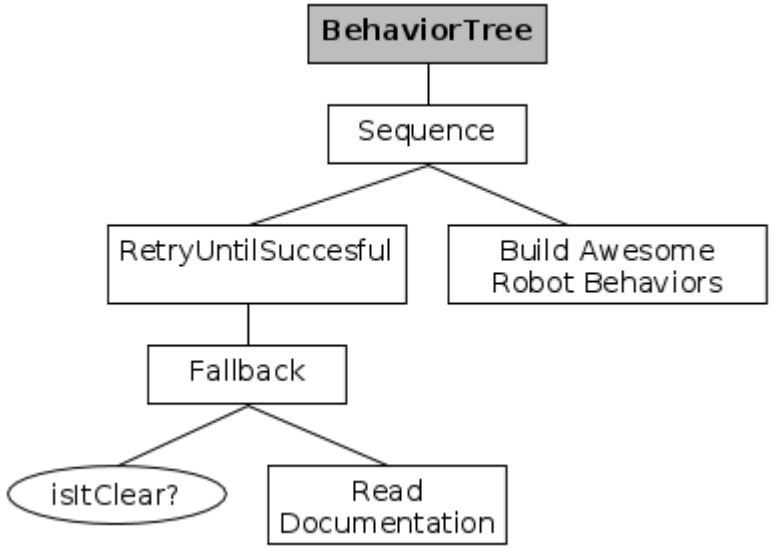
Navigation2 ROS API



Behavior Trees

What are behavior trees? - https://www.behaviortree.dev/

Program flow control decision trees, similar to state machines but hierarchical in nature

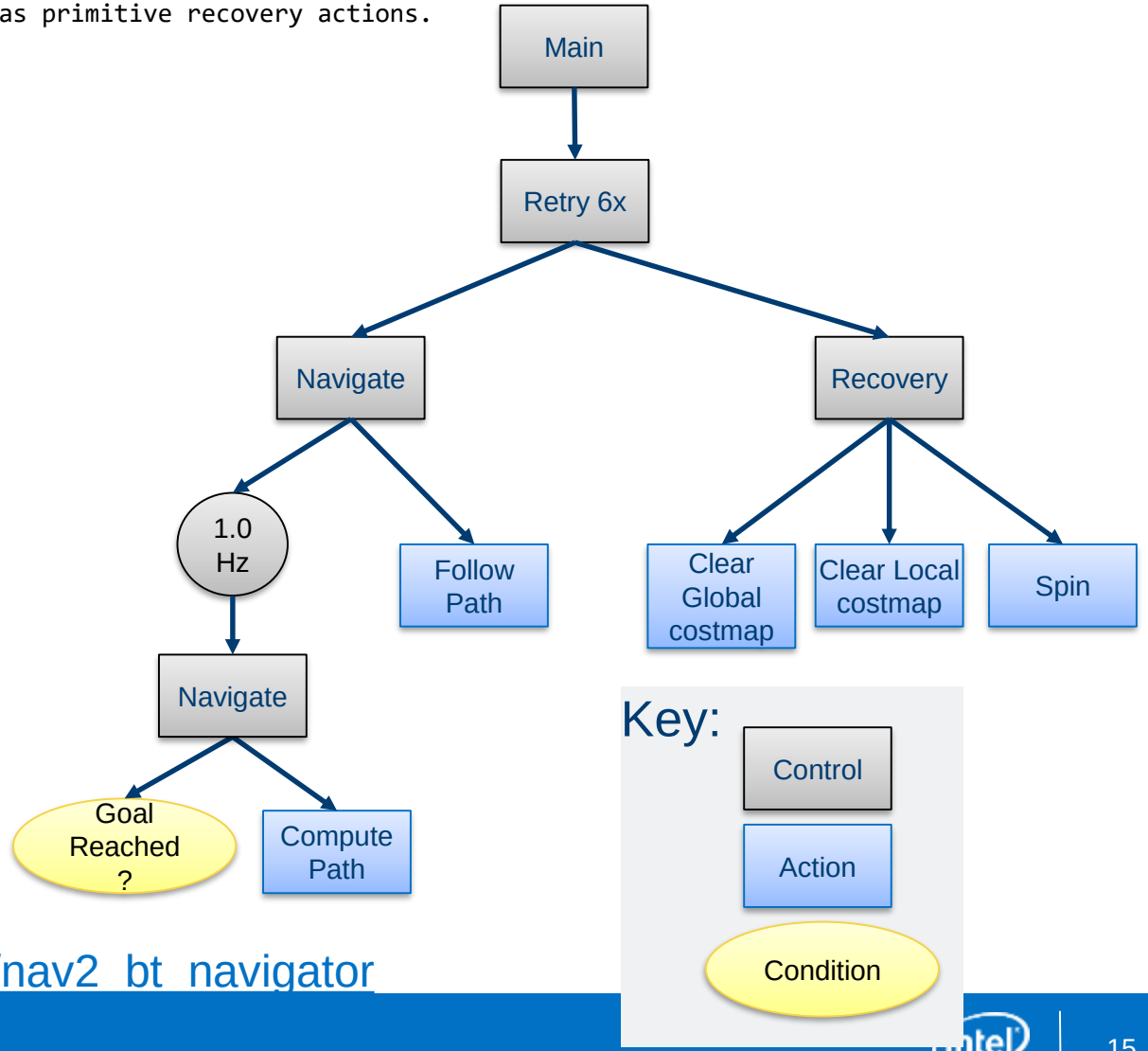


Enables **customizable** logic / behavior flows without rebuilding code!

Enables **extensibility** by adding new nodes for other non-navigation actions

Behavior Tree XML example

```
<!--
  This Behavior Tree replans the global path periodically at 1 Hz and it also has primitive recovery actions.
-->
<root main_tree_to_execute="MainTree">
  <BehaviorTree ID="MainTree">
    <RecoveryNode number_of_retries="6">
      <Sequence name="NavigateWithReplanning">
        <RateController hz="1.0">
          <Fallback>
            <GoalReached/>
            <ComputePathToPose goal="${goal}" path="${path}"/>
          </Fallback>
        </RateController>
        <FollowPath path="${path}"/>
      </Sequence>
      <SequenceStar name="RecoveryActions">
        <clearEntirelyCostmapServiceRequest
              service_name="/local_costmap/clear_entirely_local_costmap"/>
        <clearEntirelyCostmapServiceRequest
              service_name="/global_costmap/clear_entirely_global_costmap"/>
        <Spin/>
      </SequenceStar>
    </RecoveryNode>
  </BehaviorTree>
</root>
```



https://github.com/ros-planning/navigation2/tree/master/nav2_bt_navigator

ROS2 Lifecycle nodes

Lifecycle nodes are ‘managed’ nodes that have an internal state machine

https://design.ros2.org/articles/node_lifecycle.html

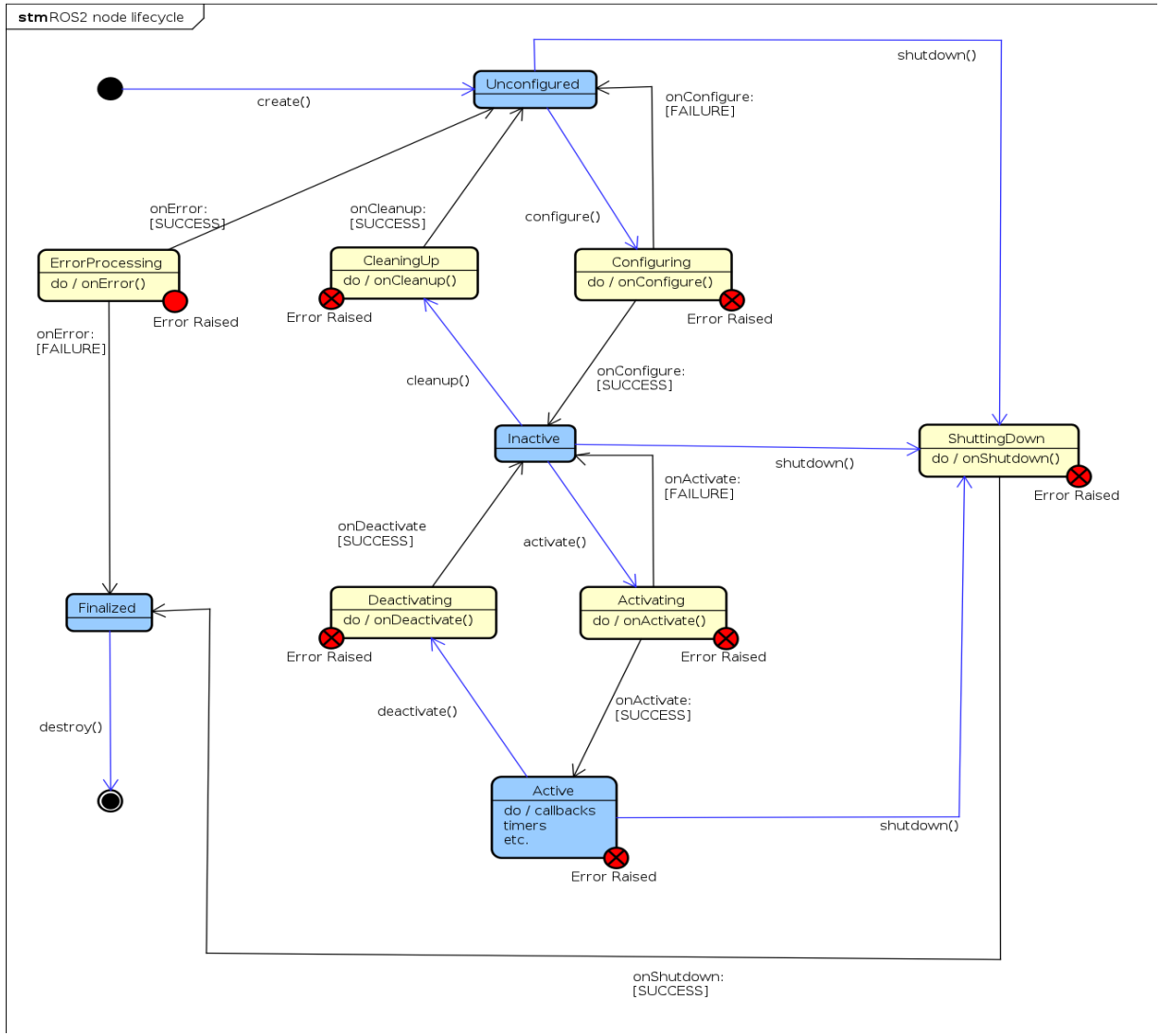
States:

- Unconfigured = created or new
- Inactive = ready to work
- Active = doing real work
- Finalized = ready to destroy

States are controlled through ‘change_state’ service

Each lifecycle node must implement the callbacks for the state transitions

- onConfigure(), onActivate(), etc.

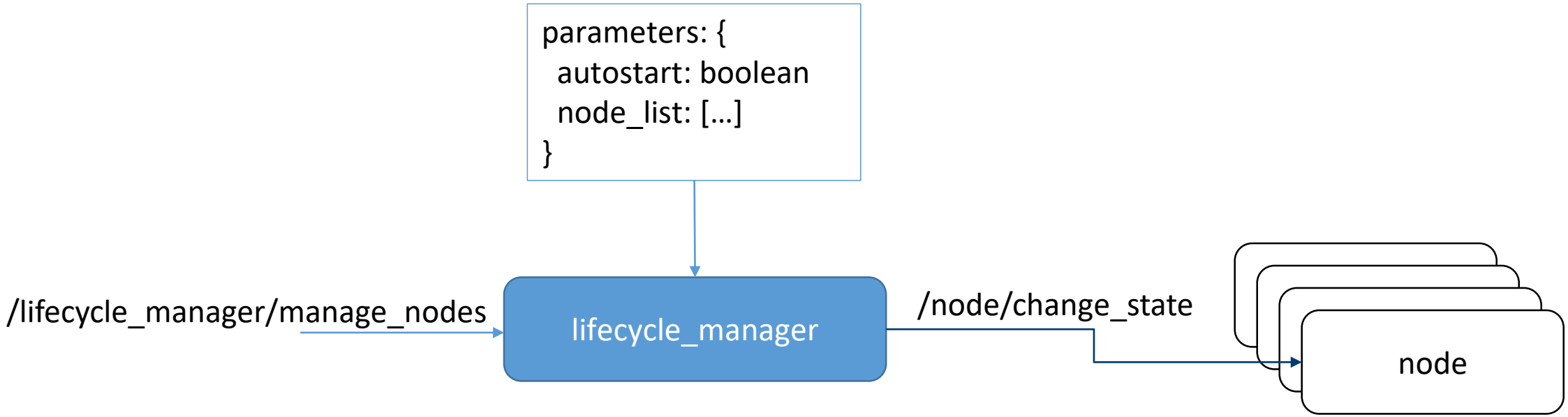


Lifecycle nodes provide **reliability** of the system launch flow

Navigation2 lifecycle manager

The lifecycle_manager node provides a ‘management’ service for controlling the startup and shutdown of the Navigation2 nodes

‘autostart’ parameter tells the lifecycle manager to start up everything in sequence automatically



Nav2 Plugin interface

The ‘nav2_core’ package contains abstract interfaces for plugins

- Global Planner – global_planner.hpp
- Local Planner – local_planner.hpp
- Recovery behaviors – recovery.hpp
- Goal checker – goal_checker.hpp
- Exceptions – exceptions.hpp

Costmap and trajectory critics are still plugins, as in ROS

Enables **extensibility** by creating new plugins without requiring rebuilding existing Navigation2

Navigation2 Bringup

nav2_bringup provides the basic instructions and launch files for starting up the Navigation2 system

https://github.com/ros-planning/navigation2/tree/master/nav2_bringup

```
sudo apt install ros-dashing-navigation2 ros-dashing-nav2-bringup
source /opt/ros/dashing/setup.bash
# Launch the nav2 system
ros2 launch nav2_bringup nav2_bringup_launch.py use_sim_time:=True autostart:=True \
map:=<full/path/to/map.yaml>
```

For best results, follow the instructions on nav2_bringup/README.md

More tutorials and documentation is in progress, watch for updates

Simulation in the loop testing - nav2_system_tests

In ROS navigation, each pull request / code change was manually tested on a physical robot prior to being merged.

- **This is a time-consuming manual process**

By contrast during the development of navigation2, extensive testing is primarily done using Gazebo

To ensure **quality** and **maintainability**, an automated system test was created that uses Gazebo and a Turtlebot3 model to test that the system:

- Localizes correctly
- Successfully transitions into the ‘active’ lifecycle state
- Navigates successfully to a known location

System test results

With the system test in place, able to find issues quickly (< 1minute to run)

- Example: prior to ROS2 Dashing release FastRTPS caused our test to break
- OSRF & Eprosima were able to reproduce the failures and fix

Able to run the test 100x/hour to find race conditions

- Drove pass rate from ~85% for Dashing to 95+% for Eloquent

Able to quickly test different DDS implementations for issues

- Found issue where CycloneDDS was initially failing more frequently than FastRTPS, ADLink was able to fix and increase to 95%+

System test is **now integrated into ROS build farm** “nightly” build

Future Plans

Release Nav2 packages for **ROS2 Eloquent**

Analyze and **improve system performance** metrics

Improve quality and robustness by improving test coverage

Increase **community involvement**

- Currently asking for input for F-turtle features

Build ROS2 expertise in academia and industry

Continuously improve!

Call to Action

Try Navigation2!

- https://github.com/ros-planning/navigation2
- Submit issues and PRs

Participate in our ROS2 Working Group

- Navigation2 WG – Thursdays 3pm Pacific time
- https://groups.google.com/forum/#!forum/ros-navigation-working-group-invites
- Contact me if you have questions: discourse.ros.org - mkhansen

Navigation2 team

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Carlos Orduno, github: orduno

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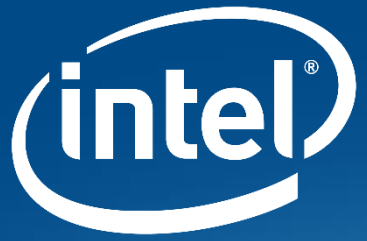
Steve Macenski, github: SteveMacenski



Thank You!

RDK Software Architecture