Revised CS Qualifying Examination

29 January 2010

This document represents a proposal approved by the CS faculty.

Executive Summary

At the faculty meeting on 10/5/09, a general concept was approved for a new PhD qualifying process based on coursework to satisfy breadth requirements and a research project and associated oral exam to evaluate research capabilities. An ad hoc committee was charged with resolving the details of this new system, and this document describes the resulting proposal that is being put before the faculty for approval. The main points of this new system are summarized first, followed by a full description. These requirements will apply to *all* Ph.D. students beginning with class entering in fall 2009. Other students will be able to choose, in consultation with their advisor, which system to follow.

Areas:

- Computer Systems (Architecture, OS, Networks)
- Software Systems (PL, Compilers, Software Engineering)
- Application Systems (Graphics, DB, AI, etc.)
- Theory (Theory, Algorithms, Security)

Breadth requirements:

- Complete 6 courses
- At least one from each of four main areas
- At most one undergraduate course in each area (from approved list)
- No universally required courses (eg. 6354)
- Plan of study approved by quals supervisory committee.
- Minimum cumulative GPA: 3.6 (strict majority of A's)
- Minimum grade: B (not B minus, but B or better)
- Must be completed by end of 4th semester for students entering with a BS, by end of the 3rd semester for MS
- Students entering the program with a prior masters must meet the same breadth requirements through a combination of their prior coursework and any UVA courses that their committee deems necessary.

Depth requirements:

- Committee size: 3 CS faculty plus advisor; 2 from primary area, 1 from secondary area

- Depth exam requirements: proposal, reading list, final paper, defense; research should be primarily individual work and project should be commensurate with a 3-credit course.
- Depth exam outcomes: fail, pass, fail and try again (with at most two total attempts)
- MCS students will register for CS 895/7995, MS students will fulfill this requirement using CS 898/8999

Timeline:

- Form committee by end of 1st month of 2nd semester
- Proposal deadline: end of second semester
- Final report deadline: 2 weeks before defense
- Deadline for first defense: end of 3rd semester
- Deadline for second try: one month after first
- Complete coursework by end of 4th semester

Transition plan:

- All students entering UVA in fall 2009 or later will use this new system. This means they must appoint their committees by the end of Feb. 2010 and defend by the end of the fall term in Dec. 2010.
- Other students, in consultation with their advisor, may select which system to follow but must decide by 1/1/2010. These students will follow the same timeline as current first-year students. They must also appoint committees by the end of Feb. 2010 and defend by the end of the fall term in Dec. 2010.

Qualifying Examination Revision Committee (as of Spring 2010):

- Jack Davidson, Chair
- Jason Lawrence
- Kevin Skadron
- Westley Weimer (current document maintainer)
- William Wulf

Preamble

At the faculty retreat on 13 February 2009, an ad hoc committee was charged with developing a new qualifying exam process that would evaluate students' abilities to pursue Ph.D. research. In subsequent discussions with the faculty, several desired goals for the new process were enumerated. These were:

- quality decisions (high confidence, consistency, fairness, etc)
- better alignment of quals with research activity in order to better identify research capabilities and minimize impact on student research productivity
- reduced faculty effort and increased faculty enthusiasm
- timely decisions (early in student's career, preferably within 2 years)

The faculty has concluded that an explicit evaluation of a student's ability to perform and defend research at a quality commensurate with PhD candidacy is an important aspect of a qualifying process that meets the above criteria. This helps make research a top priority from the very beginning of graduate studies, and can be easily integrated with the current masters curriculum in the form of CS 895/7995 or CS 898/8999. In conjunction with this "depth" exam, satisfactory completion of an approved course of study with per-course grade and overall GPA requirements will ensure that students have an appropriate "breadth" of background knowledge for Ph.D.-level research. Using these two mechanisms, a decision about whether to recommend that a student continue towards a Ph.D. degree would be made no later than student's second year of study and usually should be possible within 1 - 1.5 years for students entering with a prior masters degree.

The new qualifying process distinguishes between four main areas into which research and courses are divided: Computer Systems, Programming Systems, Application Systems, and Theory. The appendix lists the topics, courses, and faculty in each of these areas

The rest of this document describes the rules for the new depth and breadth qualifying processes in further detail.

1. Depth Requirement

In order to demonstrate research potential commensurate with Ph.D. candidacy, students will be required to present and defend an independent research project and relate their work to prior art and fundamental concepts in the field. This requires a student to show *early* leadership in conducting research, show competence in technical writing, and make research a top priority from the beginning of graduate studies.

This exam will be integrated into the course requirements for CS 895/7995 for MCS students, for 3 credit hours of CS 898/8999 for MS students, and for 3 credit hours of CS 999/9999 for students entering with a prior masters. This process will *replace* the current structure of CS 895 for MCS students planning to continue to a Ph.D. (in which individual advisors administered CS 895 for their students and the student simply gave a public presentation with at least one other faculty member present). Terminal masters students will follow the same process but their examination will only evaluate whether the project work meets the criteria for a masters degree as opposed to the criteria for Ph.D. qualification. Students will register for the appropriate course in the semester of their qualifying exam (generally no later than the 3rd semester for Ph.D. candidates) and their grade will be based on the outcome of the exam. Failure resulting in termination will receive a grade of C for CS 895/7995 or U for 898/7999 and 999/9999. In cases where the student must retake the exam, an incomplete will be assigned until the exam is retaken (which must occur within one month of the original exam).

For Ph.D. candidates, the evaluation will be conducted by a committee of *three CS faculty plus the advisor*. The exam will be based on a proposal document describing the intended research project, a final report, and a public defense (subject to standard SEAS rules) of the work that will include an oral examination regarding the project as well as an agreed-upon set of background topics and materials in the form of a reading list. The project is expected to consist of work commensurate with a 3-credit course.

In order to provide consistency over time and across students in a given area, each research area will form a standing committee that is responsible for staffing the qualifying exam committees for students whose topics fall in a particular research area. These four areas will consist of Computer Systems, Software Systems, Application Systems, and Theory. In order to further improve consistency, every faculty member will be responsible for serving on committees from two of the four areas. A breakdown of areas, faculty assigned to these areas, and courses in each of these areas is included as an appendix. Examining committees will consist of four tenure- or research-track CS faculty: A student must pick two members from the group corresponding to the primary research area, one from another group, and the advisor is an *ex officio* member. Faculty members can refuse invitations to advisory committees for load balancing purposes. The

department chair and the director of graduate studies (or their proxies) are *ex officio* members of all committees.

Students are allowed to form a special advisory committee with members spanning a greater variety of areas if their work that does not naturally fit into one of the standing areas. All committees will be approved by the director of graduate studies.

While the student's research advisor would still provide primary management of the student's research work, these standing committees (which would include the research advisor) would approve the proposed project, judge whether the project was successfully carried out, and administer the oral exam covering the completed research project and related background material. Throughout this document, we refer to this committee as the "advisory committee." The depth qualifying process will therefore consist of three artifacts: a written project proposal including a reading list of material that the oral examination may cover, a final written project report, and a project defense with oral examination. Students who have already completed significant research at the time they begin the qualifying process may petition to have their proposal waived.

For consistency across areas, the faculty will define and publish the criteria for an acceptable project (i.e., expectations for the scope of projects, expectations for the written report, and expectations for the oral presentation) and an acceptable scope of questioning during the exam.

The typical student will appoint a qualifying-exam advisory committee by the end of the first month of their second semester, submit a project *proposal* by the end of their second semester, and then meet with the advisory committee to finalize expectations. As part of the project approval process, the advisory committee would make a *reading list* of material that the student should be prepared to discuss during the exam. This reading list would typically include a textbook as well as some seminal papers in each area, with additional material tailored to the student's research project. The oral exam will then take place by the end of the 3rd semester. A final project report will be due two weeks beforehand. Based on the student's final project report and oral exam, the advisory committee would determine if the student passed this depth portion of the examination. If the committee feels that the student's performance is not acceptable but that a second attempt is warranted, a second try may be permitted, in which case the exam must be re-taken within one month. A total of at most two attempts are allowed.

All deadlines are advanced by one semester for students entering UVA with a masters degree (hence they must appoint their committee within the first month, submit a project proposal by the end of the first semester, and take the oral exam by the end of their second semester).

Standing and overlapping committees, as well as a core reading list in each area, provide the high confidence, consistency, and fairness that the faculty desires. Basing the qualifying process on the student's research aligns the objectives and the investment of time with the student's and advisor's research goals. Furthermore, it also exposes the student to faculty members that have research interests that are similar to the student's, making the exam less intimidating and providing the ancillary benefit of making it somewhat easier for a student to switch to a different advisor in the same area (hopefully such switches are infrequent).

It will now be expected that *all* CS students take CS 895/7995 and complete the course within three semesters. Making a decision at this point as to whether the student should pursue a Ph.D. degree satisfies the early decision requirement and it comes at a natural point in the student's studies, when they should in any case be completing their first major research project. For a student entering with a master's degree, we would expect that they would complete the process by the end of their first year.

2. Breadth Requirement

To ensure that PhD students achieve sufficient breadth to be prepared for effective Ph.D.-level research, the ad hoc committee recommends relying solely on coursework but with stringent performance requirements. Coursework allows an accurate assessment of the student's overall capabilities by virtue of the long-term interaction between the student and instructor and availability of diverse evaluation tools. A course-based breadth process also boosts the incentive to master advanced material outside a student's core area.

To meet the breadth requirement, students must achieve a minimum GPA of 3.6 and a minimum per-course grade of a B (not B-) across a set of 6 courses selected from a menu approved for this purpose. This coursework must be completed within 4 semesters for students entering with a bachelors degree and within 3 semesters for students entering with a masters. *The plan of study must be approved by the student's qualifier supervisory committee.* At least one course must be chosen from each of four areas: Computer Systems, Programming Systems, Application Systems, and Theory. The remaining two courses can be from any areas of the student's choice. Note that we will no longer require any universal courses that all students must take, e.g. CS 6354.

Seminar courses can be counted toward breadth requirements at the discretion of the student's advisory committee. A non-exhaustive list of such seminar courses appears at the end of this document.

Independent study courses may only be counted for the breadth requirement if taken under a professor who is *not* the student's advisor. Independent study with one's own advisor is assumed to represent standard degree research depth in one's area of specialty, not breadth.

Select courses from other departments, such as ECE, MATH or SYSTEMS, may count for the Theory breadth requirement. A course used for the Theory breadth requirement cannot also satisfy the Math requirement.

The per-course minimum and the overall high GPA ensure that students can only meet the breadth requirement if they show mastery in a diverse set of areas in computer science. This is a more stringent requirement than our current breadth mechanism, in which students currently only have to pass a majority of the six questions in each area. The somewhat less stringent minimum grade for each course ensures that only competent work will count toward the breadth requirement.

One of the breadth courses in each area can be an undergraduate course. This gives students greater flexibility and is particularly appropriate for students from non-traditional backgrounds or students working in non-traditional areas. Note that undergraduate coursework does not count toward the SEAS requirements, so students are only likely to pursue this option when it is appropriate.

The advisory committee may allow a student to bypass a normally-required course. For example, the committee may deem a student who passes the final examination in the course, or has demonstrably learned the material through some other mechanism, to have satisfied the requirement. This flexibility is particularly important in the case of students entering with a masters degree.

Students entering with a masters degree will have no specific course requirements other than the department's requirement of 6 credits of PhD coursework. However, these students must demonstrate adequate background in each of the depth areas and take any necessary coursework to satisfy gaps. As with any other student, their specific plan of study must be agreed upon with their advisory committee.

3. Advisory Committee Recommendation to the Faculty

Based on the student’s performance on both the breadth and depth components of the qualifying examination, the advisory committee would make a recommendation to the faculty as to whether the student has passed or not passed the qualifying examination and is therefore recommended to proceed into the Ph.D. program. The final decision rests with the entire faculty.

Summary

Incorporating a research project into the qualifying exam aligns the qualifying process with development and assessment of research potential, and also aligns the student's qualifying work with the advisor's research program. This should increase research productivity and also boost students' confidence in their qualifying exam. Evaluating breadth based on coursework allows a more diverse and detailed characterization of the student's abilities.

Altogether, these policies allow a more timely decision based on the student's actual research performance. For students entering with a baccalaureate degree, the decision can be made at the end of student's second year. For a student entering with a MS degree, the decision can be made within 1-1.5 years.

Transition plan

We wish to transition to the new system as quickly as possible while allowing those who began in the old system to finish that process.

- All students entering the CS program in fall 2009 or later must follow the new system.
- All prior students may enter the new system if they choose, with the permission of their advisor. They must then follow the timeline as if they were first-years, in other words selecting their committee by Feb'10, Proposal by May'10, defense by Jan'11.
- The opportunity to switch to the new system is a one-time opportunity. Students who entered the CS program prior to fall 2009 must select which qualifying exam system to use by 1/1/2010.

Appendix

Areas, Associated Faculty, Associated Courses

Faculty members can email the quals committee or the graduate program director to place a course they are teaching in a particular quals category by the second week in a semester. The quals committee or graduate program director will maintain a list (i.e., for which 651/851 courses from which years count for which areas).

Computer Systems
[Arch, OS, Networks]

Davidson
Grimshaw
Gurumurthi
Hazelwood
Humphrey
Robins
Skadron
Soffa
Son
Stankovic
Weaver
Whitehouse
Wulf

CS 644/6444 Intro to Parallel Computing
CS 654/6354 Computer Architecture
CS 656/6456 Operating Systems
CS 757/7457 Computer Networks
CS 651/851/seminar Committee's Discretion

CS 586/5487 Real Time Systems
CS 715/6415 Performance Analysis of Computer Networks

CS 465/4458 Internet Engineering
CS 457/4457 Computer Networks
CS 444/4444 Intro to Parallel Computing
CS 433/4330 Advanced Computer Architecture
CS 414/4414 Operating Systems

CS 8501 (Spring 2010, Skadron) Scalable Processor Architectures
CS 851 (Fall 2008, Whitehouse) Topics in Wireless Sensor Networks
CS 651 (Fall 2007, Whitehouse) Programming Wireless Embedded Systems

Programming Systems
[PL, Compilers, Software Engineering]

Cohoon
Davidson
Evans
Grimshaw
Hazelwood
Knight
Reynolds
Skadron
Soffa
Sullivan
Whitehouse
Weimer
Wulf

CS 655/6610 Programming Languages (also 615)
CS 671/6620 Compilers
CS 685/6240 Software Engineering
CS 686/???? Dependability
CS 651/851/seminar Committee's Discretion

CS 771/7620 Advanced Compilers

CS 471/4620 Compilers
CS 441/4240 Principles of Software Design
CS 434/4434 Fault-Tolerant Computing
CS 415/4610 Programming Languages

CS 8561 (Spring 2010, Weimer) Topics in Programming Languages

Application Systems
[Graphics, DB, AI etc.]

French
Gurumurthi
Humphrey
Lawrence
Martin
Reynolds
shelat
Son
Stankovic
Sullivan
Weaver

CS 662/6750 Database Systems
CS 647/???? Image Synthesis
CS 651/851/seminar Committee's Discretion

CS 616/6316 Knowledge-Based Systems
CS 645/6840 Computer Graphics
CS 716/7716 Artificial Intelligence
CS 782/7882 Advanced Computer Vision

CS 453/4753 Electronic Commerce Technologies
CS 462/4750 Database Systems
CS 445/4810 Intro to Computer Graphics
CS 416/4710 Artificial Intelligence
CS 448/4840 Computer Animation
CS 447/4830 Image Synthesis
CS 446/4820 Real-Time Rendering

CS 651 (Spring 2008, Stankovic) Cyber-Physical Systems

Theory
[Theory, Algorithms, Security]

Cohoon
Evans
French
Knight
Lawrence
Martin
Robins
shelat
Weimer

CS 660/6160 Theory of Computation
CS 661/6161 Design and Analysis of Algorithms
CS 651/851/seminar Committee's Discretion
ECE 7717 Information Theory and Coding (for example)
ECE 6714 Estimation Theory (for example)

CS 587/5787 Security in Information Systems

CS 432/4102 Algorithms
CS 425/4630 Defense Against the Dark Arts

History of Changes

See the main document for official details; this unofficial list is for reference only.

January 29, 2010

* Clarify that the advisory committee must consist of CS faculty only.
* Indicate that Independent Study courses can only satisfy the Breadth requirement if taught by someone other than the student's advisor.
* List a number of past and current 651/851/etc. courses that satisfy various Breadth requirements.