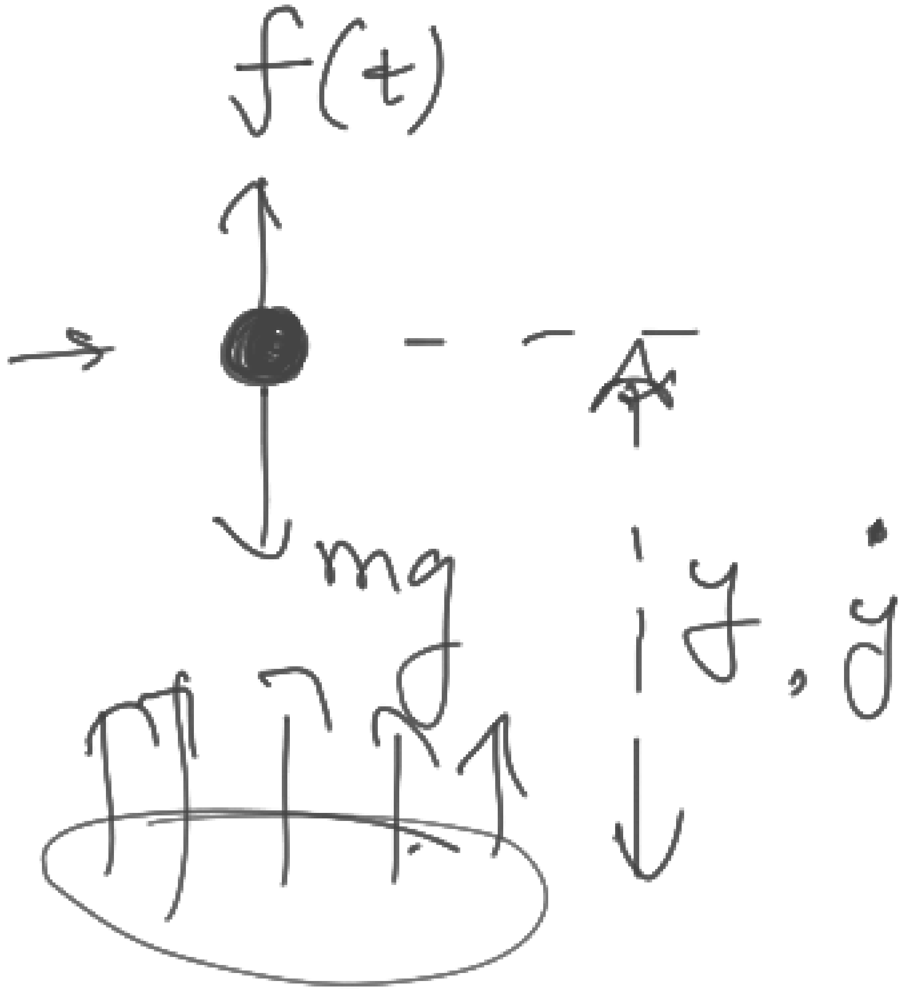
Modelling
- → Force-Balance equations. (Newtonian Methods.)
- → Lagrangian Method..
- → Hamiltonian Based formulation



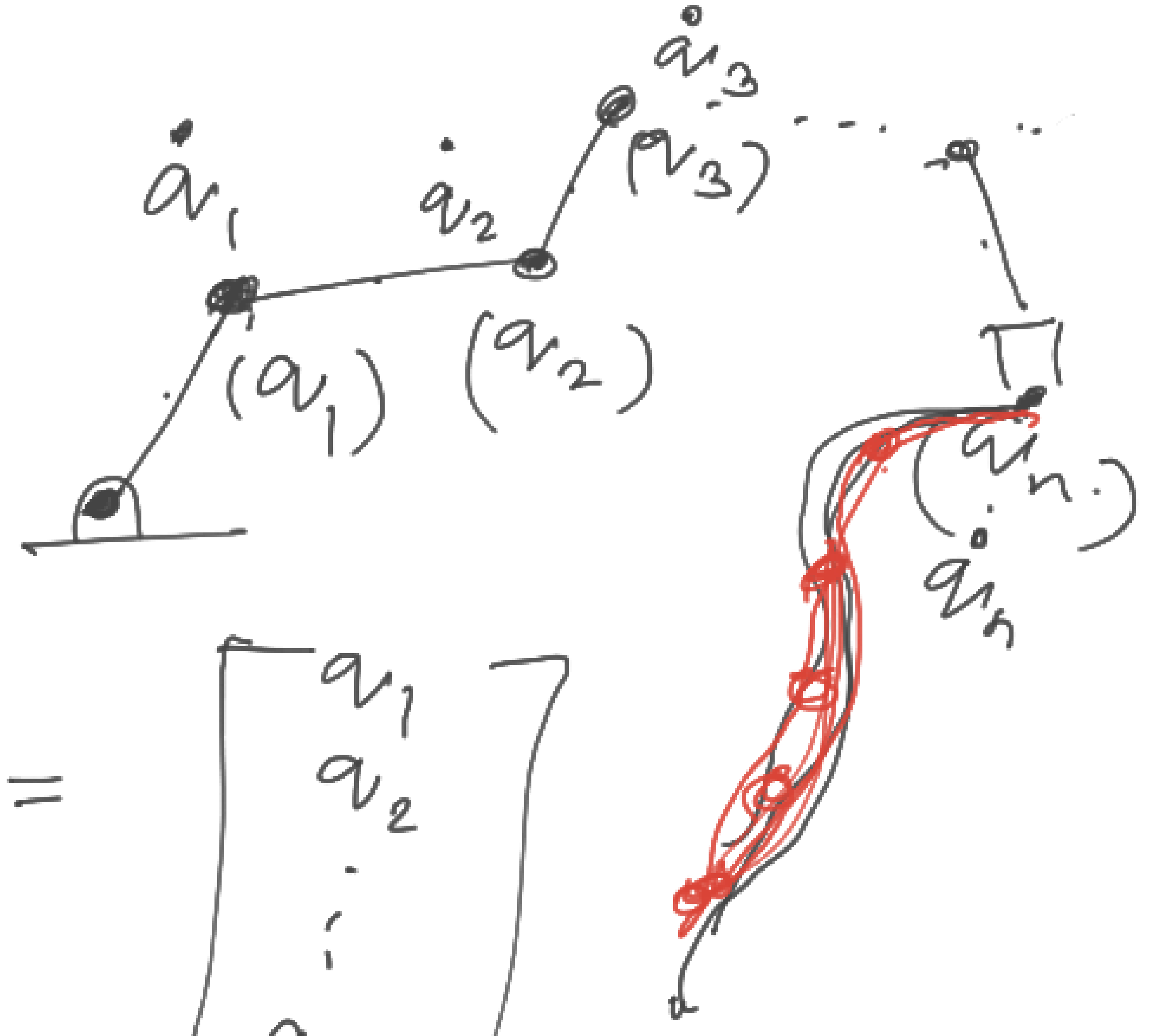
$$m\ddot{y} = f(t) - mg.$$

$$\mathcal{L} = \frac{1}{2} m\dot{y}^2 - mgy, \qquad \int_0^t \mathcal{L}(y,\dot{y})\,dt$$

$$\rightarrow \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{y}} - \frac{\partial \mathcal{L}}{\partial y} = f(t) \Rightarrow m\ddot{y} + mg = f(t)$$

n- link manipulator

$$K = \frac{1}{2}\dot{q}^T \underline{D(q)}\,\dot{q}$$



$$P = \sum_{i=1}^{n} m_i g^T \underline{r_{ci}}$$

$$q = \begin{bmatrix} q_1 \\ q_2 \\ \vdots \\ q_n \end{bmatrix}$$

$$\mathcal{L} = K - P. \quad , \quad \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{q}_k} - \frac{\partial \mathcal{L}}{\partial q_k} = \underline{\tau_k}$$

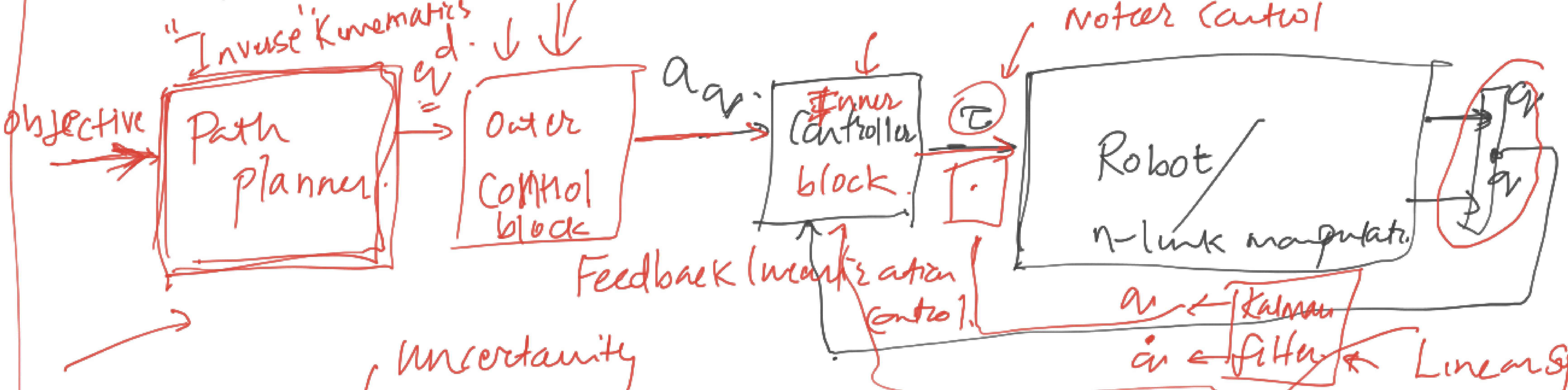
$$\boxed{\underline{M(q)}\,\ddot{q} + \underline{C(q,\dot{q})}\,\dot{q} + g(\underline{q}) = \underline{\tau}} \rightarrow \text{Non-linear Differential equation.}$$

Torque control method

$$\underline{M(q)}\,\ddot{q} + \underline{C(q,\dot{q})}\,\dot{q} + \underline{g(q)} = \underline{\tau}$$

$\boxed{\text{Adaptive Control}}$ *

Architecture for control n-link manipulator.



uncertainity

$$\underline{\tau} = M(q)\,\underline{a}_q + C(q,\dot{q})\,\dot{q} + g(q)$$

$M(q)$ is alway "invertible"? $\Rightarrow$ $\underline{\ddot{q} = a_q}$.

Linear System

* Discrete time Kalman filter
* Extended Kalman filter
* Unscented Kalman filter
* Particle filter.

$\underline{q^d}, \dot{q}^d$ Known. $\dot{q}_k^d, q_k^d$ $\Rightarrow \boxed{\dot{x} = Ax + Bu}$ K $(\cancel{A+BK})$

given desired trajectory q^d calculate

$- \; a_q$, $q, \dot{q}$, $\tilde{q} = \underline{q} - \underline{q_d}$, $\dot{\tilde{q}} = \underline{\dot{q}} - \dot{q}_d$.

$$\underline{\ddot{q}} = \underline{a_q} = \underline{\ddot{q}_d} - \underline{K_1}\tilde{q} - \underline{K_2}\dot{\tilde{q}}$$

$$\rightarrow \boxed{\ddot{\tilde{q}} + K_1\tilde{q} + K_2\dot{\tilde{q}} = 0}$$

$$\underline{\ddot{\tilde{q}}_1 + 2\zeta\omega_n\dot{\tilde{q}} + \omega_n^2\tilde{q} = 0}$$

$$K_1 = \begin{bmatrix} \omega_n^2 & \\ & \ddots \end{bmatrix}, \quad K_2 = \begin{bmatrix} 2\zeta\omega_n & \\ & \ddots \end{bmatrix}$$