BEM and the Precorrected-FFT Acceleration Technique

Wenjing Ye

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Complex Systems Design Automation Group

Hong Kong

Hong Kong located at the edge of Southern China


OLYMPUS
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PHILIPS
SAMSUNG
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Hong Kong University of Science & Technology

- Opened in 1991, HKUST is an **international research university**, leading the advance of **science and technology**, and educating the new generation of front-runners for Asia and the world.
- Undergraduate 6000
  Postgraduate 1300
  Taught postgraduate 2000
  Faculty 461

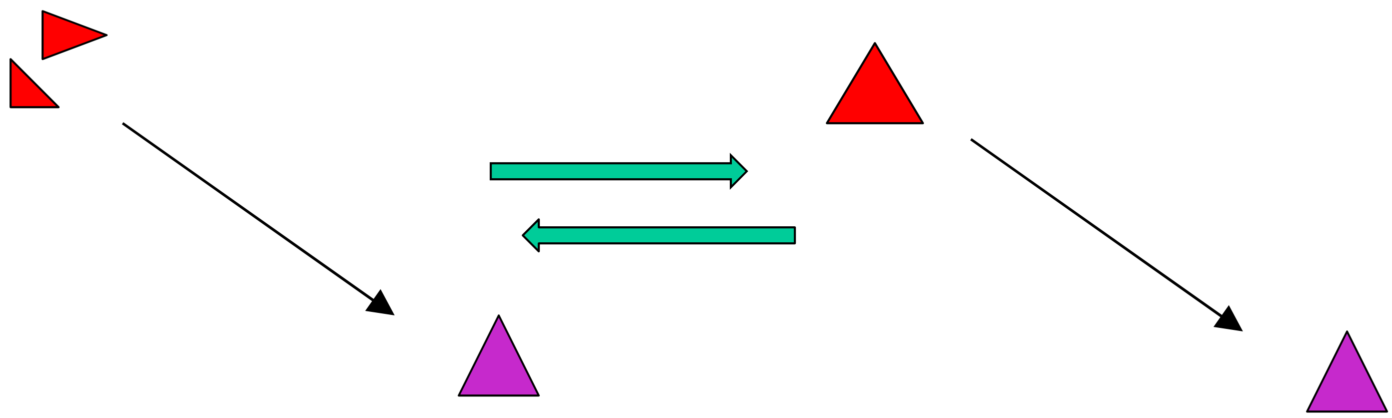
Hong Kong University of Science & Technology

Fast BEMs

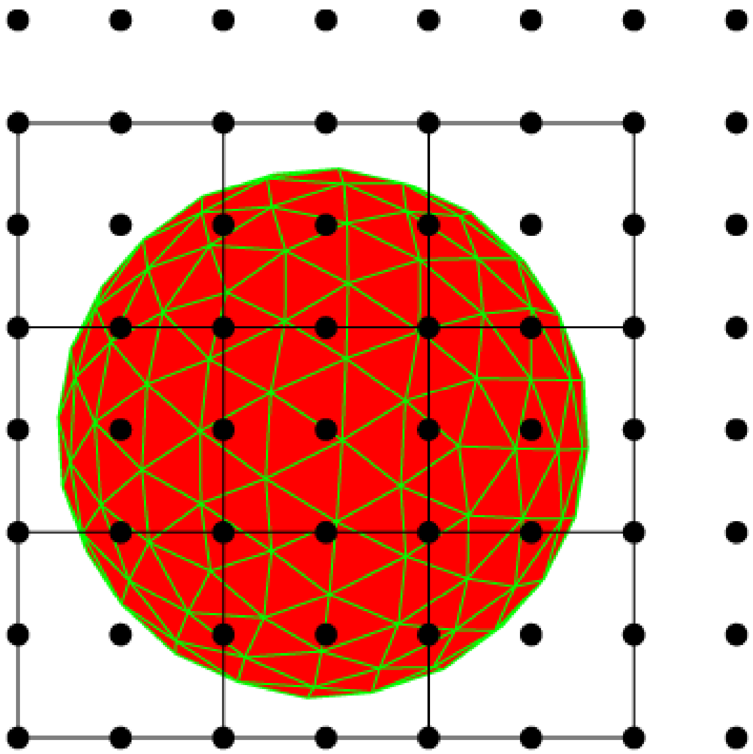
- Fast multipole BEM
- Adaptive crossing approximation BEM
- Wavelet BEM
- Precorrected-FFT technique
- etc.

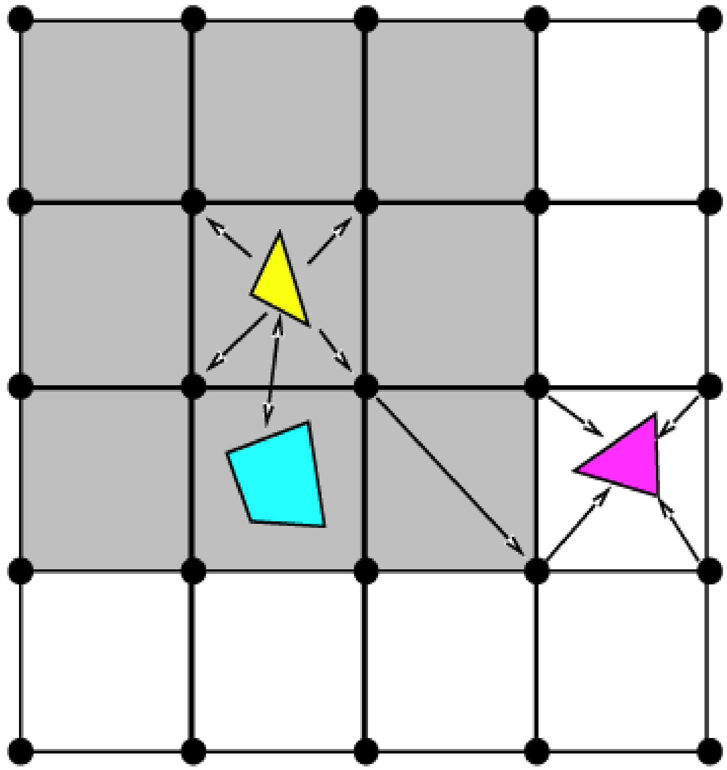
Precorrected-FFT Technique

- Basic idea
  - nearby interaction - accurate evaluation
  - far-field interaction - approximation



Precorrected-FFT Technique





Precorrected-FFT Technique

- Projection
  - Transposed polynomial interpolation
- Computation of grid-grid interaction
  - FFT
- Interpolation
  - Polynomial interpolation
- Correction
  - Direct computation of nearby interaction

Precorrected-FFT Technique

$$\int_{\Gamma} G(x,y)u(y)ds(y) \approx \sum_{\mu} W_{\mu}(x) \sum_{\nu} G(x_{\mu}, y_{\nu}) \int_{\Gamma} P_{\nu}(u(y))ds(y)$$

- Complexity

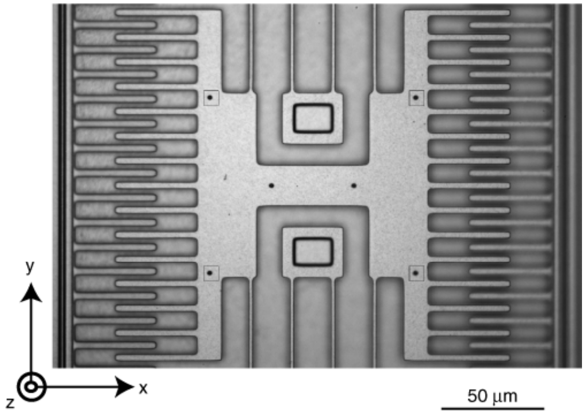
$$O(n) + O(m \log m)$$

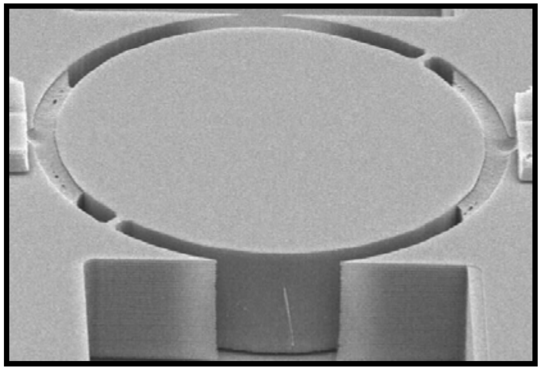
n: number of boundary elements
m: number of grid points

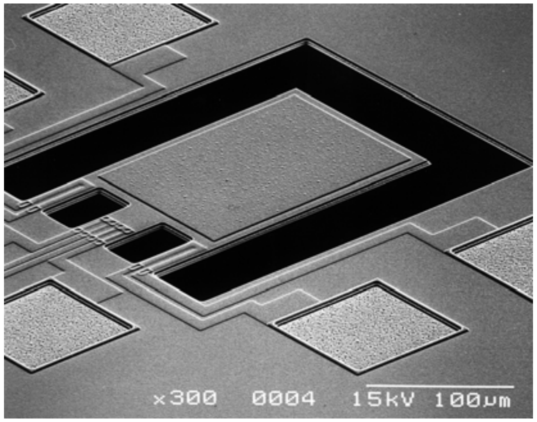
History of the Development

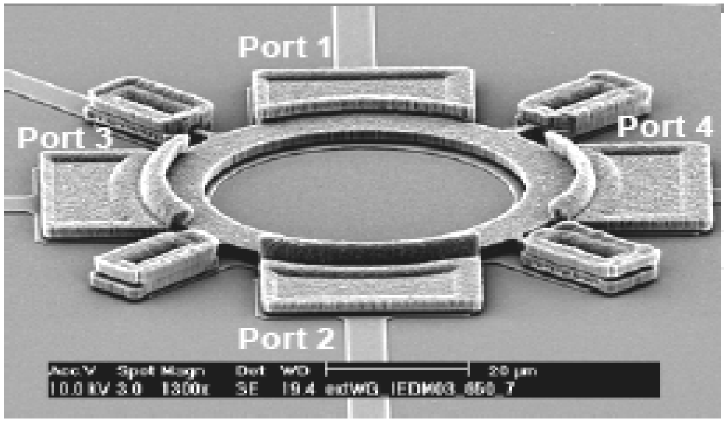
- Electrostatic problems – Fastcap (MIT, Prof. White's group)
- Electromagnetic problems – FastHenry (MIT)
- Stokes Flows – FastStokes (MIT)
  FastSlipStokes (Gatech)
- Linear Elastostatics – FastStruct (Gatech)

Air Damping on Microresonators



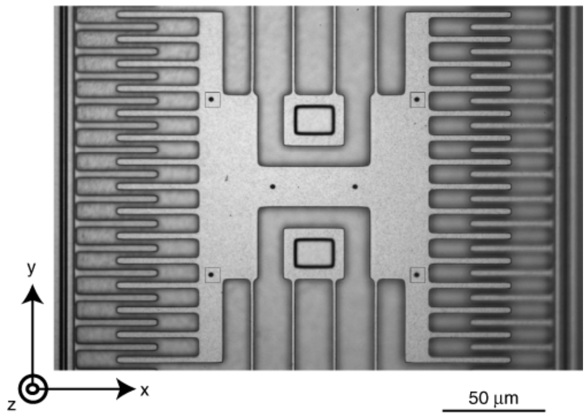


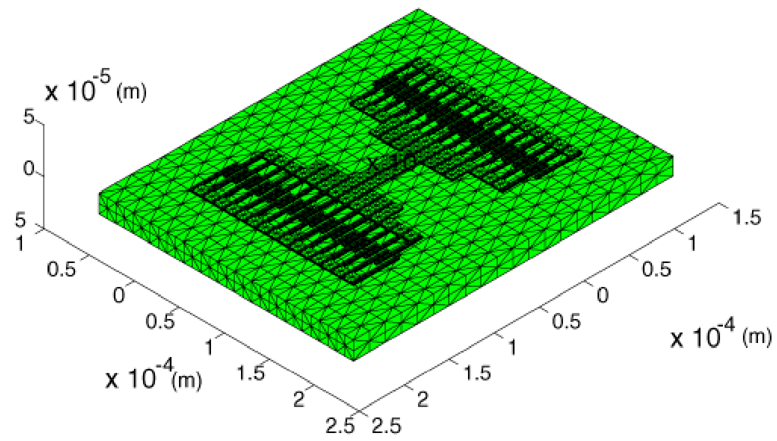




Courtesy of (a) D. Freeman (b) O. Brand (c), F. Ayazi and (d) C. Nguyen

Air Damping on Laterally Oscillating Micromachined Resonators

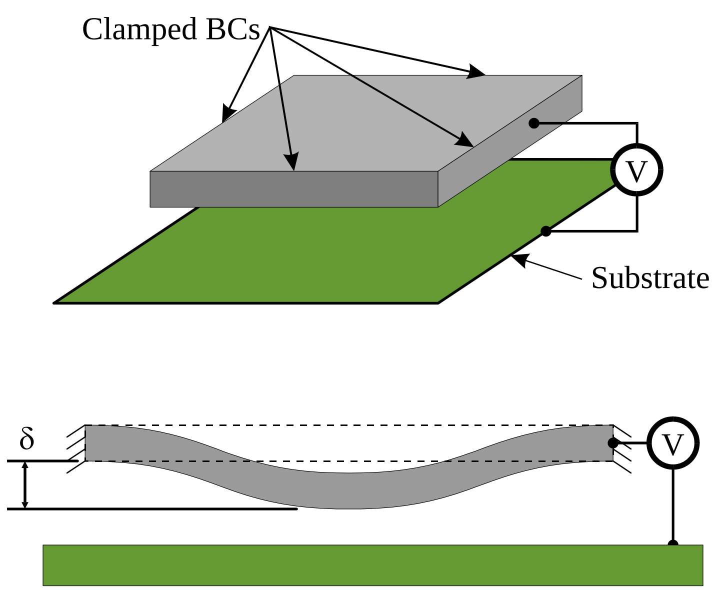


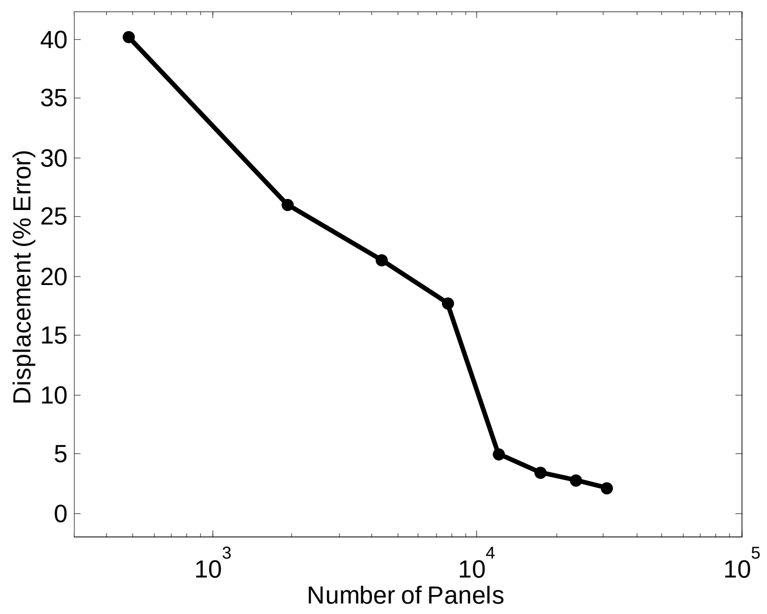


	Drag Force (nN)	Q
Couette Model	110.7	54.5
1D Stokes Model	123.2	49
FastStokes (3D)	207.6	29.1
Measurement	224	27

Coupled Structural and Electrostatic Analysis

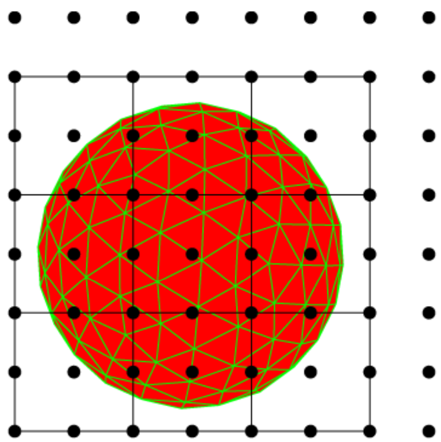
Applications: MEMS switches, pressure sensors, etc



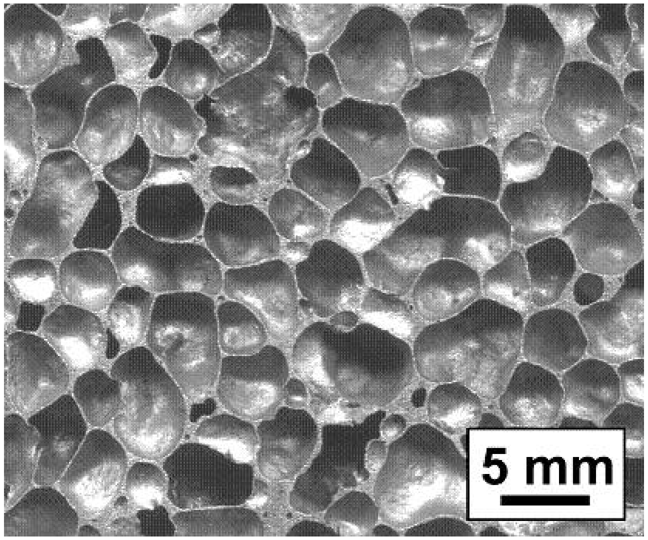


Recent Efforts

- Accelerate volume integration
  - Quasilinear problem
- Nonhomegenous problems
  - Mechanical characterization of porous solids
- Time-dependent problems
  - Wave propagation inside porous solids

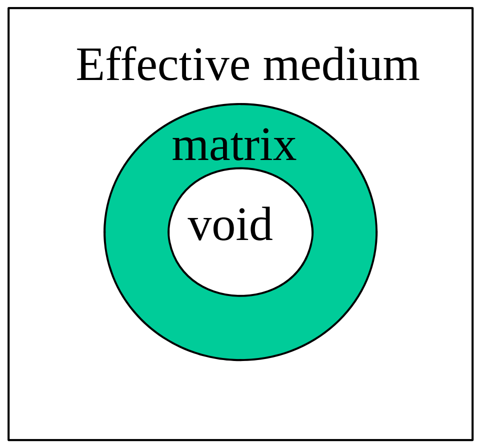


Mechanical Characterization of Porous Solids



- Random but uniformly distributed pores with uniform shape and size
- Porosity is small

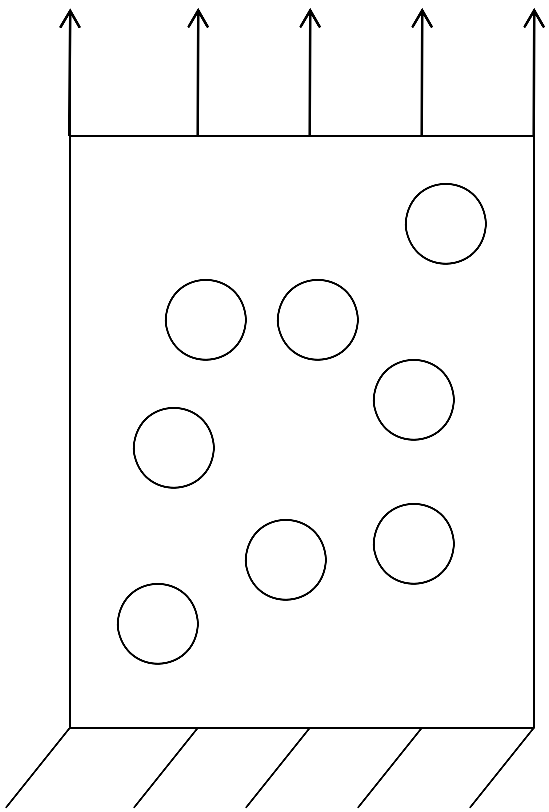
- Generalized self-consistent theory
- Differential scheme, etc



Effective Material Properties

- Effective Material Properties

σ^0 or ε^0



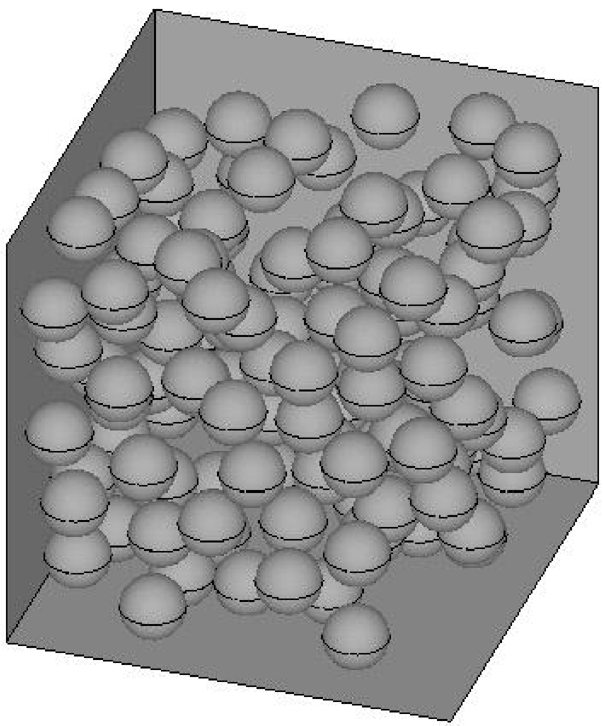
Energy equivalency

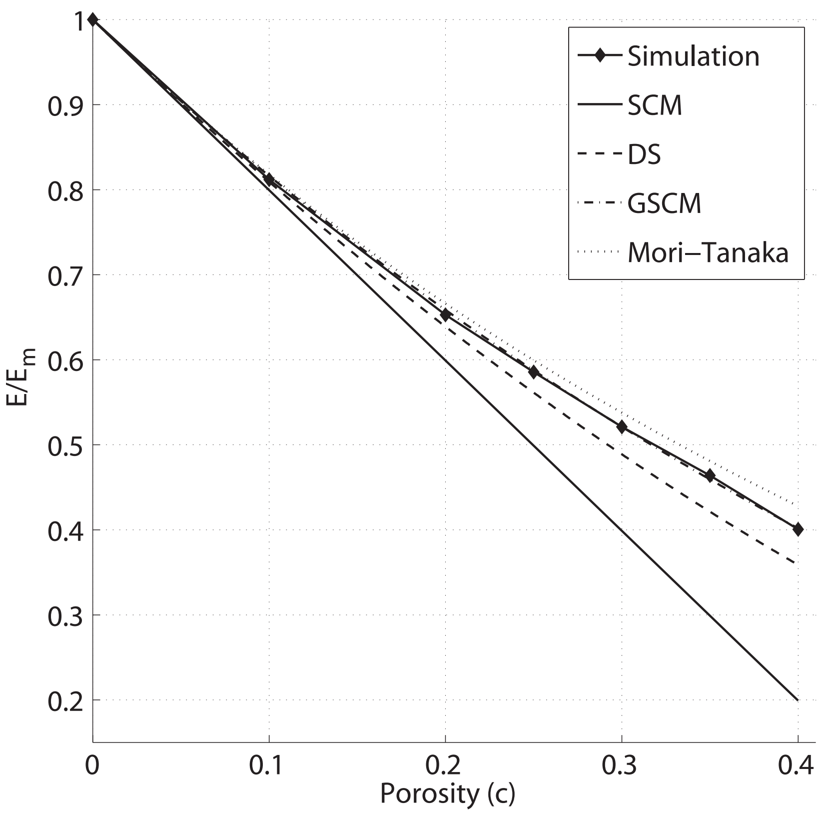
$$K^L = \frac{\sigma^0 V}{\sum_{j=1}^{M} \left(\mathbf{n} \cdot \mathbf{u} A\right)_j}$$

$$K^U = \frac{\sum_{j=1}^{M} \left(\mathbf{T} \cdot \mathbf{x} A\right)_j}{9\varepsilon^0 V}$$

Effective Material Properties

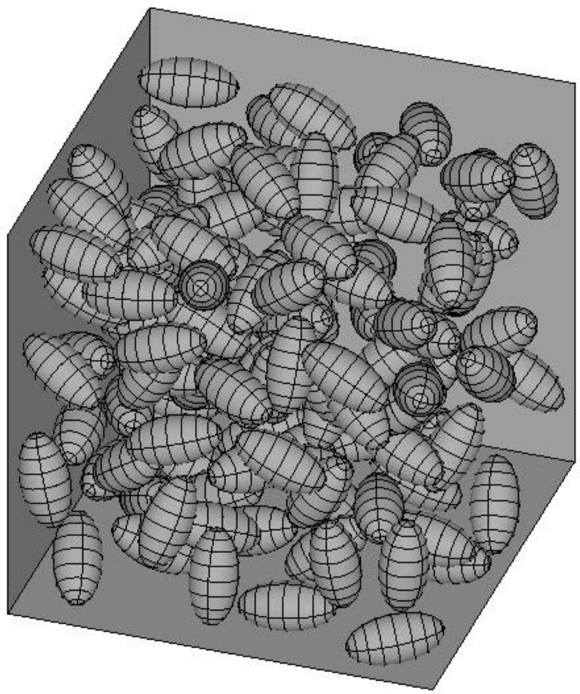
- Effective Young's Modulus

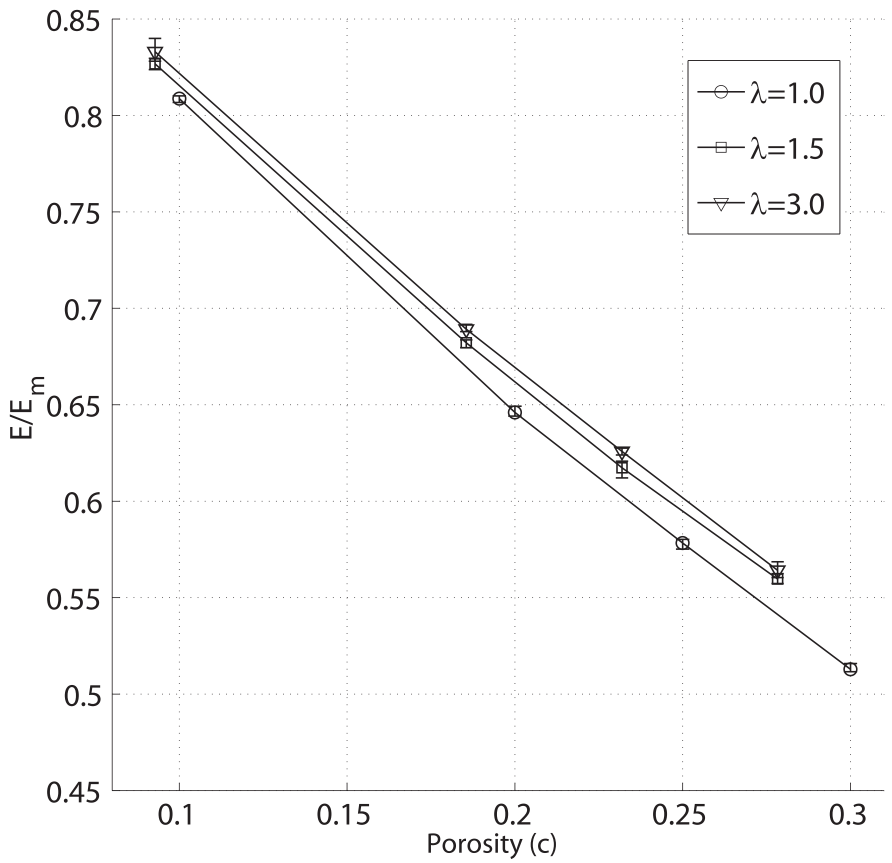




Examples – Steady Case

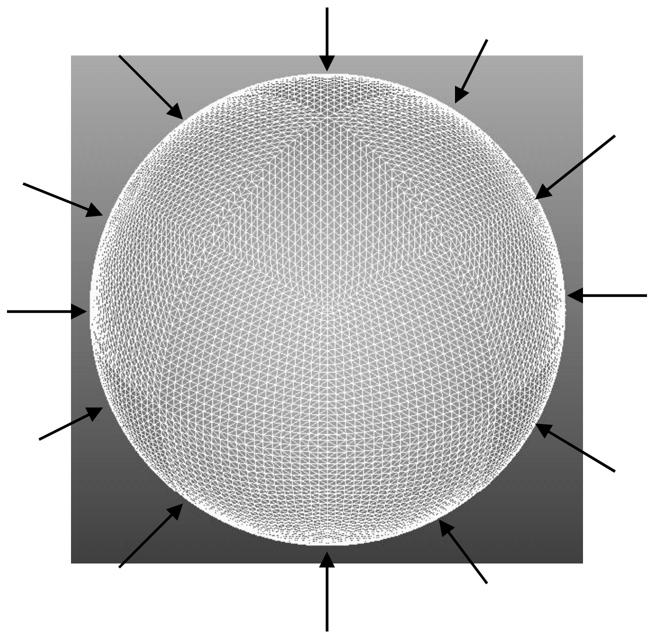
- Shape Effect on Effective Young's Modulus

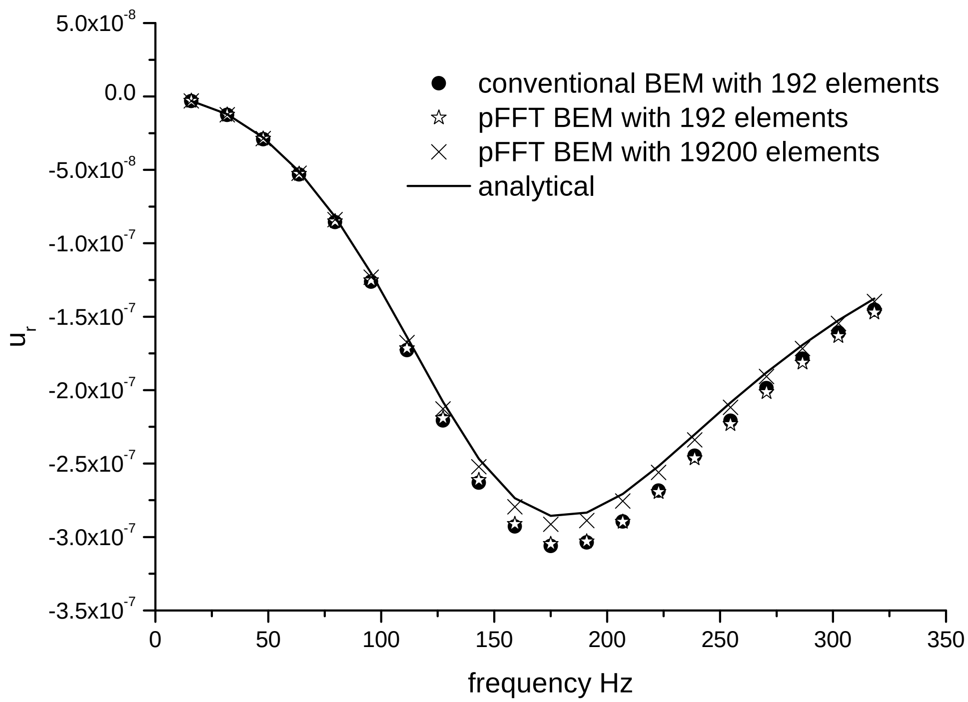




Examples – Oscillatory Cases

- ***Spherical cavity embedded in an infinite elastic medium***





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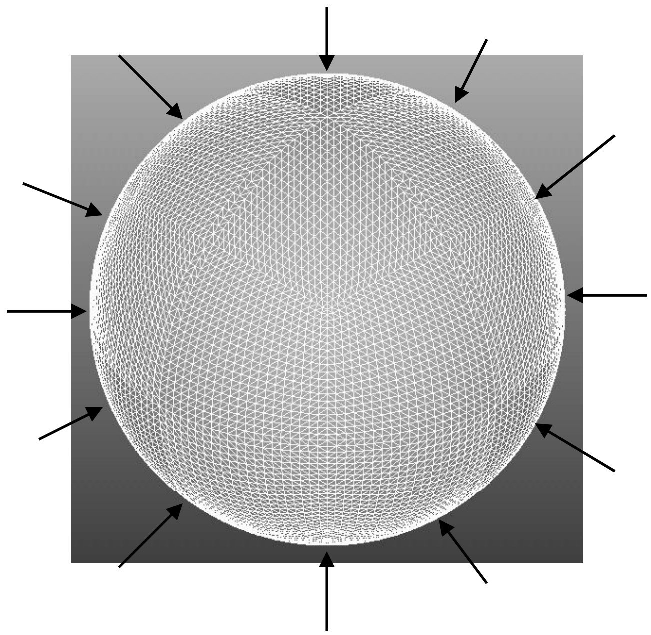

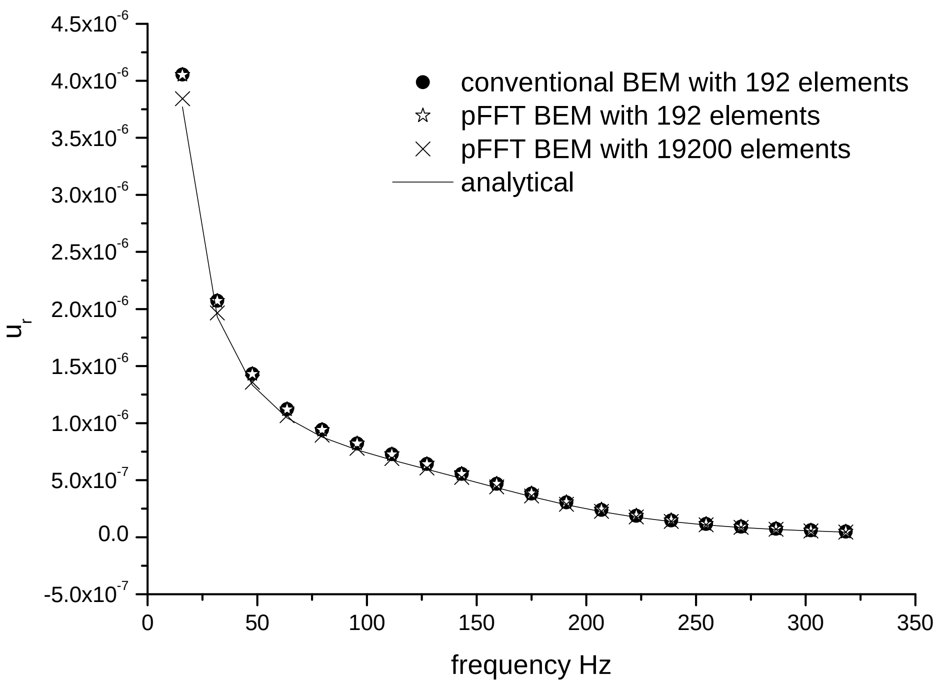

Examples – Oscillatory Cases

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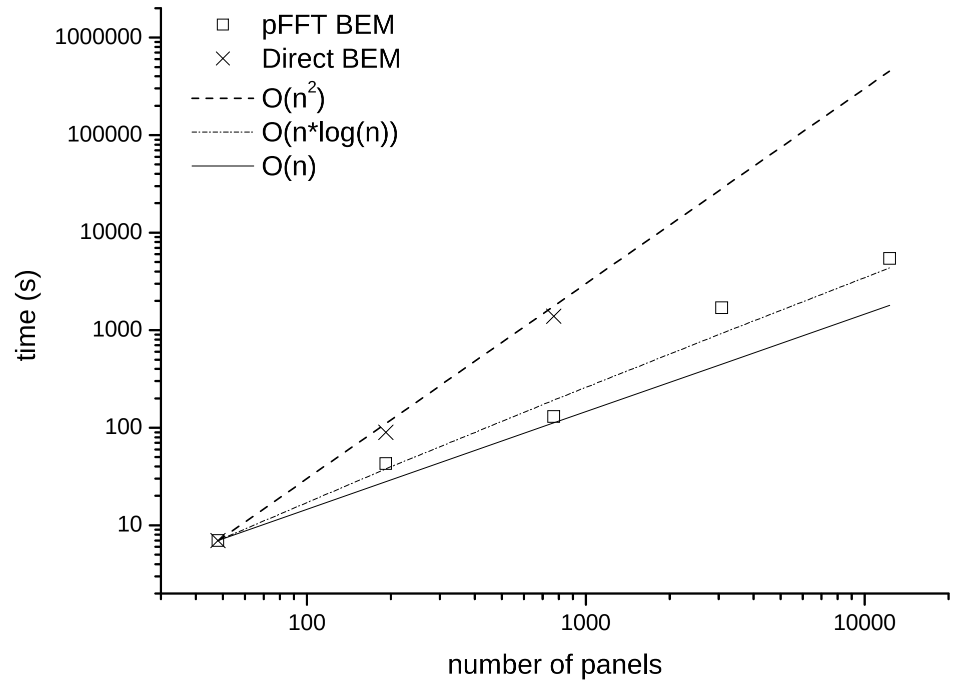
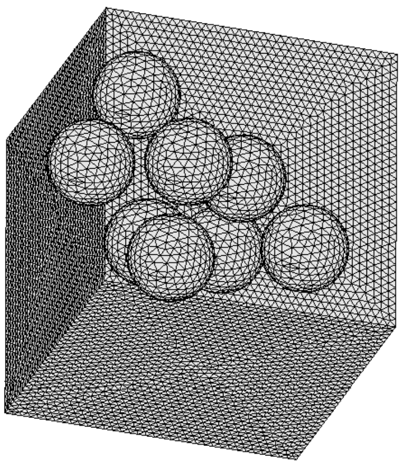
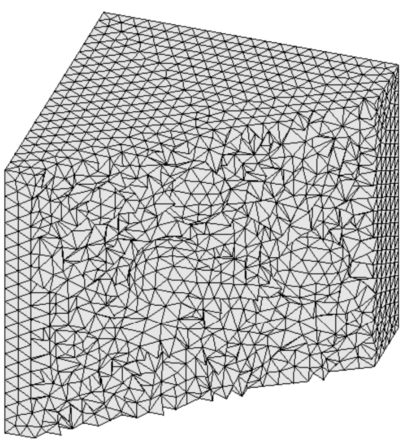
Computation Time



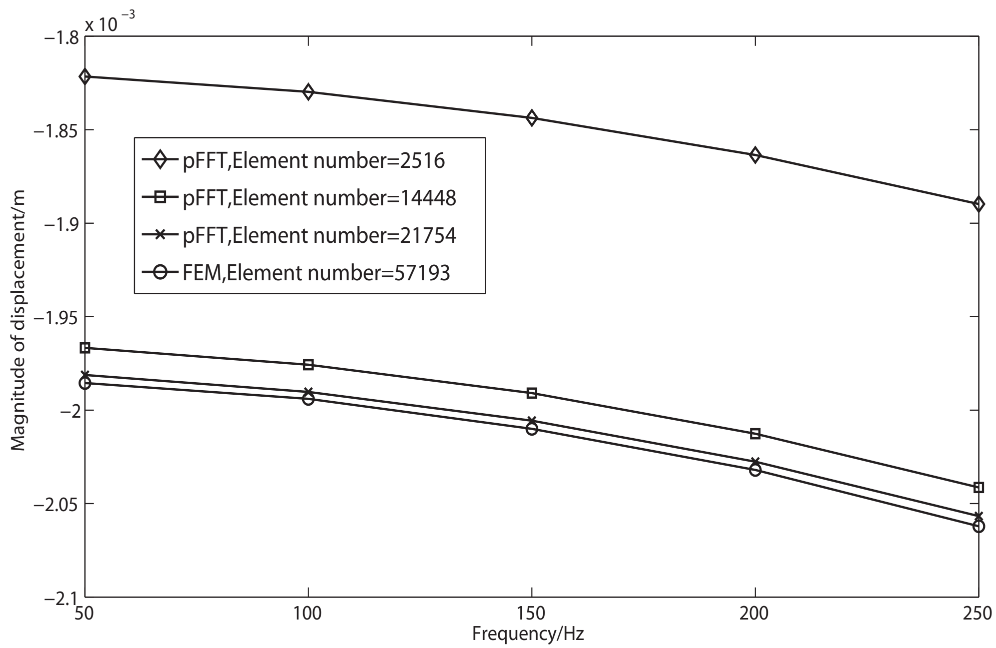
Examples – Oscillatory Cases

- ***Cube with several spherical voids***





Displacement



Future Directions

- Algorithm optimization
- Applications to large-scale problems
- Nonlinear problems?