Robotics II

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A KUKA LWR has its base mounted on a vertical wall as illustrated in Fig. 1, where the robot is shown in its zero configuration. Consider a situation in which the last three joints (constituting a spherical wrist with center at $W = O_6$) are permanently *frozen at their zero* values.

For kinematic and dynamic analysis, use the DH frame assignment as in the figure and assume that $l_1 = l_2 = l_3 = l_4 = l_5$ (while l_0 and l_6 are different). Frame 7 is drawn for clarity in a displaced position, but is actually located on the final flange of the robot at a distance l_6 from W. Each link has mass m_i ($i = 0, 1, \ldots, 7$, including the base) and its center of mass is on one of the axes of the DH frame attached to it. In particular, for the first six bodies, the center of mass lies along the (positive direction of) axis $\boldsymbol{z}_i$ for orange/even links ($i = 0, 2, 4$) or along the (negative direction of) axis $\boldsymbol{y}_i$ for yellow/odd links ($i = 1, 3, 5$). For links 6 and 7, the two centers of mass are collocated with O_6 and O_7, respectively.

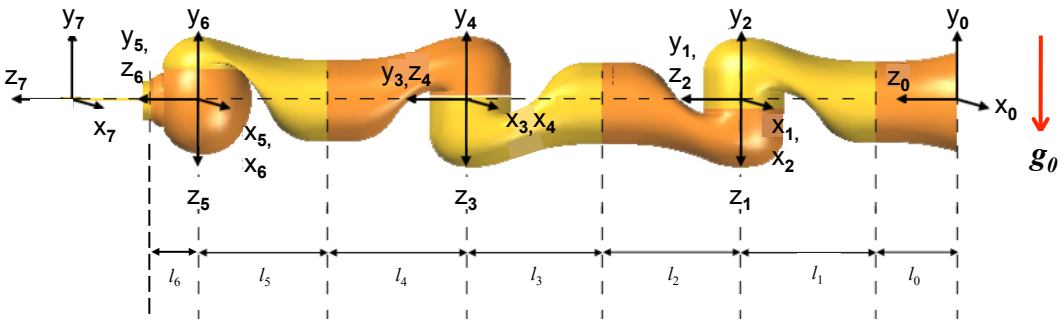

Figure 1: DH frames for a KUKA LWR robot, with direction of gravity acceleration indicated

- Let $\boldsymbol{\theta} \in \mathbb{R}^4$ be the variables of the first four active joints. Determine the symbolic expression of the gravity term $\boldsymbol{g}(\boldsymbol{\theta}) \in \mathbb{R}^4$ of this 4-dof dynamic model of the LWR robot.
- Find all unforced equilibrium configurations of the 4-dof structure.

[180 minutes; open books]