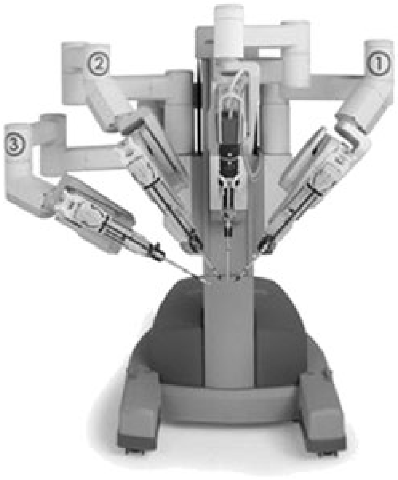
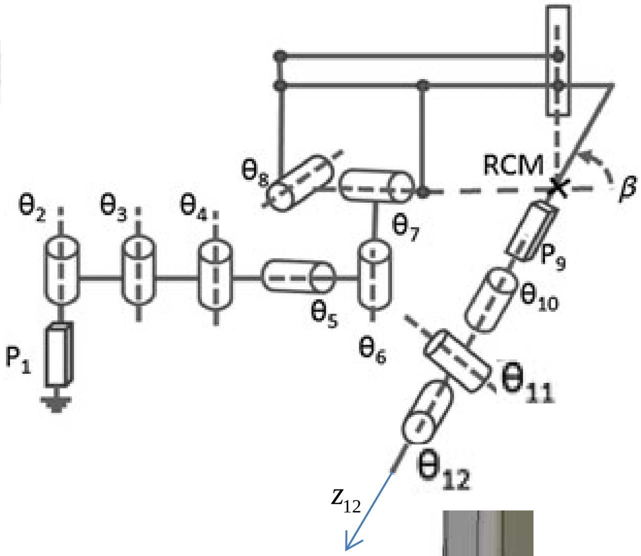
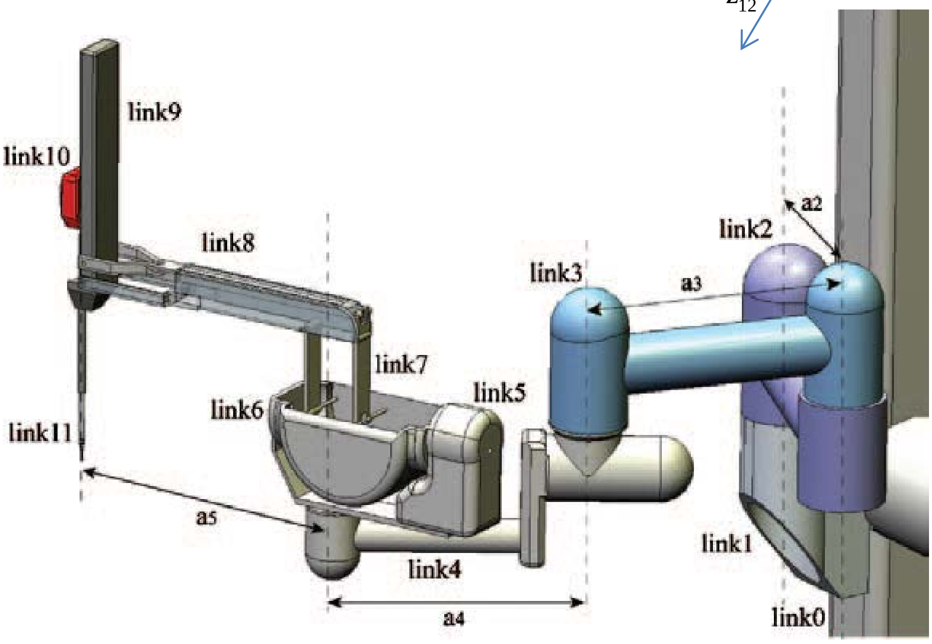
MEDICAL ROBOTICS EXAM (February 2017)

Consider the daVinci surgical manipulator, with its simplified kinematic diagram and its kinematic configuration







Let its last five Degrees of Freedom $\bar{q} = \left[q_8, \ldots, q_{12}\right]^T = \left[\theta_8, d_9, \theta_{10}, \theta_{11}, \theta_{12}\right]^T$

1. Compute in symbolic form the matrix $A_8^{12}(\bar{q}^T)$

2. Given the bounds of $\begin{bmatrix} 0^\circ \\ 0 \\ 0^\circ \\ 0^\circ \\ 0^\circ \end{bmatrix} \le \bar{q} \le \begin{bmatrix} 60^\circ \\ 200\text{mm} \\ 60^\circ \\ 45^\circ \\ 30^\circ \end{bmatrix}$ compute points of the 3D-working space

   from $\bar{p}_{3\times1}(\bar{q})$, where $A_8^{12} = \left[\begin{array}{c|c} R_{3\times3} & \bar{p}_{3\times1} \\ \hline 0_{3\times1} & 1 \end{array}\right]$

3. Solve the inverse kinematics problem, or given compatible values with the kinematic configuration of matrix $T_8^{12} = \left[\begin{array}{c|c} \tilde{R}_{3\times3} & \tilde{\bar{p}}_{3\times1} \\ \hline 0_{3\times1} & 1 \end{array}\right]$, compute $\bar{q}$

4. Select any spiral trajectory within your working space
$x(t) - x_c = r\cos\left(\frac{2\pi t}{T}\right), y(t) - y_c = r\sin\left(\frac{2\pi t}{T}\right), z(t) - z_c = d\left(\frac{2\pi t}{T}\right), r \neq 0, d \neq 0$,
where the coordinates $x(t), y(t), z(t)$ are not expressed necessarily with respect to the coordinate system $O_8x_8y_8z_8$. Approximate two circular motions of this spiral with at least 36×2 points under the assumption that $T = 1$. Solve for these 72 points the inverse kinematics problem by computing $\bar{q}\left(0:\frac{1}{36}:2\right)$.

5. Under the assumption that two successive points $q_i(t), q_i(t+\frac{1}{36}), i = 8,...,12,$
$t = 0, \frac{1}{36}, \frac{2}{36},...$ are connected by a third order polynomial with a stop-and-go trajectory, or $\dot{q}_i(t) = \dot{q}_i(t+\frac{1}{36}) = 0, t = 0, \frac{1}{36}, \frac{2}{36},...$ plot the joint trajectories $\bar{q}(t), t \in \Re$ and the resulting end-effector trajectory $\bar{p}(t)$.