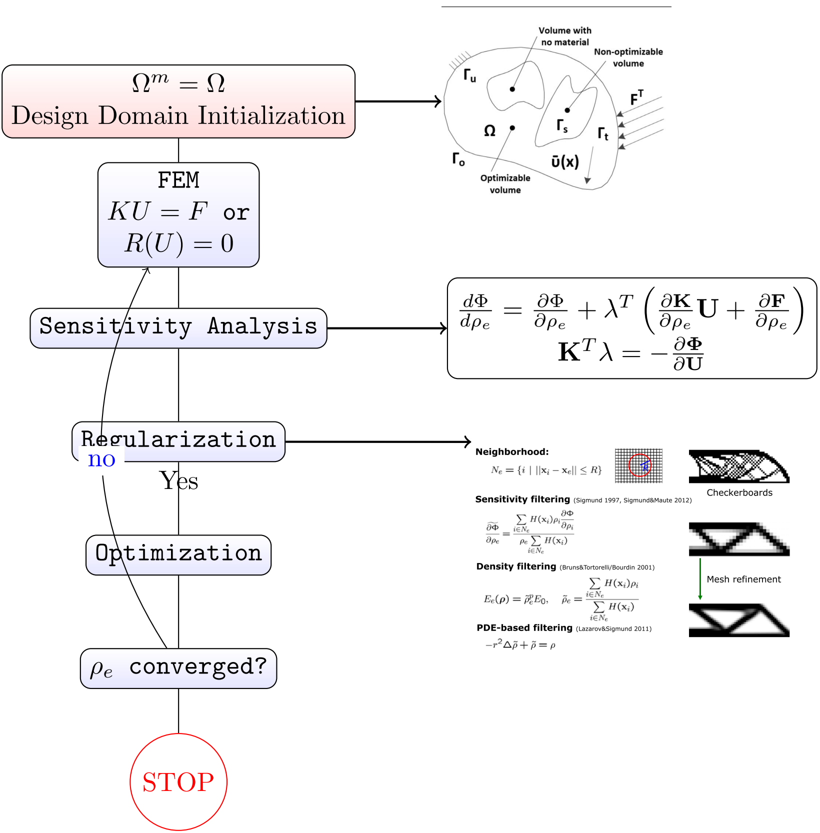

$\Omega^m = \Omega$
Design Domain Initialization
FEM
$KU = F$ or
$R(U) = 0$
Sensitivity Analysis
Regularization
no
Yes
Optimization
ρ_e converged?
STOP
Volume with no material
Non-optimizable volume
Γ_u
$\mathbf{F}^T$
Ω
Γ_s
Γ_t
Γ_o
$\bar{u}(x)$
Optimizable volume
$\frac{d\Phi}{d\rho_e} = \frac{\partial\Phi}{\partial\rho_e} + \lambda^T \left(\frac{\partial \mathbf{K}}{\partial\rho_e}\mathbf{U} + \frac{\partial \mathbf{F}}{\partial\rho_e} \right)$
$\mathbf{K}^T\lambda = -\frac{\partial\mathbf{\Phi}}{\partial\mathbf{U}}$
Neighborhood:
$N_e = \{i \mid \|\mathbf{x}_i - \mathbf{x}_e\| \le R\}$
Checkerboards
Sensitivity filtering (Sigmund 1997, Sigmund&Maute 2012)
$\widetilde{\frac{\partial\Phi}{\partial\rho_e}} = \frac{\sum_{i\in N_e} H(\mathbf{x}_i)\rho_i \frac{\partial\Phi}{\partial\rho_i}}{\rho_e \sum_{i\in N_e} H(\mathbf{x}_i)}$
Density filtering (Bruns&Tortorelli/Bourdin 2001)
$E_e(\boldsymbol{\rho}) = \tilde{\rho}_e^p E_0, \quad \tilde{\rho}_e = \frac{\sum_{i\in N_e} H(\mathbf{x}_i)\rho_i}{\sum_{i\in N_e} H(\mathbf{x}_i)}$
Mesh refinement
PDE-based filtering (Lazarov&Sigmund 2011)
$-r^2\Delta\tilde{\rho} + \tilde{\rho} = \rho$