

### Global data

Displacements history

$$\mathbf{u}_t, \quad t = 0, \dots, n_t$$

External forces history

$$\mathbf{f}_t^{\text{ext}}, \quad t = 0, \dots, n_t$$

Reaction forces history

$$\mathbf{f}_t^{\text{r}}, \quad t = 0, \dots, n_t$$

### Force equilibrium loss

$$\mathcal{L} = \mathcal{L}(\mathbf{f}^{\text{int}}(\mathbf{u}), \mathbf{f}^{\text{ext}}, \mathbf{f}^{\text{r}})$$

### Global data

Internal force history

$$\mathbf{f}_t^{\text{int}}, \quad t = 0, \dots, n_t$$

### Integration (FEM)

Internal force history  
of all finite elements

$$\mathbf{f}^{\text{int}} = \int_{\Omega} \mathbf{B}^T(\mathbf{x}) \boldsymbol{\sigma}(\mathbf{x}) \, \text{d}v$$

### Local data

Strain history

$$\boldsymbol{\varepsilon}_t, \quad t = 0, \dots, n_t$$

### Material model

$$\boldsymbol{\sigma}(\mathbf{x}) = \mathcal{M}(\boldsymbol{\varepsilon}(\mathbf{x}); \boldsymbol{\theta})$$

### Local data

Stress history

$$\boldsymbol{\sigma}_t, \quad t = 0, \dots, n_t$$

Forward propagation  
(differentiable)

Backward propagation  
(automatic differentiation)

LOCAL OPTIMIZATION

GLOBAL OPTIMIZATION