

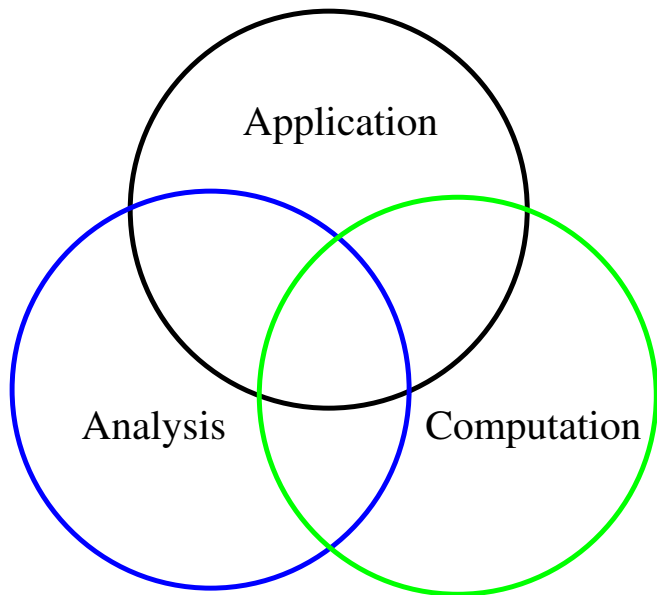
A CSE Sampler

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The Computational Science & Engineering Picture

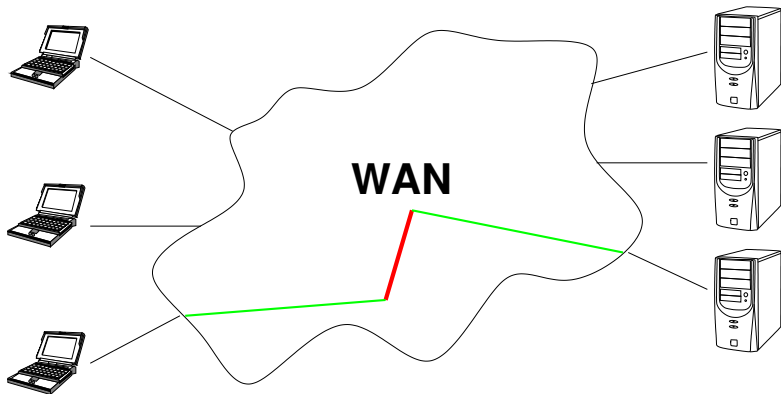


My CS&E Picture

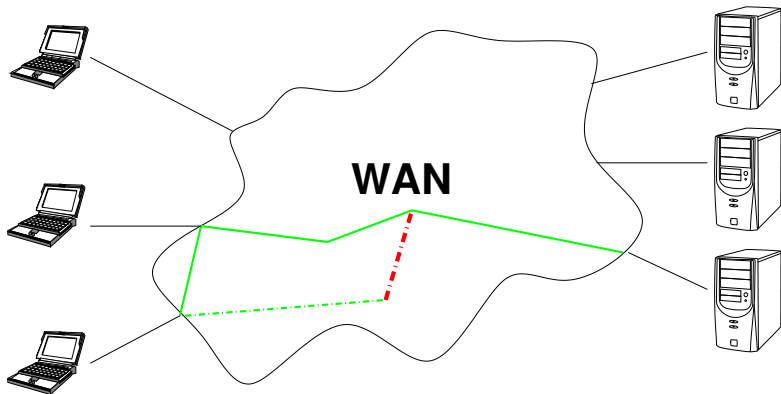
Most of my work involves applied numerical linear algebra:

- ▶ Applications
 - ▶ Physics: microsystems, bone mechanics, materials
 - ▶ CS: computer network tomography, opinion formation in social networks, detecting overlapping clusters
- ▶ Analysis
 - ▶ $Ax = \lambda x$, $A(\lambda)x = 0$, $Ax = b$, $f(\lambda) = u^T(A - \lambda I)^{-1}v$
 - ▶ Typically large and *structured* (sparsity, rank structure, perturbative structure, ...)
- ▶ Computation
 - ▶ Algorithms: Structured eigensolvers, structured-preserving model reduction, continuation for eigenproblems, fast solvers for rank-structured matrices
 - ▶ Software: SUGAR, HiQLab, deal2lab, bonefea, ...

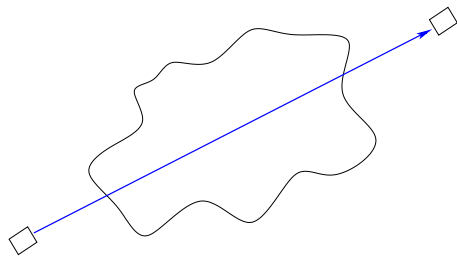
Application: Computer Network Tomography



Find and Fix or Route Around?

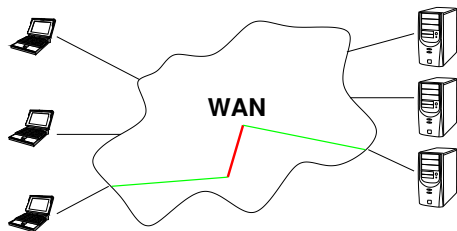


Discrete Radon transform



Radon transform:

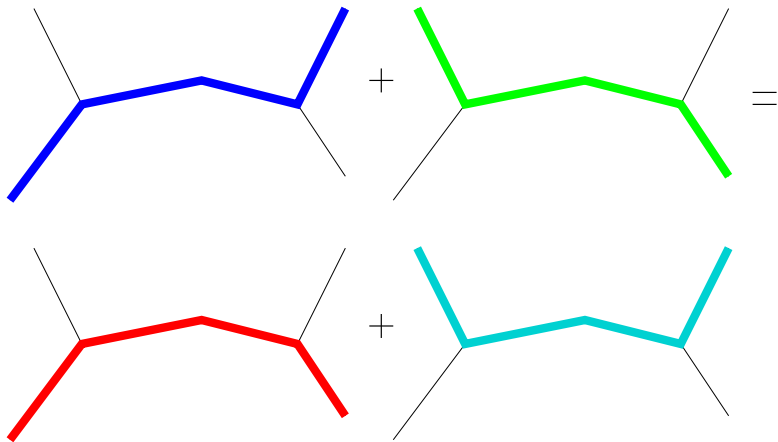
$$(Ru)(L) = \int_L u(\mathbf{x}) |d\mathbf{x}|$$



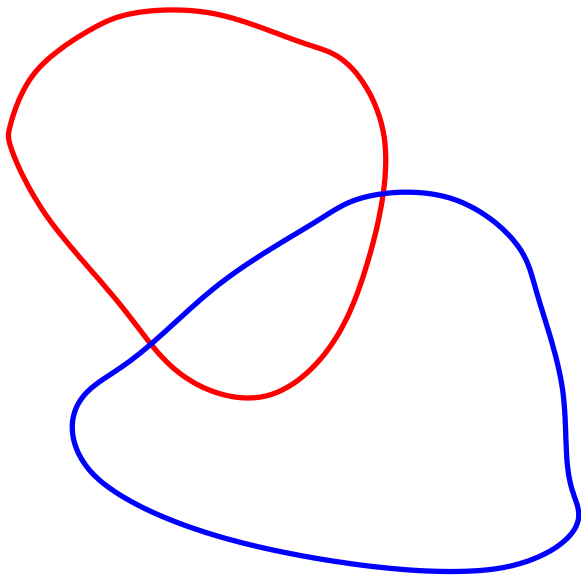
Discrete version:

$$(Gu)_i = \sum_{j \in \text{links}(i)} u_j$$

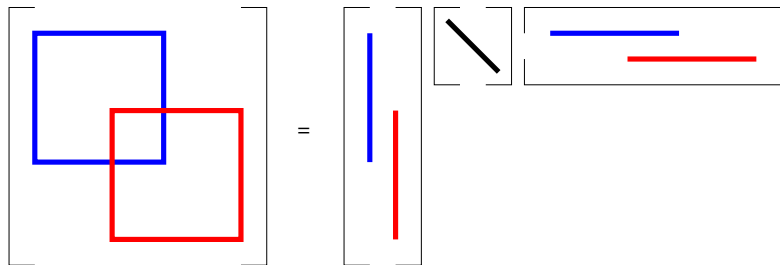
Linear Algebra of Paths



Application: Detecting Overlapping Communities



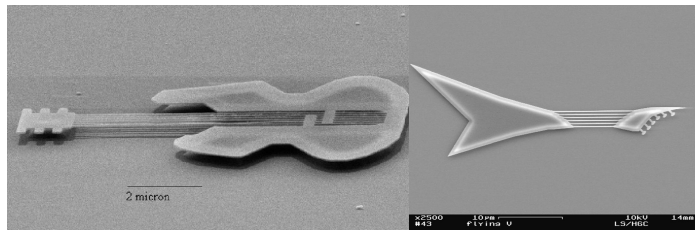
Linear Algebraic View



$$\hat{A} \approx CDC^T$$

- ▶ Find dominant subspace for range of \hat{A}
- ▶ Find sparse indicator vector in space (linear programming)
- ▶ Deflate and repeat to decompose A

Application: Resonating MEMS



Microguitars from Cornell University (1997 and 2003)

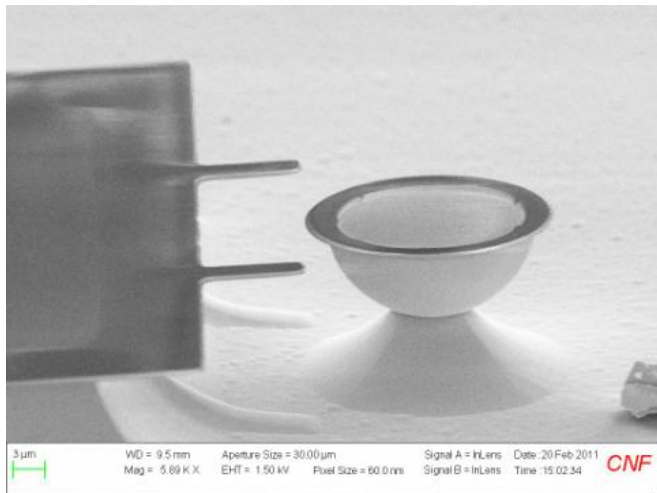
- ▶ MEMS = Micro-Electro-Mechanical Systems
- ▶ Micron-scale *mechanical* structures with IC fab technology
- ▶ Widely used for sensing and signal processing ...
- ▶ ... and sometimes really high-pitch guitars!

Current example: Micro-HRG / GOBLiT / OMG

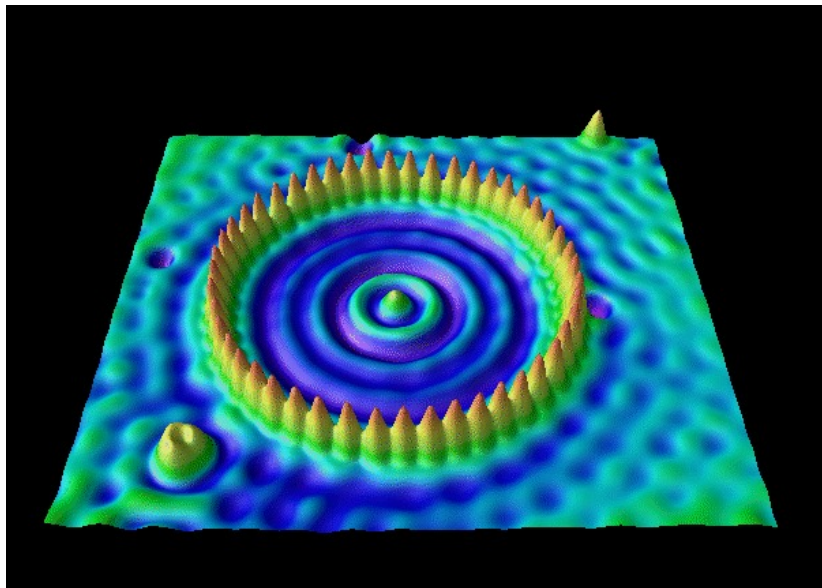


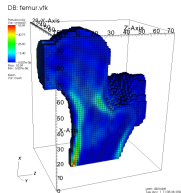
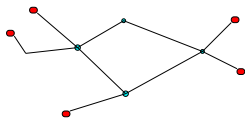
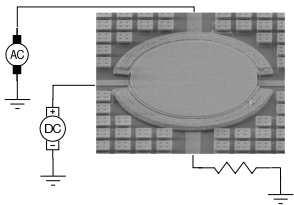
- ▶ This is a gyroscope!
- ▶ We want to make it 1mm across.
- ▶ Collaborator roles:
 - ▶ Basic design
 - ▶ Fabrication
 - ▶ Measurement
- ▶ Our part:
 - ▶ Detailed physics
 - ▶ Fast software
 - ▶ Sensitivity
 - ▶ Design optimization

A little GOBLiT



Application: Resonance and Metastable Behavior





Application modeling

Analysis

$$\rho \ddot{u} = \nabla \cdot \sigma$$

$$Ax = b$$

$$Ax = \lambda x$$

Algorithms and software

HiQLab, Matscat, ...

Model reduction methods

Structured linear solvers

<http://www.cs.cornell.edu/~bindel>