Tailoring Structural Dynamic Behavior through Topology Optimization with Multiresolution Polygons

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Motivation

- Topology optimization can be used to tailor cost effective structures or microstructures with specialized dynamic characteristics

Potential applications

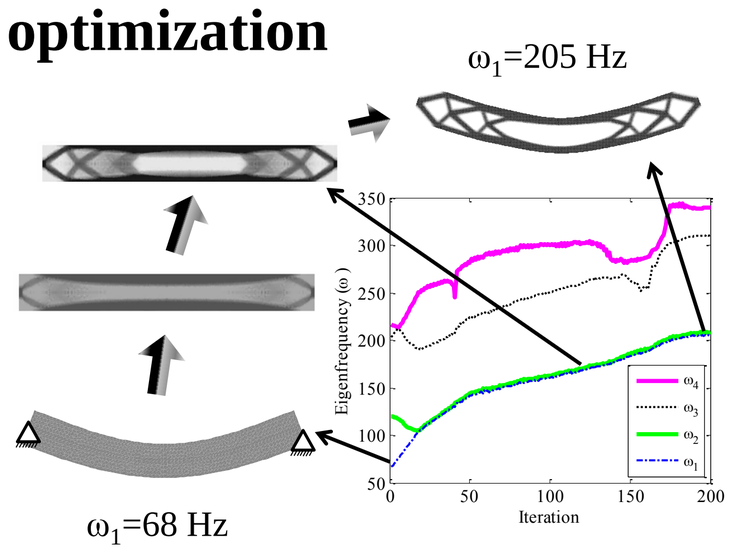
- Buildings designed to minimize seismic or wind vibrations, e.g. tune mass damper of Taipei 101 (Figure on right)
- Aircraft wings created to avoid resonance from turbulence
- Frequency passband and stopband filters for use in audio equipment

Eigenfrequency optimization

Maximize lowest eigenfrequency:

$$\max_{\rho} \left\{ \lambda_{min} \min_{j=1,\dots J} \{ \omega_j^2 \} \right\}$$

$$\text{s.t. } V(\rho) = \int_\Omega \rho dV \le V_s$$



Forced vibrations

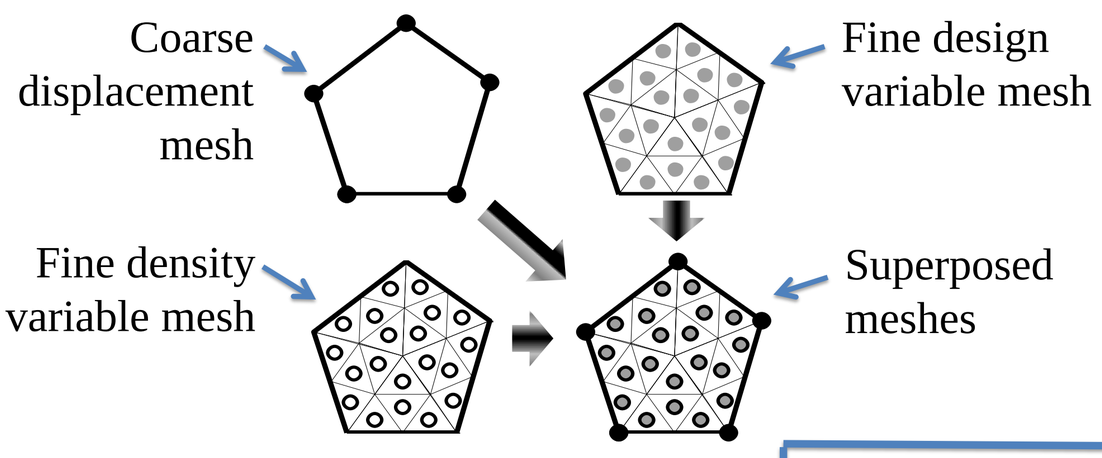
Minimize dynamic compliance:

$$\min_{\rho} \Phi(\rho) = \int_{\omega_s}^{\omega_e} |\mathbf{F}^T \mathbf{U}| d\omega$$

$$\text{s.t. } [\mathbf{K} + i\omega\mathbf{C} - \omega^2\mathbf{M}]\mathbf{U} = \mathbf{F}$$

$$V(\rho) = \int_\Omega \rho dV \le V_s$$

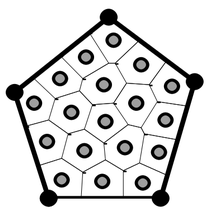
Polygonal multiresolution framework



Polygonal elements can:

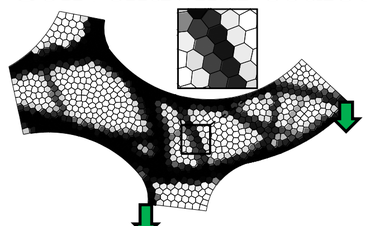
- Model irregular domains
- Avoid instabilities in optimization
- Provide mesh independent solutions

Nonconforming sub-discretization

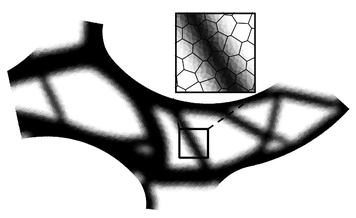


Comparison of forced vibration results

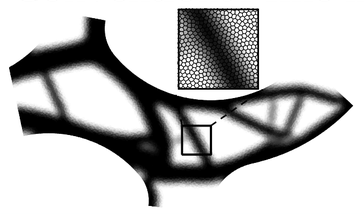
1. Conventional coarse mesh



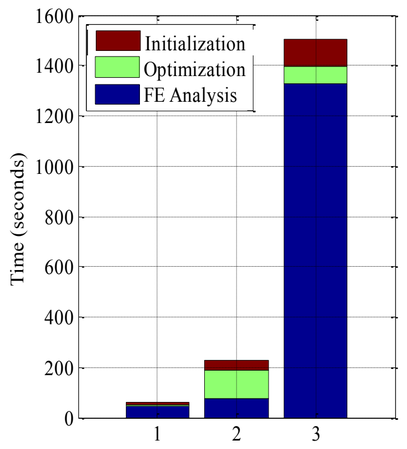
2. Multiresolution mesh



3. Conventional fine mesh

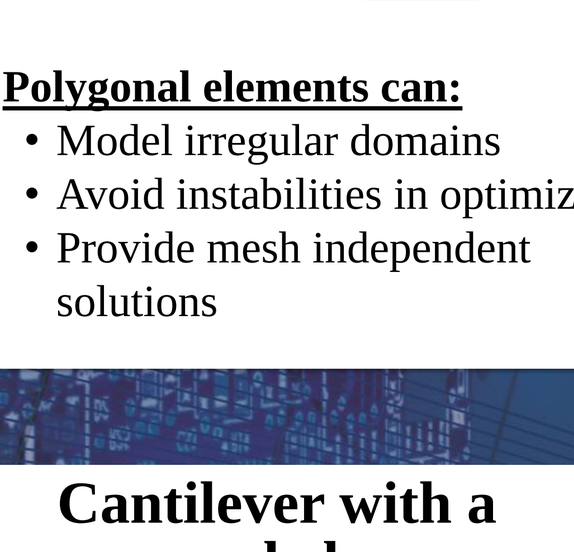


Computational time for the three meshes



Cantilever with a suspended mass

Maximize ω_1



Arch with band-gap maximization

Conclusions

- Topology optimization can be used for advanced structural eigenfrequency or forced vibration problems
- Polygonal elements allow for optimization of complex domains and improved solutions
- Multiresolution approach provides a higher resolution of the topology for a lower computational cost

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