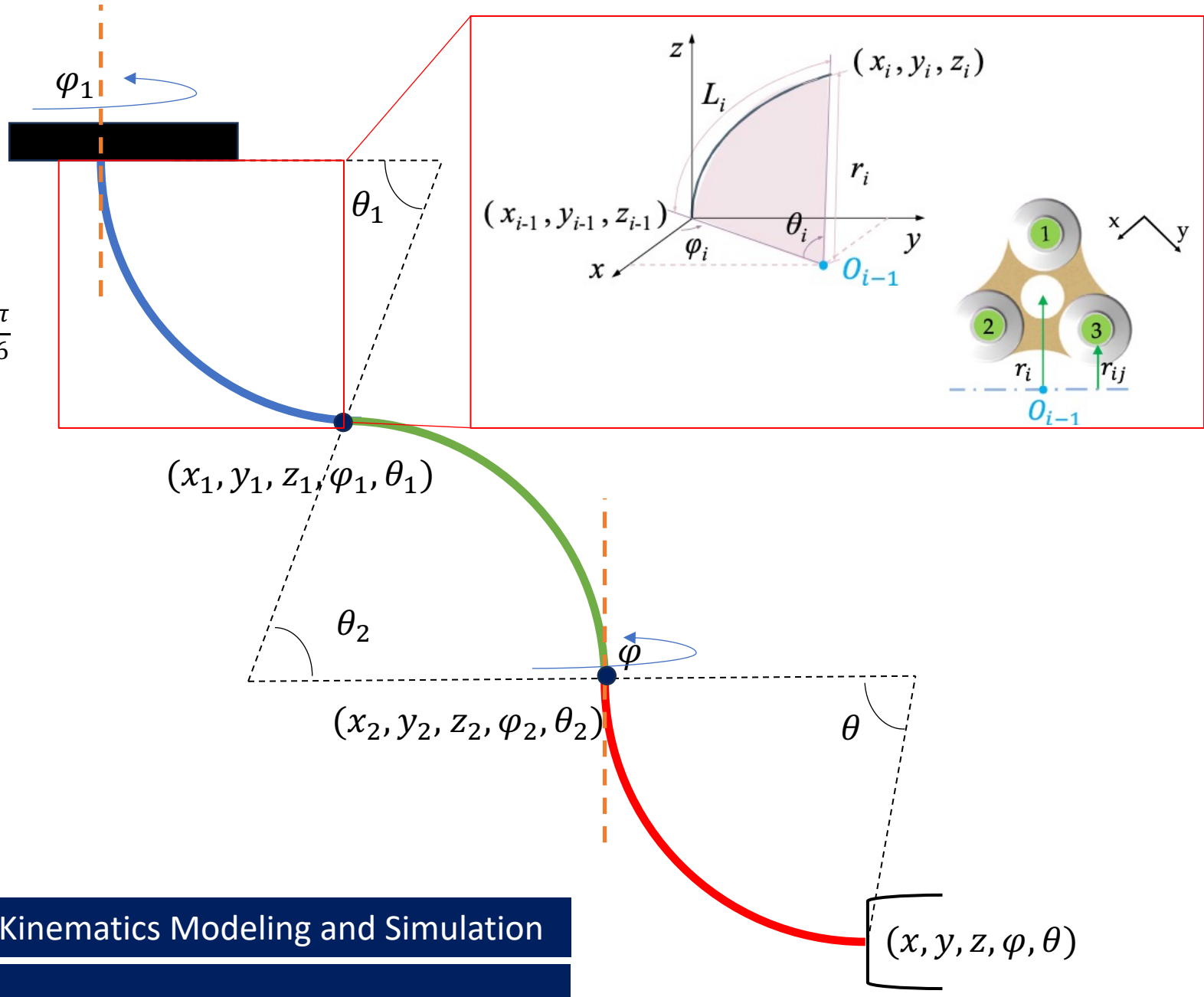
$$\begin{cases} \theta_1 = \theta_2 \\ \varphi_1 = \varphi_1 + \pi \\ r_1 = r_2 \\ l_{1j} = l_{2j}\ (j = 1,2,3) \end{cases}$$

$$\begin{cases} l_{31init} = \theta(r_1 - d\ \sin\varphi)\ , if\ \frac{\pi}{6} \le \varphi < \frac{5\pi}{6} \\ l_{32init} = \theta\left[r_1 + d\ \sin\varphi\left(\varphi - \frac{\pi}{6}\right)\right], if\ \frac{5\pi}{6} \le \varphi < \frac{3\pi}{6} \\ l_{33init} = \theta\left[r_1 - d\ \cos\varphi\left(\varphi + \frac{\pi}{6}\right)\right], if\ \frac{3\pi}{2} \le \varphi < 2\pi, 0 \le \varphi < \frac{\pi}{6} \\ r_3 = \frac{l_{init}}{\theta} + \frac{d}{2}\cos\left(\varphi + \frac{\pi}{6}\right) \end{cases}$$

$$\begin{cases} 2z_1 = z - r_3 \sin\theta = 2r_1 \sin\theta_1 \\ 2x_1 = x - r_3(1 - \cos\theta)\cos\varphi = r_1(1 - \cos\theta_1)\cos\varphi_1 \\ 2y_1 = y - r_3(1 - \cos\theta)\sin\varphi = r_1(1 - \cos\theta_1)\sin\varphi_1 \\ \varphi_1 = \tan^{-1}\frac{y_1}{x_1} \\ \theta_1 = 2\tan^{-1}\frac{2x_1}{z_1} \end{cases}$$

$$\begin{cases} l_{i1} = \theta_i(r_i - d\ \sin\varphi_i) \\ l_{i2} = \theta_i\left[r_i + d\ \cos\left(\varphi_i - \frac{\pi}{6}\right)\right] \\ l_{i3} = \theta_i\left[r_i + d\ \cos\left(\varphi_i + \frac{\pi}{6}\right)\right] \end{cases}$$



5Degree Of Freedom Soft Manipulator Inverse Kinematics Modeling and Simulation

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Ref: Z. Gong, J. Cheng, K. Hu, T. Wang and L. Wen, "An inverse kinematics method of a soft robotic arm with three-dimensional locomotion for underwater manipulation," 2018 IEEE International Conference on Soft Robotics (RoboSoft), Livorno, Italy, 2018, pp. 516-521