

Constraints given by:

- initial state
- boundry conditions
- access to limited resources
- contractual covenants
- juristic law

Modelling movement (change of state) under constraints:

1. Movement is characterized by change of energy, Lagrangian  $\mathcal{L} \neq 0$ :

$$\mathcal{L} = E_{kin} - E_{pot} \quad (1)$$

2. Movement happens within constraints of forces:

$$\hat{F}_i + \tilde{F}_i = \hat{F}_i + \sum_{k=1}^{s_d} \lambda_k a_{ki} = \frac{d}{dt} \left( \frac{\partial \mathcal{L}}{\partial v_i} \right) - \frac{\partial \mathcal{L}}{\partial r_i} \quad (2)$$

and at same time, constraining conditions delimitate movement:

$$\sum_{l=1}^f a_{kl} v_l + b_k = 0 \quad (3)$$

3. Rest is characterized by unchanged energy, Hamiltonian  $\mathcal{H} = E_{kin} + E_{pot} = const..$   
There is movement from state of rest if  $\mathcal{H} \neq 0$ :

$$\mathcal{H} = \sum_i p_i v_i - \mathcal{L} = pv - \mathcal{L} = Fr - \mathcal{L} = W - \mathcal{L} = (\Delta E - \Delta H) - \mathcal{L} \quad (4)$$

4. Change of state/position is characterized by movement:

$$\dot{r}_i = v_i = \frac{\partial \mathcal{H}}{\partial p_i} \quad \dot{p}_i = F_i = -\frac{\partial \mathcal{H}}{\partial r_i} \quad (5)$$

see description of “work” ?@eq-workgeom

where:

$s_d = \text{constraints}$   $i = 1, \dots, f = \text{degrees of freedom}$   $k = 1, \dots, s_d = \text{constraints}$

$\hat{F}_i = \text{known constraining forces}$   $\tilde{F}_i = \sum_{k=1}^{s_d} \lambda_k a_{ki} = \text{unknown constraining forces}$

$\lambda_k(t) = \text{Eigenvalues for transformation of reference system}$

$a_{ki} = \text{Eigenvectors of transformation matrix}$

$\lambda_k \cdot \vec{r}_i = \lambda_k \cdot [a_{ki}]_{matrix}$