Quantum Random Walks and Synthetic Lethality

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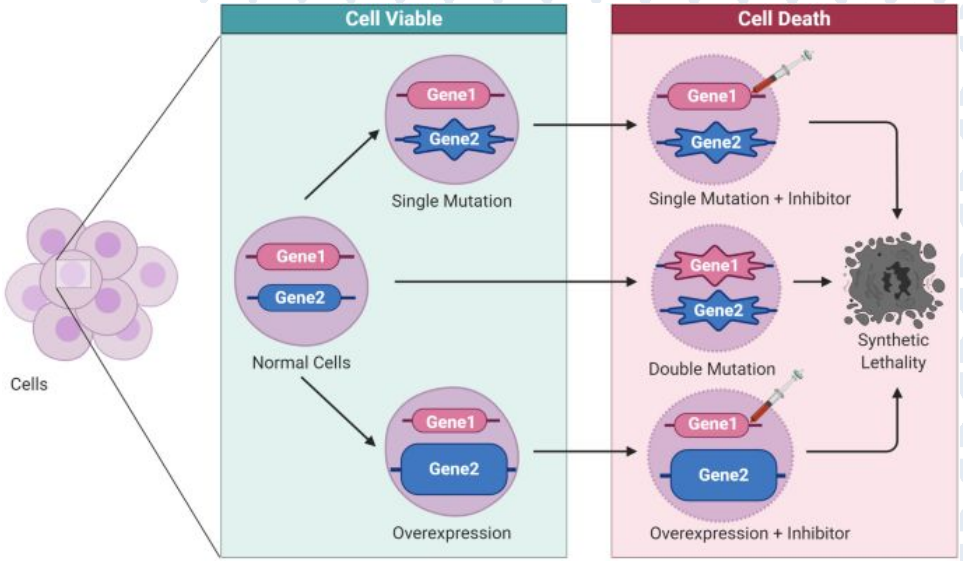
Synthetic Lethality



Mutations in Cancer

Genetic Disease

Experimental Perturbations

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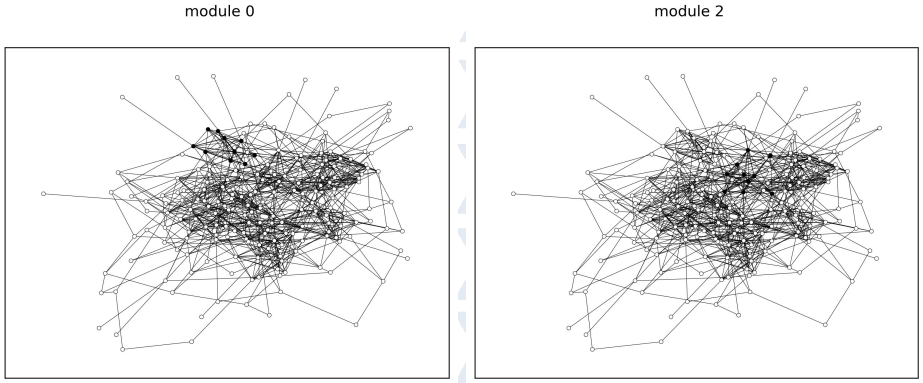
Topatana, W., Juengpanich, S., Li, S. et al. Advances in synthetic lethality for cancer therapy: cellular mechanism and clinical translation. J Hematol Oncol 13, 118 (2020). https://doi.org/10.1186/s13045-020-00956-5

Combinatorial Search and Grover's Alg.



Suppose we have two disease modules in a network and mutations in BOTH, but NOT ONE, of two disease modules is enough to cause the disease.

We simulate "patient data".

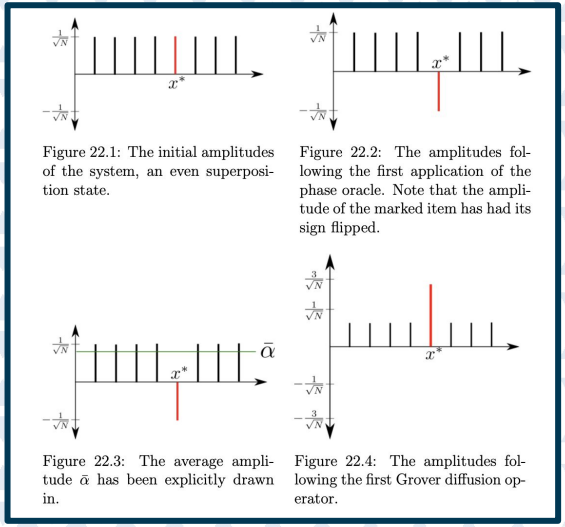


Figure 22.1: The initial amplitudes of the system, an even superposition state.

Figure 22.2: The amplitudes following the first application of the phase oracle. Note that the amplitude of the marked item has had its sign flipped.

Figure 22.3: The average amplitude $\bar{\alpha}$ has been explicitly drawn in.

Figure 22.4: The amplitudes following the first Grover diffusion operator.

Can we construct a Hamiltonian which picks out the correct disease modules based on resulting "patient data"?

https://www.scottaaronson.com/qclec.pdf

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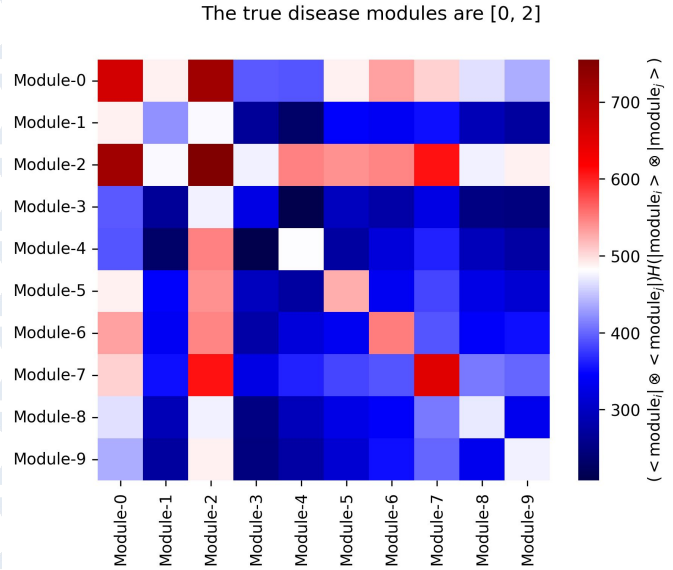
Hamiltonian for Correlated Modules

$$(\langle i| \otimes \langle j|)(|D_1\rangle \otimes |D_2\rangle) = \begin{cases} 1, & \text{if } i \in D_1 \text{and} j \in D_2 \\ 0, & \text{otherwise} \end{cases}$$

The combinatorial problem can be translated into Linear Algebra.

$$\sum_{S_k} \sum_{i,j \in S_k} (|i\rangle \otimes |j\rangle)(\langle i| \otimes \langle j|)$$

Which in turn, suggests this Hamiltonian.



Testing indicates that it indeed can pick out the relevant disease modules, albeit with some “bleed-through”.

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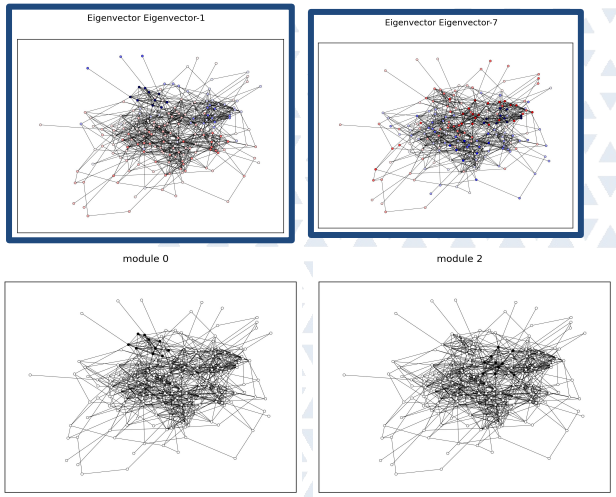
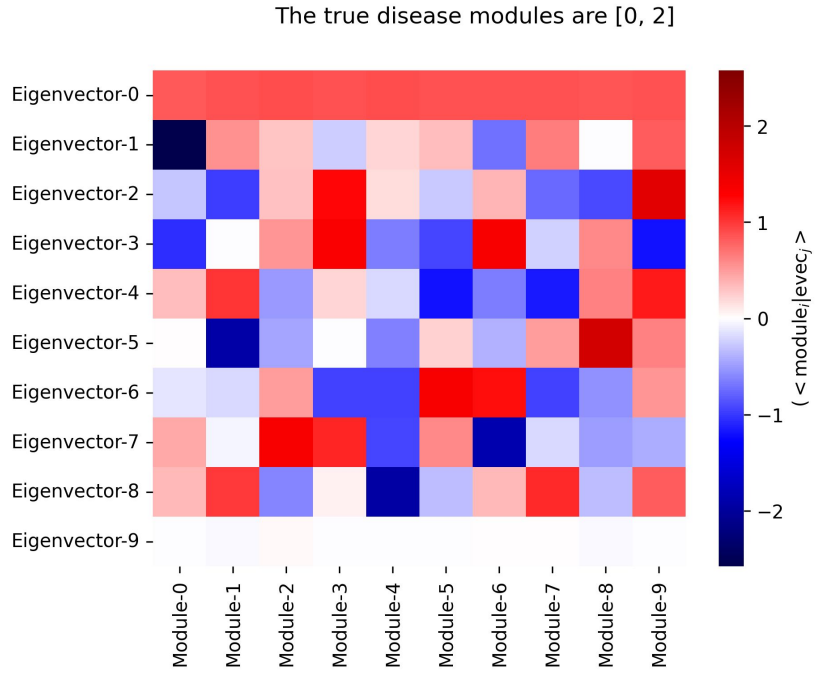
Eigenvectors Stand in for Gene Modules



We can use the PPI Eigenvectors as proxies for the ground truth gene modules.



If the clusters are pronounced enough, they will have a representative eigenvector.

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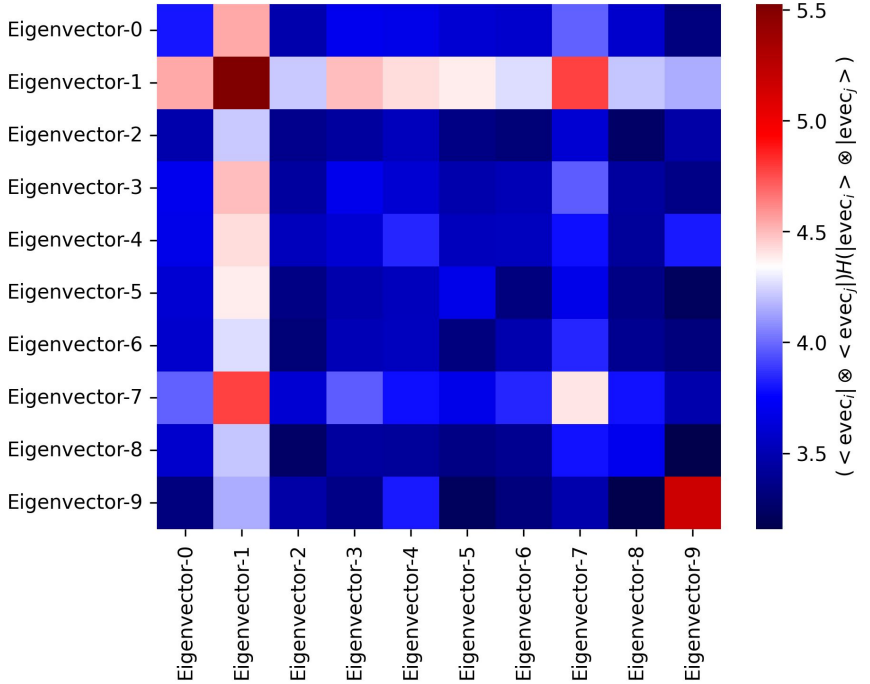
Hamiltonian on PPI Eigenvectors

$$\sum_{S_k} \sum_{i,j \in S_k} (|i\rangle \otimes |j\rangle)(\langle i| \otimes \langle j|)$$

This Hamiltonian can be incorporated into a Double QRW.



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Suitably tweaked it will discover pairs of components with complementary behaviour.

Thank you

All code at
https://github.com/seasonsOfTheSun/qrw_for_synthetic_lethality/tree/main
Also posted on Slack, will grant access on request.

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