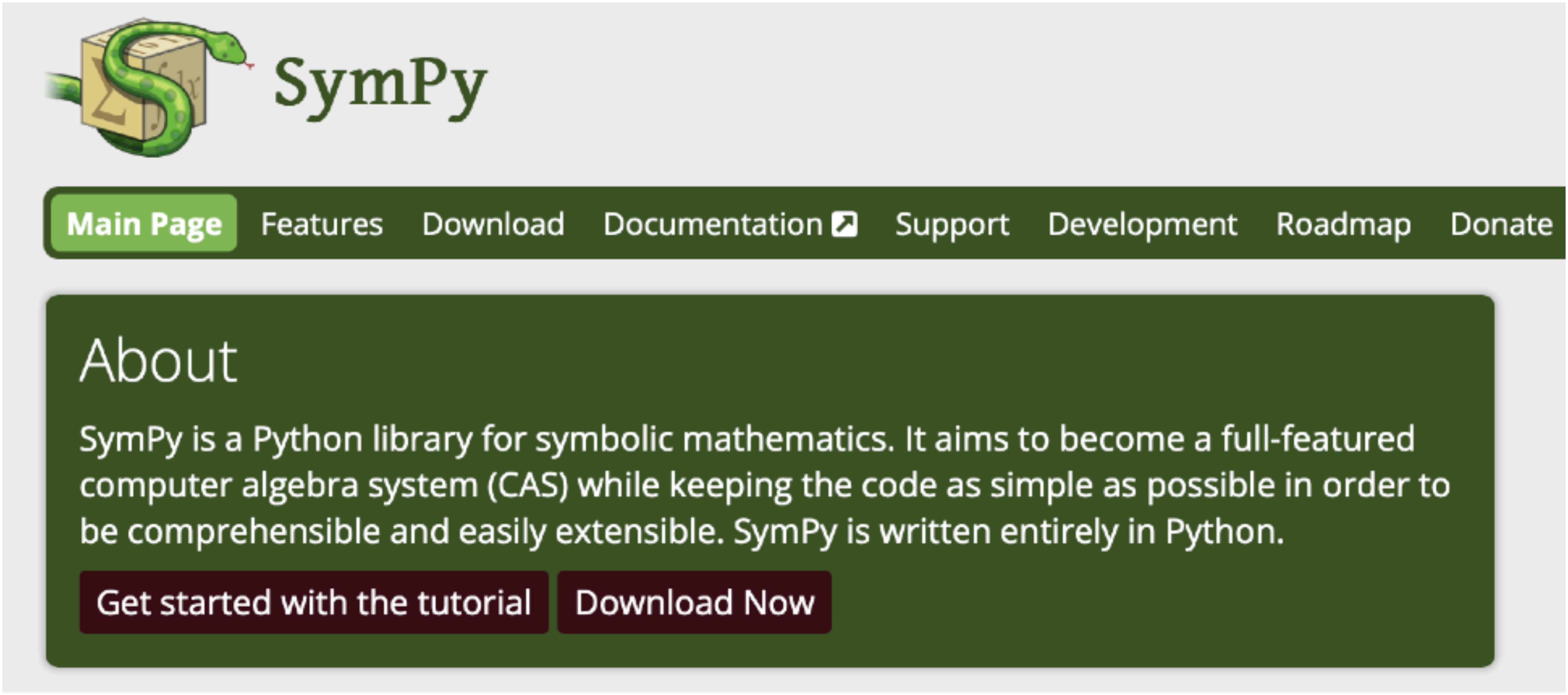
Experiment

Experiment 3: Extended Kalman Filter（每1秒分析一次，使用擴展卡爾曼濾波器）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$$\theta_{1_i} = \theta_{1_{i-1}} + \dot{\theta}_{1_i}\Delta t$$

$$\theta_{2_i} = \theta_{2_{i-1}} + \dot{\theta}_{2_i}\Delta t$$

$$\dot{\theta}_{1_i} = \dot{\theta}_{1_{i-1}} + \frac{m_2 g \sin\theta_{2_i}\cos(\theta_{1_i} - \theta_{2_i}) - m_2\sin(\theta_{1_i} - \theta_{2_i})(l_1 z_1^2\cos(\theta_{1_i} - \theta_{2_i}) + l_2 z_2^2) - (m_1 + m_2) g \sin\theta_{1_i}}{l_1(m_1 + m_2\sin^2(\theta_{1_i} - \theta_{2_i}))}\Delta t$$

$$\dot{\theta}_{2_i} = \dot{\theta}_{2_{i-1}} + \frac{(m_1 + m_2)[l_1 z_1^2\sin(\theta_{1_i} - \theta_{2_i}) - g\sin\theta_{2_i} + g\sin\theta_{1_i}\cos(\theta_{1_i} - \theta_{2_i})] + m_2 l_2 z_2^2\sin(\theta_{1_i} - \theta_{2_i})\cos(\theta_{1_i} - \theta_{2_i})}{l_2[m_1 + m_2\sin^2(\theta_{1_i} - \theta_{2_i})]}\Delta t$$

$$\left[\begin{matrix}0 & 0 & 1 & 0\\0 & 0 & 0 & 1\\- \frac{2 m_{2} \left(- g m_{2} \sin{\left(\theta_{1} - 2 \theta_{2} \right)} - g \left(2 m_{1} + m_{2}\right) \sin{\left(\theta_{1} \right)} - 2 m_{2} \left(l_{1} \dot{\theta}_{1}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)} + l_{2} \dot{\theta}_{2}^{2}\right) \sin{\left(\theta_{1} - \theta_{2} \right)}\right) \sin{\left(2 \theta_{1} - 2 \theta_{2} \right)}}{l_{1} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)^{2}} + \frac{- g m_{2} \cos{\left(\theta_{1} - 2 \theta_{2} \right)} - g \left(2 m_{1} + m_{2}\right) \cos{\left(\theta_{1} \right)} + 2 l_{1} m_{2} \dot{\theta}_{1}^{2} \sin^{2}{\left(\theta_{1} - \theta_{2} \right)} - 2 m_{2} \left(l_{1} \dot{\theta}_{1}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)} + l_{2} \dot{\theta}_{2}^{2}\right) \cos{\left(\theta_{1} - \theta_{2} \right)}}{l_{1} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} & \frac{2 m_{2} \left(- g m_{2} \sin{\left(\theta_{1} - 2 \theta_{2} \right)} - g \left(2 m_{1} + m_{2}\right) \sin{\left(\theta_{1} \right)} - 2 m_{2} \left(l_{1} \dot{\theta}_{1}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)} + l_{2} \dot{\theta}_{2}^{2}\right) \sin{\left(\theta_{1} - \theta_{2} \right)}\right) \sin{\left(2 \theta_{1} - 2 \theta_{2} \right)}}{l_{1} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)^{2}} + \frac{2 g m_{2} \cos{\left(\theta_{1} - 2 \theta_{2} \right)} - 2 l_{1} m_{2} \dot{\theta}_{1}^{2} \sin^{2}{\left(\theta_{1} - \theta_{2} \right)} + 2 m_{2} \left(l_{1} \dot{\theta}_{1}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)} + l_{2} \dot{\theta}_{2}^{2}\right) \cos{\left(\theta_{1} - \theta_{2} \right)}}{l_{1} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} & - \frac{4 m_{2} \dot{\theta}_{1} \sin{\left(\theta_{1} - \theta_{2} \right)} \cos{\left(\theta_{1} - \theta_{2} \right)}}{2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}} & - \frac{4 l_{2} m_{2} \dot{\theta}_{2} \sin{\left(\theta_{1} - \theta_{2} \right)}}{l_{1} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)}\\- \frac{4 m_{2} \left(g \left(m_{1} + m_{2}\right) \cos{\left(\theta_{1} \right)} + l_{1} \dot{\theta}_{1}^{2} \left(m_{1} + m_{2}\right) + l_{2} m_{2} \dot{\theta}_{2}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)}\right) \sin{\left(\theta_{1} - \theta_{2} \right)} \sin{\left(2 \theta_{1} - 2 \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)^{2}} + \frac{2 \left(- g \left(m_{1} + m_{2}\right) \sin{\left(\theta_{1} \right)} - l_{2} m_{2} \dot{\theta}_{2}^{2} \sin{\left(\theta_{1} - \theta_{2} \right)}\right) \sin{\left(\theta_{1} - \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} + \frac{2 \left(g \left(m_{1} + m_{2}\right) \cos{\left(\theta_{1} \right)} + l_{1} \dot{\theta}_{1}^{2} \left(m_{1} + m_{2}\right) + l_{2} m_{2} \dot{\theta}_{2}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)}\right) \cos{\left(\theta_{1} - \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} & \frac{2 m_{2} \dot{\theta}_{2}^{2} \sin^{2}{\left(\theta_{1} - \theta_{2} \right)}}{2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}} + \frac{4 m_{2} \left(g \left(m_{1} + m_{2}\right) \cos{\left(\theta_{1} \right)} + l_{1} \dot{\theta}_{1}^{2} \left(m_{1} + m_{2}\right) + l_{2} m_{2} \dot{\theta}_{2}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)}\right) \sin{\left(\theta_{1} - \theta_{2} \right)} \sin{\left(2 \theta_{1} - 2 \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)^{2}} - \frac{2 \left(g \left(m_{1} + m_{2}\right) \cos{\left(\theta_{1} \right)} + l_{1} \dot{\theta}_{1}^{2} \left(m_{1} + m_{2}\right) + l_{2} m_{2} \dot{\theta}_{2}^{2} \cos{\left(\theta_{1} - \theta_{2} \right)}\right) \cos{\left(\theta_{1} - \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} & \frac{4 l_{1} \dot{\theta}_{1} \left(m_{1} + m_{2}\right) \sin{\left(\theta_{1} - \theta_{2} \right)}}{l_{2} \left(2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}\right)} & \frac{4 m_{2} \dot{\theta}_{2} \sin{\left(\theta_{1} - \theta_{2} \right)} \cos{\left(\theta_{1} - \theta_{2} \right)}}{2 m_{1} - m_{2} \cos{\left(2 \theta_{1} - 2 \theta_{2} \right)} + m_{2}}\end{matrix}\right]$$

切線性模型：

$$\theta_{1_i} = \theta_{1_{i-1}} + \dot{\theta}_{1_i} \Delta t$$

$$\theta_{2_i} = \theta_{2_{i-1}} + \dot{\theta}_{2_i} \Delta t$$

$$\dot{\theta}_{1_i} = \dot{\theta}_{1_{i-1}} + \frac{m_2 g \ \sin\theta_{2_i} \cos(\theta_{1_i} - \theta_{2_i}) - m_2 \sin(\theta_{1_i} - \theta_{2_i})(l_1 z_1^2 \cos(\theta_{1_i} - \theta_{2_i}) + l_2 z_2^2) - (m_1 + m_2) g \ \sin\theta_{1_i}}{l_1(m_1 + m_2 \sin^2(\theta_{1_i} - \theta_{2_i}))} \Delta t$$

$$\dot{\theta}_{2_i} = \dot{\theta}_{2_{i-1}} + \frac{(m_1 + m_2)[l_1 z_1^2 \sin(\theta_{1_i} - \theta_{2_i}) - g \ \sin\theta_{2_i} + g \ \sin\theta_{1_i} \cos(\theta_{1_i} - \theta_{2_i})] + m_2 l_2 z_2^2 \sin(\theta_{1_i} - \theta_{2_i}) \cos(\theta_{1_i} - \theta_{2_i})}{l_2[m_1 + m_2 \sin^2(\theta_{1_i} - \theta_{2_i})]} \Delta t$$