

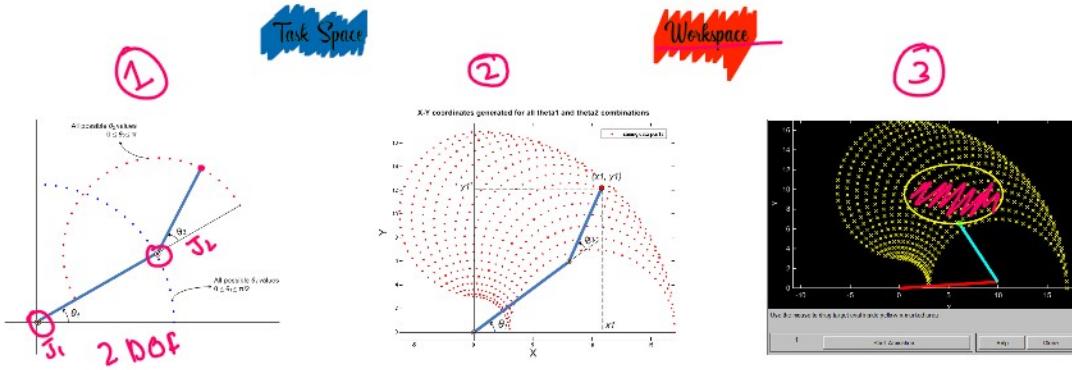
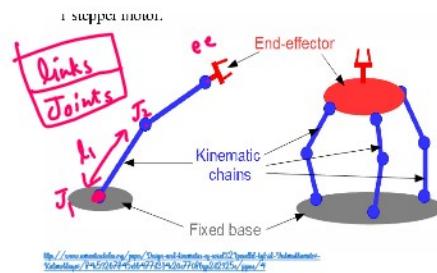
Section 1

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How Robotic Arms Work

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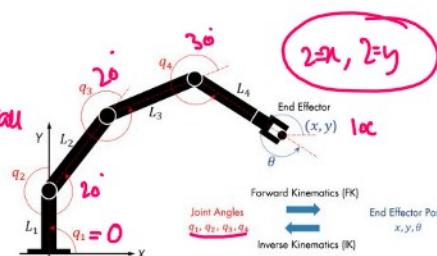
- Type of Manipulator
- Serial / Chain
 - Parallel



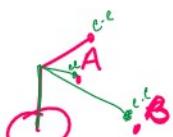
Kinematics

- Forward
 $O_{ori} \rightarrow EE(x, y, \theta)$

- Inverse
 $EE(x, y) \rightarrow O_{ori}$



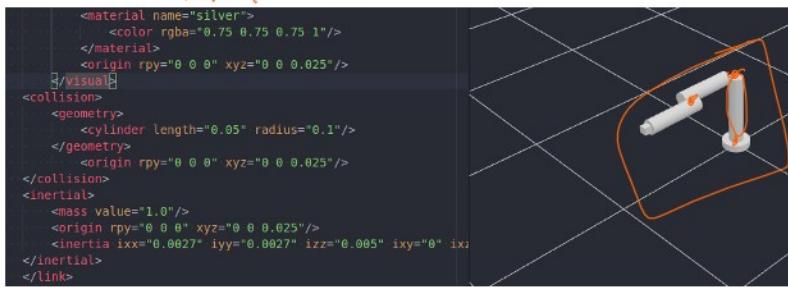
Trajectory Generation



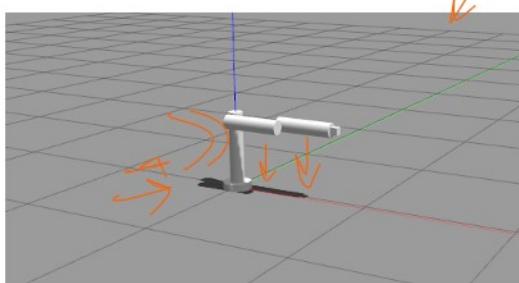


ROS (only simulation in Gazebo)

1- Robot Design or download URDF



2- Gazebo/Vrep (which test physical properties)



5- Motion and Trajectory Planning

Sum of paths

3- Controllers (simple scripts)

```
controller.yaml x
1 arm_controller:
2   type: "position_controllers/JointTrajectoryController"
3   joints:
4     - One_joint
5     - Two_joint
6     - Three_joint
7     - Four_joint

simple_arm.urdf x
143 <!-- ONE-->
144 <transmission name = "Trans_1">
145   <type>transmission_interface/SimpleTransmission</type>
146   <joint name="One_joint">
147     <hardwareInterface>PositionJointInterface</hardwareInterface>
148   </joint>
149   <actuator name="Motor1">
150     <hardwareInterface>PositionJointInterface</hardwareInterface>
151     <mechanicalReduction>1</mechanicalReduction>
152   </actuator>
153 </transmission>
154
155 <!-- Two-->
156 <transmission name = "Trans_2">
157   <type>transmission_interface/SimpleTransmission</type>
158   <joint name="Two_joint">
159     <hardwareInterface>PositionJointInterface</hardwareInterface>
160   </joint>
161   <actuator name="Motor2">
162     <hardwareInterface>PositionJointInterface</hardwareInterface>
163
```

4- Solve for inverse Kinematics and send to controllers

$T_{symbolic} = T_{symbolic \simplified}$

$$N = \text{MatrixSize Symbolic, N}$$

$$\begin{bmatrix} 1.0\cos(q_1)\cos(q_1+q_2) & 1.0\sin(q_1+q_2)\cos(q_1) & 1.0\sin(q_1) & 6.1232399573077 \cdot 10^{-1} \sin(q_1) \sin(q_2) + 1.0 \cdot \cos(q_1) \cos(q_2) + 1.0, \cos(q_1) \\ 1.0\sin(q_1)\cos(q_1+q_2) & -1.0\sin(q_1)\sin(q_1+q_2) & -1.0\cos(q_1) & 1.0, \sin(q_1) \cos(q_2) + 6.1232399573077 \cdot 10^{-1} \cdot \sin(q_1) \cos(q_2) + 1.0, \sin(q_1+q_2) \\ 1.0\sin(q_1+q_2) & 1.0\cos(q_1+q_2) & 6.1232399573077 \cdot 10^{-1} & 1.0, \sin(q_1+q_2) \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$T_{symbolic} = T_{symbolic \simplified}$

$$\begin{bmatrix} 6.1232399573077 \cdot 10^{-1} \sin(q_1) \sin(q_2) - 1.0 \cdot \cos(q_1) \cos(q_2) + 1.0, \cos(q_1) \cos(q_2+q_1) \\ 1.0, \sin(q_1) \cos(q_2) - 6.1232399573077 \cdot 10^{-1} \cdot \sin(q_1) \cos(q_2) + 1.0, \sin(q_1) \cos(q_2+q_1) \\ 1.0, \sin(q_1+q_2) - 6.1232399573077 \cdot 10^{-1} \cdot \sin(q_1+q_2) \\ 1.0, \sin(q_1+q_2) + 1.0, \sin(q_1+q_2) \end{bmatrix}$$

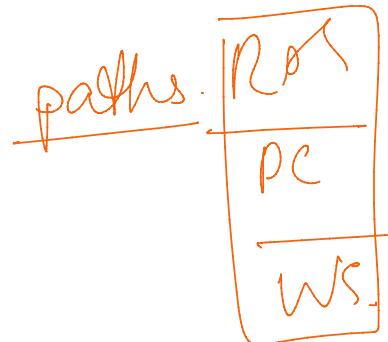
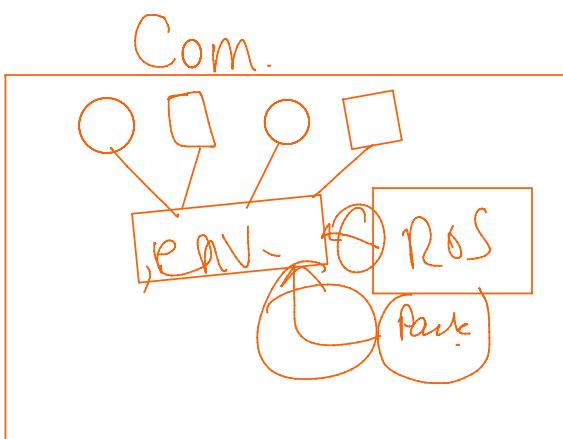
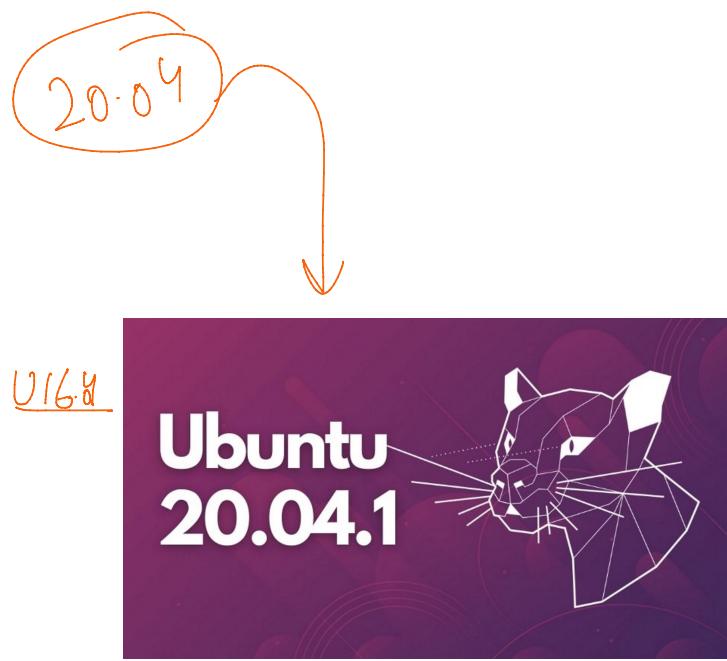
δtb

Peter.

ROS Installations and Paths Setup

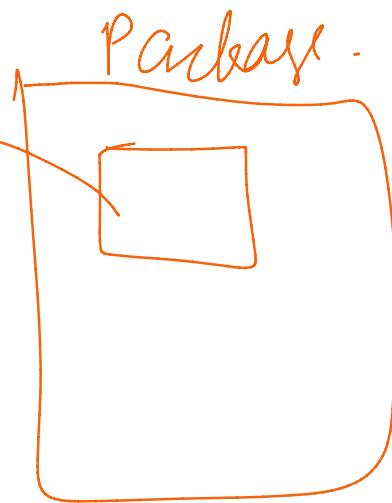
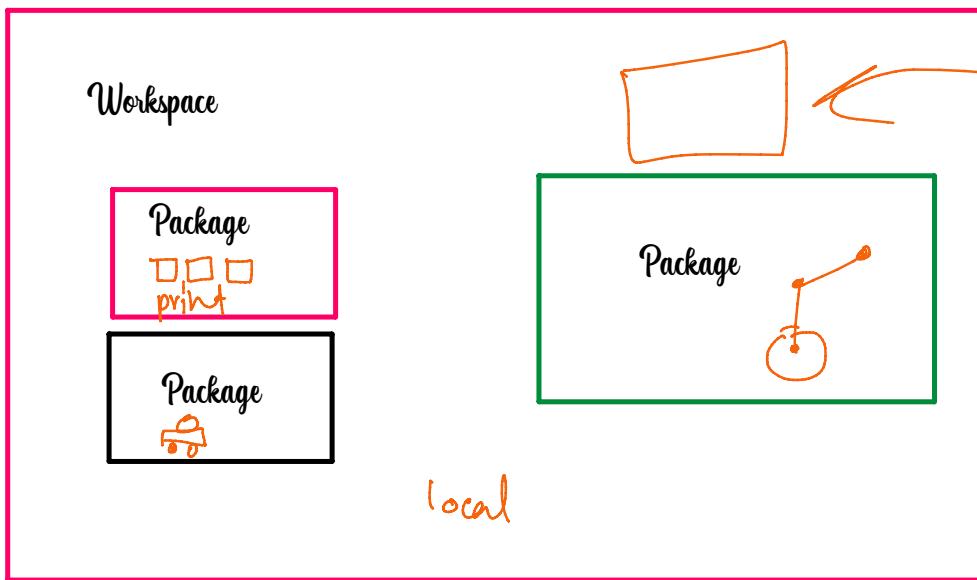
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Distribution	Release date	Poster	EOL date
Noetic Ninjemys (last ROS 1 release)	23 May 2020		May 2025
Melodic Morenia	23 May 2018		2023-05-30
Lunar Loggerhead	23 May 2017		2019-05-30
Kinetic Kame	23 May 2016		2021-05-30
Jade Turtle	23 May 2015		2017-05-30
Indigo Igloo	22 July 2014		2019-04-30
Hydro Medusa	4 September 2013		2014-05-31
Groovy Galapagos	31 December 2012		2014-07-31

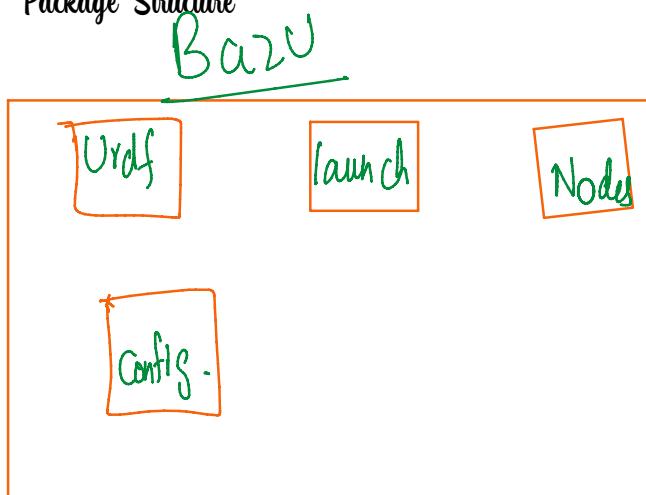


Workspace and Custom Package Creation

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"Bazu" Package Structure



Section 2

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Custom Robotic Arm Design into URDF

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Questions ?

- Type of arm
Serial

- Degree of freedoms
3

- Joint Types

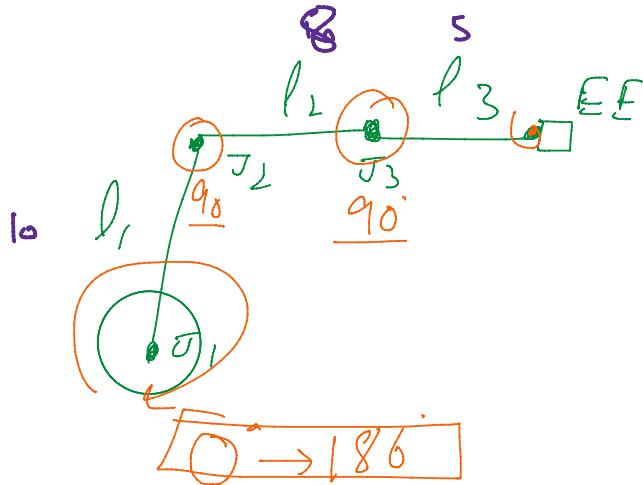
Revolute

S, e

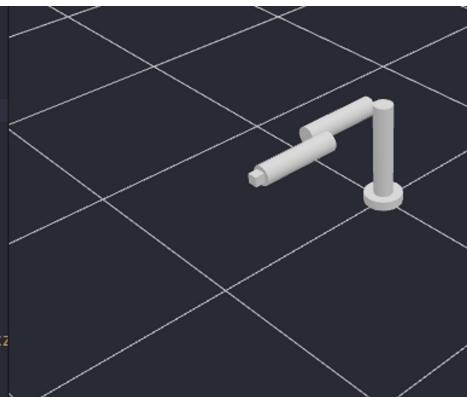
- Links Lengths

10, 8, 5

- Total Reachable Space



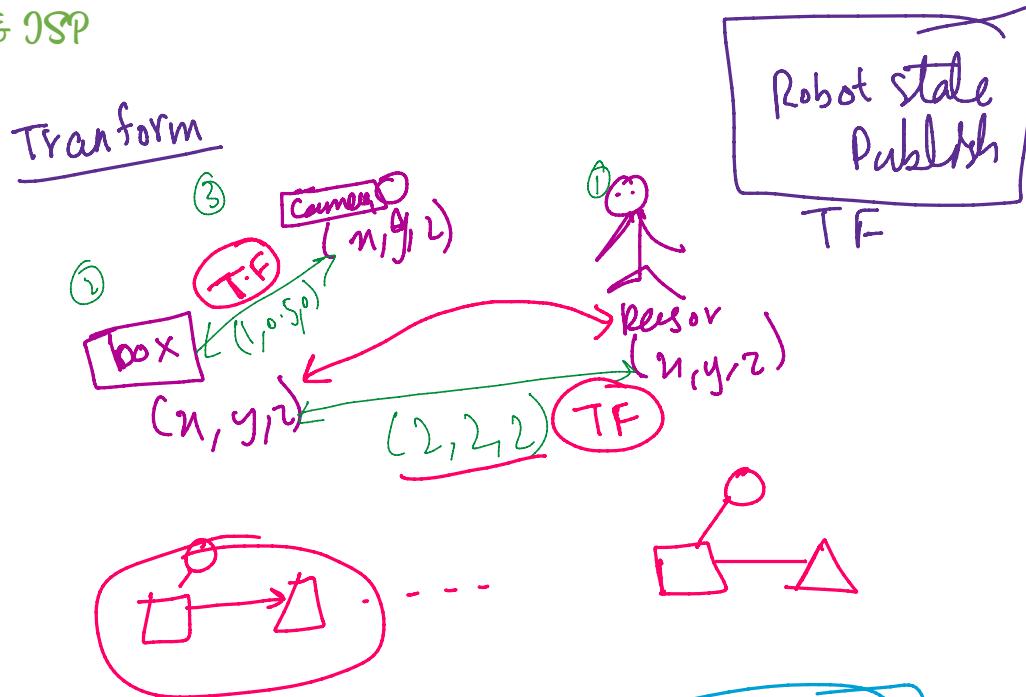
```
<material name="silver">
    <color rgba="0.75 0.75 0.75 1"/>
</material>
<origin rpy="0 0 0" xyz="0 0 0.025"/>
</visual>
<collision>
    <geometry>
        <cylinder length="0.05" radius="0.1"/>
    </geometry>
    <origin rpy="0 0 0" xyz="0 0 0.025"/>
</collision>
<inertial>
    <mass value="1.0"/>
    <origin rpy="0 0 0" xyz="0 0 0.025"/>
    <inertia ixx="0.0027" iyy="0.0027" izz="0.005" ixy="0" ixz="0" iyz="0"/>
</inertial>
</link>
```



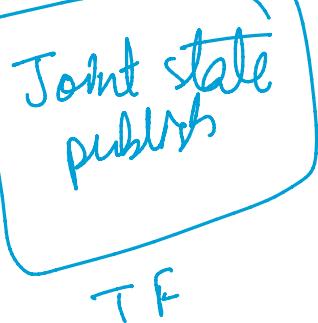
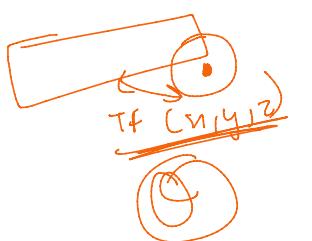
RVIZ and TF States publishing RSP & JSP

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- Actuated Joints
 - Non Actuated Joints
- parent child



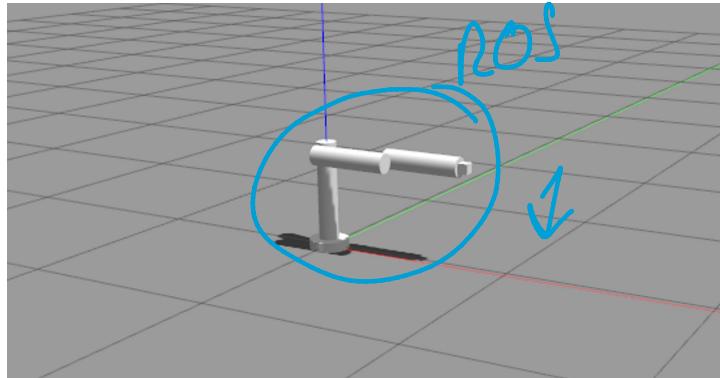
Ad = Revolute



Gazebo and Physical Properties

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- Gazebo \leftrightarrow ROS
 - Spawning a model process
 - Forces action on Robot
- (1) (2)



- ① Launch Gazebo
- ② bring /inertia-
③ Controllers

Section 3

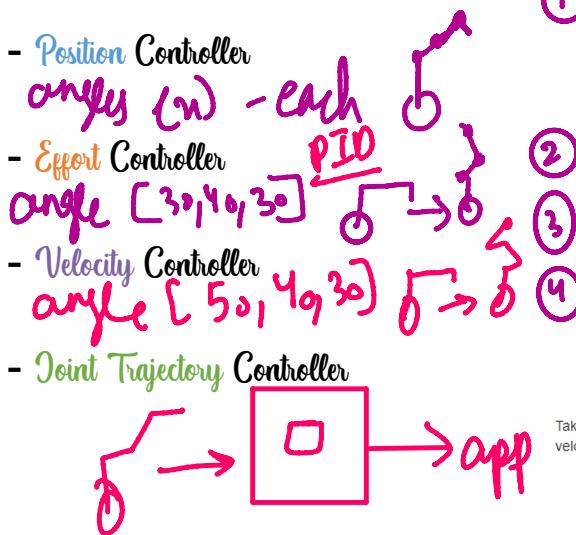
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ROS Control and Controllers Workflow

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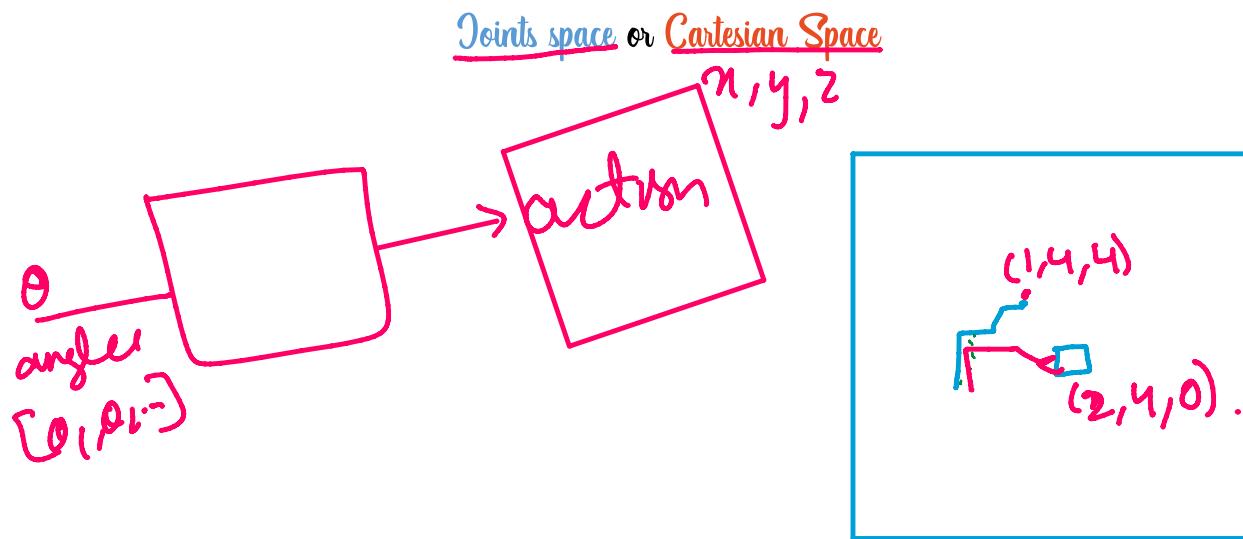
2. Controllers

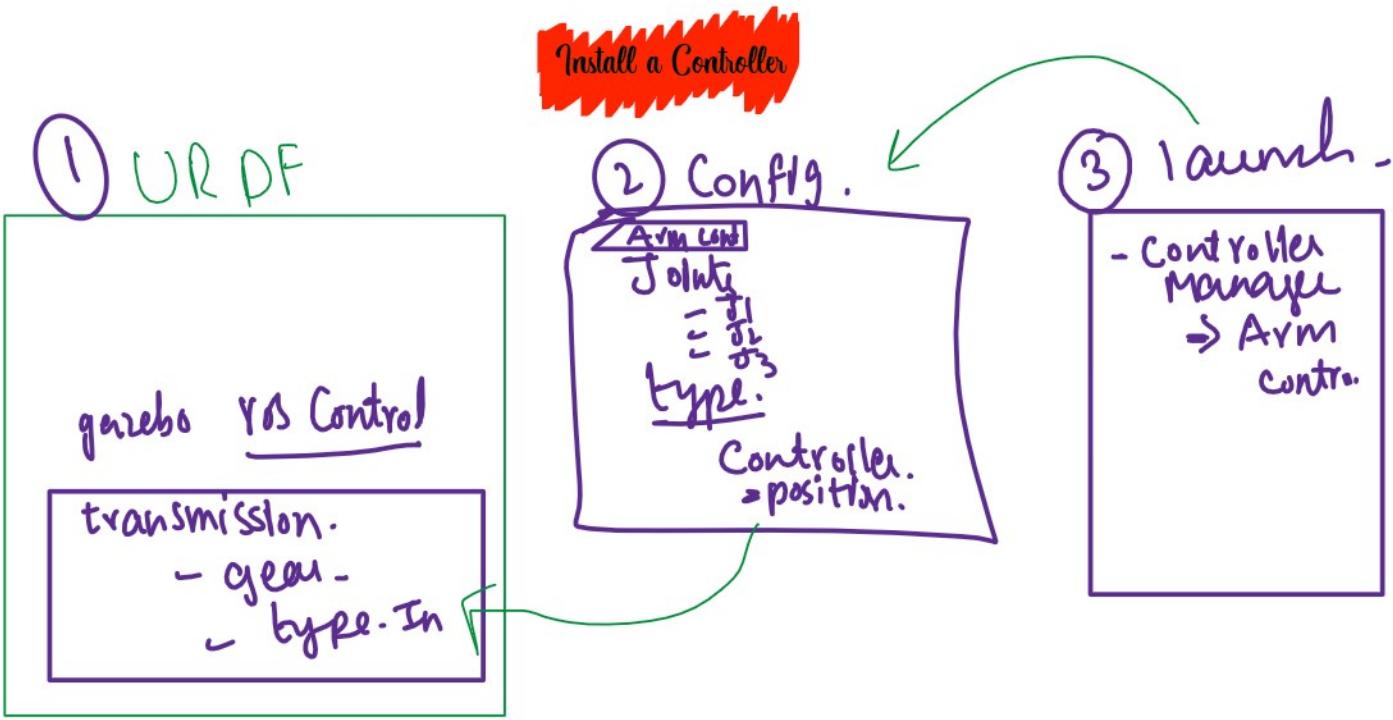
A list of available controller plugins, contained in `ros_controllers`, as of this writing. You can of course create your own and are not limited to the below list. All controllers use the `forward_command_controller` to send commands to a hardware interface.



- ① • `effort_controllers` - Command a desired force/torque to joints.
 - `joint_effort_controller` (force/torque input is directly output to the joint)
 - `joint_position_controller` (position input goes into a PID controller that outputs force/torque to the joint)
 - `joint_velocity_controller` (velocity input goes into a PID controller that outputs force/torque to the joint)
- ② • `position_controllers` - Set one or multiple joint positions at once.
 - `joint_position_controller`
 - `joint_group_position_controller`
- ③ • `velocity_controllers` - Set one or multiple joint velocities at once.
 - `joint_velocity_controller`
 - `joint_group_velocity_controller`
- ④ • `joint_trajectory_controllers` - Extra functionality for splining an entire trajectory.
 - `position_controller`
 - `velocity_controller`
 - `effort_controller`
 - `position_velocity_controller`
 - `position_velocity_acceleration_controller`

Take a look at the [source file](#) to understand how the `joint_trajectory_controller` is namespaced with the `position_controller`, `velocity_controller`, etc.



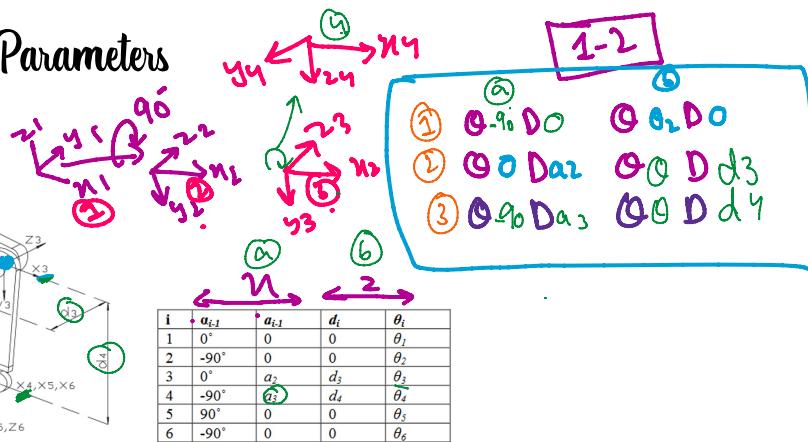


Denavit Hartenberg Parameters

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$$\textcircled{1} (x_i, \epsilon_{unit})$$

$$\textcircled{5} (z_i, \epsilon_z)$$

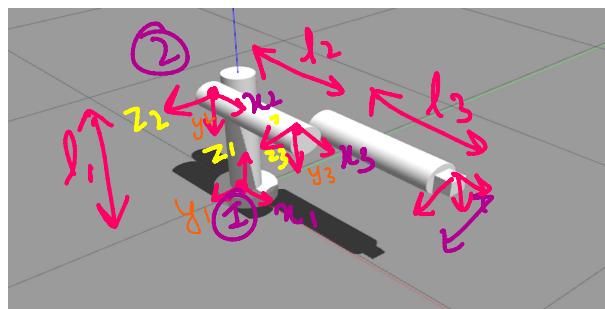
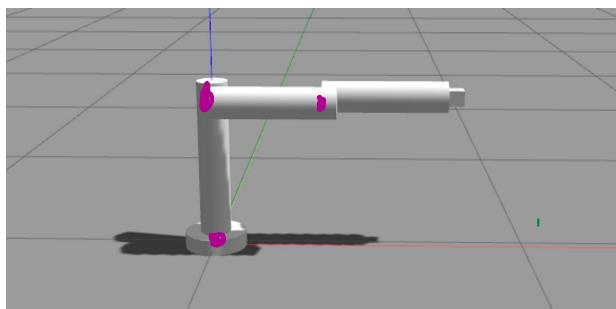
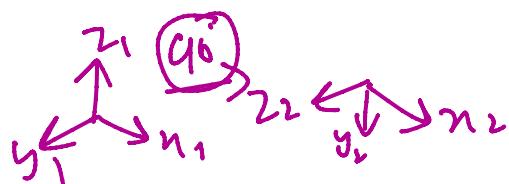


Picture 1: Robotic manipulator PUMA 560 with assigned link parameters according to J.J. Craig

https://ediba.stackexchange.com/questions/11879/motional_dh_params_for_puma_560

Table 1: Link parameters for PUMA 560 robotic manipulator

Solve DH table for our "BA2U"

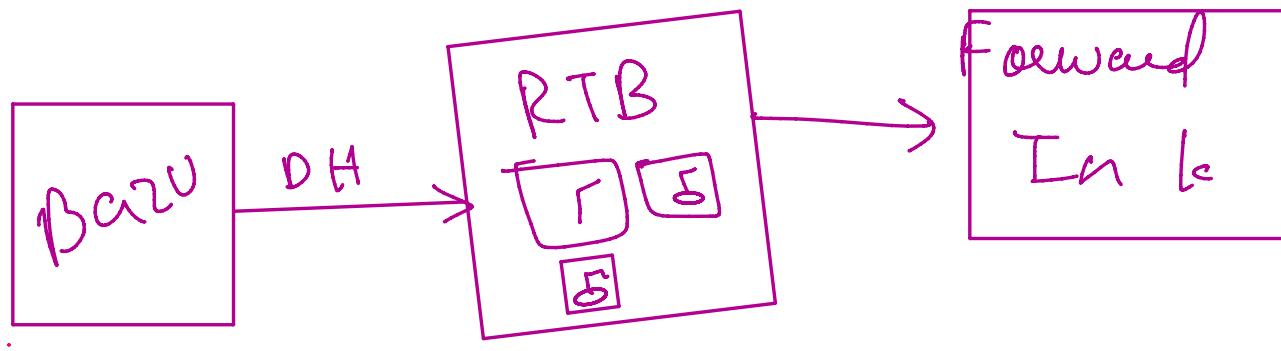


D-H Table

	(a) O	(d)	O	D(d)
①	0	0	θ_1	a_1
②	a_1	0	θ_2	0
③	0	a_2	θ_3	$-a_1$
④	0	a_2	θ_4	0
⑤	a_2	0	θ_5	0
⑥	0	a_2	θ_6	0

Forward and Inverse Kinematics

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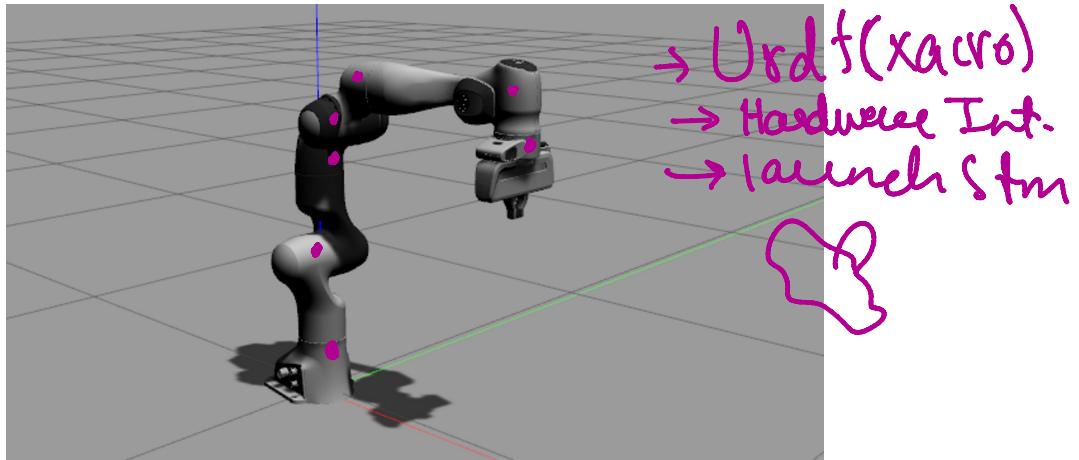
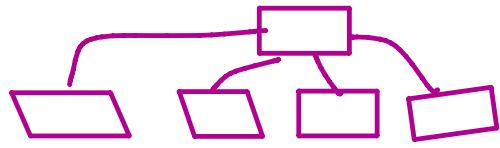
Section 4

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Franka Emeka -> Panda 7-DOF

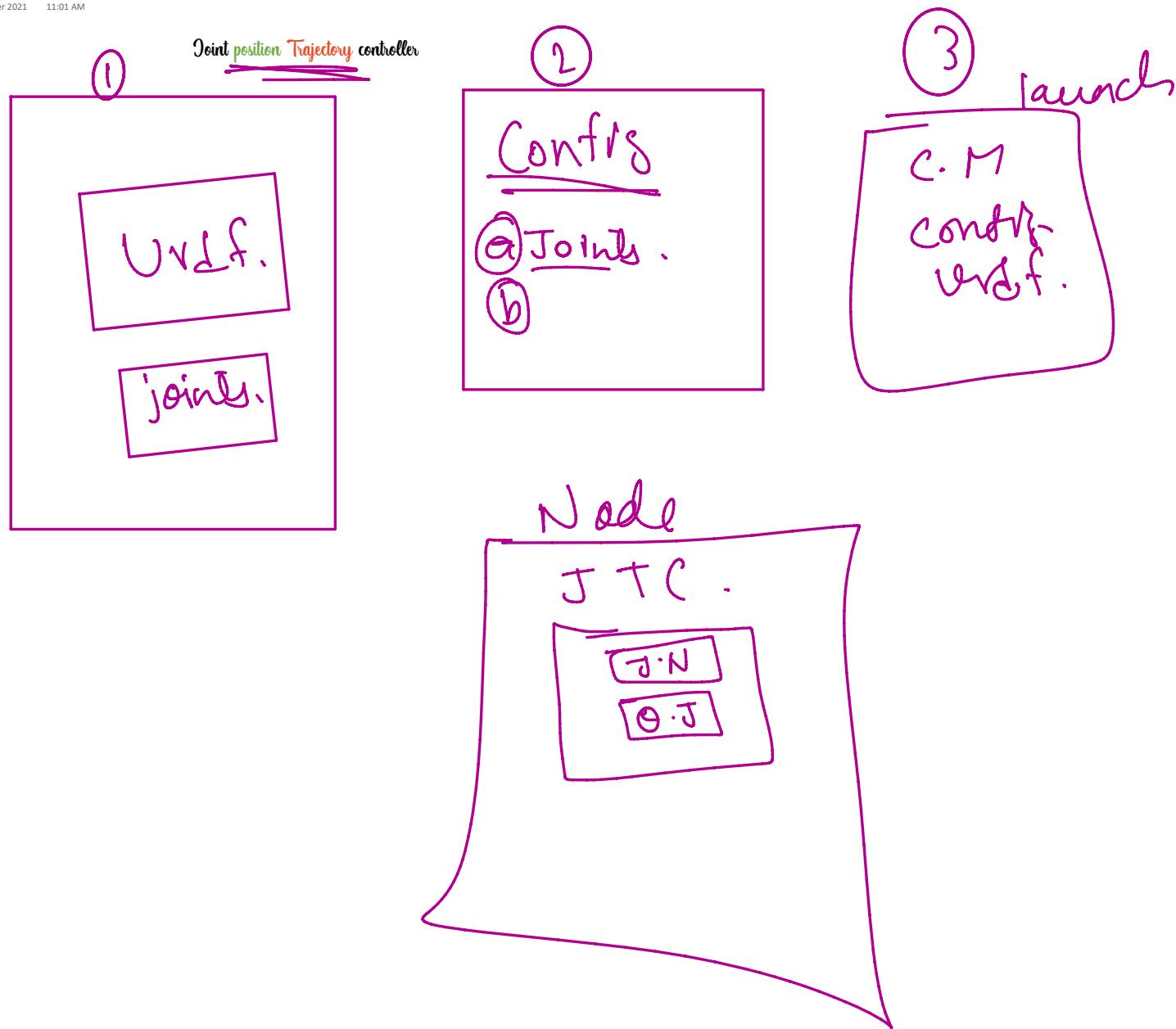
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Understanding Package Design



Adding Custom Controllers

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Kinematics solution with RTB

Tuesday, 21 September 2021 11:01 AM

D H.

ERobot: panda (by Franka Emika), 7 joints (RRRRRRR), geometry, collision

id	link	joint	parent	ETS
1	panda_link0		BASE	{panda_link0} = {BASE}
2	panda_link1	0	panda_link0	{panda_link1} = {panda_link0} e tz(0.333) e Rz(q0)
3	panda_link2	1	panda_link1	{panda_link2} = {panda_link1} e Rx(-90°) e Rz(q1)
4	panda_link3	2	panda_link2	{panda_link3} = {panda_link2} e ty(-0.316) e Rx(90°) e Rz(q2)
5	panda_link4	3	panda_link3	{panda_link4} = {panda_link3} e tx(0.0825) e Rx(90°) e Rz(q3)
6	panda_link5	4	panda_link4	{panda_link5} = {panda_link4} e tx(-0.0825) e ty(0.384) e Rx(-90°) e Rz(q4)
7	panda_link6	5	panda_link5	{panda_link6} = {panda_link5} e Rx(90°) e Rz(q5)
8	panda_link7	6	panda_link6	{panda_link7} = {panda_link6} e tx(0.088) e Rx(90°) e Rz(q6)
9	@panda_link8		panda_link7	{panda_link8} = {panda_link7} e tz(0.107)

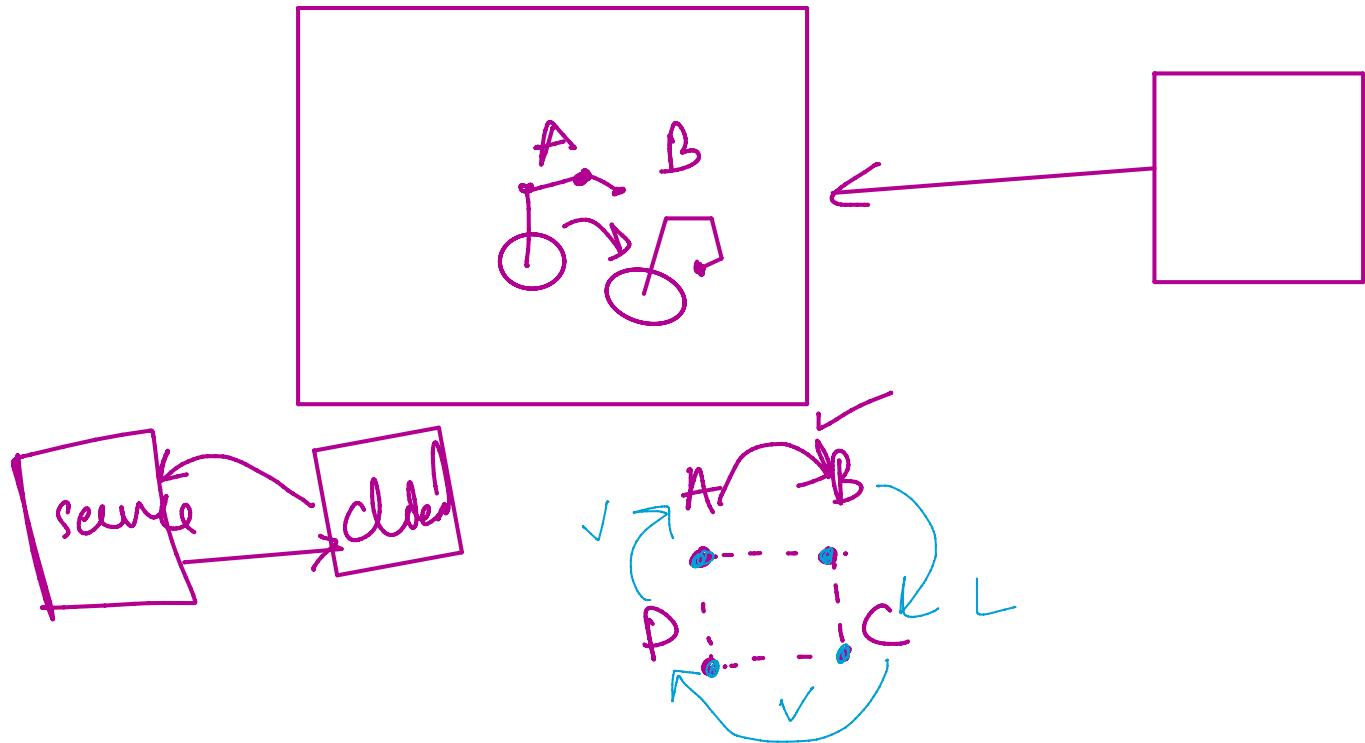
name	q0	q1	q2	q3	q4	q5	q6
qz	0°	0°	0°	0°	0°	0°	0°
qr	0°	-17.2°	0°	-126°	0°	115°	45°

0 - 6 → Joint 7 8 → finger -

F · k → IK

Action Client Interface for Square Waypoints

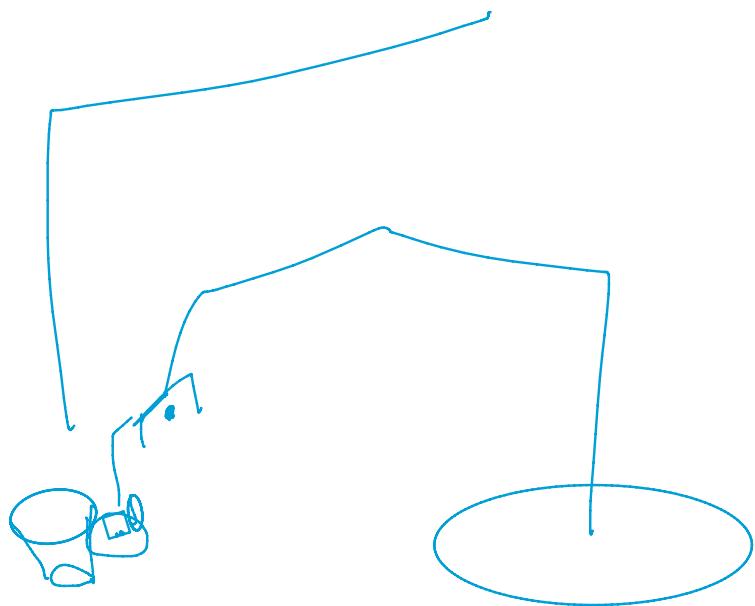
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Lets pick up the CUP

Tuesday, 21 September 2021 11:01 AM

- Waypoints .
- Claw
- o pick up -
- fingers power .



Can we create a Circle?

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