Fast and Accurate Memristor-Based Algorithms for Social Network Analysis

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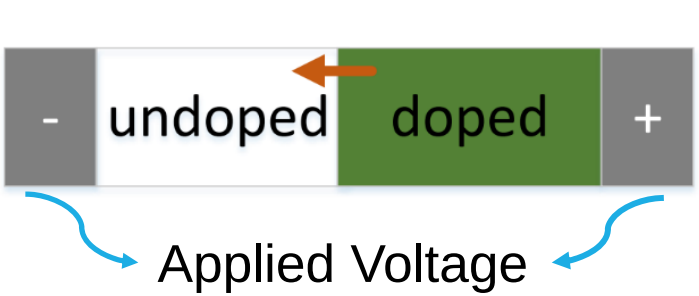
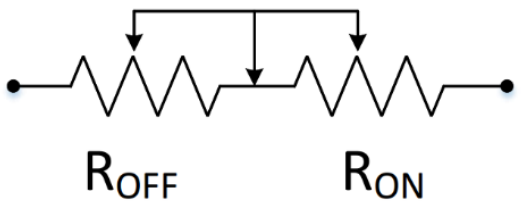
Overview of Memristors

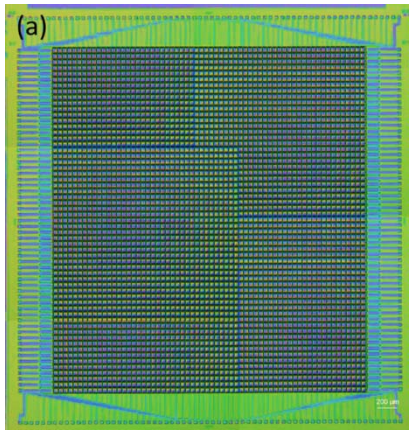
- Invented by HP Labs in 2008
- Resistance changes if voltage greater than V_{thresh} is applied
- Otherwise, acts like resistor



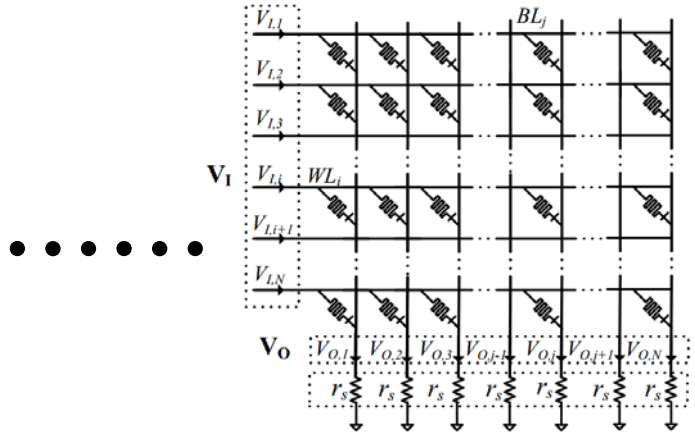


Fast Matrix Multiplication with Memristor Crossbars

- Can be fabricated into a high-density grid (aka *crossbar*)



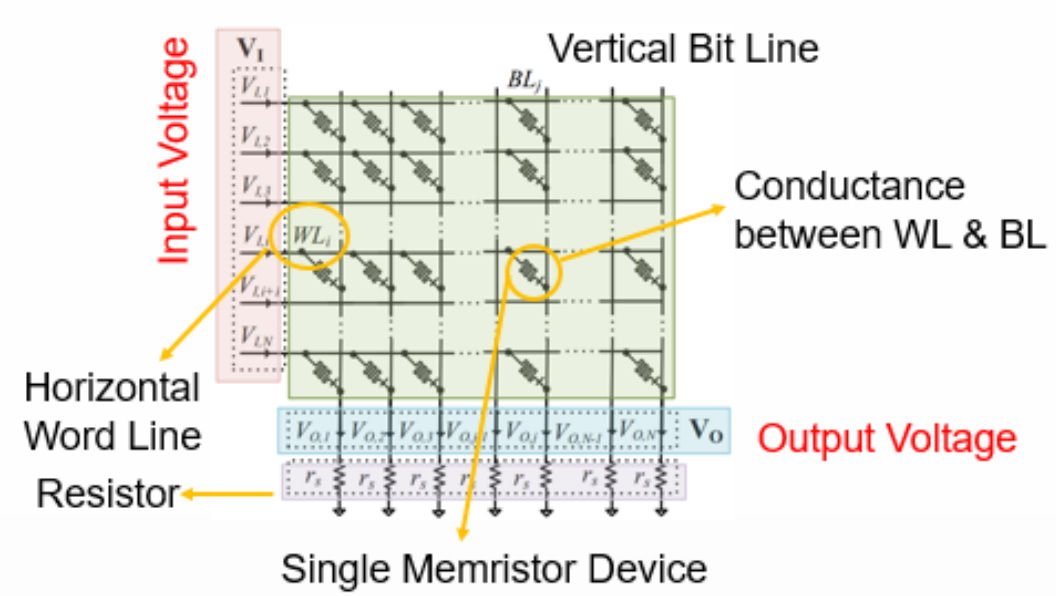
Fabricated memristor crossbar



The equivalent circuit model

Fast Matrix-Vector Multiplication and Solving of Linear Systems of Equations

- A memristor crossbar can conduct matrix-vector multiplication in O(1) computational complexity
- The reverse operation – solving of linear systems of equations can be performed in O(1) as well



$$\mathbf{V_O} = \mathbf{C} \times \mathbf{V_I}$$

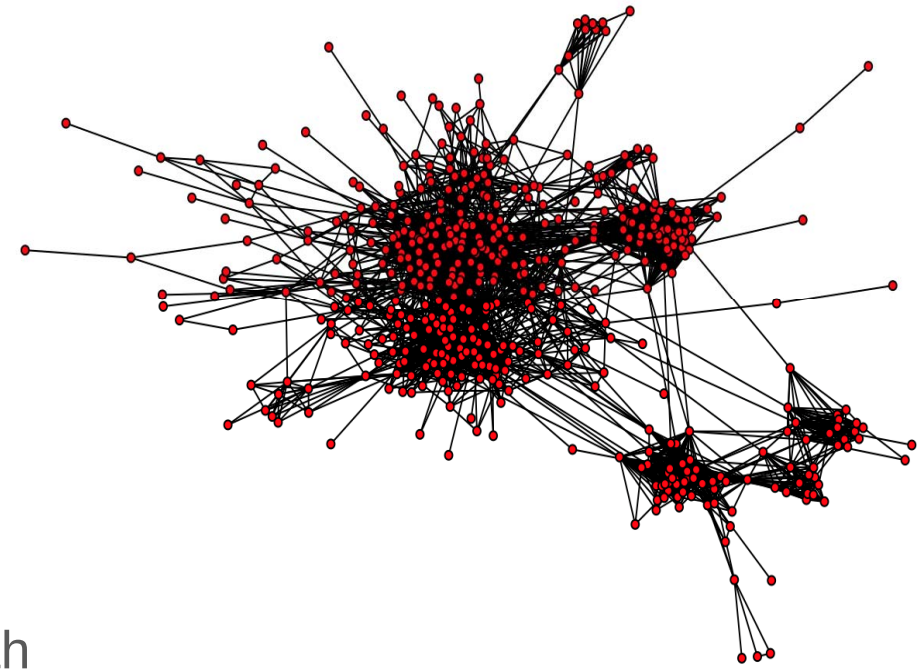
$$\mathbf{C} = diag(d_1, \ldots, d_N) \cdot \begin{bmatrix} g_{1,1} & \cdots & g_{1,N} \\ \vdots & \ddots & \vdots \\ g_{N,1} & \cdots & g_{N,N} \end{bmatrix}$$

The PIs' Preliminary Work on Applications of Memristor Crossbars

- Solving linear programming problems: IEEE SoCC 2016.
- Solving cone programming and quadratic convex optimization problems: ACM/IEEE ASPDAC 2017.
- Solving robust compressed sensing problems: IEEE ICASSP 2017: Best Paper Award, Best Student Presentation Award.

Matrices are Everywhere in Social Network Algorithms!

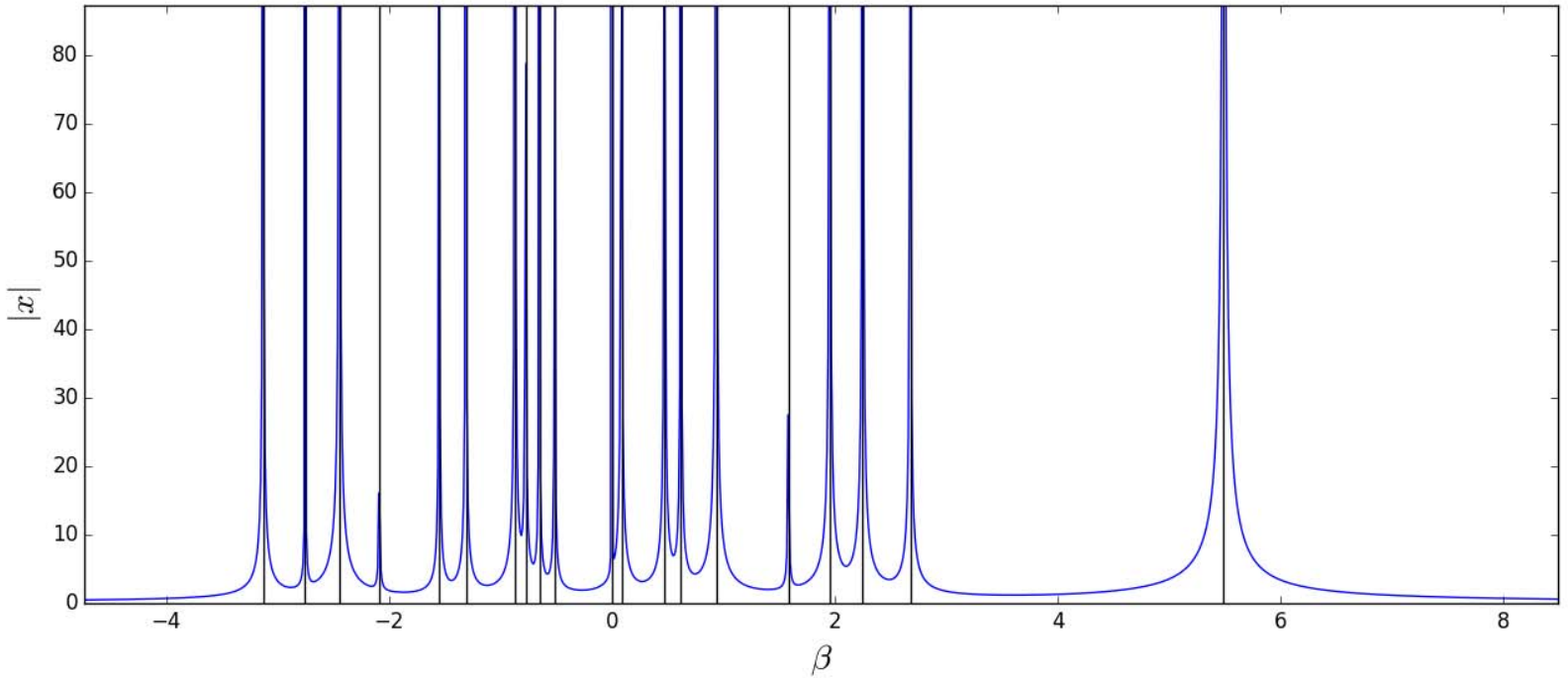
- How fast does disease spread?
  - Leading eigenvalue tells us "capacity" of the matrix
- What are the major clusters in the network?
  - Use eigenvectors to perform community detection
- Which nodes can be reached in *k* steps?
  - Matrix multiplication finds path lengths



Finding Eigenvalues and Eigenvectors

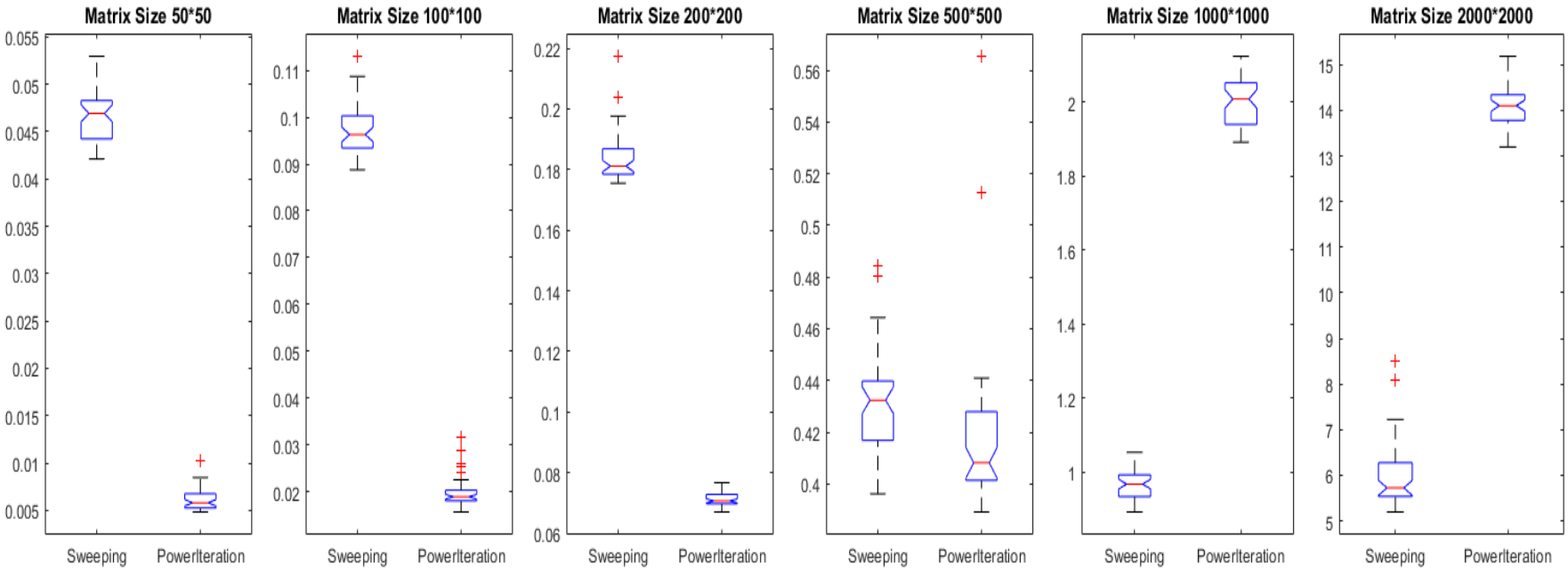
- Let A be a real symmetric matrix, b be a random vector.
- Then for any β, $(A - \beta I)x = b$ has a solution iff β is not an eigenvalue of A.
- The Sweeping Algorithm:
  - Set b to be a random vector
  - Vary β, and use the memristor crossbar to solve $(A - \beta I)x = b$.
  - Observe $|x|$. When it becomes very large, we've found an eigenvalue.

Finding Eigenvalues and Eigenvectors: Example



Results on an Erdos-Renyi graph with 20 nodes

Finding Eigenvalues and Eigenvectors: Example



Finding Eigenvalues and Eigenvectors: Challenges

- How can we detect if there are multiple eigenvectors associated with the same eigenvalue? Idea: perturb the original matrix slightly, see which eigenvalues "split"
- Given approximate eigenvalues, how do we find corresponding eigenvectors? Idea: inverse iteration method
- How do we select the stepsize for β? Still working on this
- How can we partition a large matrix to fit onto the crossbar? Still working on this

Thanks!

Any questions?