Industrial Motion Primitives

in ros2_control

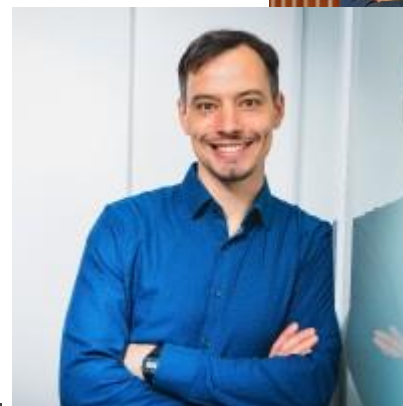**Felix Exner (Universal Robots)**

Dr. Denis Stogl (b»robotized group)

ROSCon DE, 19. Nov. 2025

What are we talking about?

» "Industrial motion primitives" (name by Rune Søe-Knudsen (UR))

» Base movements with which every robot is usually programmed

   » PTP/MOVEJ – linear movement in joint space

   » LIN/MOVEL – linear movement in Cartesian space

   » CIRC/MOVEC – circular movement in Cartesian space

» *Blending* – smooth transitions between movements (execution time improvement)

$whoarewe

» Dr. Denis

  » Owner and CEO at **b»robotized** group

  » PhD in Robotics from KIT

  » ros2_control Maintainer

  » Organizer ROSCon DE *(and HR)*

» Felix Exner

  » Software Engineer at **Universal Robots A/S**

  » ros2_control contributor, Maintainer of Universal Robots packages

$whoarewe

Work in this presentation was done by Mathias Fuhrer, Master Student from Hochschule Karlsruhe, lead by Dr. Denis, payed by b»robotized and supported with reviews/features by Felix (Universal Robots)

How UR sees their robots

Motion Control

Calibrated kinematics

Free Drive

Force mode

Industrial robot

Safety System
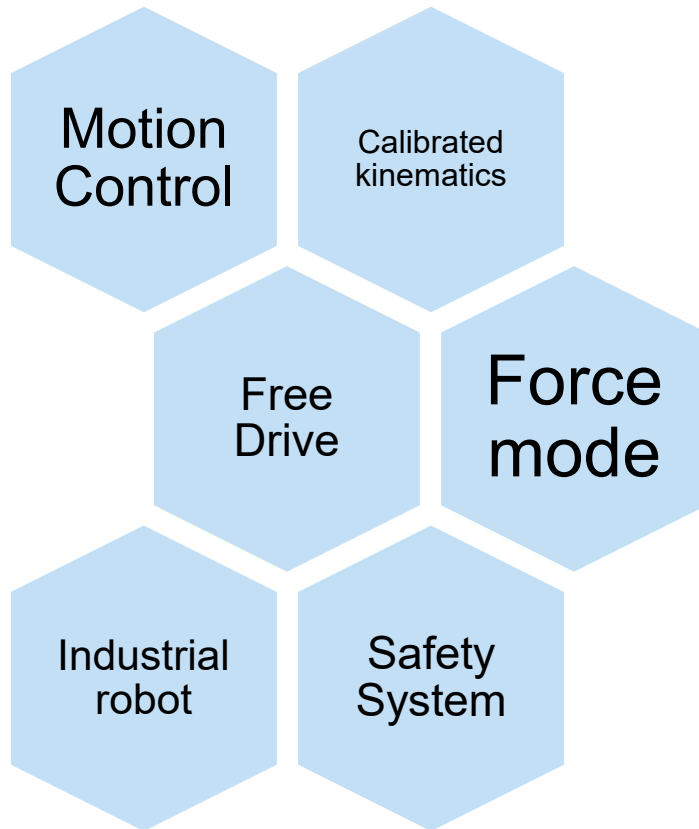
How ROS sees a robot

6-DOF manipulator
receiving targets
at 500 Hz
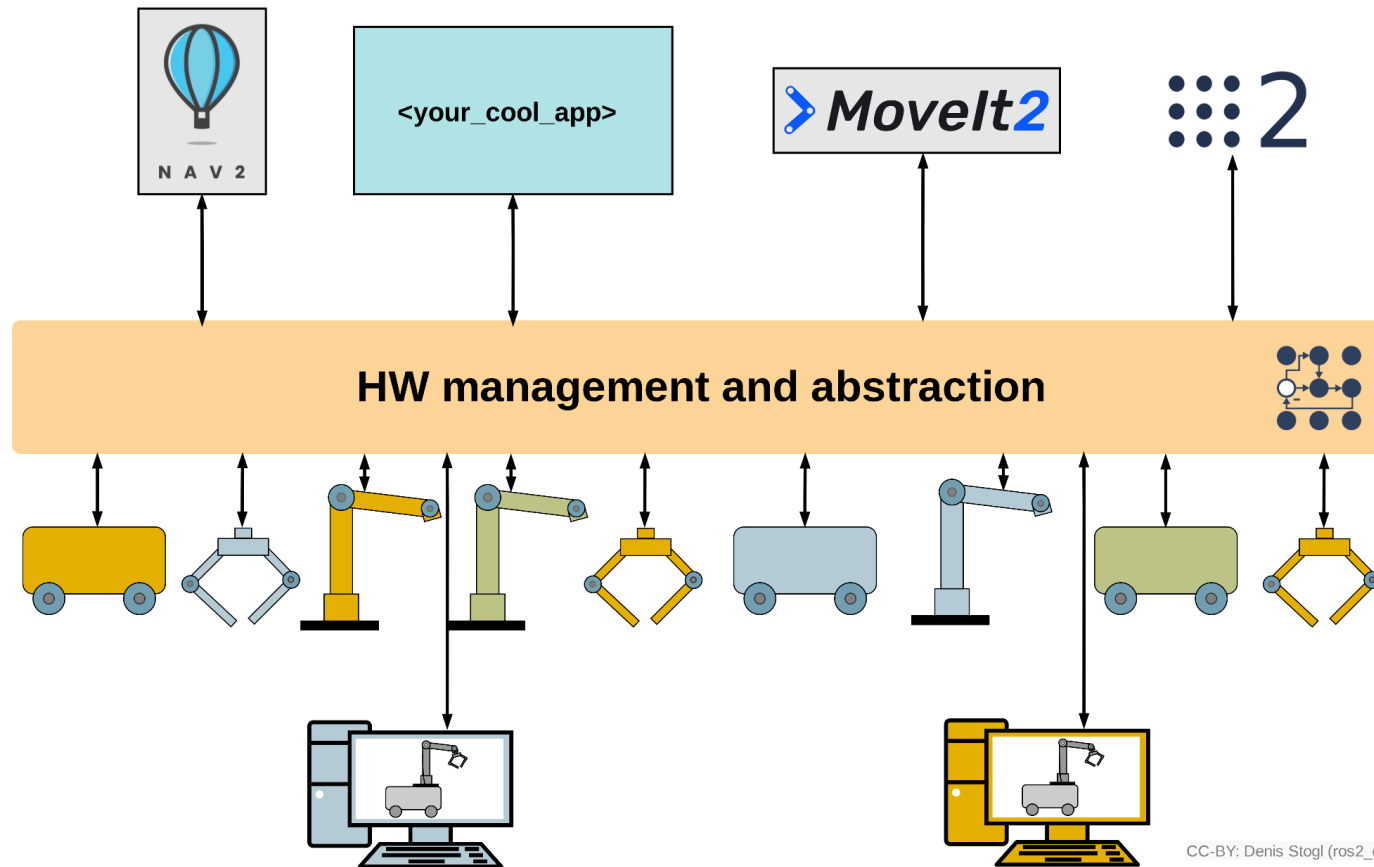
Why do we do this?

» Make ROS 2 more accessible to people used to classical robot programming

» Use vendor-optimized motions like *OptiMove*

» Interpolation on robot controller no RT setup required
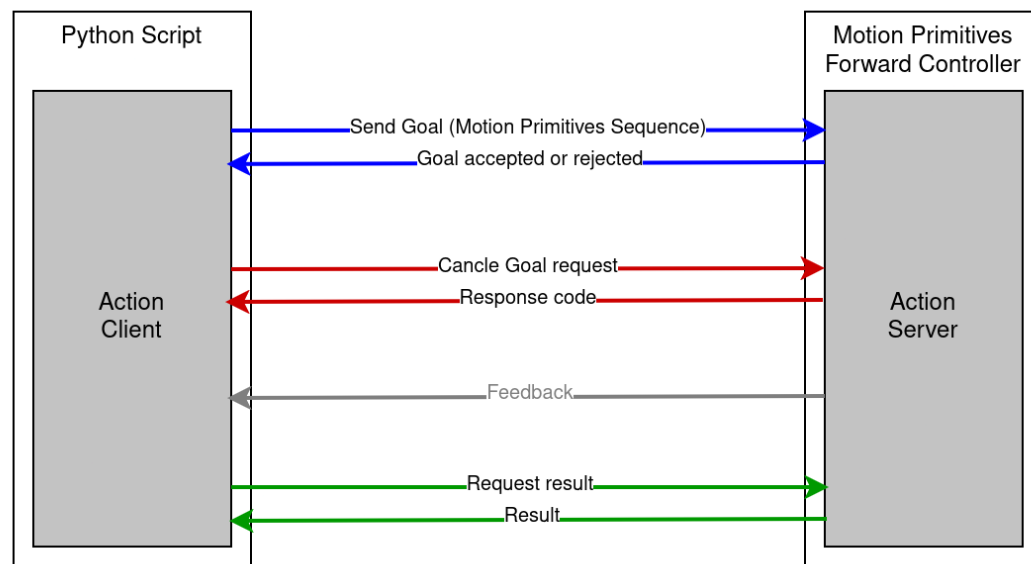
» Exact Cartesian motions
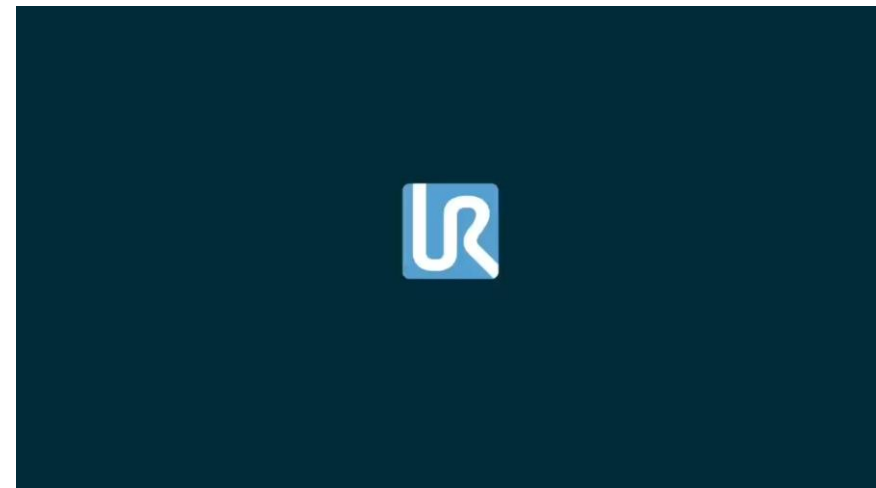
What would we like to have?

Forwarding Motion Primitives Controller

» More *manager* than *controller*
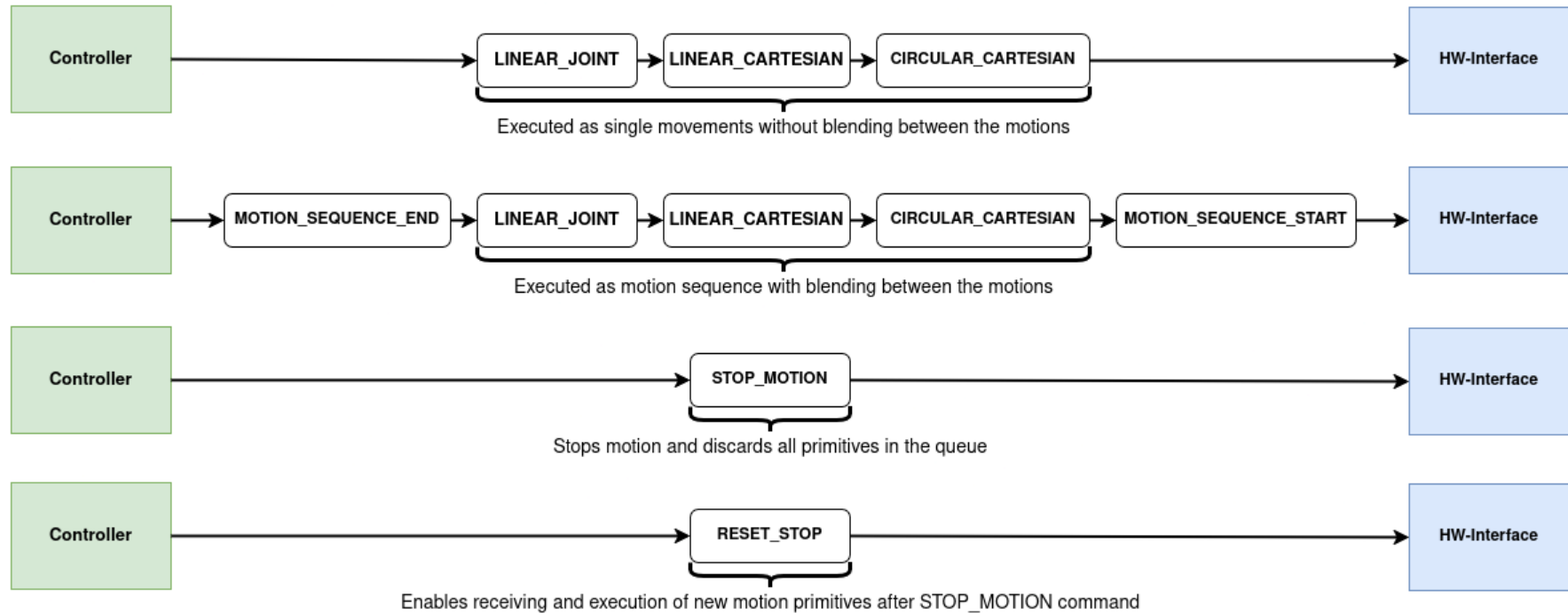
» *Sends a sequence of motion primitives to HW driver*

Forwarding Motion Primitives Controller

» More *manager* than *controller*

» *Sends a sequence of motion primitives to HW driver*
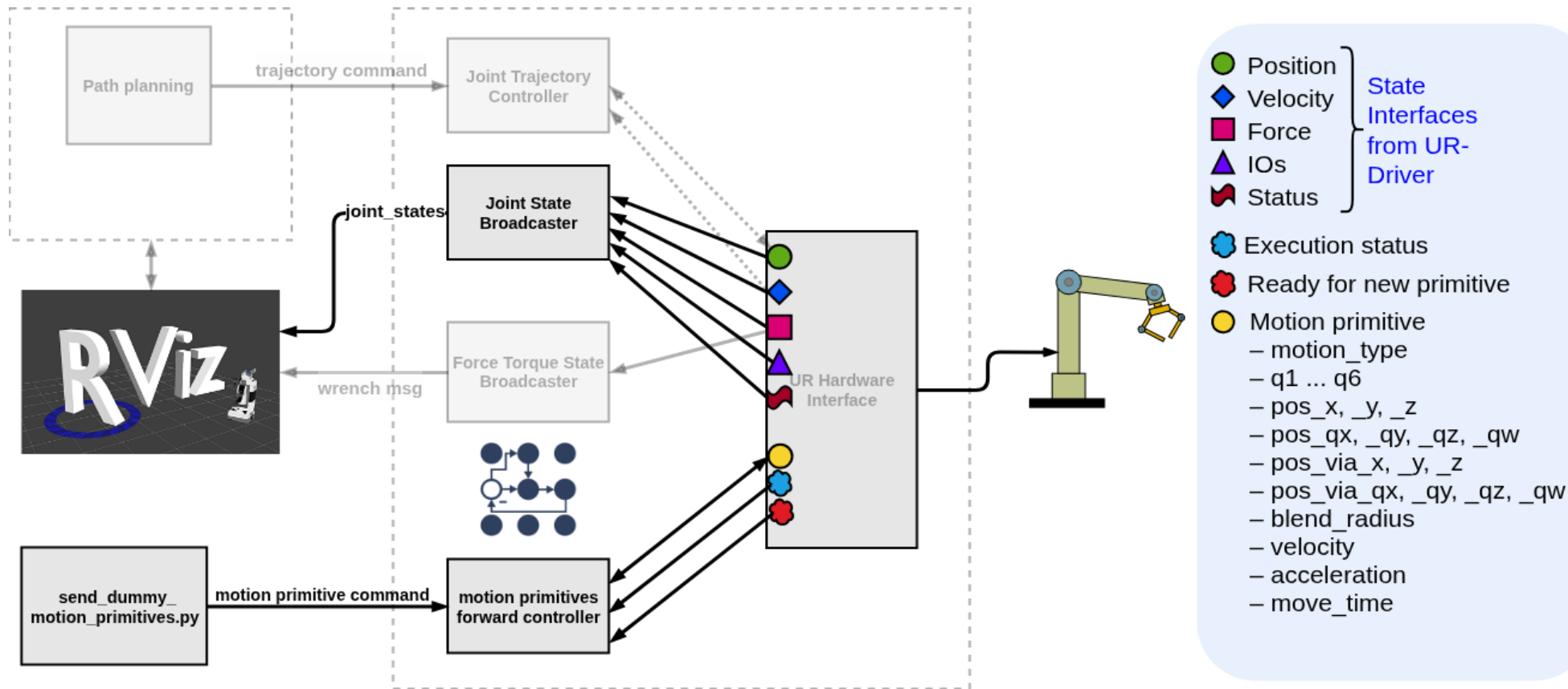
How it works?

» More *manager* than *controller*

What's the interface?

```
MotionPrimitive[] motions
        int8 type
        float64 blend_radius
        MotionArgument[] additional_arguments
                string name
                float64 value
        geometry_msgs/PoseStamped[] poses
        float64[] joint_positions
```

How to implement driver for this functionality?

State Interfaces from UR-Driver:
- 🟢 Position
- 🔷 Velocity
- 🟥 Force
- 🔺 IOs
- Status

- Execution status
- Ready for new primitive
- 🟡 Motion primitive
  - motion_type
  - q1 ... q6
  - pos_x, _y, _z
  - pos_qx, _qy, _qz, _qw
  - pos_via_x, _y, _z
  - pos_via_qx, _qy, _qz, _qw
  - blend_radius
  - velocity
  - acceleration
  - move_time

How to implement driver for this functionality?

» *Controller pushes motion instruction to HW interface*

» *HW interface sends instruction to robot*

  » *Can be asynchronous*

» *Execution / Interpolation is up to the robot*

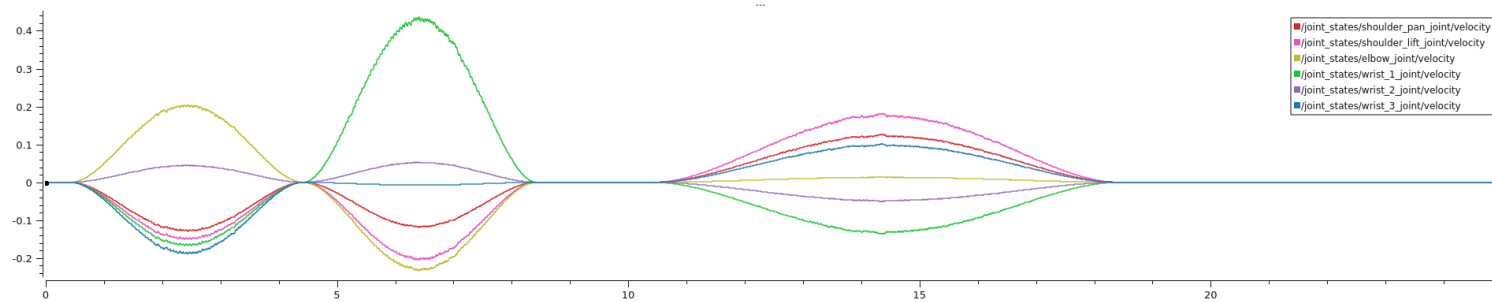» *Robot state is read by the "usual" interfaces*

Evaluation

» *Motion with 3 segments, executed on*

    » *JTC ros2_control*

    » *JTC interpolated on the robot*

    » *Motion_primitives using OptiMove*

» *Simulated robot*

» *No real-time system*

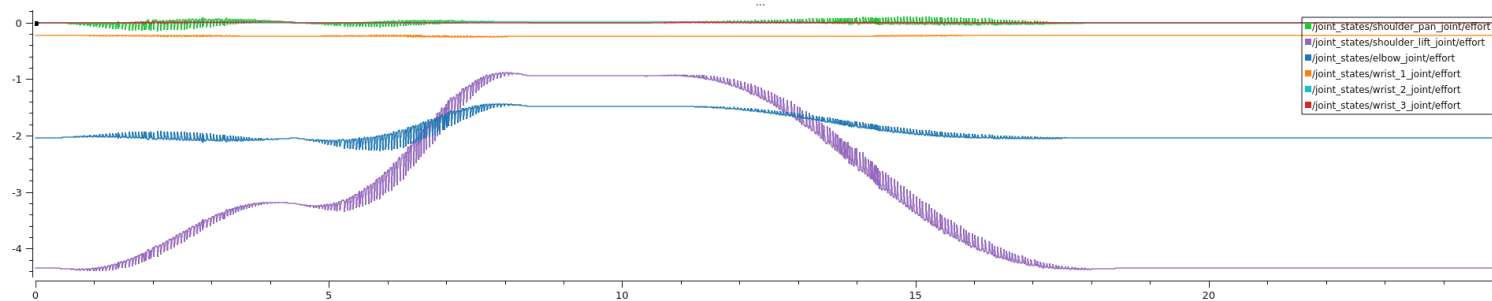» *0 velocity and acceleration after each segment*
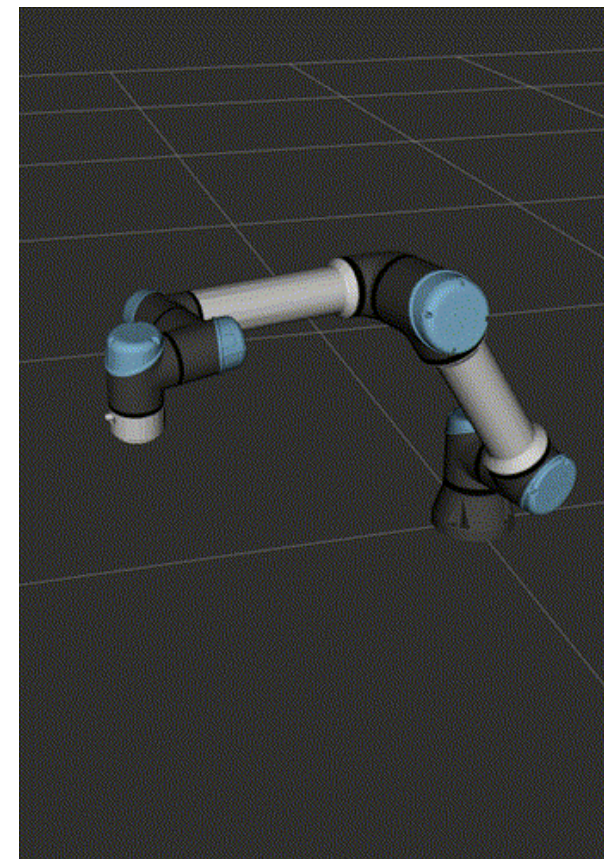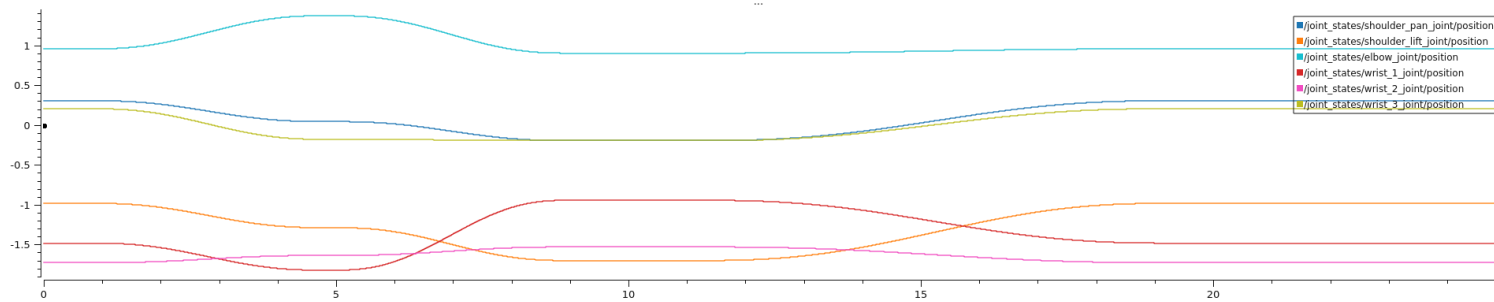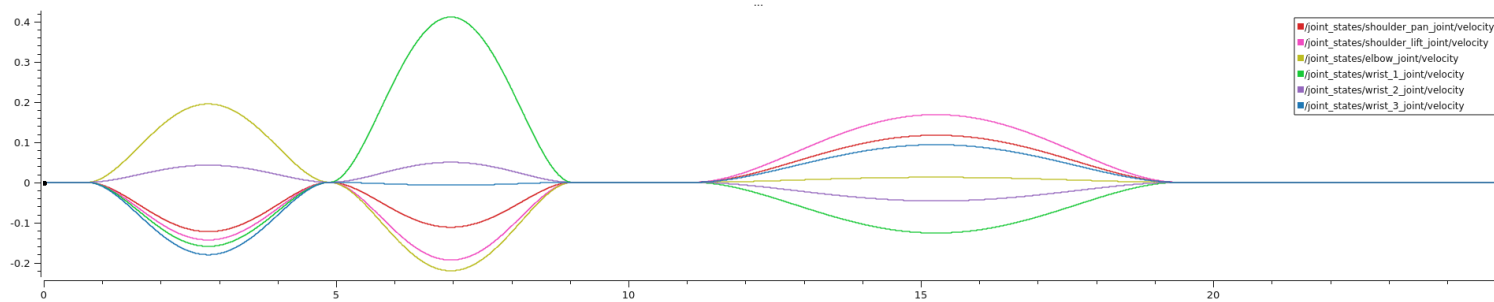
Evaluation— JTC ros2_control
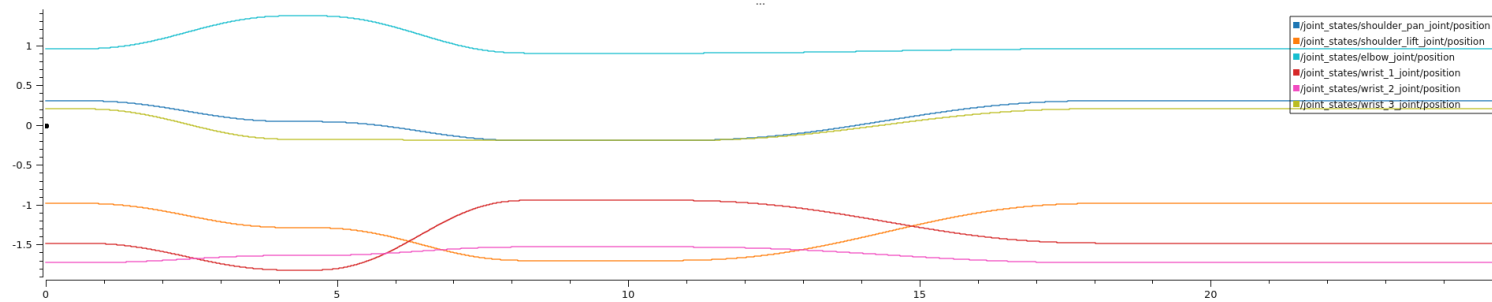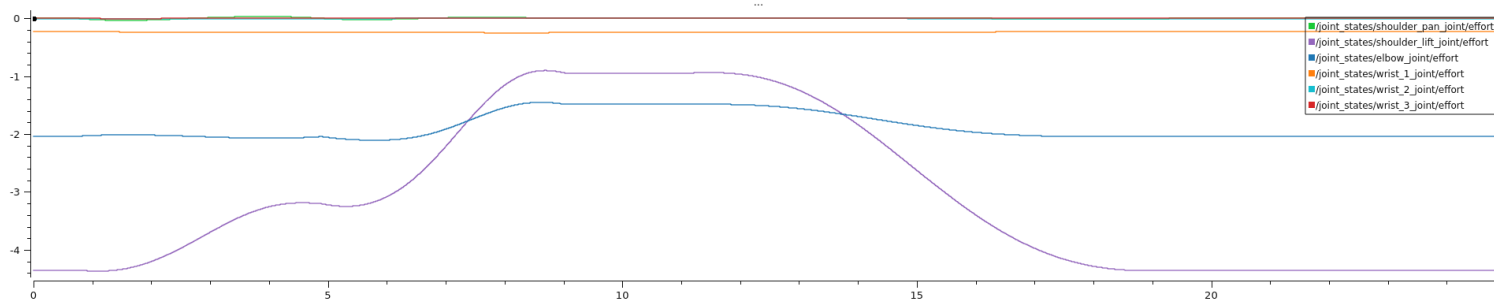

positions

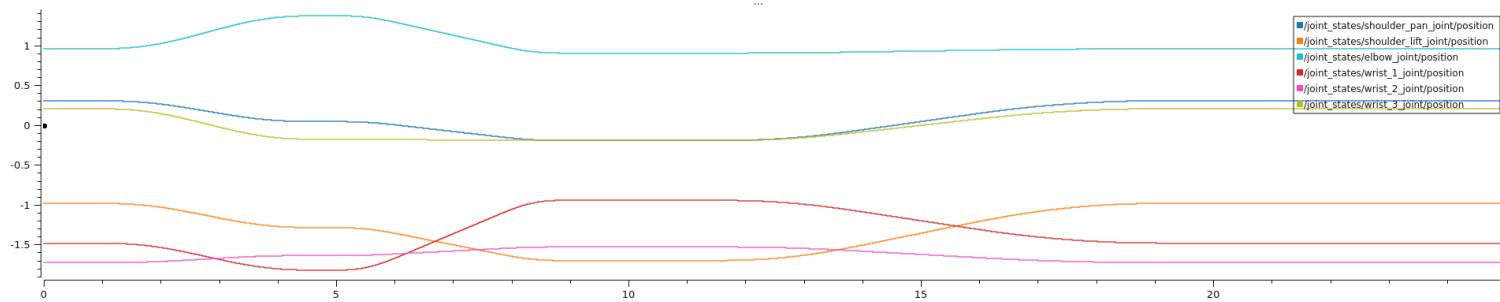velocities

efforts

Evaluation— JTC on robot
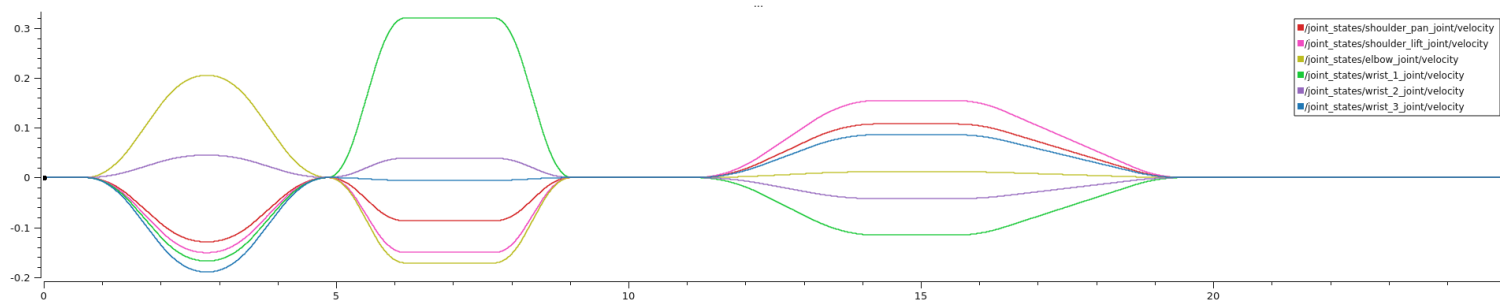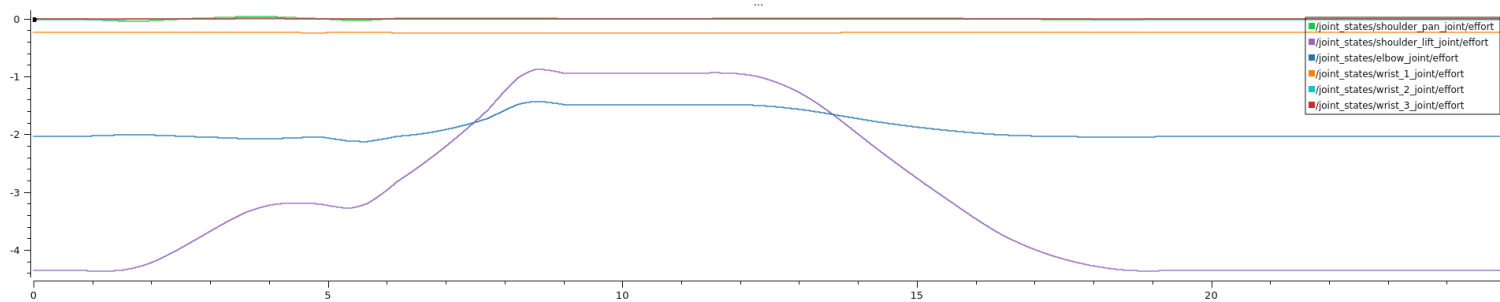

positions

velocities

efforts

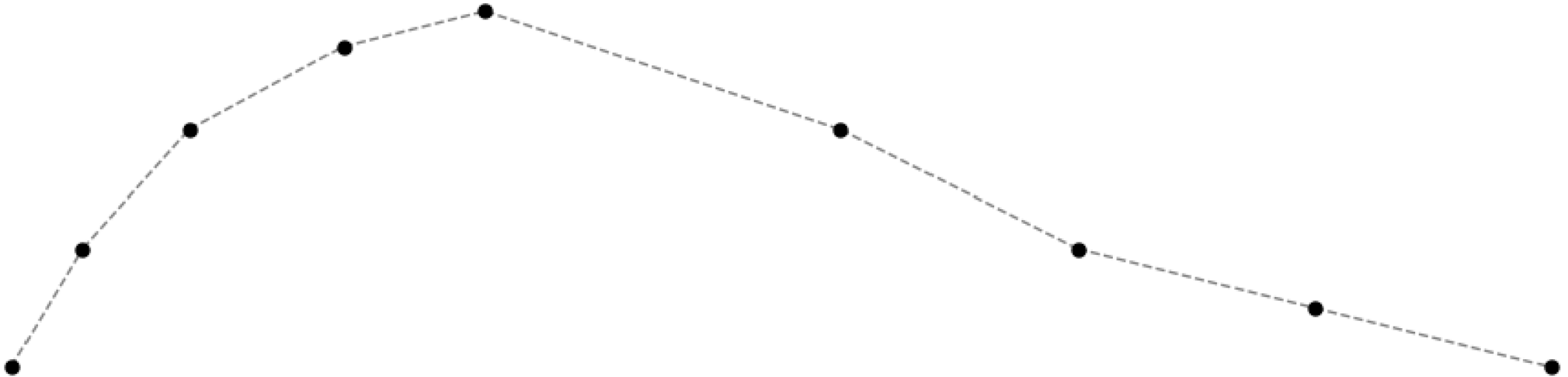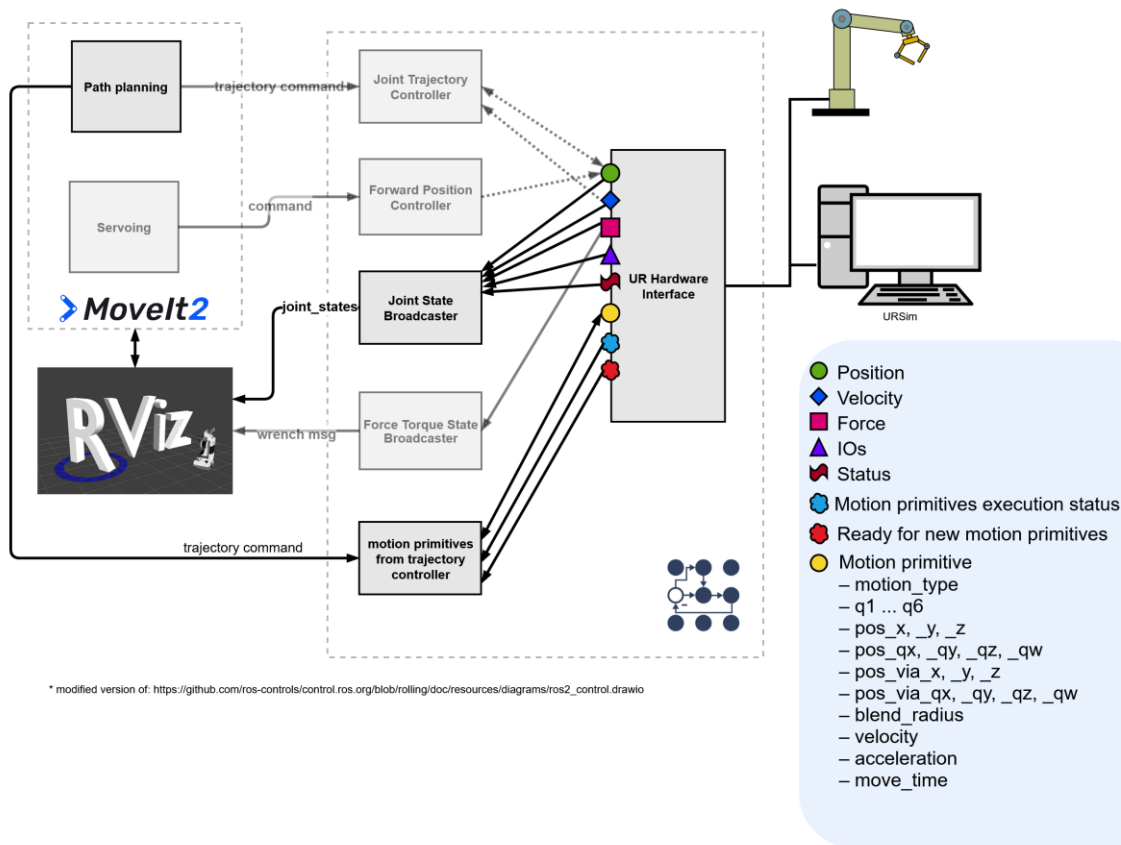# Evaluation— motion primitives (OptiMove)

positions

velocities

efforts

What do we do with Trajectories?

Motion Primitives Controller From Trajectory Controller

* modified version of: https://github.com/ros-controls/control.ros.org/blob/rolling/doc/resources/diagrams/ros2_control.drawio

Legend:
- 🟢 Position
- 🔷 Velocity
- 🟥 Force
- 🔺 IOs
- 🔻 Status
- ⬡ Motion primitives execution status
- 🔴 Ready for new motion primitives
- 🟡 Motion primitive
  - motion_type
  - q1 ... q6
  - pos_x, _y, _z
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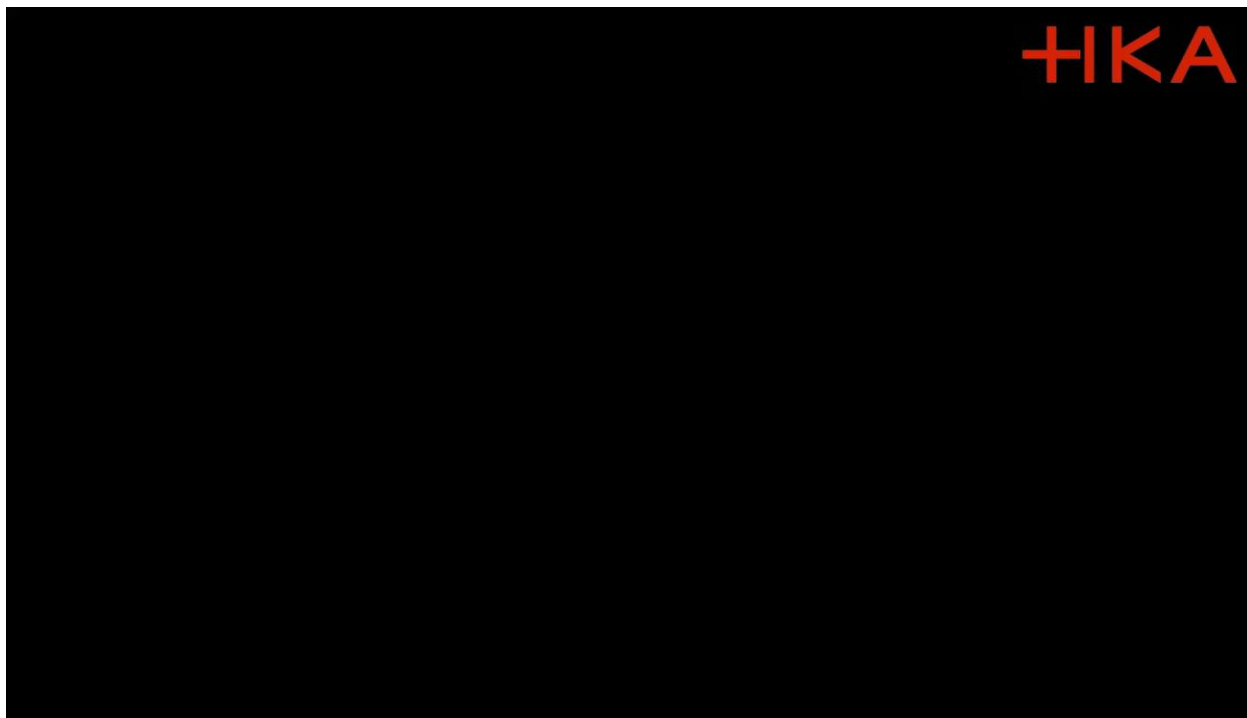 - blend_radius
  - velocity
  - acceleration
  - move_time

Motion Primitives Controller From Trajectory Controller

» Ramer-Douglas-Peucker (RDP) Algo
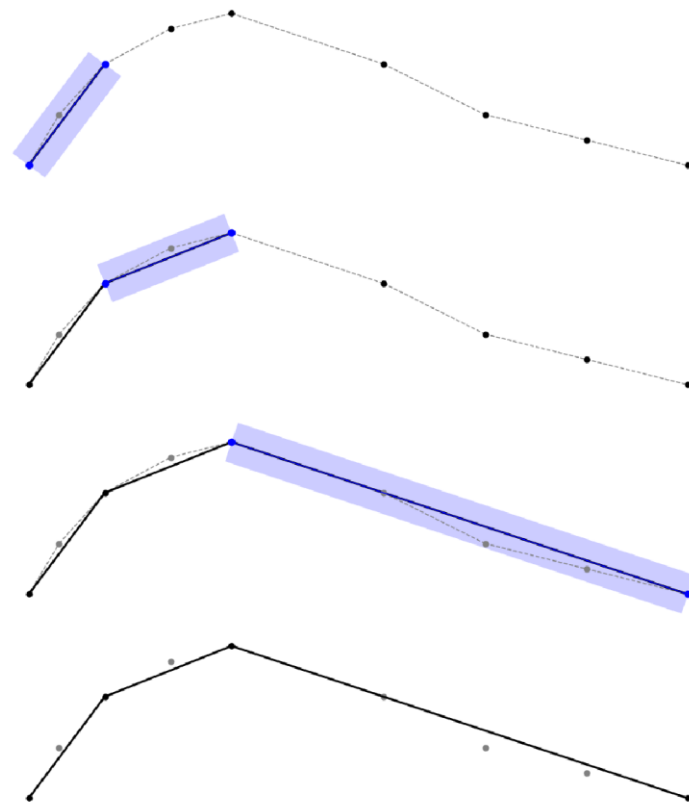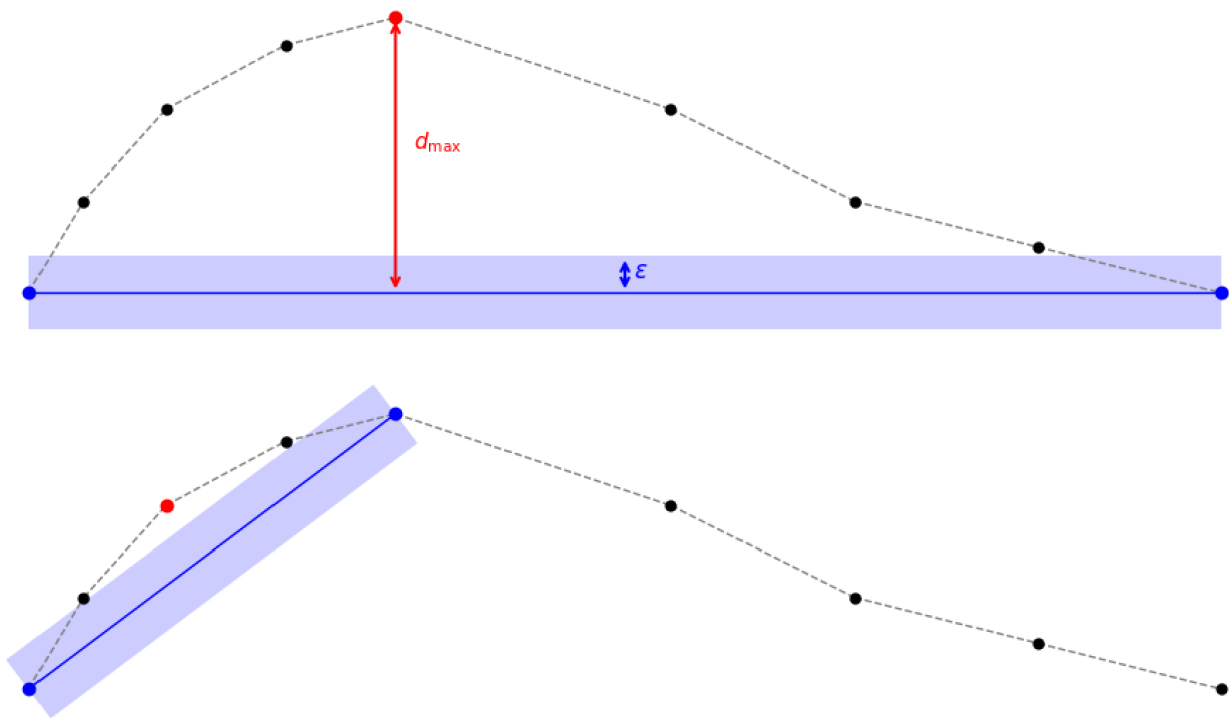
Motion Primitives Controller From Trajectory Controller

» *https://www.youtube.com/watch?v=Z_NCaSyE-KA*

What's next?

» Approximation of Trajectories with MOVEC-primitives

» Combined approximation

» Support for further robots

» Integration with protocols like SRCI *(maybe standard language?)*

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Motion Pritmitives Forward Controller