

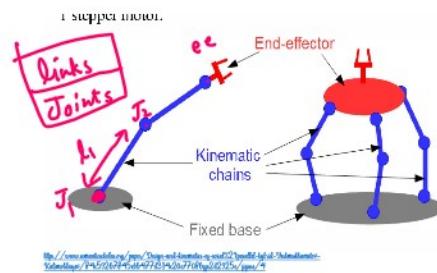
Section 1

Tuesday, 21 September 2021 10:45 AM

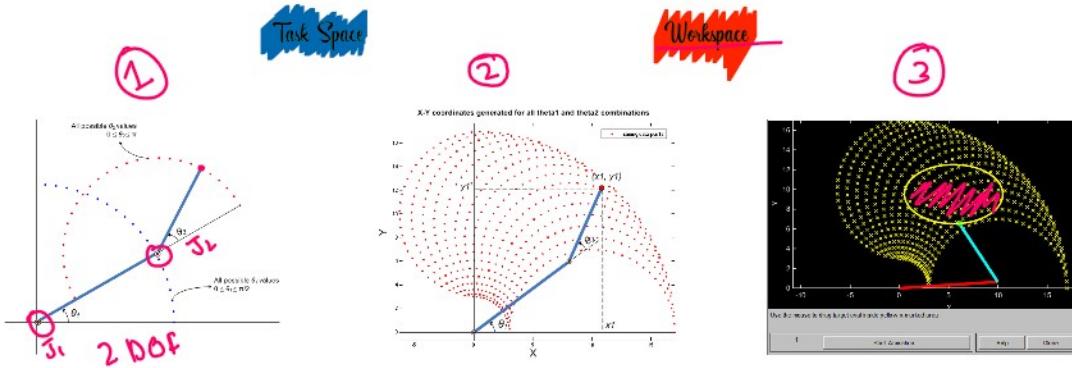
How Robotic Arms Work

Tuesday, 21 September 2021 10:46 AM

- Type of Manipulator
- Serial / Chain
 - Parallel



<https://www.mathworks.com/help/robotic-mechanisms/ug/links-and-joints-in-a-serial-manipulator.html>

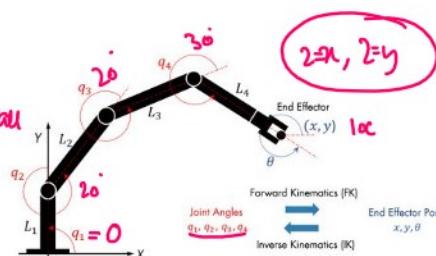


<https://www.mathworks.com/help/paggg/modelling-series-manipulators-in-a-while-loop.html>

Kinematics

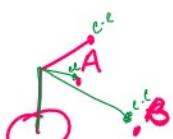
- Forward
 $O_{all} \rightarrow EE(x, y, \theta)$

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



<https://www.mathworks.com/discovery/inverse-kinematics.html>

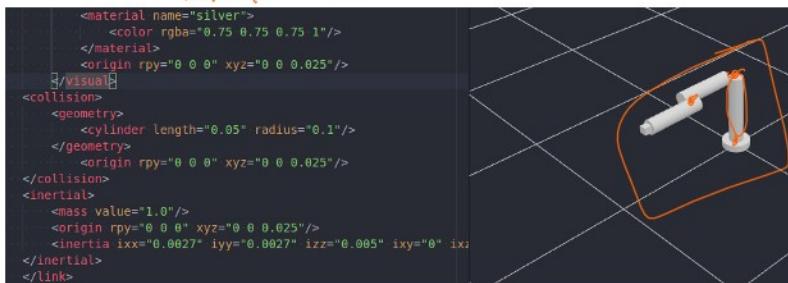
Trajectory Generation



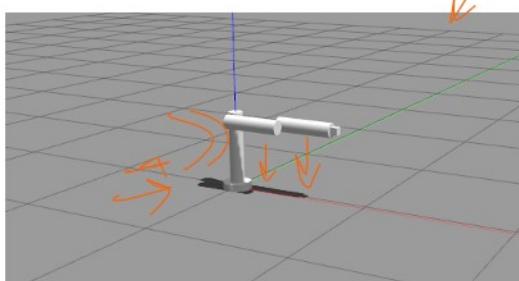


ROS (only simulation in Gazebo)

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

$T_s \text{ symbolic} = T_s \text{ symbolic simplify}$
 $N = \text{MatrixSymbol}(\text{Symbol}, N)$

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

$T_s \text{ Matrix} = \text{extracting translation part}$

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

δtb

Peter.

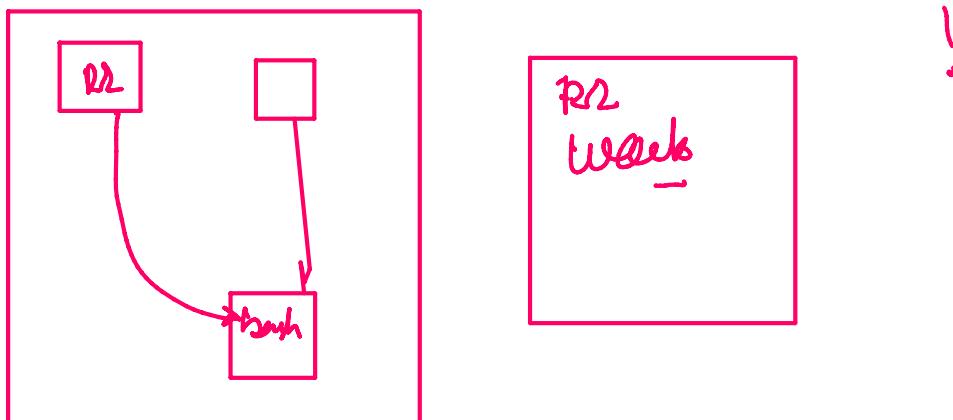
ROS Installations and Paths Setup

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Distro	Release date	Logo	EOL date
Galactic Geochelone	May 23rd, 2021		November 2022
Foxy Fitzroy	June 5th, 2020		May 2023
Eloquent Elusor	November 22nd, 2019		November 2020
Dashing Diademata	May 31st, 2019		May 2021
Crystal Clemmys	December 14th, 2018		December 2019

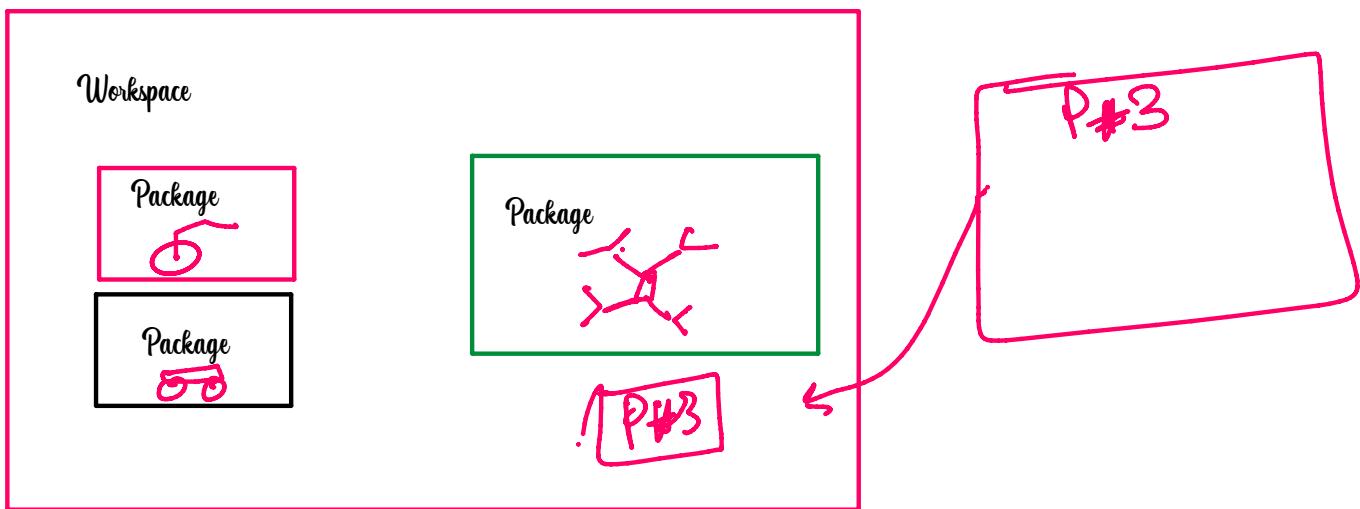


Ros Installation and Path Setup

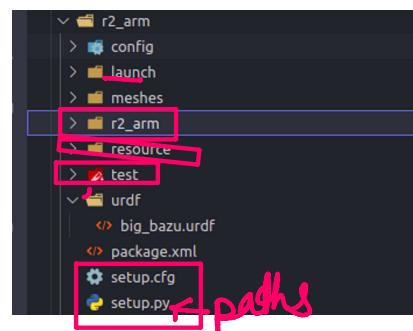
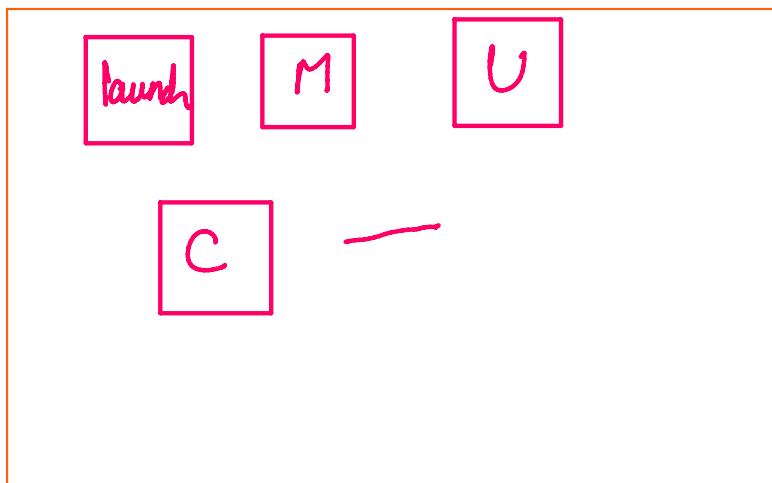


Workspace and Custom Package Creation

Tuesday, 21 September 2021 10:46 AM



"Big Bazu" Package Structure



Section 2

Tuesday, 21 September 2021 10:45 AM

Custom Robotic Arm Design into URDF

Tuesday, 21 September 2021 10:47 AM

Questions ?

- Type of arm
Serial

- Degree of freedoms
3

- Joint Types

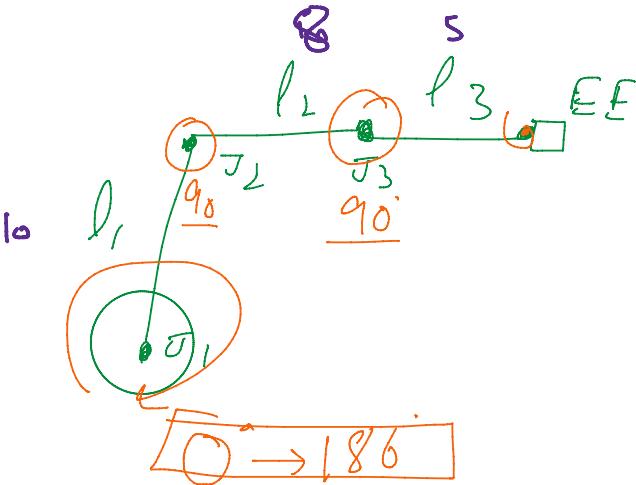
Revolute

S, e

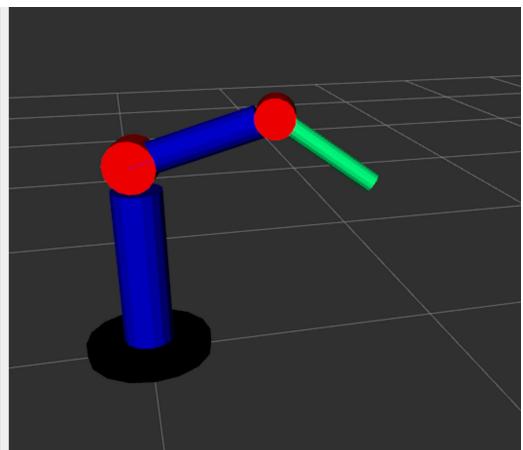
- Links Lengths

10, 8, 5

- Total Reachable Space



```
<inertial ixx="0.107" ixy="0.0" ixz="0.0" iyy="0.107" iyz="0.0" />
</inertial>
</link>
<joint name="joint_1" type="continuous">
<axis xyz="0 0 1"/>
<parent link="base_link"/>
<child link="link_1"/>
<origin rpy="0 0 0" xyz="0.0 0.0 0.05"/>
</joint>
<link name="link_2">
<inertial>
<origin rpy="0 0 0" xyz="0 0 0.2"/>
<mass value="2.0"/>
<inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" />
</inertial>
<visual>
<geometry>
<cylinder length="0.1" radius="0.08"/>
</geometry>
<material name="Red"/>
</visual>
```

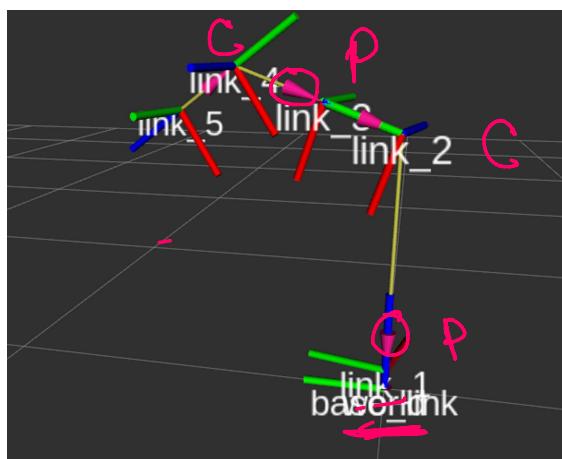
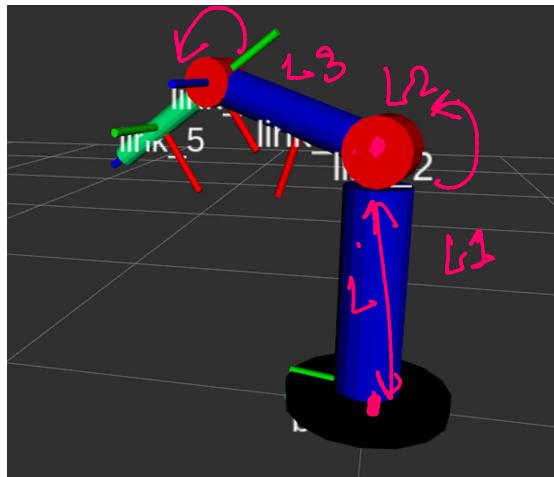
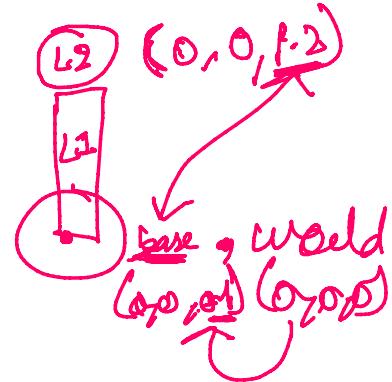


Transforms , States publishing RSP & JSP

Tuesday, 21 September 2021 10:47 AM

Joints
Links

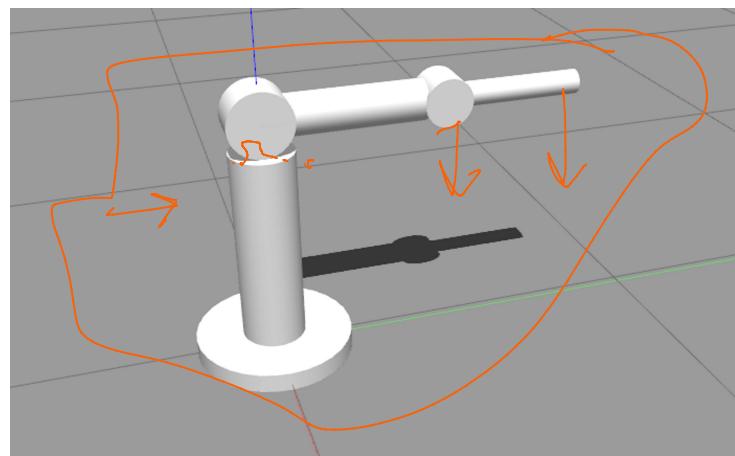
- Transforms
 - Actuated Joints
 - Non Actuated Joints
- Parent - Child



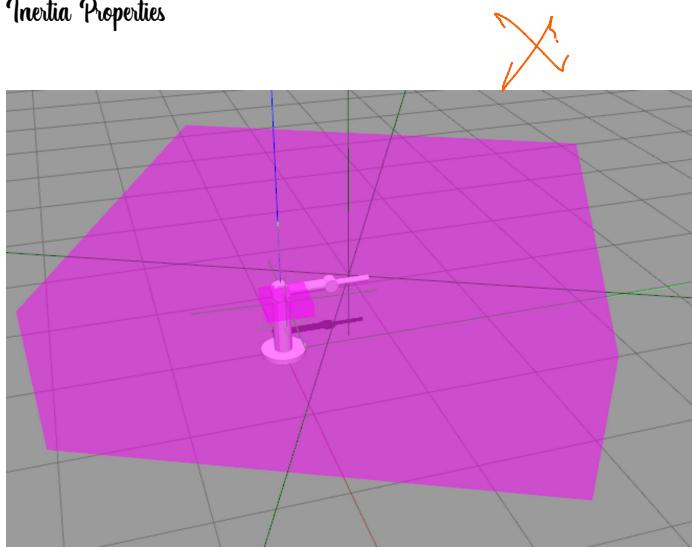
Gazebo and Physical Properties

Tuesday, 21 September 2021 10:48 AM

- Gazebo \leftrightarrow ROS
- Spawning a model process
- Forces action on Robot



Inertia Properties

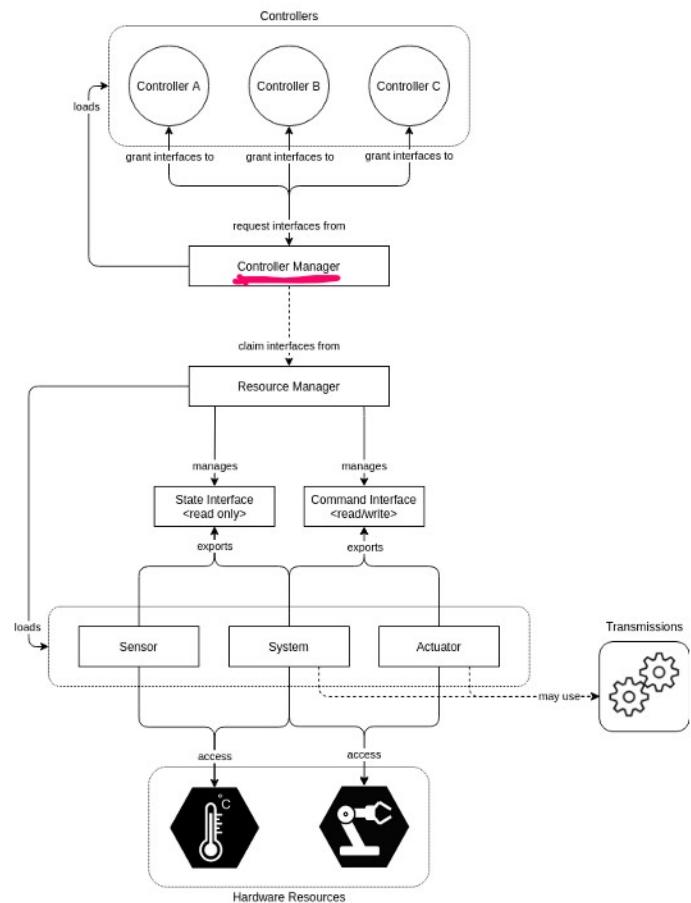


Section 3

Tuesday, 21 September 2021 10:45 AM

ROS-2 Control

- Command Interface
- State Interface

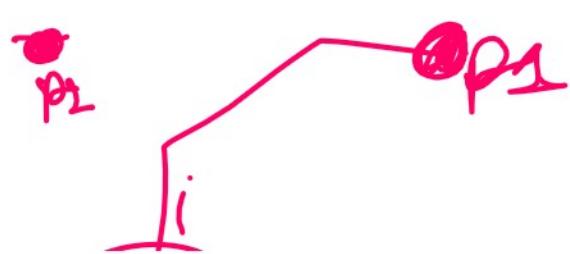


http://control.ros.org/getting_started.html

Controllers Workflow

- Position Controller
- Acceleration Controller

Position Controller



- Velocity Controller
- ~~Joint Trajectory Controller~~



Install a Controller

Fronts
type
Hz
Command
State

/> Control >

G:I
S:I

< >

controller.yaml

Wolfram

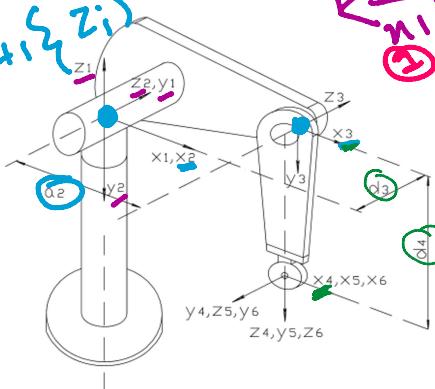
Controller
manager.
Wolfram
controller

bunch

Denavit Hartenberg Parameters

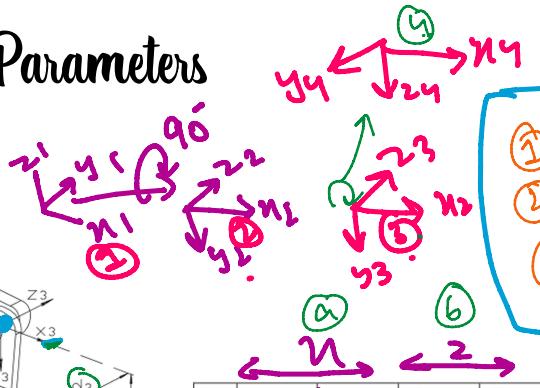
Tuesday, 21 September 2021 10:51 AM

$$\begin{array}{l} \textcircled{1} (x_i, \epsilon_{unit}) \\ \textcircled{2} (z_i + \epsilon_z z_i) \end{array}$$



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

<https://robotics.stackexchange.com/questions/11878/modified-dh-parameters-for-puma-560>



1-2

①	$\alpha_{1,0}$	$\theta_{1,0}$
②	$\alpha_2 D_{a2}$	$\theta_2 D_{d3}$
③	$\alpha_3 D_{a3}$	$\theta_3 D_{d4}$

i	a_{i-1}	$a_{i,1}$	d_i	θ_i
1	0°	0	0	θ_1
2	-90°	0	0	θ_2
3	0°	a_3	d_3	θ_3
4	-90°	a_4	d_4	θ_4
5	90°	0	0	θ_5
6	-90°	0	0	θ_6

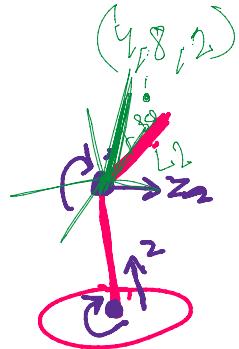
Table 1: Link parameters for PUMA 560 robotic manipulator

Forward and Inverse Kinematics

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5

Joints space or Cartesian Space
($x \ y \ z$)

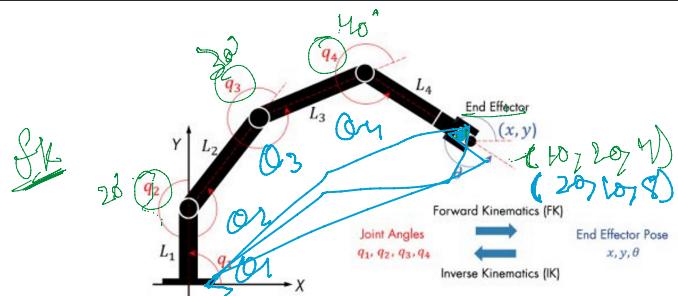
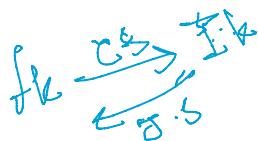


→

```
def robot_initialize(self):
    self.kuka_robot = ikpy.chain.Chain.from_urdf_file("/home/luqman/r2_ra_ws/src/kuka_arm/urdf/kuka_model.urdf")
```

Forward Kinematics

Inverse Kinematics



Section 4

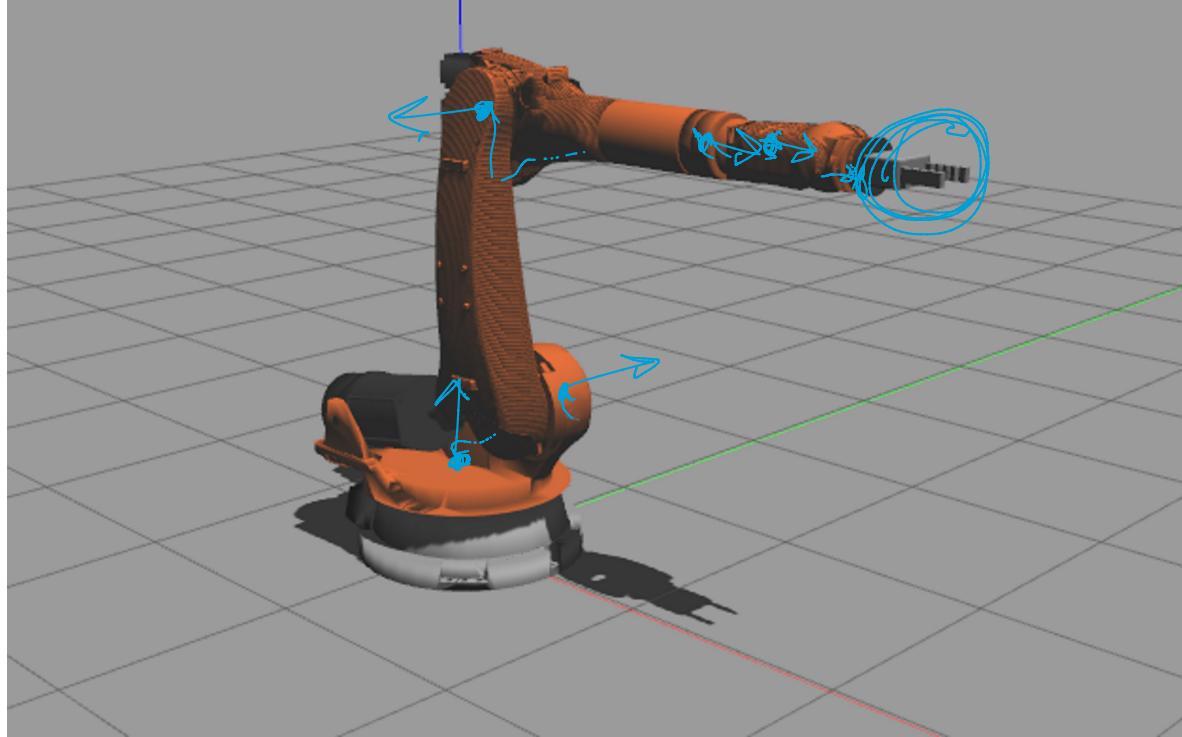
Tuesday, 21 September 2021 10:45 AM

Kuka -> KR-150 6-DOF

Tuesday, 21 September 2021 10:51 AM

Understanding Package Design

gouthub



Adding Custom Controllers

Tuesday, 21 September 2021 11:01 AM

- Interface Decide **JTC**
- Yaml File
- Urdf Ros2 Tags
- Launching Control Manager

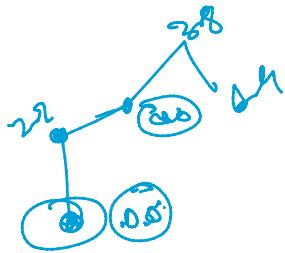
```
controller_manager:  
  ros_parameters:  
    update_rate: 100 # Hz  
  
  joint_state_broadcaster:  
    type: joint_state_broadcaster/JointStateBroadcaster  
  joint_trajectory_controller:  
    type: joint_trajectory_controller/JointTrajectoryController  
  
  ...  
  
  joint_trajectory_controller:  
    ros_parameters:  
      joints:  
        - joint_1  
        - joint_2  
        - joint_3  
        - joint_4  
        - joint_5  
        - joint_6  
        & left_gripper_finger_joint  
        & right_gripper_finger_joint  
  
      command_interfaces:  
        - position  
  
      state_interfaces:  
        - position  
  
      state_publish_rate: 50.0 # Defaults to 50  
      action_monitor_rate: 20.0 # Defaults to 20
```

Joint position **Trajectory** controller

Kinematics solution with Tkine-Py

Tuesday, 21 September 2021 11:01 AM

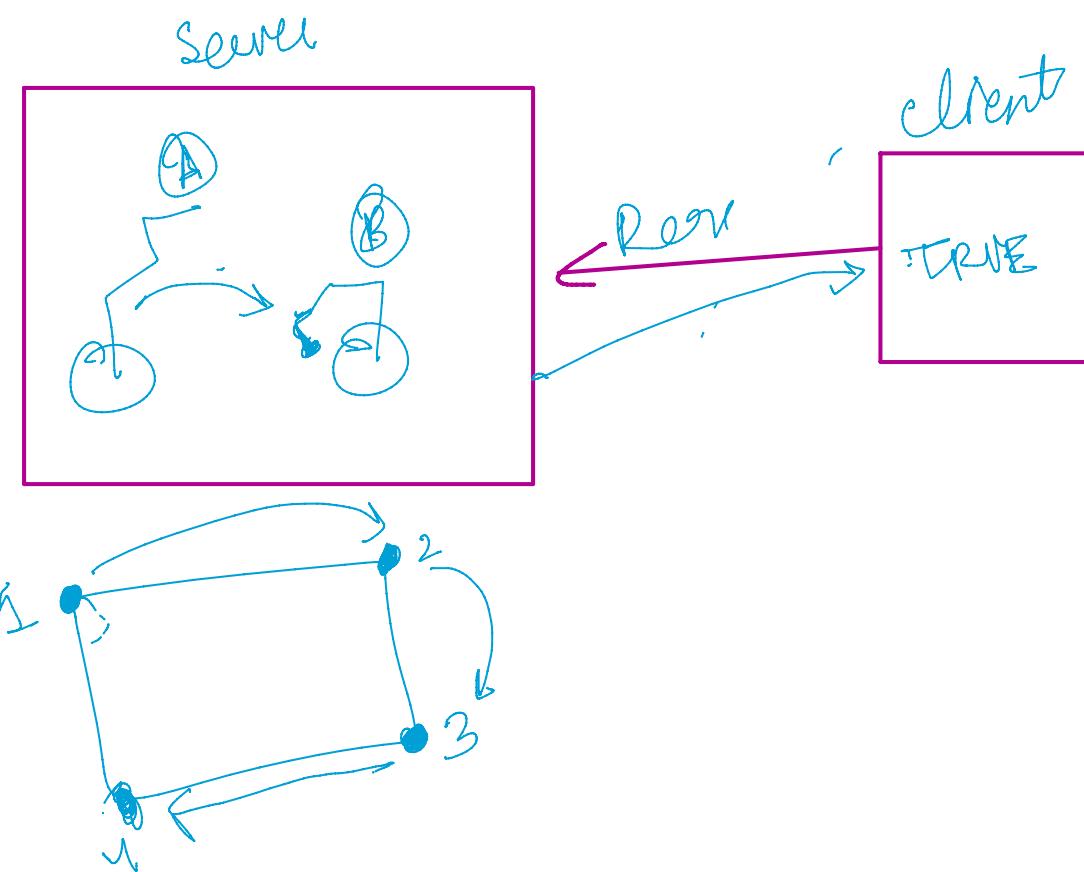
- Urdf Read
- ④ Transformation Matrix
- ④ Kinematic Solutions
- Delete Fixed Joints



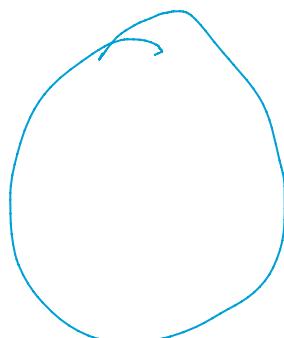
```
def robot_initialize(self):  
    ... self.kuka_robot = ikpy.chain.Chain.from_urdf_file("/home/luqman/r2_ra_ws/src/kuka_arm/urdf/kuka_model.urdf")
```

Action Client Interface for Square Waypoints

Tuesday, 21 September 2021 11:02 AM



Can we create a Circle?



Tuesday, 21 September 2021 11:03 AM