

EXPLICIT-DYNAMIC TOPOLOGY OPTIMIZATION UNDER TIME-DEPENDENT DISPLACEMENT CONSTRAINTS

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Abstract

This work proposes a topology optimization formulation for structures under transient loading in which local displacement limits are enforced over the entire time history. The structural response is computed using a fully explicit central-difference scheme with lumped mass, so each time step proceeds without solving a global linear system, making the approach suitable for short-duration, impact-like dynamics. The design task is posed as minimum volume, constrained by displacement bounds applied to selected degrees of freedom (DOF) at every time step. Constraint enforcement follows an augmented Lagrangian framework with standard multiplier and penalty updates, and sensitivities are computed consistently via a discretize-then-differentiate adjoint procedure applied to the explicit time-discrete system.

A key difficulty of this formulation is the cost of the sensitivity evaluation, dominated by the accumulation of adjoint contributions over all time steps. Two strategies are introduced to alleviate this issue while leaving the core formulation unchanged. First, an adjoint-equivalence approximation uses the small explicit time step to treat consecutive adjoint vectors as nearly identical, resulting in approximately a factor of 2 reduction in sensitivity analysis cost. Second, a temporal subsampling strategy evaluates adjoint terms at selected time indices and reconstructs intermediate contributions by interpolation, producing an additional reduction of about a factor of 2.5, that is, about a factor of 5 relative to the baseline consistent sensitivity analysis. Across examples, these reductions are achieved without significant changes to the optimized topology or to the worst-case displacement-over-time metric.

Demonstrations on two-dimensional problems with short-duration dynamic loading indicate that the optimizer can handle up to 7 million local displacement constraints while satisfying the prescribed limits. The explicit time integration removes the repeated implicit solves that typically dominate cost in implicit schemes, and the two cost-reduction procedures help keep adjoint evaluations practical for the tested cases.