Term Project

Submit your proposal, presentation slides and final paper online.

One of the goals of this class is to make it possible for you to follow and contribute to work at the current research frontier. Since the lectures cannot go into depth on any one topic, the final project is an opportunity to explore some topic more thoroughly. Projects can be done either individually or in teams of two.

- *Individual projects* should be roughly 10 pages long and may or may not contain original research. If you do not do any original research, then try to write a paper that prepares you for doing research. For example, if you do a survey, then identify important open questions and describe plausible approaches for tackling them.
- *Team projects* should be 15 or so pages long and must contain original research, although it is ok to have most of the paper reviewing existing knowledge. You may divide up some writing or research tasks but each partner should put in roughly similar effort and should be able to explain every piece of the work.

In each case, the page guidelines are approximate. Longer is ok, but you should not be *much* longer unless this length is due to appendices with code or tables or other supplementary information. Shorter is ok if you can concisely express enough material. The recommended format is PRA 2-column 11pt format, which you can achieve with line

```
\documentclass[pra,11pt,twocolumn,tightenlines,longbibliography]{revtex4-1}
```

If you prefer, then you can also do:

```
\documentclass[11pt]{article}
\usepackage[margin=1in]{geometry}
```

What is more important than the specific length is that they contain both good background/discussion/context and some calculations or other technical work. Your presentation should be at a level where your fellow 8.S372 students can follow it.

1 Assignments

The project has three components.

- *Proposal.* The proposal is due on **Friday, Nov 6** but you are welcome to turn it in earlier and you will receive earlier feedback. It should consist of a title, a paragraph or two on what you plan to write about, an outline of the proposed paper, and a preliminary list of references. Also mention any points where you have questions and need to learn or find out more, especially if you are doing original research. These could be gaps in your knowledge (i.e. "I need to read more about X") or issues where no one knows the answer (i.e. "we will

test these codes and we don't know how well they will perform"). Your proposal does not have to be very detailed but you should think of it as an opportunity to get feedback, and the more you put in it, the more we can help you get your project off to a good start. Finally please also include your email address so that we can contact you about scheduling a meeting to discuss your proposal.

- *Peer proposal feedback.* You will read one of your peers' proposals and will give them brief feedback on it, say $\approx$ 100 words. There is no required format for the feedback but some recommended topics include: What do you find interesting or would like to know more about? What looks confusing? If you know the topic, then do you have any suggestions, including useful references? It is ok, and in some ways better, if you don't know the topic. Your feedback should be sent to your peer with instructor and TA cc'ed.

- *Paper.* The paper is due on the last day of class: **Tuesday, Dec 8** and is worth 20% of your grade. Significant extensions may not be possible because of grading deadlines.

- *Presentation.* The last few classes will be devoted to project presentations, worth 10% of your grade. The presentation should explain your results at a level where your classmates can understand it. Presentations will be 15-25 minutes long, with the exact length determined in November by how many students are doing projects.

The proposal and paper should be turned in online via the canvas website using the links at the top of this document. Please upload your presentation slides *before* your presentation to make it easier to write comments during the talk.

The class papers will be collected into a "book" that will be featured on the class website. You can choose whether you'd like your paper to be publically available, available to class participants only, or not shared.

2 Possible Projects

You can choose any topic on quantum computing or quantum information. If it is not on this list, and especially if it doesn't resemble anything on this list, you may want to check with us before writing your project proposal. In some cases we have listed a few possible papers to look at, but these lists are not exhaustive and you do not need to use these as starting points.

Beside the topics below, you should look at the talks in the last few QIP conferences, or even some of the top rated papers at scirate.com.

Information Theory

- Recovery maps (1410.0664 and papers citing this, e.g. 1410.4184, 1509.07127, 1608.07325, 1609.06636)

- Non-additivity of Holevo capacity (0809.3972)

- Gaussian states and channels (1110.3234)

- Entropy accumulation (1607.01796)

- Random quantum states and channels (1509.04689).

- Expanders, designs, scrambling and other aspects of pseudo-randomness.

- Monogamy of entanglement and de Finetti theorems
- Hypothesis testing (e.g. composite hypothesis testing, 1709.07268)
- Single-shot information theory (e.g. 1203.2142, or look at proceedings of the Beyond IID conferences)
- Entropic uncertainty relations (1511.04857)
- Security of quantum key distribution (1506.08458)
- Post-selection theorem / de Finetti reductions (0809.3019, 1605.09013)
- Zero-error communication capacities (1310.7120, 1409.3426, 1502.02987)

Connections to Physics

- The Margolus-Levitin theorem (quant-ph/9710043, 1610.09619, 1701.01175). This topic may be a bit simple so think of ways of going beyond the literature.
- The black-hole information problem
- Thermalization (1409.3435, 1609.07877)
- Kitaev's anyon paper: cond-mat/0506438
- The area law conjecture
- Matrix product states, PEPS, MERA, etc. (1603.03039)
- Approximate ground-state projectors

Other topics in quantum computing Most of these are topics that are not covered in lecture this year.

- Coding theory
- Fault-tolerant quantum computing
- Quantum algorithms
- Interactive verification of quantum computers (1804.01082)
- Other quantum cryptographic primitives such as bit commitment, coin flipping, secure randomness generation, homomorphic encryption, etc.
- The quantum PCP/NLTS/LTC conjectures.
- Quantum communication complexity
- Quantum streaming complexity (quant-ph/0606066)
- Quantum money