CS-631 Term papers

Instructions: Students should form groups of 1-4 and submit a term paper of 4-10 pages on a topic of their choice.

In more detail: Here are the steps that you should perform:
1- Form a small group. I encourage groups of moderate size, 2-3 seems ideal, but there is flexibility on this. I encourage you to reach out to students with different background than your own. Towards this, see below.
2- Narrow down on a topic. Below is an indicative list of ideas. I will add suggestions over time and you are free to add your own. If you are interested in a topic, add your name (or the names of your group if you already have a group) to the document, under the chosen topic. If too many people choose a topic we may refine it. This should also enable you to identify groups, simply by checking names on a topic you are interested in and contacting them. (Of course, everyone is free to prefer not to form a group; if you do not want to be contacted then you can tell me your topic of interest, as opposed to using this publicly viewable document.)
3. Once you have a (tentative) group and a (tentative) topic, you should schedule a meeting with me (or come to OH) so that we can discuss it.
4. After your group and topic are confirmed, you should read 2-3 papers on the topic and synthesize them. My preference is to focus on your assessment of the work than on the results themselves (which I can read by myself). For example, by placing them in context, criticizing them (why this definition, why this theorem is not strong, why not…or…?), and suggesting avenues for future work. I prefer a text that is personal and opinionated rather than a copying of the results.
5- If you are unsure about scope or expectations, please discuss with me.

The area law has been partially extended to 2D systems, under a certain “uniform gap” condition:
https://arxiv.org/abs/2103.02492
Name(s):

Quantum error-correcting codes provide rich families of local Hamiltonians. Although the minimal energy problem for quantum codes is not hard, it is still thought that code constructions could play a role in a resolution of the quantum PCP conjecture. The following paper provides some attempts at constructing quantum locally testable codes:
https://arxiv.org/abs/2209.11405
Name(s):

Some problems about Hamiltonians can be surprisingly hard! The most famous such result is probably the undecidability of the spectral gap in the thermodynamic limit:
https://arxiv.org/abs/1502.04573
Name(s):

The local Hamiltonian problem has a "dual" QMA-complete problem, the "Consistency of Local Density Matrices" problem. The proof of QMA-completeness is involved and uses very different ideas from the QMA-completeness of the local Hamiltonian problem:
https://arxiv.org/abs/1911.07782
Name(s):

An interesting attempt at providing a more error-robust circuit-to-Hamiltonian construction than the one seen in clase (the history state construction), based on the use of tensor networks:
https://arxiv.org/abs/2309.16475
Name(s):

The notion of a "universal" quantum Hamiltonian extends the focus of the local Hamiltonian problem, i.e. the minimal energy, to the entire spectrum of the Hamiltonian and considers when a class of Hamiltonians is able to entirely "simulate" another class in this way:
https://arxiv.org/abs/1701.05182
Name(s):

The local Hamiltonian problem can be billed as a "quantum" version of classical constraint satisfaction problems. One can make a similar "non-commutative" generalization of classical CSPs, by taking things in a different direction: see, for example,
https://arxiv.org/abs/2312.16765
https://arxiv.org/abs/2410.21223
https://arxiv.org/abs/2409.20028
Name(s):

In absence of a quantum PCP theorem, there is virtually no hardness of approximation result for problems in QMA, such as the local Hamiltonian problem. See however the following attempt, which is based on a conjecture and aims to derive hardness of approximation for the quantum MAXCUT problem:
https://arxiv.org/abs/2111.01254
Name(s):