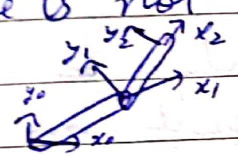
18110131

Midsem

5.) ~~A~~ Yes. As per DH convention joint axes are aligned with respective z-axis

6.) No. When taking DH convention, the last frame is not on any joint. Example 2R →



Frame 2 ~~has~~ doesn't have origin on a joint

7.) Yes. $H = \begin{bmatrix} R & d \\ 0 & 1 \end{bmatrix}$

8.) Yes. You are basically rotating it in turns/steps instead of direct, provided sequence is in correct order

9.) Yes. Let $R_0^n = R_0^1 R_1^2 \cdots R_{n-1}^n$

$R_0^{nT} = (R_0^1 R_1^2 \cdots R_{n-1}^n)^T = R_{n-1}^{nT} \cdots R_1^{2T} R_0^{1T}$

$R_0^n R_0^{nT} = R_0^1 R_1^2 \cdots R_{n-1}^n R_{n-1}^{nT} \cdots R_1^{2T} R_0^{1T}$

We know that, R_{n-1}^n is orthogonal (∵ single rotation)

∴ $R_{n-1}^n R_{n-1}^{nT} = I$ & $AIB = AB$

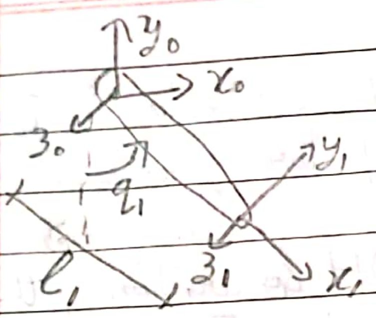
∴ We have $R_0^n R_0^{nT} = R_0^1 R_1^2 \cdots R_{n-2}^{n-1} R_{n-2}^{n-1\,T} \cdots R_0^{1T}$

Continuing we get, $R_0^n R_0^{nT} = I$

∴ R_0^n is orthogonal

$|R_0^n| = |R_0^1 \cdots R_{n-1}^n| = |R_0^1||R_1^2| \cdots |R_{n-1}^n| = 1 \times 1 \times 1 \times 1 \cdots 1 = 1$

4.)



(a) DH Parameters

	Type	a	α	d	θ
$0\to 1$	R	l_1	0	0	$q_1 + \frac{3\pi}{2}$

(b) Assuming stationary position is along $-y_0$ axis ($q_1 = 0$). Assume no gravity interaction in this case. We know that torsional springs give out torque equation as

$$\tau_i = -k q_1$$

(c) Kinetic energy ~~of~~ $K = \frac{1}{2} I_0 \dot{q}_1^2 = \frac{1}{6} m l_1^2 \dot{q}_1^2$

Potential $V = mg \frac{l_1}{2} \cos q_1$

Using Lagrange's, $L = K - V$ & $\frac{d}{dt}\left(\frac{dL}{d\dot{q}}\right) - \frac{dL}{dq} = \tau$

$$\therefore \tau = \frac{1}{3} m l_1^2 \ddot{q}_1 + mg \frac{l_1}{2} \sin q_1$$

& Total energy, $T = \frac{1}{6} m l_1^2 \dot{q}_1^2 + mg \frac{l_1}{2} \cos q_1$

$$\tau \to \tau + \tau_i$$

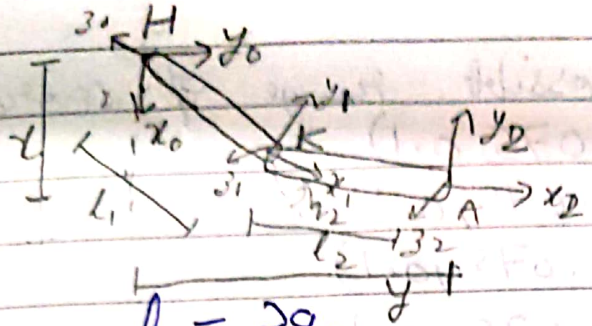
Observation: Energy is being stored in spring so T equation is not constant, rather $T + \frac{1}{2} k q_1^2$ will be const.

Simple harmonic oscillation about $-y_0$ axis

If spring replaced by torsional damper then oscillations damp down to steady state position ($-y_0$ axis)

Scanned with CamScanner

3.) (a)



H → hip
K → knee
A → Ankle

$l_1 = 39$ cm
$l_2 = 40$ cm

Gait trajectory is defined by the motion of ankle w.r.t. hip to get analysis of leg during motion.
Step length : Length covered when one step taken
Step height : Vertical height achieved during a step
Stride length : Length covered when 2 steps taken 1 from each foot.

(b) Gait_Cycle_plot.png in output folder

(c) For inverse Kinematics :

$$q_2 = \cos^{-1}\left(\frac{x^2+y^2-l_1^2-l_2^2}{2 l_1 l_2}\right)$$

$$q_1 = \tan^{-1}\left(\frac{y}{x}\right) - \tan^{-1}\left(\frac{l_2 \sin q_1}{l_1 + l_2 \cos q_1}\right)$$

$x_0 = 0 \qquad y_0 = 0$

$x_1 = l_1 \cos q_1 \qquad y_1 = l_1 \sin q_1$

$x_2 = x_1 + l_2 \cos(q_1+q_2) \qquad y_2 = y_1 + l_2 \sin(q_1+q_2)$

2.) (a) Soft grippers can take ~~sp~~ shape (to some extent) of that of object whereas hard grippers cannot. This provides an ~~o~~ advantage of better grip on object, especially the ones with curved surfaces (like cylinder) or Spikes.

And as they have better grips they don't have much needs for orientation of wrist, as for hard grippers you sometimes need specific orientation for complex shapes thus more requirements of DOF on manipulator

(b) Paper based grippers don't seem to have high use life as they can get torn easily.

~~Both~~ Universal gripper ~~& flexible mechanism~~ grippers seem ~~great~~ best for such small pills to be picked up.

Flexible & soft are great too but universal has ~~f~~ more freedom.

Links in Output / Readme.md

1.) Maximum possible range of coordinates (in m)

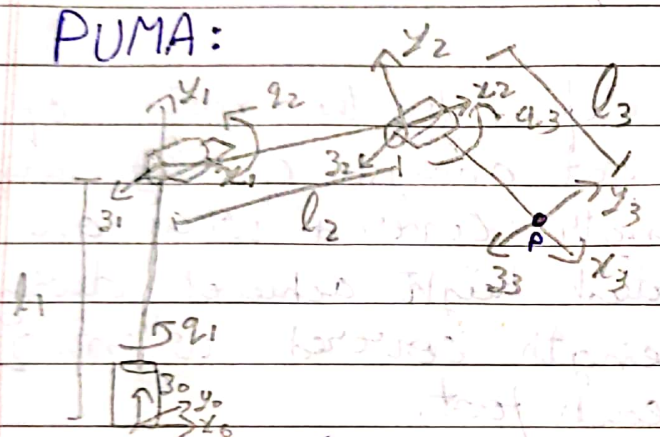
A $(0.~~5~~45, 0.075, 0.1)$

B $(0.45, -0.075, 0.1)$

C $(0.25, -0.075, 0.1)$

D $(0.25, 0.075, 0.1)$

PUMA:



DH Parameters:

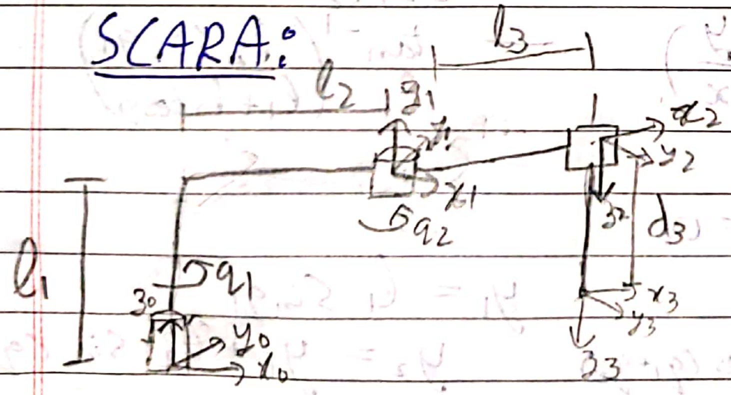
	Type	a	α	d	θ
0-1	R	0	$\pi/2$	l_1	q_1
1-2	R	l_2	0	0	q_2
2-3	R	l_3	0	0	q_3

~~For maximum Range~~

Let $l_1 = 0.15m$ $\quad l_2 = 0.3m$

$l_3 = \cancel{0.15}\ 0.2m$ $\quad l_2 + l_3 > 0.45$

SCARA:



DH Parameters

	Type	a	α	d	θ
0-1	R	l_2	0	l_1	q_1
1-2	R	l_3	π	0	q_2
2-3	P	0	0	d_3	0

Inverse Kinematics SCARA:

$z = l_1 - d_3 \qquad d_3 = l_1 - z$

$$q_2 = \cos^{-1}\left(\frac{x^2+y^2-l_2^2-l_3^2}{2 l_2 l_3}\right)$$

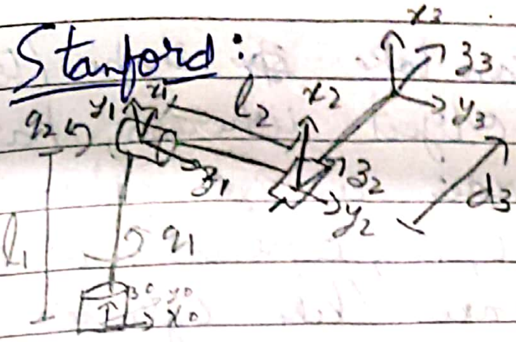
$$q_1 = \tan^{-1}\left(\frac{y}{x}\right) - \tan^{-1}\left(\frac{l_3 \sin q_2}{l_2 + l_3 \cos q_2}\right)$$

For Scara: let $l_1 = 0.2 > 0.1$ $\quad l_2 + l_3 \geq 0.4562 = \sqrt{0.013 + \ldots}$

$l_2 = 0.3$

$l_3 = 0.2$

Stanford:



DH Parameters

	Type	a	α	d	θ
0-1	R	0	$\frac{\pi}{2}$	l_1	q_1
1-2	R	0	$\frac{\pi}{2}$	l_2	$q_2+\frac{\pi}{2}$
2-3	P	0	0	d_3	0

Let $l_1 = 0.2\,m$

$l_2 = 0.25\,m < \min(x) = 0.25$

Inverse Kinematics Stanford:

$$q_1 = \tan^{-1}\left(\frac{y}{x}\right) + \tan^{-1}\left(\frac{l_2}{\sqrt{x^2+y^2-l_2^2}}\right)$$

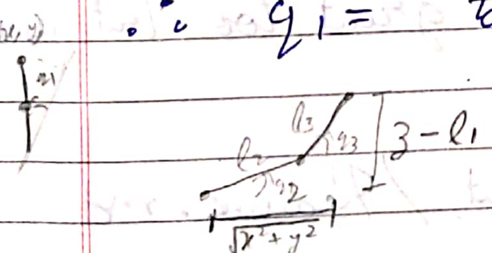
$$q_2 = \tan^{-1}\left(\frac{z-l_1}{\sqrt{x^2+y^2-l_2^2}}\right)$$

$$d_3 = \frac{z-l_1}{\sin q_2}$$

Inverse Kinematics Puma:

q_1 governs x, y & q_2, q_3 govern z & $\sqrt{x^2+y^2}$

$$\therefore q_1 = \tan^{-1}\left(\frac{y}{x}\right)$$



$$\therefore q_3 = \cos^{-1}\left(\frac{x^2+y^2+(z-l_1)^2-l_2^2-l_3^2}{2 l_2 l_3}\right)$$

$$q_2 = \tan^{-1}\left(\frac{z-l_1}{\sqrt{x^2+y^2}}\right) - \tan^{-1}\left(\frac{l_3 \sin q_3}{l_2 + l_3 \cos q_3}\right)$$

For link 2 not coincide with the work piece we need q_3 -ve. So $q_3 \to -q_3$

This is possible as $\cos(-q_3) = \cos(q_3)$ & $\cos^{-1}$ returns only $[0, \pi]$ so we can do $q_3 \to -q_3$

1(d) Process:

Positions

↓ Inverse Kinematics

Joint Variables

↓ Jacobian creation

Jacobian matrix

↓ Inverse

Inverse Jacobian (J^{-1}

↓ multiply ← End velocities

$J^{-1} V$

↓

Joint Velocities

Compute this at all intervals of 1 cm