RRR + 1DOF

Assumption University (ABAC)
Classwork 8 (19 Aug 2020)

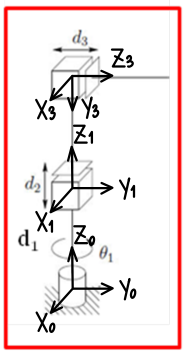
Name...Todsavad T................... **ID**...6114215............

a. ***Obtain forward kinematic equations for this mechanism with 1 DOF wrist.***
b. ***Obtain the End point position when***
   $\theta_1^* = 0 = 0, d_2^* = 10, d_3^* = 5, d_4 = 0.5, \theta_4^* = 0$
c. ***Obtain the End point position when***
   $\theta_1^* = 90° = 0, d_2^* = 10, d_3^* = 5, d_4 = 0.5, \theta_4^* = 0$
d. ***Obtain the End point position when***
   $\theta_1^* = 90° = 0, d_2^* = 10, d_3^* = 5, d_4 = 0.5, \theta_4^* = 90°$

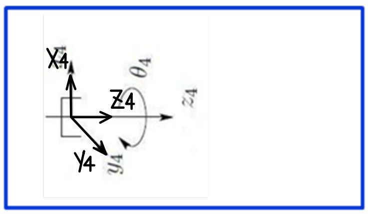
Chapter 5

Attached your code and answers from workspace.

Links	θ	d	a	α
1	θ_1^*	d_1	0	0
2	0	d_2^*	0	$-90°$
3	0	d_3^*	0	0
4	θ_4^*	d_4	0	0



RPP



1 DOF Wrist Mechanism

a)

```
CW8Robotequation =

[ cos(d4)*cos(th1), -sin(d4)*cos(th1), -sin(th1), - d3*sin(th1) - d4*sin(th1)]
[ cos(d4)*sin(th1), -sin(d4)*sin(th1),  cos(th1),   d3*cos(th1) + d4*cos(th1)]
[         -sin(d4),          -cos(d4),         0,                     d1 + d2]
[                0,                 0,         0,                           1]
```

b) $P_{end} = \begin{bmatrix} 0 \\ 5.5 \\ 10 \\ 1 \end{bmatrix}$ c) $P_{end} = \begin{bmatrix} -5.5 \\ 0 \\ 10 \\ 1 \end{bmatrix}$ d) $P_{end} = \begin{bmatrix} -5.5 \\ 0 \\ 10 \\ 1 \end{bmatrix}$

Inv Geometric

Atan2

Chapter 6

Assumption University (ABAC)
Classwork 9 (24 Aug 2021)

Name……Todsavad T……………………………**ID**……6114215……………

a. For 2 links, let $\alpha_1 = 3$ and $\alpha_2 = 5$, obtain the possible values of θ_1 and θ_2 for point (-7.75,-1.95). **Show your calculation**.
b. Draw the diagrams with your possible values.
.

(a)

$$D = \frac{(-7.75)^2+(-1.95)^2-3^2-5^2}{2(3\times5)} = 0.9955$$

$$\theta_2 = \tan^{-1}\left[\frac{\pm\sqrt{1-0.9955^2}}{0.9955}\right] = \pm 5.4376$$

$$\theta_2 = +5.4376^\circ$$

$$\theta_1 = \tan^{-1}\left(\frac{-1.95}{-7.75}\right) - \tan^{-1}\left(\frac{5\sin 5.4376^\circ}{3+5\cos 5.4376^\circ}\right)$$

$$= \cancel{10.7242^\circ} \; -169.3^\circ$$

fix from atan2d

$$\theta_2 = -5.4376^\circ$$

$$\theta_1 = \tan^{-1}\left(\frac{-1.95}{-7.75}\right) - \tan^{-1}\left(\frac{5\sin(-5.4376^\circ)}{3+5\cos(-5.4376^\circ)}\right)$$

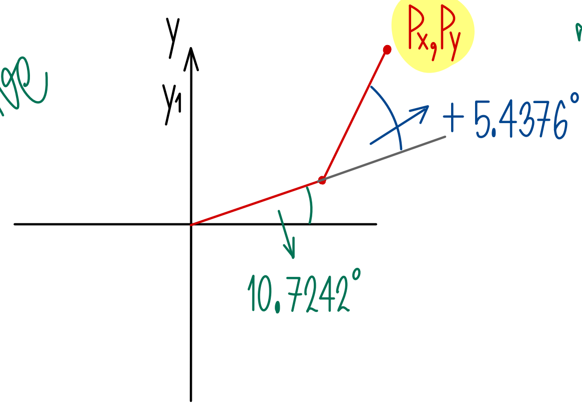
$$= \cancel{17.522^\circ} \; -162.4^\circ$$

$$\begin{array}{r} 360 \\ -\,169.3 \\ \hline 190.7 \\ -\,180 \\ \hline 10.7 \end{array} \qquad \begin{array}{r} 360 \\ -\,162.4 \\ \hline 197.6 \\ -\,180 \\ \hline 17.6 \end{array}$$

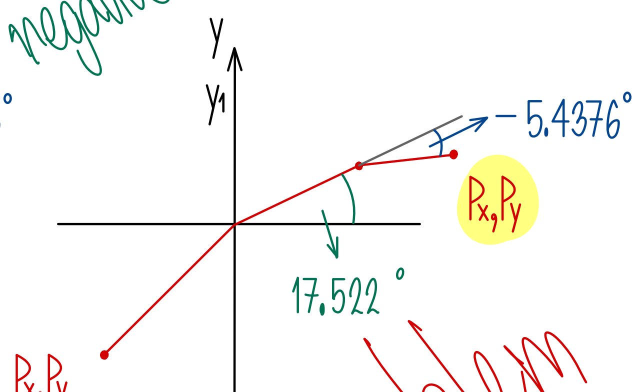
Wrong due to theta position

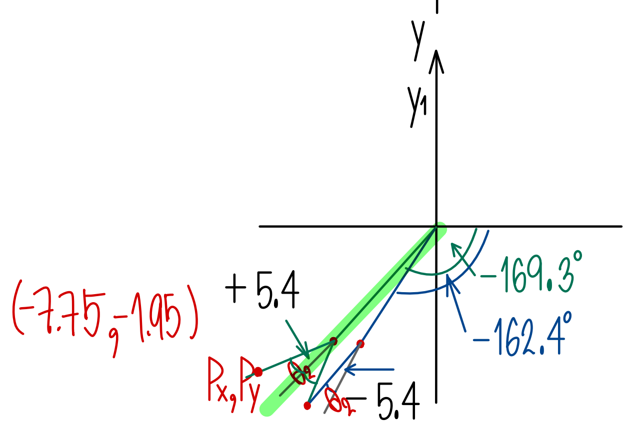
(b)

positive



negative





it has a problem
continuous CW 10

Inv Geometric

Atan2

Chapter6

Assumption University (ABAC)
Classwork 10 (26 Aug 2021)

Name......Todsawad T..**ID**.....6114215.................

RRR with no offset configuration.

a. Let $\alpha_2 = 3$ and $\alpha_3 = 5$, $d_1 = 2$, obtain one set of the possible values of θ_1, θ_2 and θ_3 for point (7.75, 1.95, 1.8). Compute with using Atan2 function. Show calculation steps.

b. Draw the following configurations of RRR, specify arm up and arm down configuration.

(a) $$\frac{x_c^2 + y_c^2 + (z_c - d_1)^2 - a_2^2 - a_3^2}{2a_2a_3} := D$$

$$D = \frac{(7.75)^2+(1.95)^2+(1.8-2)^2 - 3^2 - 5^2}{2(3\times5)} = 0.9968$$

$$\theta_3 = A\tan2(D, \pm\sqrt{1-D^2})$$

$$\theta_3 = \tan^{-1}2d\left[\frac{\pm\sqrt{1-0.9968^2}}{0.9968}\right] = \pm4.5609^\circ$$

$$\theta_2 = A\tan2\left(\sqrt{x_c^2+y_c^2}, z_c - d_1\right) - A\tan2\left(a_2 + a_3\cos(\theta_3), a_3\sin(\theta_3)\right)$$

$$\theta_2 = \tan^{-1}2d\left[(1.8-2), \sqrt{(7.75)^2+(1.95)^2}\right] - \left[\tan^{-1}2d(5\sin4.56, 3+5\cos(4.56))\right] = -4.2845^\circ$$

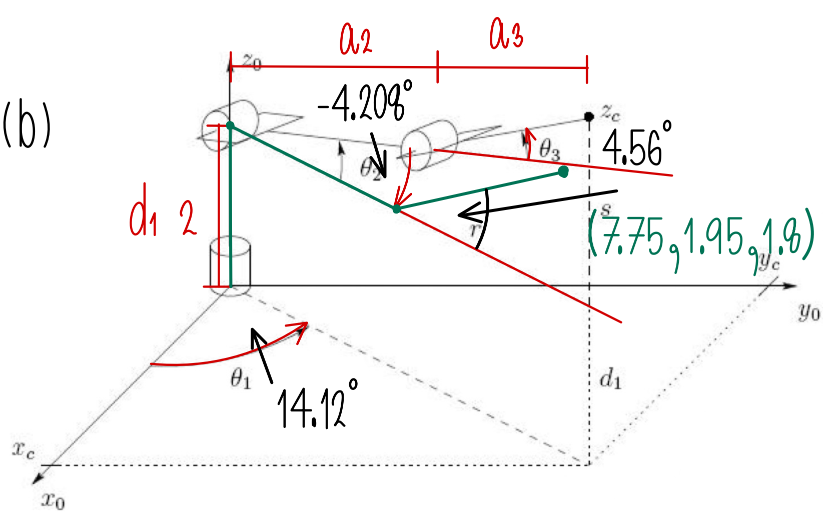
matlab

$$\theta_1 = A\tan2(x_c, y_c)$$

$$\theta_1 = \tan^{-1}2d\left[7.75, 1.95\right] = 14.1232^\circ$$

matlab

(b)



	Z	Z	X	X
Links	θ	d	a	α
1	θ_1^*	d_1	0	90°
2	θ_2^*	0	a_2	0
3	θ_3^*	0	a_3	0

Inv Geometric

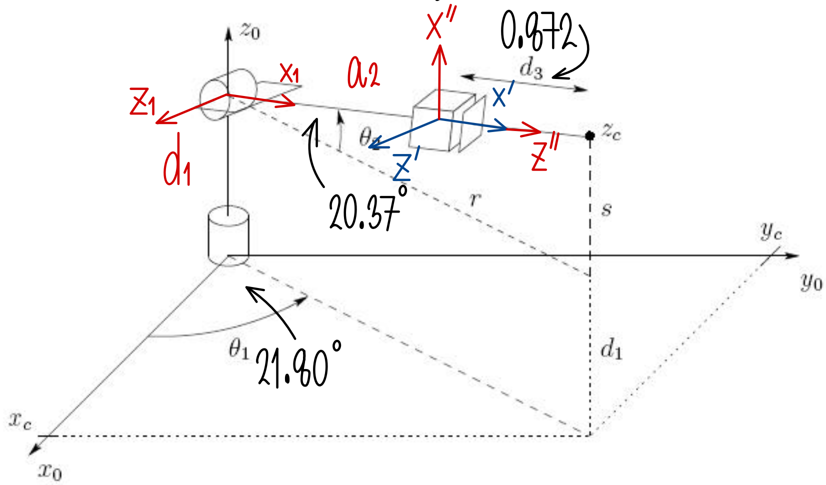
Chapter6

Assumption University (ABAC)
Classwork 11 (2 Sept 2021)

Name...Todsavad T...**ID**.6114215...

Please obtain required data for position (2.5, 1, 6) for the end point using Geometry method. Given $d_1 = 5$, and $a_2 = 2$ for RRP robot with no offset.
After obtained the variables, check with FK from your above answer.

Links	θ (Z)	d (Z)	a (X)	α (X)
1	θ_1^*	d_1	0	90°
2	θ_2^*	0	a_2	90°
3	90°	0	0	90°
4	0	d_3	0	0



$$r = \sqrt{(2.5)^2 + (1)^2} = 2.69$$

$$S = 6 - 5 = 1$$

$$d_3 = \sqrt{(2.5)^2 + (1)^2 + (1)^2} - 2 = 0.872$$

$$\theta_2 = \tan^{-1} 2d \left[\sqrt{(2.5)^2 + (1)^2},\ 6-5 \right] = 20.37°$$

$$\theta_1 = \tan^{-1} 2d \left[2.5, 1 \right] = 21.80°$$

$$\boxed{\theta_2 = A\tan 2(r, s) = A\tan 2\left(\sqrt{x_c^2 + y_c^2}, z_c - d_1\right)}$$

$$\boxed{\theta_1 = A\tan 2(x_c, y_c)}$$

```
T03_Endpoint =

    2.4999
    0.9999
    5.9997
    1.0000
```

```
%CW11
d1 = 5; a2 = 2;
Xc = 2.5; Yc = 1; Zc = 6;
r = sqrt(Xc^2+Yc^2)
s = Zc - d1
d3 = sqrt(Xc^2+Yc^2+(Zc-d1)^2)-a2
th2 = atan2d(Zc-d1, sqrt(Xc^2+Yc^2))
th1 =  atan2d(Yc, Xc)
%
%%L = link([alpha A theta D])
L1 = link([pi/2 0 0 d1, 0]); %%0 is revolute (and default), 1 is prismatic
L2 = link([pi/2 a2 0 0, 0]);
L23 = link([pi/2 0 pi/2 0,0]); %dummy link
L3 = link([0 0 0 1, 1]);
RRPRobot = robot({L1 L2 L23 L3});
th1 = deg2rad(21.8); th2 = deg2rad(20.37); d3 = 0.872;
T03 = fkine(RRPRobot,[th1 th2 pi/2 d3])
T03_Endpoint = T03*[0;0;0;1]
%
th1_1 = 21.8; th2_1 = 20.37;
T01 = rotz(th1_1*pi/180);
T12 = transl(0,0,5);
T23 = roty(-th2_1*pi/180);
T34 = transl(2,0,0);
T45 = transl(d3,0,0);
T05 =r2t(T01)*T12*r2t(T23)*T34*T45
Pend = T05*[0;0;0;1]
```

Inv analytic

Robotics Engg 1/2021

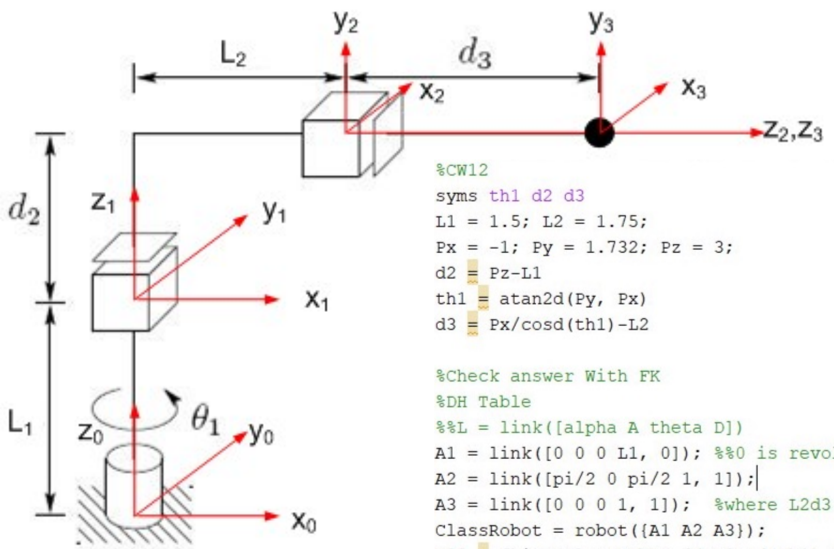
Chapter7

Assumption University (ABAC)
Classwork 12 (7 Sept 2021)

Name……Todsavad T……………………**ID**……6114215……………

i) Find the required values for θ_1^*, d_2^*, d_3^*, if desire position is P(-1, 1.732, 3), with $L_1 = 1.5$ and $L_2 = 1.75$. Show your working steps.

Links	θ (Z)	d (Z)	a (X)	α (X)
1	θ_1^*	L_1	0	0
2	90°	d_2^*	0	90°
3	0	$L_2+d_3^*$	0	0




```
%CW12
syms th1 d2 d3
L1 = 1.5; L2 = 1.75;
Px = -1; Py = 1.732; Pz = 3;
d2 = Pz-L1
th1 = atan2d(Py, Px)
d3 = Px/cosd(th1)-L2

%Check answer With FK
%DH Table
%%L = link([alpha A theta D])
A1 = link([0 0 0 L1, 0]); %%0 is revolute (and default), 1 is
A2 = link([pi/2 0 pi/2 1, 1]);
A3 = link([0 0 0 1, 1]);  %where L2d3 = L2+d3
ClassRobot = robot({A1 A2 A3});
T03 = fkine(ClassRobot,[deg2rad(th1) d2 L2+d3])
Pend = T03*[0;0;0;1]
```

ii) Check your answer and show how your working steps.

```
T03 =
[ -sin(th1), 0, cos(th1), cos(th1)*(L2 + d3)]
[  cos(th1), 0, sin(th1), sin(th1)*(L2 + d3)]
[         0, 1,        0,            L1 + d2]
[         0, 0,        0,                  1]
```

→ P(x,y,z)

```
R03 =
[ -sin(th1), 0, cos(th1)]
[  cos(th1), 0, sin(th1)]
[         0, 1,        0]
```

→ θ_1^* value

```
T03 =

   -0.8660    0.0000   -0.5000   -1.0000
   -0.5000   -0.0000    0.8660    1.7320
         0    1.0000    0.0000    3.0000
         0         0         0    1.0000
```

$\sin\theta_1(L_2+d_3^*) = -1 \rightarrow \sin 120.0°(L_2+d_3) = -1 \rightarrow d_3 = 0.25$

$\cos\theta_1(L_2+d_3^*) = 1.732$

$\theta_1 = \mathrm{Atan2}(x_c, y_c)$

$L_1 + d_2 = 3$

$\theta_1 = \tan^{-1}2d(1.732, -1)$

$d_2 = 1.5$

$= 120.0°$

```
Pend =

   -1.0000
    1.7320
    3.0000
    1.0000
```

iKine

Assumption University (ABAC)
Classwork 13 (16 Sept 2021)

Name……Todsavad T……………………………**ID**…6114215……………

RRR

The RRR manipulator with spherical 3 DOF wrist, where `d1 = 5; a2 =3; a3 = 5; d6 = 0.1;`

+3DOF

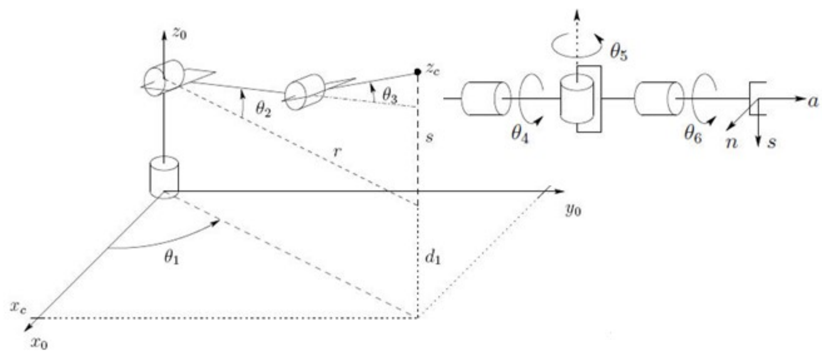


Table 1: DH parameter for Cylindrical manipulator

Link	a_i	α_i	d_i	θ_i
1	0	90	d_1	θ_1^*
2	a_2	0	0	θ_2^*
3	a_3	0	0	θ_3^*

Table 2: DH parameter for Spherical wrist

Link	a_i	α_i	d_i	θ_i
4	0	−90	0	θ_4^*
5	0	90	0	θ_5^*
6	0	0	d_6	θ_6^*

Obtain the inverse kinematic solutions in degree for P(0,7,3) by MATLAB.
Using IG as `IG = [0.1 -0.1 0 -0.1 0.1 0.1];`

Ans: $\theta_1 = 90^\circ$ $\theta_2 = 48.14^\circ$ $\theta_3 = 49.68^\circ$

$\theta_4 = 268.46^\circ$ $\theta_5 = -90^\circ$ $\theta_3 = 360^\circ$

Check your obtained answer with forward kinematic function by MATLAB. Is your end point location obtained agreed with the given point? Write down T_{end}^0 matrix value.

$T_{end}^0 =$

```
T06_values =

    1.0000   -0.0000    0.0000    0.0000
    0.0000    1.0000    0.0000    7.0000
   -0.0000   -0.0000    1.0000    3.0000
         0         0         0    1.0000
```

Ans:……Yes/No…………

```
Pend =

    0.0000
    7.0000
    3.0000
    1.0000
```

```
Px = 0;
Py = 7;
Pz = 3;
a2 =3;
a3= 5;
d1= 5;
d6 = 0.1;
D = (Px^2+Py^2+(Pz-d1)^2-a2^2-a3^2)/(2*a2*a3)
th3 = atan2d(sqrt(1-D^2),D)
th2 = atan2d(Pz-d1,sqrt(Px^2+Py^2))-atan2d(a3*sind(th3),(a2+a3*cosd(th3)))
th1 = atan2d(Py,Px)

th1rad = deg2rad(th1)
th2rad = deg2rad(th2)
th3rad = deg2rad(th3)

L1 = link([pi/2 0 th1rad d1, 0]);
L2 = link([0 a2 th2rad 0, 0]);
L3 = link([0 a3 th3rad 0, 0]);
RRR = robot({L1 L2 L3});
R03 = fkine(RRR,[th1rad th2rad th3rad])
th4rad = 0
th5rad = 0

L4 = link([-pi/2 0 th4rad 0, 0]);
L5 = link([pi/2 0 th5rad 0, 0]);
L6 = link([0 0 th6rad d6, 0]);
wrist = robot({L4 L5 L6});
R36 = fkine(wrist, [th4rad th5rad th6rad])

U = transpose(R03)*(R03*R36)

S = solve(atan2(U(2,1),U(1,1))-th6rad == 0, th6rad)

th6 = rad2deg(s)
R36 = fkine(wrist, [th4rad th5rad S])
T0end = round(R03*R36)
Pend = T0end*[0;0;0;1]
```