Applying to Ph.D. Programs in Computer Science

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1 Introduction

This document is intended for people applying to Ph.D. programs in computer science or related areas. The document is informal in nature, and is meant to express only the opinions of the author. The author is currently an assistant professor of computer science at CMU, and has been involved in the Ph.D. admissions process at CMU, U.C. Berkeley, and MIT.

Please direct any further questions you have after reading this document to the admissions coordinator Martha Clarke (mwc@cs.cmu.edu). Do not send email to the author of this document.

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2.1 What is a Ph.D.?

A Ph.D. is a long, in depth research exploration of one topic. By *long* we're typically talking about 6 years. By *in depth* we mean that at the end of the Ph.D. you will be the world expert or close to it in your particular area. You will know more than your advisor about your particular research area. You will know about your research than anyone at your school. By *one* we mean that by the last couple years of your Ph.D., you will typically be working on only one narrow problem. The Ph.D. is not about breadth, it is about depth.

2.2 Lack of emphasis on courses

The M.S. and B.A. degrees are about *breadth* not depth. The main requirement in the M.S. and B.A. degrees is often a large numbers of courses. A B.A. or B.S. in CS often entails taking 3 or 4 classes a semester in CS or Math or Engineering. An M.S. is similar.

In contrast, a Ph.D. program typically requires typically less than 10 courses during the entire 6 years (at CMU there are 5 required "core" courses, and 3 required "electives"). The emphasis in the Ph.D. is not on classes, but rather on research. A Ph.D. student will typically take classes only when she feels that they will be useful in her research. The classes she takes may not even be in CS at all. They may be in Statistics, Operations Research, Psychology, Linguistics, or anything else useful for her particular research topic.

2.3 The research process and advisor/advisee relationships

As stated earlier, the main focus of a Ph.D. is on research. You typically begin your research at the time when you select an advisor. At most schools you pick an advisor sometime after your first year. At CMU, we like you to start research right away, so you pick an advisor within a month or two of starting the program.

Research is very different from taking classes. Many students never make the transition between taking classes and doing research – in fact, at most schools only 1/2 of the students who enter the Ph.D. program leave with a Ph.D. (at CMU, about 3/4 end up with a Ph.D.). Keep in mind that we're typically talking about students who came in with 4.0 GPA's from their undergraduate program.

Some key differences between classes and research:

- In classes, the homework problems all have known answers and the techniques needed for solving the problems have (usually) been introduced in class. In research, you may be working on a problem for years without a clue of whether it is solvable. You will be the one inventing or finding the techniques for solving the problem.
- In classes, you are assigned certain problems to work on. In research, you get to pick the problems. In fact it is your job to find good problems. By "good" we mean problems which are "fundamental." For example, finding a system hack which makes a particular product like Cisco's Local Director run better is something that Cisco would love, but would not count as fundamental research. However discovering better algorithms for the problem of task assignment of jobs to hosts in a server farm is considered fundamental research. You are also responsible for making sure that no one else has already solved this problem. This typically involves reading hundreds of papers on earlier research in this area.
- In classes, if you can't solve your homework problem, you can always ask other classmates. Even if none of your classmates know, you can ask the professor, who certainly knows the answer. In research, you are often working *alone*, or at best with you advisor and maybe one other student. You are free to ask anyone in the world for help, but they will typically not be able to help you, since they don't know the answer either – if they did, it wouldn't be research. Many students have a hard time with working independently.

- In classes, you are constantly being given grades and you are constantly being told what to do next. In research, there are no grades. There is some instruction (from your advisor), but mostly it's up to you to be self-motivated and pro-active.

- In the classroom, there is a distance between you and your professor. In research, you and your advisor will work side-by-side. Your advisor will still tell you what to do – give you ideas for problems to work on, assign papers for you to read, give you programming assignments, and often give you a time-line and schedule. However, when you and your advisor are working on a problem together, you will work as equals. You will both learn from each other. You will make discoveries together. Many students are surprised to find that their advisor is very different in research than in the classroom. A professor who is very dry in the classroom and often looks bored and uncomfortable will often become extremely enthusiastic and excited when working on research problems. In the classroom, you hear your professor discuss results which he/she has already worked out. All problems are always solved by the end of lecture. In research, you will watch your advisor think out loud and see how he/she thinks and reasons. Students often find this very exciting. You may find that you think more quickly than your advisor, but your advisor has more ideas than you. Or you may find that you are better at computations or coding, but your advisor is better at proofs or writing or speaking. This surprises many students, who expect their advisor to be better than they are at everything. Don't pout, this is an unrealistic expectation. As in all of life, you will be most successful if you simply figure out what skills your advisor has that you don't and work hard at picking up all of those skills without complaining.

- When taking classes, you will almost never see your professor alone. When doing research with an advisor, you will typically have 1 hour per week when you meet with your advisor alone. If your advisor is especially busy (remember, professors have to do research, teach, apply for grants, serve on committees, fly around giving talks, etc.) you may only get 1/2 hour a week. If your advisor is a newer faculty, you may get as much as 2 hours per week. It's your job to plan ahead so as to maximize the utility of your time together.

Keep in mind that no one can give you a complete picture of what research is. The best way to learn what research is, and whether you like it, is simply to start doing it. The earlier the better!

2.4 Frustrations and joys of research

Research can be very rewarding and very frustrating. Most students describe graduate school as a roller-coaster with tremendous highs and tremendous lows.

Frustrations can come from not being able to solve a problem that you're working on, or from having someone else beat you to the solution. Frustrations can come from loneliness. However, probably the biggest frustration is the realization that you're not as great as you thought you were. Here's a very typical story:

> Student X comes from famous school Y in country Z, where he was ranked 5th out of

> over hundreds of thousands of students. He was also ranked #1 in his class for the year in terms of GPA. The student comes to graduate school expecting to be the best and starts working very hard on research. By the end of his first or second year, the student realizes that he has not yet published any papers. His friends and family from home start asking what's wrong with him. He feels frustrated and ashamed. He blames his advisor, he blames his department, he blames his school. Finally, he grows up and accepts the fact that maybe he's not the best, but he can still do well if he works hard. He starts listening better, works harder, and ends up quite successful.

For all the frustrations, research can be extremely joyous. For some people, the joy of research is the *joy of discovering something new* that no one knew about. You might be discovering a new algorithm, a new operating system design idea, a new idea for maximizing the performance of disk arrays, etc.. For others, there's the *joy of truly understanding*. You've probably noticed that in classes a professor or book will stop just when things are getting really interesting and say, "the rest is beyond the scope of this class." In research, you can take a problem as far as you want and understand everything about it. For many, the joy of research comes from being able to *make an impact* – to change the way systems are built and design them in a smarter way. There's also the *joy of doing it right*. In a company, the aim is to get a working product and ship it out quickly. In research, you can take your time and plan out your project so that you are proud to defend every one of your design decisions. Research is not about simple heuristics or quick hacks. Many people also relish the *joy of being the authority on an area* and of having their work *cited by others*.

2.5 Funding during the Ph.D.

Unlike the B.A., where you or your parents pay many tens of thousands of dollars, or the M.S., where you typically work as a teaching assistant and possibly continue to pay many tens of thousands of dollars, the Ph.D. is a time where funding is not a concern to you. At most schools, you will not pay tuition during the time that you are getting a Ph.D.. Typically, you will also receive a living stipend – on the order of $1700 per month, from which you will pay your living expenses. Ideally, your only responsibility will be research. This is called doing an **RAship** (Research Assistantship).

The Ph.D. is a *tremendous opportunity*. You get to pick an advisor in any research area you like and then you get to do research in that area, receive mentoring, think deeply on problems, publish papers, become famous, while paying zero tuition for 6 years and receiving a salary. Your advisor is paying for this opportunity by writing grant proposals to companies and to the government to ask for funding. A single graduate student can cost an advisor upwards of 50K per year (given the cost of tuition, the stipend, the overhead tax charged by the school, cost of equipment and physical space, etc.).

Important note 1: At most schools, you can only do an RAship if you have an advisor who has funding for you. Since some advisors don't apply for grants or are in areas which aren't well-funded, you may have to work as a teaching assistant every semester to get your stipend. This is called a **TAship** (Teaching Assistantship). When I was a graduate student, I had a few friends who were forced to TA 13 semesters, to fund their way through school! Alternatively, you will have to restrict your choice of advisors to those who have funding. At CMU, every Ph.D. student is guaranteed a stipend plus tuition regardless of which advisor she chooses to work with.

Important note 2: There are many companies and government organizations which offer **Graduate Fellowships** for Ph.D. students. If you are lucky enough to get one of these, they will cover your full way through graduate school, and you will never have to worry about whether your advisor has funding or not. Details about graduate fellowships will be discussed in Section 4.

2.6 Life after the Ph.D.

When making a decision about the next 6 years of your life, it's good to stop and think about what you might do when you finish. Most students upon completing a Ph.D. either go into academia (research university or teaching school) and become a professor, or they go to a research lab. Some people never do research again after completing a Ph.D.. For such people, the Ph.D. was largely a waste of time.

If you choose to be a professor at a research university, your life will consist of the following tasks: (i) doing research on anything you like, (ii) working with graduate students, (iii) teaching classes, (iv) applying for grants, (v) flying around to work with other researchers and to give talks on your research, (vi) doing service for your department and school (like giving this talk). Note that I say "your life" rather than your job, because for new faculty, your life becomes your job. It's a fantastic job/life for me because I love these activities, so I'm happy to work hard at all of them, but it's not right for everyone.

If you choose to be a professor at a teaching college, your job will consist of the following: (i) teaching lots of classes, (ii) doing service for your department or school, (iii) occasionally advising undergraduates on undergraduate research, or doing a little of your own research.

If you choose to go to a research lab, your job will consist of the following: (i) doing research (half will be on whatever you want, half will be on whatever the company wants you to do), (ii) working with other people in the company, (iii) traveling around a little to give talks and work with others.

2.7 Should I get a Ph.D.?

Here are some things to keep in mind when making this decision:

i. A Ph.D. is not for everyone!

ii. A Ph.D requires 6 years on average. The opportunity cost is high.

iii. Do not even think of applying for a Ph.D. if you have not tried research and/or teaching and found that you like at least one of those. (Note: the Ph.D. program will require mostly *research*, not teaching, but a love of teaching may help motivate you to get through, so that you can go on to be a teacher. I have seen many examples of this.)

iv. A Ph.D. requires a particular type of personality. You need to be someone who is obsessed with figuring out a problem. You need to have tremendous perseverence and be capable of hard work. You need to be willing to do whatever it takes to solve your problem (e.g., take 5 math classes, learn a whole new area like databases, rewrite the whole kernel, etc.).

v. You need to know why you want a Ph.D. You need to have vision and ideas and you need to be able to express yourself.*

vi. Obviously, many people are still unsure straight after a B.A.. I was one of them, so I understand. For such people working in a research lab or in an industrial lab which involves doing research for a few years will help them decide. If you are unsure, I **highly recommend** working for a few years before starting a Ph.D.. Do not apply to graduate school until you are sure you know what you want.

   My own story: After I finished my B.A. in CS and Math, I went to work at the Advanced Machine Intelligence Lab at GTE in Massachusetts. At first I was very excited by my paycheck and the great feeling of being independent. I also really enjoyed my area of research at the time: pattern recognition and classification. I was working with frame-of-reference transformations involving eigenvectors of autocorrelation matrices. It was exciting! However I quickly realized that I wanted to know more. I wanted to know *why* some algorithms produced good results and others didn't. I wanted to come up with my *own* algorithms. I worried that I didn't have enough of a mathematics background to answer my own questions. In summary, I wanted to delve *deeper*. Everyone around me thought I was odd for wanting these things. I left after 2 years and went to graduate school. That first month of graduate school I looked around and realized that everyone there was just as weird and obsessed as I was, and I knew I had made the right decision.

3 The Application Process

The Ph.D. application has several parts:

i. Transcript – Grades and classes

ii. GRE scores

iii. Personal Statement

iv. Previous research experience (possibly in industry).

v. Recommendation letters

vi. Awards and extracurricular activities

*In case you didn't notice, the words "you need to be smart" are purposely absent from the above list. Anyone accepted is more than smart enough. The rest is up to your own determination.

I will elaborate on each of these below in detail. People often ask me which of these is *most important*. The answer is: it depends. For the top Ph.D. programs in CS, the only thing that's really important is your prior research experience and what your recommendation letters and personal statement have to say about your prior research experience. At these schools every application is carefully scrutinized by at least 3 faculty, all of whom are trying to gauge your research potential. At lesser-ranked schools, there may be a simple formula which looks at GRE scores and GPA and undergraduate school and based on that classifies applications into piles of "highly-desirable", "less-desirable", etc.. Everyone in the highly-desirable pile is then admitted.

Since my view is that of the top-ranked CS programs, my description below will follow the perspective of those schools. By a top-ranked program, I'm typically talking about a Ph.D. program ranked in the top 10 or so.

3.1 Transcript – grades and classes

When applying to a Ph.D. program in CS, you'd like your grades in CS and Math and Engineering classes to be at least 3.3 out of 4.0, as a rough guideline. These are not meant to be absolute numbers. At CMU the mean GPA of students admitted is over 3.8 (even though we don't use grades as a criterion), however students have also been admitted with GPAs below 3.0, since research is what matters, not grades. *A GPA of 4.0 alone with no research experience will not get you into any top CS program.* Keep in mind that GPAs are evaluated in the context of the undergraduate program. A 3.4 GPA from a top-ranked CS undergraduate program like CMU counts the same as a 3.8 or 3.9 GPA from a less well-known CS undergraduate program.

Some questions I hear frequently are "will taking extra classes make me look good" and "will it make me look good to take advanced graduate classes?" The answer to both questions is "only if these extra courses lead you to work on an interesting research problem." Taking arbitrary extra classes usually does not lead to doing more research. However, taking one or two carefully selected graduate classes, and cutting back on other classes that semester, will often lead you to find interesting research problems to work on.

Note: Your grades may be somewhat low – under 3.0 – because you were having a good time in college and you may therefore be having trouble getting into a Ph.D. program. In this case, you may want to do an MS and use the time to boost your grades and reapply after the MS.

3.2 GRE scores

The GRE exam has 2 parts, which you can take on the same day or different days.

i. The general GRE exam – This is very much like the SAT test you took to get into undergraduate school, except that it has Math, English, and an Analytic Writing portion.

ii. The subject exam – If applying to a CS Ph.D. program, you should probably take your subject exam in CS, Math, or Engineering. Check with the school you're applying to.

Each exam is 3 hours long. You **can** study for these exams. I did. Most bookstores have study guides with old exams. Study guides are also on the Web.

The GRE verbal (English) portion is very similar to the SAT. However, just because you got an 800 on your Verbal SAT does not mean that you will repeat this performance. If you've been in a CS program for 4 years, your vocabulary and reading speed are not what they were 4 years ago. Also, you'll be competing with people who majored in English for 4 years.

The Analytic Writing portion is different from the SAT. You will be asked to write two essays. In the first you will be given an argument and asked to analyze it. In the second you will be asked to give your perspective on some topic. There are examples given on the GRE web page.

The Math portion is very similar to the SAT math test. It doesn't go beyond the 10th grade level.

The GRE exam is offered every 2 months. Check out this web site:

`www.gre.org`

for everything you ever wanted to know about the GREs, including test dates, test center locations, and lots of information on how to study.

Once again: Your score on the GRE will be largely ignored by the top schools. At CMU we look at the Verbal GRE score only when the applicant is not a native speaker of English. We look at the Subject test score only when we have an application from a school whose CS department we're not familiar with.

At lesser-ranked schools, however, your GRE score can be the difference between your getting in or not.

Note: If you are planning to work for a few years between completing your undergraduate degree and applying to graduate school, I highly recommend taking the GRE exam before leaving your undergraduate school. The material is fresh in your mind while you are an undergraduate, and more importantly, your test-taking skills will diminish while you're working.

3.3 Personal statement

It's misleading that the personal statement is called a "personal" statement, since what admission committees are really looking for is a **research statement**. What admission committees want is a statement about what research you have done, what research you hope to do, and why you like research.

Here's a template if you need one:

i. First paragraph – Describe the general areas of research that interest you and why. (This is helpful for a committee to determine which professors should read your application.)

ii. Second paragraph and Third paragraph – Descibe some research projects that you worked on. Tell us what you found, what you learned, what approaches you tried. It's fine to say that you were unable to prove what you wanted or to solve your problem.

iii. Fourth paragraph – Tell us why you feel you need a Ph.D.. Look back to section 2 and explain what in there appealed to you.

iv. Fifth paragraph – Tell us why you want to come to CMU. Whom might you like to work with? What papers have you looked at from CMU that you enjoyed reading? What will CMU teach you?

It's important to realize that the research statement is *not* a commitment to do research in that area. A third of all applicants end up working in an area different from that which they described on their research statement.

Here are the common mistakes that half of our applicants make:

- **The grade regurgitator –** "In my high school, I was ranked Number 1. Then I got a perfect score on my college entrance exams. Then I competed in a statewide math competition and I was the best. Then I competed in a national programming competition and I was 5th. In college, my GPA was 3.95 out of 4.0. For these reasons, I believe I will do well in your graduate department."

  What's wrong with this? This portion of the essay is a waste of space. Awards are certainly relevant, however any award you won should be listed on a separate piece of paper which is titled "Awards and Honors" and which you can include with your application. There is no reason to tell us all this in your essay. It will only piss-off the people reviewing your application because they already read all this information earlier in your application and they now want to hear about research only.

- **The boy genius –** "When I was born, my mother gave me a glass ball to play with. I would lay and look at the prisms of light shining through my ball. At age 3, my father brought home our first computer and I disassembled it and then put it back together. It was then that I knew I wanted to become a computer scientist. By age 5, I had taken apart every appliance in our house. At age 6, I became a chess whiz ...."

  What's wrong with this? We simply don't care what you did as a child, and we don't believe you either. You'd be surprised how many applications from Einstein-wanna-be's we get. If you really think this is relevant, put the important facts on a separate sheet of paper, and include it in your application. It's best if your essay can stick with stuff you did in college and later.

3.4 Previous Research Experience

As I've said earlier, to get into a top graduate school you need prior research experience. This is not necessarily true for schools below the top 10, or maybe even the top 5. Note that prior research experience does not mean that you need to have published a paper. It does not even mean that your research needs to have yielded a result – results can sometimes take years. We just need to have confidence that you know what doing research is like. At CMU we receive hundreds of applications each year from 4.0 GPA students who have never done research. These are all put into the high risk pile and are subsequently rejected.

So the question is, where can you get this research experience?

There are five places where you might get research experience:

i. As an undergraduate, you can do research with a professor. I did this. You can even get course credit for this, and sometimes if you're really lucky you can get paid a little (e.g., during the summer).

ii. As an undergraduate, you can apply for a summer internship at a research lab, e.g., AT&T. I did this. They will pay you a little and you will learn a lot about doing research. This was a great experience for me! Here's the web site for the AT&T summer program that I attended:

    `http://www.research.att.com/academic/`

    When you go to this web site, click on "Special Programs and Fellowships."

iii. After graduating, you can get a job, where sometimes you can do research on the job. I did this.

iv. As an MS student, you will work on an MS project.

v. You can work alone or with a friend. Ask professors in your classes to tell you about interesting open problems and new research (most professors enjoy doing this). Ask them to tell you names of conference proceedings. For example in my area (performance modeling of computer systems) a relevant conference proceeding is Sigmetrics. Sit down and start reading these proceedings. You will come across all sorts of interesting problems. Think about how you can improve upon the solution proposed in the paper.

Since most of you reading this are probably undergraduates in your Junior year, I will spend most of my time talking about option 1 above. Unfortunately, convincing a professor to take you on for a research project is sometimes easier said than done. I have therefore put together the following guide:

How to ask a professor to do research with him:

i. Make a list of professors with whom you might want to work. Most professors have a web page with lots of papers and descriptions of their research. Take your time and read these.

ii. Make a **summary sheet** about yourself. This is a one-page piece of paper which you will be giving out. It should have the following information about you:

(a) Your photo. Professors can't remember names, but they do remember faces.
(b) Your name and contact info.
(c) Brief description of your research interests.
(d) Your availability – are you looking for a full-time summer position, a part-time fall position, both? How many hours can you devote to this project? Are you looking for class credit?
(e) List of every class you took and your grade and the professor you took it with (professors like to talk to each other about you).
(f) Relevant previous experience and skills.

iii. Talk with your undergraduate advisor – at CMU this is Mark Stehlik – about whether anyone has an open position for undergraduate research. Mark maintains many such lists.

iv. Pick a professor from your list. Go to his/her office hours or send email to schedule an appointment (most professors prefer office hours). Explain your situation and give your summary sheet. Be prepared for the following questions which he may ask you:

(a) Do you have any ideas about what you might want to do research on?
(b) Which of my projects are you most interested in working on?
(c) Describe your math background.
(d) Describe your programming background.

With very high probability the professor will thank you for your interest, but tell you that he isn't taking on any undergraduates this term. This does not mean that he hates you! Be brave! Try the next person on your list. You may have to try this 10 times. Hang in there. If the professor does say yes, you need to be prepared with your own list of questions:

(a) What is the goal of the project?
(b) What exactly will be my responsibilities?
(c) Whom will I work with? – e.g., will you work directly with the professor, with one of his graduate students, with another undergraduate?
(d) What background material can I read to learn more about this project?
(e) What textbooks can I study to learn more about this research area?

Warning for international applicants: The admissions committee needs to be able to evaluate your research. If your publications appear in conferences/journals which we are not familiar with and have no access to, then we cannot evaluate the quality of your work. In my experience, this usually leads us to discount such publications. If you don't want this to happen, here are two things you should do:

i. Publish in internationally recognized conferences – ask your advisor.

ii. Create a web site that has links to all of your papers in English in either postscript or pdf. Explain in your application that all of your papers can be found on your web site.

3.5 Recommendations

Perhaps the most important part of your application is the letters of recommendation. You will need 3 letters of recommendation for the Ph.D. program, and typically 4 letters of recommendation for a fellowship.

3.5.1 Whom to ask for a letter

Ideally you would like to make all your letters of recommendation count. Consider the following two letters:

i. Letter 1: "I highly recommend student X for your graduate program. Student X received an A+ in my undergraduate algorithms class. He was ranked Number 2 out of 100 students. He got the highest score on the final. He worked very hard all semester, never missed a class, and was always able to answer the questions that I asked in class. This conscientious attitude makes him an excellent candidate for any graduate program. "

ii. Letter 2: "I highly recommend student Y for your graduate program. Student Y received a B in my undergraduate algorithms class. He was ranked Number 29 out of 100 students. Halfway through the semester we started working on network flows. Student Y seemed extremely excited by this topic. He disappeared for 4 weeks and even missed an exam. However when he came back, he showed me some work he had been doing on a new network flow algorithm for high-degree graphs. He had done some simulations and had some proofs. I've been working with student Y for the past couple months since then and he is full of ideas for new algorithms. I think student Y's initiative makes him an excellent candidate for any graduate program."

Which letter do you think is stronger? It turns out that Letter 2 is very strong. Letter 1 actually counts as 0. At CMU we mark all letters like letter 1 with the acronym **D.W.I.C.**. This stands for "Did Well In Class" which counts for 0, since we already know from the student's transcript that he did well in class. By contrast, student Y's letter gives us a lot of information. It explains that the reason student Y didn't do better in class was that he was busy doing research. It also tells us that student Y started doing research on his own initiative, and that he is quite good at doing research. The professor was impressed enough with student Y's ideas that he took him on as a student researcher despite student Y not having high grades.

You want your letters to all be of type 2 (this doesn't mean that you should skip class!). Remember that letters of type 1 will not count. You want words like *self-motivated*, *strong research potential* , *own initiative*, *independent*, and *driven* to appear in your letters. These are the words that we circle when reading recommendation letters. You therefore want to ask letters from people who have seen you do research. These may be professors or employers.

One caveat: It makes some difference whom you ask for a letter. As a general rule (there are always exceptions due to people's fame), letters from professors count the most. Next highest are letters from research scientists. After that come letters from lecturers, systems scientists, employers, or postdocs. Please do not get a letter from a graduate student. If you found yourself doing research where you were supervised by a graduate student or postdoc, you should ask the professor for whom they work if she can co-write the letter. The reason is simple: professors are the ones reading the letter, and they are most likely to know other professors.

There is an issue for students who have been working for a while. You will certainly want a letter from your employer, but you will also want two letters from professors. This was an issue for me when I applied to graduate school. What I did was to keep touch with a few professors during my time at work. When I was ready to apply to graduate school, I contacted the professors who knew me well and scheduled a meeting with them to discuss the research that I had done while I worked. I gave them each an oral presentation. I also gave them each writeups of each of my projects.

3.5.2 How to ask for a letter

Asking for a letter of recommendation won't be a problem if you have been doing research with this person, but that won't be possible in every case. Here's a guideline which will maximize the contents of your letter. This works on the theory that professors have very little time and little memory (both of which are good assumptions):

i. Prepare a packet for each recommender. This packet should contain all the relevant information about you that could help the recommender. Be careful not to make the packet too large. Here's what should be in it:

   (a) Your statement of purpose.
   (b) A summary of every research project you worked on and with whom, regardless of whether this was at a school or research lab. If you have published a paper, or have a technical report, please include that too.
   (c) A sheet of paper listing all math/cs/engineering/science classes you have taken with the names of professors and grades.
   (d) A list of extracurricular activities and awards/competitions.

   At the top of the packet should be:

   (a) A recent photo of you – professors receive many such packets and don't remember you the second after you leave the office.
   (b) Directions. E.g., please seal and sign and send to this address by Jan. 5. Put an earlier date than the real deadline – professors are notoriously late.
   (c) Confirmation information: Please send me email at blank address after you send this off. If I don't hear from you by Jan. 5th, I will send you an email reminder. (You need this confirmation information because otherwise you'll never know if the recommendation was sent and you'll be sitting around biting your nails wondering.)

ii. Go to your potential recommender with your packet and ask him/her the following question: "Do you feel comfortable writing a strong letter of recommendation for me to graduate school?" You need to phrase the question this way so that the potential recommender has a way out. Do not be upset if the potential recommender says no. It is good that he/she let you know. This is much better than getting a weak letter.

iii. Check with the school to confirm that they have received a letter from each of your recommenders.

iv. Remember to at least send your recommender a thank you card! It's a lot of work to write a decent recommendation letter.

3.6 Awards and Extracurriculars

Often applications do not have sufficient space for listing awards you may have received, or extracurricular activities which you participate in. Think about anything relevant and include it on a separate sheet of paper, which you attach to your application. A particularly relevant extracurricular activity which many people do, but don't think to note is tutoring or previous TA experience. A long history of tutoring suggests that you are a good teacher, which is highly correlated with being a good researcher as well.

3.7 How many schools should you apply to?

There is no rule about how many applications you should send out. People generally apply to 3 schools at their level, 2 schools above their level (you may get lucky), and 1 or 2 schools below their level (you need a safety school). If you are unsure about what your level is, find a student with a similar application to yours and consider where he was accepted/rejected. You can also ask your recommenders to evaluate your application and tell you your approximate level. In choosing a school, you may also want to consider schools which are very strong in your particular area of interest, but possibly not as strong overall. Read Section 5 on how to choose a school.

4 Fellowship Information

4.1 Why you need to apply

Even **before** you decide which schools you want to apply to, you should pick out which outside fellowships you are eligible for and apply to all of these. I myself applied to 5 outside fellowships. Many outside fellowships require a U.S. citizenship, so not everyone is eligible. There are at least 4 reasons to apply for a fellowship:

i. If you are awarded the fellowship, it is an honor that will forever appear on your cv.

ii. An outside fellowship typically pays for several years of graduate school. This leaves you free to pick any advisor you want to work with and never have to worry about whether this person has funding or not.

iii. An outside fellowship makes you an attractive target for any school and for any advisor. When I received a 6-year fellowship, I immediately sent every school I had applied to a postcard notifying them. Within a week they all accepted me – Why not? I came free of charge.

iv. You're a fool not to apply for at least a couple fellowships. If you're good enough to get into a top school, then you're good enough to get a fellowship.

Warning: The deadlines for fellowships are usually a month or two earlier than the deadlines for graduate school.

4.2 List of fellowships

Below is a list of the fellowships that I am personally familiar with. Please check the web for other fellowships:

NSF Graduate Research Fellowship – This is the fellowship that everyone applies for. It pays for 3 years of your tuition and stipend. It is only available to permanent residents or US citizens. All information is available here:

`http://www.orau.org/nsf/nsffel.htm`

NDSEG Graduate Fellowship – This fellowship pays for 3 years of your tuition and stipend. It is only available to U.S. citizens. All information is available here:

`http://www.asee.org/ndseg/`

Hertz Fellowship – This fellowship pays for 5 years of your tuition and stipend. It is only available to US citizens and permanent residents. The fellowship has a pretty tough interview process. When I applied they asked me to write the Taylor Series expansion for some functions. All information is available here:

`http://www.hertzfoundation.org/app.html`

AT&T Labs Graduate Fellowship – This fellowship pays for 6 years of your tuition and stipend. It is only available to permanent residents or US citizens who are women or minorities. All information is available here:

`http://www.research.att.com/academic/`

When you go to this web site, click on "Special Programs and Fellowships."

National Physical Science Consortium (NPSC) – This fellowship pays for 6 years of stipend. It was originally designed for women and minorities, but they often consider white males to be minorities. All information is available here:

`http://www.npsc.org/`

The above fellowships are all general fellowships that don't put any restriction on your studies. There are also specialty fellowships like **DOE Computational Science Fellowship** or the **DOE High-Performance Computer Science Fellowship** for students whose research emphasis is high-performance computing.

5 Choosing the right Ph.D. program for you

By March, you will hear from all the Ph.D. programs to which you applied. If you haven't heard, you should send email to the person in charge of admissions. You will need to make a decision by April 15, which doesn't give you much time. During the next month and a half, most schools will have an **Open House**, during which they invite accepted prospective Ph.D. students to visit the school and meet with faculty and other students. **Do not skip these visits.** They are a highly valuable source of information. Remember that you are choosing a place where you will spend the next 6 years, and choosing faculty with whom you will work for the next 6 years.

Below are just a few things to consider in the schools that you visit. You will need to decide for yourself which things are most important to you.

i. Count the faculty in your chosen area of research. Now subtract all the ones who are not actually present (their name appears on the web page, but they're actually on leave). The number left are the resources you will have to help you with your thesis research. Since half of all people end up changing their research area, it's a good idea to repeat this count for at least two more areas that you might be interested in going into.

ii. Count the number of faculty whose research you feel really excited about. Now subtract off the number who are not taking on students. What's left is the number of faculty whom you might be choosing from when you look for an advisor.

iii. Try to assess the atmosphere within the department. Is the atmosphere competitive or collaborative? Do people tend to mix areas (e.g., research combines systems and theory) or stick to one area. A lot of hints can be gleaned by looking at the seating arrangements: Are areas separated by floor, or mixed up? Are the students within an office all working in the same area, or are students mixed up? Are the faculty offices separated in floors from the student offices, or are faculty offices side-by-side with student offices.

iv. How are graduate students treated within your area? Perhaps the most important question here is: How freqently do the grad students in your area meet with their advisors? Talk with students of professors with whom you are considering working with. What do they work on? Are they excited by their research? Is their advisor helpful? Do they like the other students? Graduate students will reveal all!

v. How are graduate students treated by the department overall? What is the equipment and office space given to students? Does the department have a method for reviewing grad students and sending them progress reports every semester (this is very important to get you through your Ph.D.). What is the fraction of students who come in wanting a Ph.D. and actually leave with a Ph.D., (not an M.S.)?

vi. How does funding work within the department? Are you restricted to choosing an advisor who has funding? What happens if that advisor loses her funding? Will you have to then become a teaching assistant?

vii. What are the hurdles associated with completing the Ph.D. degree? What are the course requirements? What exams will you have to pass? What are the teaching requirements?

viii. Pay some attention to what is outside the department. For example the Department of Computer Science at CMU (which consists of about 66 faculty) is contained within the School of Computer Science (which consists of over 200 faculty). The School of Computer Science is made up of about 6 individual departments including the Computer Science department, the Robotics Institute, the Language Technology Institute, the Human Computer Interaction Institute, etc.

ix. Consider the overall ranking of department. This is important only because it determines the average quality of your peers (the other graduate students). Your peers are the people who will teach you the most in graduate school.

x. Lastly, keep in mind the cost of living. At almost every graduate school, you can expect a stipend of around $1700 per month. In some cities, you will live like a king off of this. In others you will be live like a churchmouse. This may not bother you at first, but it can grow old after 6 years.

6 Current 2002 Rankings of CS Ph.D. programs in the U.S.

I'm including the 2002 Rankings from the U.S. News & World Report for the **top 40 CS PhD programs**: (Ranking score is out of 5)

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1.  Carnegie Mellon University (PA) 4.9
    Massachusetts Institute of Technology 4.9
    Stanford University (CA) 4.9
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    University of California-Berkeley 4.9
5.  University of Illinois-Urbana-Champaign 4.6
6.  Cornell University (NY) 4.5
7.  University of Texas-Austin 4.4
    University of Washington 4.4
9.  Princeton University (NJ) 4.3
10. California Institute of Technology 4.1
    University of Wisconsin-Madison  4.1
12. Georgia Institute of Technology 4.0
    University of Maryland-College Park 4.0
14. Brown University (RI) 3.9
    University of California-Los Angeles 3.9
    University of Michigan-Ann Arbor 3.9
17. Rice University (TX) 3.8
    University of North Carolina-Chapel Hill 3.8
    University of Pennsylvania 3.8
20. Columbia University (NY) 3.7
    Duke University (NC) 3.7
    Harvard University (MA) 3.7
    Purdue University-West Lafayette (IN) 3.7
    University of California-San Diego 3.7
25. University of Massachusetts-Amherst 3.6
    Yale University (CT) 3.6
27. University of Southern California 3.5
    University of Virginia 3.5
29. Johns Hopkins University (MD) 3.3
    New York University 3.3
    Rutgers State University-New Brunswick (NJ) 3.3
    SUNY-Stony Brook 3.3
    University of California-Irvine 3.3
    University of Utah 3.3
35. Ohio State University 3.2
    Penn State University-University Park 3.2
    University of Arizona 3.2
    University of Chicago 3.2
    University of Colorado-Boulder 3.2
    University of Minnesota-Twin Cities 3.2
    Washington University in St. Louis 3.2
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Take this ranking with a grain of salt. Ranking is based on people's opinions. Even very low ranked schools have some truly great professors and some very famous professors. Also remember that a famous professor does not imply a great advisor.