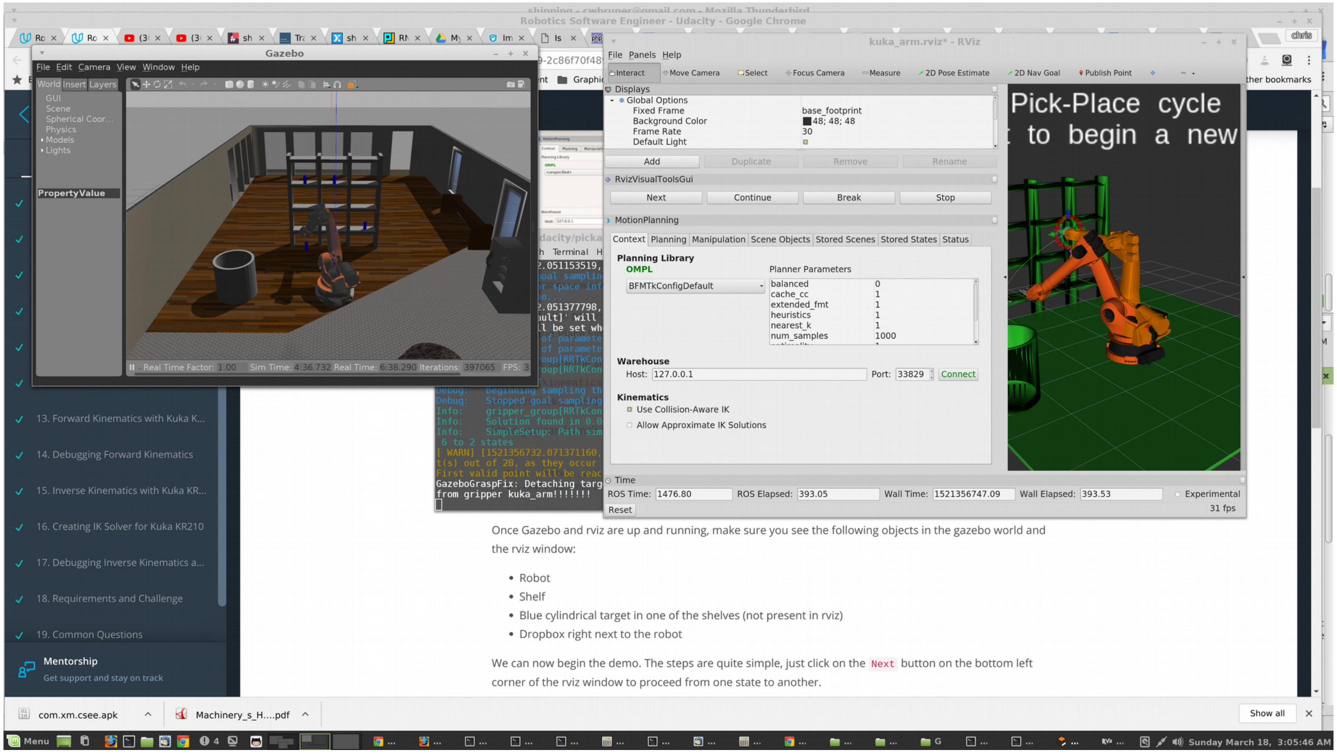
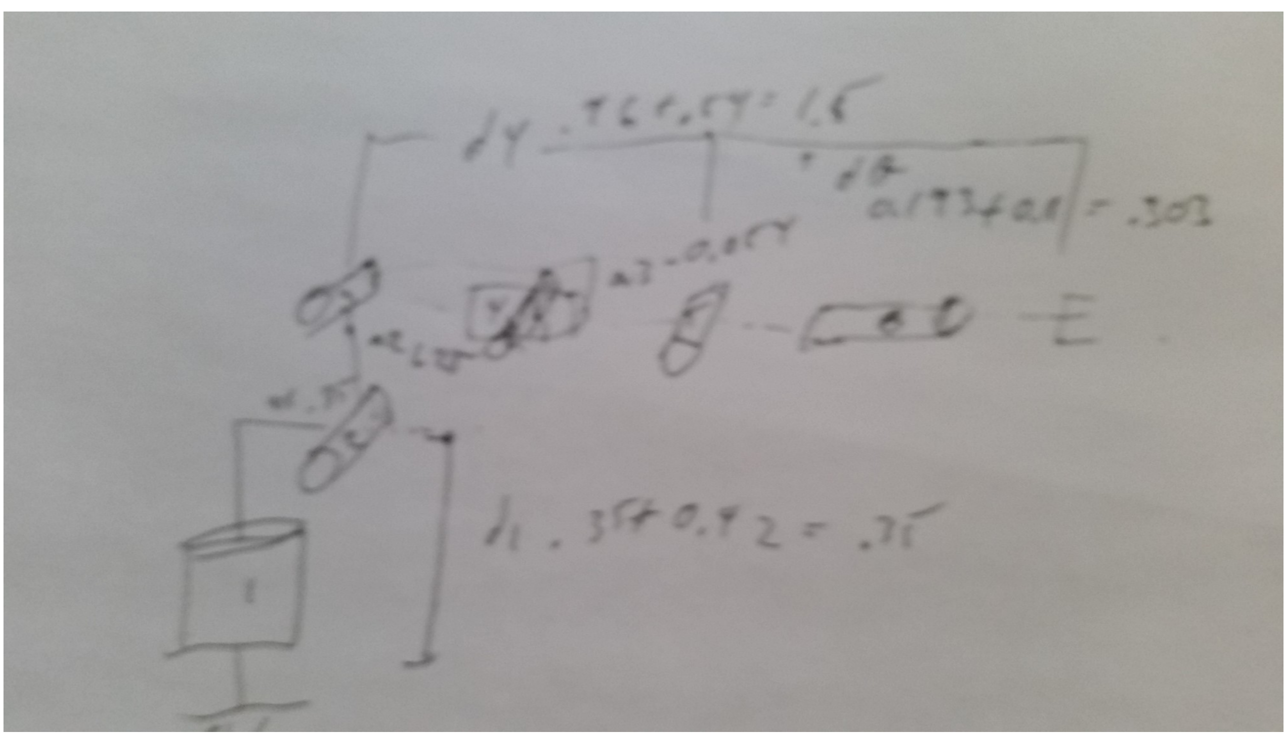


The joint values shown in the kr210.urdf.xcro are:

joint_1	0,	0,	0.33
joint_2	0.35,	0,	0.42
joint_3	0,	0,	1.25
joint_4	0.96,	0,	-0.054
joint_5	0.54,	0,	0
joint_6	0.193,	0,	0



```
# Create Modified DH parameters
DH_Table = { linkTwist0:    0,          linkLength0: 0,      linkOffset1: 0.75,   joint1:   joint1,
             linkTwist1:    -pi/2.,     linkLength1: 0.35,   linkOffset2: 0,      joint2: -pi/2. + joint2,
             linkTwist2:    0,          linkLength2: 1.25,   linkOffset3: 0,      joint3:   joint3,
             linkTwist3:    -pi/2.0,    linkLength3: -0.054, linkOffset4: 1.5,    joint4:   joint4,
             linkTwist4:    pi/2.0,     linkLength4: 0,      linkOffset5: 0,      joint5:   joint5,
             linkTwist5:    -pi/2.0,    linkLength5: 0,      linkOffset6: 0,      joint6:   joint6,
             linkTwist6:    0,          linkLength6: 0,      linkOffset7: 0.303,  joint7:   0.0 }


def TF_Matrix(twist,length,Offset,q):
        TF = Matrix([[cos(q), -sin(q),    0.0,  length],
                [sin(q) * cos(twist),cos(q) * cos(twist), -sin(twist), -sin(twist) * Offset],
                [sin(q) * sin(twist),cos(q) * sin(twist), cos(twist),     cos(twist) * Offset],
                [0.0,                   0.0, 0.0,              1.0]])
        return TF


T0_1 = TF_Matrix(linkTwist0, linkLength0, linkOffset1,joint1).subs(DH_Table)
T1_2 = TF_Matrix(linkTwist1, linkLength1, linkOffset2,joint2).subs(DH_Table)
T2_3 = TF_Matrix(linkTwist2, linkLength2, linkOffset3,joint3).subs(DH_Table)
T3_4 = TF_Matrix(linkTwist3, linkLength3, linkOffset4,joint4).subs(DH_Table)
T4_5 = TF_Matrix(linkTwist4, linkLength4, linkOffset5,joint5).subs(DH_Table)
T5_6 = TF_Matrix(linkTwist5, linkLength5, linkOffset6,joint6).subs(DH_Table)
T6_EE =TF_Matrix(linkTwist6, linkLength6, linkOffset7,joint7).subs(DH_Table)
T0_EE = T0_1 * T1_2 * T2_3 * T3_4 * T4_5 * T5_6 * T6_EE;
```

$$ {}_0T^1 = \begin{bmatrix} \cos(joint1) & -\sin(joint1) & 0.0 & 0.0 \\ \sin(joint1) & \cos(joint1) & 0 & 0 \\ 0 & 0 & 1 & 0.750000000000000 \\ 0.0 & 0.0 & 0.0 & 1.00000000000000 \end{bmatrix} $$

$$ {}_1T^2 = \begin{bmatrix} \cos(joint1) & -\sin(joint1) & 0.0 & 0.0 \\ \sin(joint1) & \cos(joint1) & 0 & 0 \\ 0 & 0 & 1 & 0.750000000000000 \\ 0.0 & 0.0 & 0.0 & 1.00000000000000 \end{bmatrix} $$

$$ {}_2T^3 = \begin{bmatrix} \cos(joint3) & -\sin(joint3) & 0.0 & 1.250 \\ \sin(joint3) & \cos(joint3) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix} $$

$$ {}_3T^4 = \begin{bmatrix} \cos(joint4) & -\sin(joint4) & 0.0 & -0.0540 \\ 0 & 0 & 1 & 1.50 \\ -\sin(joint4) & -\cos(joint4) & 0 & 0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix} $$

$$
{}_{4}T^{5} = \begin{bmatrix} \cos(joint5) & -\sin(joint5) & 0.0 & 0.0 \\ 0 & 0 & -1 & 0 \\ \sin(joint5) & \cos(joint5) & 0 & 0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}
$$

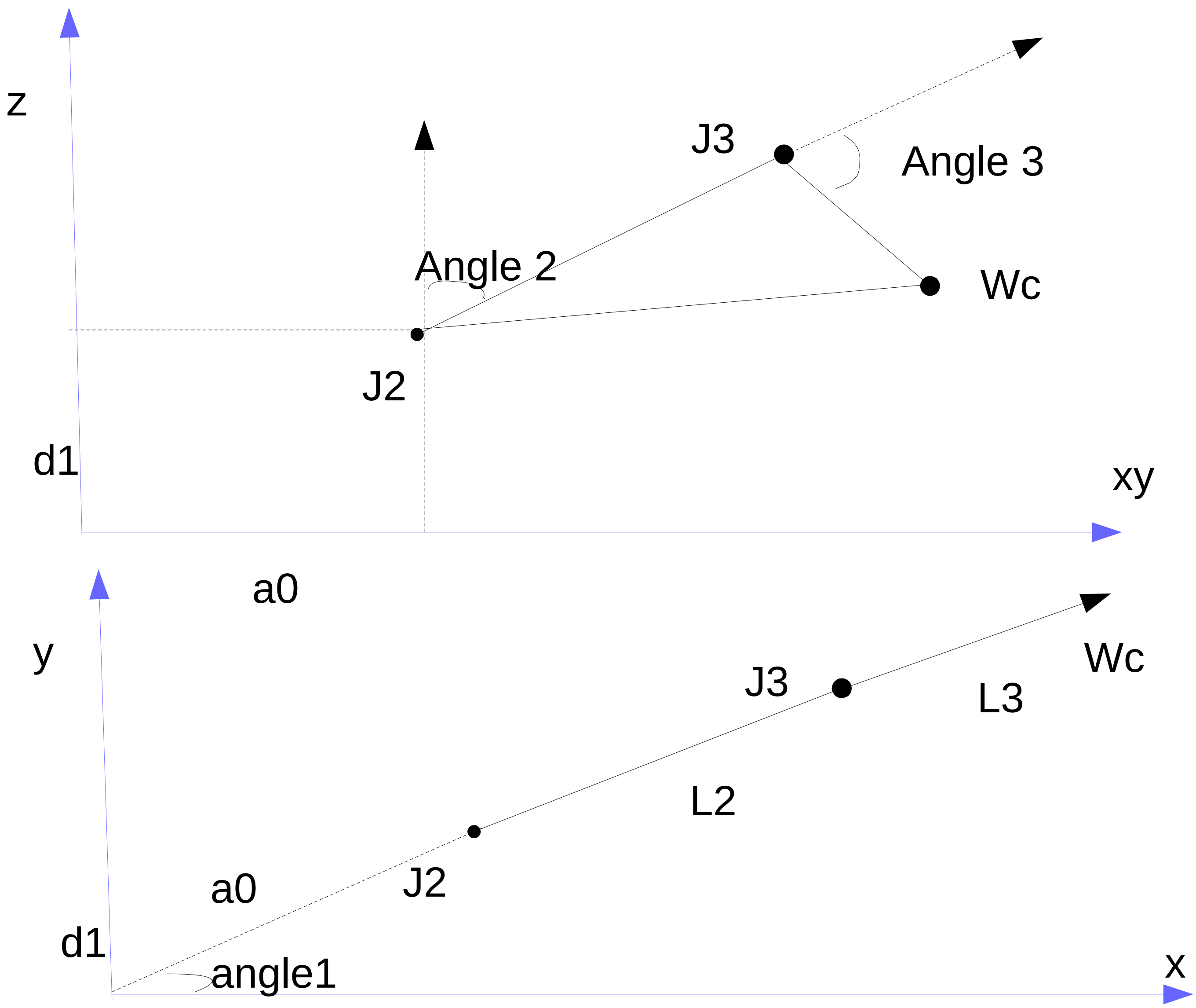
$$
{}_{5}T^{6} = \begin{bmatrix} \cos(joint6) & -\sin(joint6) & 0.0 & 0.0 \\ 0 & 0 & 1 & 0 \\ -\sin(joint6) & -\cos(joint6) & 0 & 0 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}
$$

$$
{}_{5}T^{6} = \begin{bmatrix} 1 & 0 & 0.0 & 0.0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0.3030 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix}
$$

Inverse Kinematics

The problem is broken into two parts, one for the revolute arm, another for a spherical arm. The revolute arm would return the joint angles for joints 1 through 3 and the spherical arm for joints 4 through 6.

So for the revolute part we would have:



For angle 1, it only lies on the xy plane so is atan2(y,x)

For the 2^{nd} and 3^{rd} angles, on the z plane use the cosine rule to obtain the angle first for angle 3, then calculating angle 2.

L3 =

$$l2 = angle2$$
$$l3 = \sqrt{(a3^2 + d4^2)}$$
$$Angle3 = 180 - \theta 3$$
$$xy = \sqrt{(Wc_x^2 + Wc_y^2)} - a0$$

using the cosine rule

$$D^2 = xy^2 + z^2 = l2^2 + l3^2 - 2(l2)(l3)\cos(Angle3)$$
$$\cos(angle3) = (xy \wedge 2 + z^2 - l3^2 - l2^2)/(2 * l3 * l2) = r$$
$$angle3 = atan2(\sqrt{(1 - r^2)}, r), where \sqrt{(1 - r^2)} = \sin(angle3)$$
$$angle3 = atan2(-\sqrt{(1 - r^2)}, r)$$
$$angle2 = y - a0 = atan2(xy, z) - atan2(l3 * \sin(angle3), l2 + l3 * \cos(angle3))\, angle3 = angle3 - pi/2$$

Angle 3 has to be -90 degrees as the starting point is horizontally right not vertically up.