Scientific Computing Group

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Connections

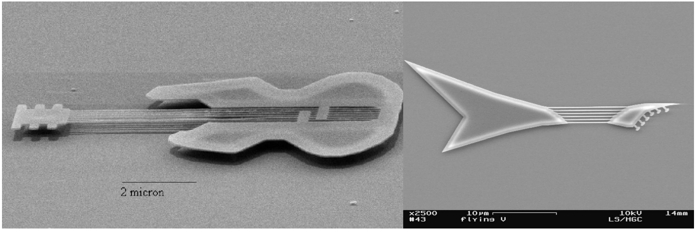
What we do:

- Matrix computations
- Fast transforms
- Physical simulations
- Network modeling
- HPC

Who we talk to:

- Graphics and vision
- Machine learning
- Theory
- Computer systems
- Engineering
- Physical sciences

Example: 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 project: Micro-HRG / GOBLiT / OMG

- This is a gyroscope!
- Collaborator roles:
  - Basic design
  - Fabrication
  - Measurement
- Our part:
  - Detailed physics
  - Fast software
  - Sensitivity
  - Design optimization

Tensor Computations

What is a tensor? Think of it as a higher dimensional matrix.

A fourth-order tensor...

$$A = A(1:n_1, 1:n_2, 1:n_3, 1:n_4)$$

They are typically very large data objects...

$$N = n_1 \cdot n_2 \cdot n_3 \cdots n_d$$

Why?

Make it possible for scientists to extract information from high-dimensional datasets that arise from modeling...

$$\mathcal{A}(i,j,k,\ell) \;=\; \text{\textit{a measurement that results by setting the value of four independent variables}}$$

or discretization...

$$\mathcal{A}(i,j,k,\ell) \;=\; f(w_i, x_j, y_k, z_\ell)$$

How?

A tensor

$$\mathcal{A} = \mathcal{A}(1\!:\!4, 1\!:\!3, 1\!:\!n_3, 1\!:\!n_4)$$

can be "flattened" into a block matrix:

$$A = \begin{bmatrix} \mathcal{A}(1,1,:,:) & \mathcal{A}(1,2,:,:) & \mathcal{A}(1,3,:,:) \\ \mathcal{A}(2,1,:,:) & \mathcal{A}(2,2,:,:) & \mathcal{A}(2,3,:,:) \\ \mathcal{A}(3,1,:,:) & \mathcal{A}(3,2,:,:) & \mathcal{A}(3,3,:,:) \\ \mathcal{A}(4,1,:,:) & \mathcal{A}(4,2,:,:) & \mathcal{A}(4,3,:,:) \end{bmatrix}$$

Methodology: Extract information from A using "classical" matrix computations. Then draw conclusions about tensor $\mathcal{A}$.

Focus: Low Rank Approximation

Given: $\mathcal{A}(1:n, 1:n, 1:n, 1:n, 1:n, 1:n)$.

Find: n-by-n matrices $B_1, \ldots, B_p$, $C_1, \ldots, C_p$, and $D_1, \ldots, D_p$ so that

$$\mathcal{A}(i_1, i_2, i_3, i_4, i_5, i_6) \approx \sum_{s=1}^{p} B_s(i_1, i_2) C_s(i_3, i_4) D_s(i_5, i_6)$$

Approximating an $O(n^6)$ data object with $3pn^2$ numbers.

Vehicle: Multilinear optimization

Goal: Make intractable problems tractable through approximation.