Getting Started with a Masters/BSc Project Under my Supervision

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Note that this is not official course material, but more of a collections of tips and advice I have gained from running projects like this in the past

This document may be updated over time, the latest version can be found at:

http://nicholas-chancellor.me/Nick_Chancellor_masters_BSc_projects.pdf

1 Introduction and About Me

First, I'm glad to have you doing a project with me, I personally find supervising this kind of project very enjoyable and rewarding. As some context for what projects you might do it is worth briefly introducing myself. I am a half-time lecturer in the School of Computing, and do quantum-computing-related consulting indpendently for the other half of my employment. My background is in near-term and applied quantum computing, with formal training as a physicist (my PhD is in Physics and I have worked in Physics departments before coming to the School of Computing). I specifically am interested in combinatorial optimisation applications. Since these are my areas of expertise, I tend to like to do related projects, but I know the importance of flexibility, especially dealing with students who are not trained in quantum mechanics. I have plenty of experience supervising masters level projects from previous jobs. For more information about me, please see my personal webpage http://nicholas-chancellor.me/.

2 Starting out

In my experience what is important about these kinds of projects is to be sure to structure the project so that you can get good results relatively early, meaning that if later parts of the project are more difficult than anticipated, or other issues arise, you already have something to show for your work. This approach helps reduce stress and being able to design projects in this way is highly relevant in both industry and academia. My personal feeling is that learning the skills to plan a project like this is probably actually more important than learning the content of your project. In my experience numerical simulations are a really good type of project for this approach, since results are possible once a minimal example of the code is working, and you can start with simple code and build upon it. I also generally believe that it is good to start "getting your hands dirty" and writing code early in the project, it can help understanding in a way just reading papers can't.

There are still many choices for projects you can do, I think a key question to ask at the beginning is:

How much do I want to learn Quantum?

This is a ligitimate question, and I can run projects which do not involve quantum mechanics at all, depending on your answer I have different recommended starting points.

I know I don't want to do any quantum mechanics

In this case, I recommend that you start by looking at classical algorithms for optimisation. Simulated annealing is one such algorthm, it is basically solving problems by effectively rolling weighted dice, as a classical algorithm you can run large instances of simulated annealing on your own machine. The document which can be found here seems to be a good review of simulated annealing https://enac.hal.science/hal-01887543/document. There is also pre-packaged simulated annealing as part of the D-Wave optimisation package https://docs.ocean.dwavesys.com/projects/neal/en/latest/ although it requires a quadratic formulation.

I'm comfortable learning some quantum mechanics, but I don't want to get into details

In this case, it is probably best to start with some of the pre-packaged software that companies make available and some of their excellent online material, for example IBM Qiskit https://www.ibm.com/quantum?lnk=ProdC. Qiskit is a Python based package for simulating (and actually running) gate-model quantum algorithms. It abstracts away some of the details, but still allows a study of quantum algorithms at a low level. Pennylane https://pennylane.ai/ is a simular package from Xanadu, a different company but also seems to have good tutorials. QAOA is a good optimisation algorthm to look at starting out or you can start with an even more basic example of Grover search. Alternatively, starting on the D-Wave page could be good

https://www.dwavesys.com/learn/quantum-computing/, and particularly starting with their simulated annealing package, "neal" (referenced previosly) which is classical but makes you formulate problems the same way you would for quantum annealing could be a good start. It is worth noting that these are both companies which sell products, so not unbiased sources, but they are still useful resources as long as you keep that in mind.

I really want to know how quantum works on a detailed level

In this case, it is probably worth looking at examples which code up simple quantum simulations directly from a vector and matrix formulation. The two options here would be to write your own simulation of quantum annealing as detailed in these notes http://nicholas-chancellor.me/QOpt_project_final.pdf (I will have to help with the notiation, but I am happy to do it, in future years I may write up an explainer). You could also start with a quantum walk, how to code one up in Python is explained in this blog post by one of my colleagues http://susan-stepney.blogspot.com/2014/02/mathjax.html. This option seems intimidating, but actually isn't so bad once you get past some of the initial understanding.

I'm not sure

In this case, I recommend looking at some of the matrerial for each of the previous answers as well as the background material. The course of your project can be adjusted to an extent, depending on initial results.

3 Recommendations

I've already given some recommendations, in terms of what kind of problems tend to work well here, but here are a few more.

Don't be afraid to ask questions

My job as a supervisor is to help you work through these projects, I am happy to answer questions both in email and in meetings.

Don't rely on me for deadlines reminders

My job as supervisor is to help you with the technical content of your project, not to make sure you meet the deadlines. I will still try to remind you when I can, but I don't make any promises here, especially since I supervise several types of projects with different deadlines and requirements.

Discussions and proofreading with your peers

While this is not a group project and you are expected to submit your own work as well as your own distinct project, I strongly encourage you to help each other. I will be sure to email all of my students on the same email at some point early in the projects so you can have the contacts for the other students (and there is a good chance I might be supervising someone you already know). When it makes sense I might meet with multiple students at once as well. Discussing the concepts can be very helpful to your understanding, and sometimes outside eyes on your code can be very useful, you can even compare results for some simple problems as a way to check you have both done it correctly. Agreeing to proofread each others reports can also be useful, and can test how understandable they are to someone who has not done your exact project. Some forms of working together are not allowed (and would be considered plagerism), for example you cannot use code one of your peers wrote in your project. Avoid those!

Start Working in Python

For better or worse, most quantum packages and code examples I know of are in Python, and it is a language I know well. Even if you don't know Python, I think it will be easier to figure out how to use Python than port examples to other languages. Most other languages will technically have most of the features you need, but won't have the existing examples and quantum-specific packages. Python also has jupyter notebooks which can be a very useful environment to rapidly test and develop code. Python also has amasing plotting capabilities through the matplotlib package. While I **strongly recommend** Python, I won't force you to use it if you really want to use a different language.

4 Extending Your Project

Once you have a general feeling of what you are doing, there are broadly speaking two simple ways to extend your project (there will be others as well of course, and doing both is fine).

4.1 More Interesting Problems

It is usually best to start with a simple toy problem, one thing you can do is to continue to use a simple algorithm but examine more intersting problems.

4.2 More Advanced Algorithms

Another way to extend is to continue to solve simple problems but play around with more advanced techniques.

5 Additional resources

Textbooks

A very standard textbook for quantum computing is the one by Nielson and Chuang, the full pdf can be found online here and print copies are available from the library. The disadvantage of this book is that it was written a long time ago (by quantum computing standards) so does not cover many modern algorithms.

Wikipedia

While Wikipedia is not a scholarly source it is a good way to find scholarly sources through the references (of course check that the paper actually says what Wikipedia claims). This is especially true for finding early papers on a topic and review papers. It also tends to be decently accurate for advanced math/CS so can be helpful for getting started.

You Tube

Again not a scholarly source, and this can definitely be a "mixed bag", there is some very good material and some very bad material for learning the background. Sorting which is which can be tricky, but one thing to do is to look for sources affiliated with well respected universities. You can also check if the content agrees with more scholarly content, if it doesn't than beware!

Arχiv

Arχiv is a repository of pre-prints, most recent quantum computing papers will be there, note that arχiv does have very basic quality checks but is not peer reviewed on it's own (although many papers are also published in peer-reviewed journals). Searching arχiv directly is usually not very useful (unless you look at the arχiv page for an individual researcher, for example my page), but web browser searchs will often turn up arχiv papers. A pro-tip for both arχiv and published papers is to use the citations in one paper to find another.

Google Scholar

Google scholar is useful in two ways it can be used to search only sources which Google considers scholarly, but can also be used to find the papers which cite a given paper, so can be a good way to find related work.

Review Papers

This paper reviews industrial applications of quantum annealing and is generally fairly accessible (although it has a hardware focus) . This paper gives a good review of how to formulate problems in the quadratic way which is commonly used in quantum devices. This paper reviews variational quantum algorithms, a common class of near-term quantum algorithms. This paper reviews continous-time quantum computing in an equation-free way, aimed at quantum non-experts.

Other Papers

Although it is not a quantum paper, this paper contains good discusion and references for advanced versions of classical Monte Carlo (parallel temporing and population annealing).