McCormick

Northwestern Engineering

graduate study manual

2007-2008

Electrical Engineering & Computer Science Department

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1. Welcome

As the Associate Chair for Graduate Affairs for the Department of Electrical Engineering and Computer Science at the McCormick School of Engineering and Applied Science, it gives me great pleasure to welcome you to this department. The Department of Electrical Engineering and Computer Science is the largest department in the McCormick School with 49 full time faculty members, about 250 undergraduate and 160 graduate students.

The Department offers graduate degree programs in Electrical and Computer Engineering or Computer Science. Our EECS department has an internationally renowned faculty, state-of-the-art research equipment, and the considerable resources offered by a great university. We combine those advantages with an uncommon commitment to our students.

We have faculty who are Fellows of IEEE, OSA, APS, AAAI, and AAAS. Several faculty members have received PYI, NYI or CAREER awards from the National Science Foundation. Two of our emeritus faculty are members of the National Academy of Engineering.

Research in EECS spans a wide variety of disciplines essential to the future of information technology. The faculty of EECS are organized into six divisions: Solid State and Photonics (SSP), Computer Engineering & Systems (CES), Computing, Algorithms & Applications (CAA), Cognitive Systems (CSD), Signals and Systems (SSD), Graphics & Interactive Media (GIM)

In addition, the department is involved with a number of interdisciplinary research centers, including: Optimization Technology Center; Center for Quantum Devices; Motorola Center for Telecommunications Research; Center for Photonic Communication and Computing; Center for Ultra-scale Computing and Information Security; Council on Dynamic Systems and Control; Center for Connected Learning and Computer Based Modeling; Northwestern Institute on Complex Systems; Spatial Intelligence and Learning Center.

This Graduate Study Manual provides detailed information about the educational opportunities in the Graduate Programs in Electrical Engineering, Computer Engineering and Computer Science. It includes descriptions of our curricula, suggestions for course work, various options, and information about our faculty, computer facilities, and student activities.

On behalf of the faculty of the Electrical Engineering and Computer Science Department, I would like to welcome you and wish you very successful and pleasant years at Northwestern University.

Christopher Riesbeck
Associate Chair for Graduate Affairs

Overview

1.1 Student Responsibilities

It is the responsibility of the student to insure that all the requirements of the Graduate School and the Department are met by the program he or she selects, that necessary examinations are properly scheduled, and that deadlines dependent on current university calendars are observed. Academic calendars can be found on-line at http://www.registrar.northwestern.edu/calendar/index.html. The current procedures and degree requirements of the EECS Graduate Programs are detailed in this document. In addition, students are strongly urged to consult regularly with their faculty advisors. They may also consult with the Associate Chair for Graduate Affairs for any questions related to procedures and requirements.

1.2 Planning the Program of Study

Students are advised to plan their programs of study for an advanced degree before commencing such study. An initial program advisor is assigned for each student to assist with planning for the first quarters of study. Students are encouraged to find a permanent research advisor by the end of the first quarter of registration. The research advisor will be the student's primary contact with the Department for the remainder of the student's program and should be chosen to match the student's research interests (see Section 5). Each student should fill out his/her study plan on a form supplied by the Department. The study plan should be approved by the student's advisor prior to registration and updated with any program changes and grades each quarter. Should the student decide to change advisors, the old advisor and the Associate Chair for Graduate Affairs must be informed, and a new plan, at the new advisor's option, may be prepared. Graduate courses in electrical engineering, computer engineering, computer science, and related fields are described in this bulletin and the bulletin of the Graduate School.

The normal full-time program of graduate study is three units per quarter. The maximum permitted is four. All students receiving financial aid in the form of fellowships, research assistantships or teaching assistantships must register as full-time students.

1.3 Graduate Internships

Students wishing to combine research work with industrial experience may, with the permission of their advisors, elect to participate in the Crown Family Graduate Internship Program. The experience permits the graduate student to gain a broader understanding of some problems that eventually can serve as the background for his/her thesis or project. For more information on the Crown Family Graduate Internship Program, see Section 3.15 of this guide.

1.4 General Admission Requirements

The primary objective of the admission process in the Department is to determine an applicant's qualifications and judge the applicant's prospects for success in their desired program of study. To maintain a proper balance between Department resources and the size of the graduate student population, we must limit offers of admission to a small number of the most qualified applicants. Thus the admission process is highly selective and competitive in nature.

It is the policy of the EECS Department that requests for admission are reviewed during the Winter Quarter for admission the following Fall Quarter. Requests for financial aid for doctoral students are also reviewed during the Winter Quarter, with awards made for study beginning the following Fall Quarter. It is the policy of the department that students begin their programs in the Fall Quarter. Rarely, and under special circumstances, students are allowed to begin in the Winter or Spring Quarter.

Initial evaluations of each application are performed by faculty whose research interests fall into the area of specialization specified by the applicant. A typical applicant is expected to have a Bachelor of Science in Electrical Engineering, Computer Engineering, Computer Science, or a related discipline from a recognized institution. Highly qualified candidates with other academic backgrounds may also be considered.

The specific undergraduate preparation required for graduate study depends on the program and the area of specialization. An applicant with insufficient undergraduate preparation in any particular area, but well qualified in every other respect, may be required to take certain undergraduate courses as soon as possible after enrolling at Northwestern. A student would be informed of such a requirement at the time of admission, along with grade expectations, and whether such courses will carry graduate credit.

Refer to the *Policy Guide* of The Graduate School for a list of the materials applicants are required to submit for application for graduate study at Northwestern University.

TGS *Policy Guide*: http://www.tgs.northwestern.edu/abouttgs/policyguide/

In addition to this list of required materials, all applicants for graduate study in Electrical Engineering and Computer Science must submit verbal, quantitative, and analytical scores from the Graduate Record Examination (GRE).

1.5 Financial Aid

Ph.D. Students The policy of the McCormick School is to admit only Ph.D. students for whom financial support can be provided. The School, or the Department, provides support in the form of Cabell and Murphy Fellowships, research assistantships, and teaching assistantships. Students who have financial support from outside institutions or governmental grants will also be considered for admission. If a student is denied aid and unable to demonstrate necessary funds, the Department will be unable to recommend admission of the student to the Graduate School.

M.S.-Only Students The Department encourages M.S.-only students, especially from industry, to apply. However, the Department does not provide financial support to M.S.-only students. Such students can be supported by a company, government, or other external fellowship, or be self-supported. M.S. students who wish to pursue a Ph.D. at Northwestern upon completion of the M.S. program must follow the steps outlined above and reapply for admission and financial support.

1.6 Department Administration

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Program Facilitator
George Nejmeh (george@eecs.northwestern.edu, 491-5931, Tech M389)

1.7 EECS Faculty Committees 2007-08

Graduate Committee:

Chris Riesbeck (Chair), Allen Taflove, Hooman Mohseni, Selim Shahriar, Ying Wu, Randy Berry, Jorge Nocedal, Robert Dick, Ian Horswill, Bryan Pardo, Yan Chen, and Graduate Students (TBD)

Electrical Engineering Undergraduate Curriculum Committee:

Randy Berry (Chair), Alan Sahakian,, Prem Kumar, Dongning Guo, Chang Liu, Manijeh Razeghi, Thrasos Pappas, Ying Wu, Xu Li and UG student (TBD)

Computer Engineering Undergraduate Curriculum Committee:

Yehea Ismail (Chair), Alok Choudhary, Aleksandar Kuzmanovic, Chi-haur Wu, Hai Zhou, Seda Memik, Ben Scholbrock (student) and Ryan Cortez (student)

Computer Science Undergraduate Curriculum Committee:

Peter Dinda (Chair), Larry Birnbaum, Yan Chen, Robert Dick, Ken Forbus, Justine Cassell, Jason Hartline, Bryan Pardo, Ian Horswill, Aleksandar Kuzmanovic, Gokhan Memik, and student

Instructional Labs Committee:

Chi-haur Wu (Chair), Larry Henschen, Alan Sahakian, Hooman Mohseni, Jack Tumblin, Matthew Grayson and Norm Flasch (ex officio)

Computing Facilities Committee:

Aggelos Katsaggelos (Chair), Yan Chen, Peter Scheuermann, Jorge Nocedal, Gokhan Memik, Fabian Bustamante, Michael Honig, Ian Horswill, and Pred Bundalo (ex officio)

Publicity, Alumni and Industrial Relations Committee:

Seng-Tiong Ho (Chair), Fabian Bustamante, Abe Haddad, Ming Kao, Kris Hammond, W. Lin, Don Norman, Peter Scheuermann, and Yan Chen

Teaching and External Awards Committee:

Randy Freeman (Chair), Abe Haddad, CC Lee, Aggelos Katsaggelos, Prem Kumar, Hai Zhou, Ken Forbus, Martin Plonus, and Michael Honig

Distinguished Seminar Committee:

Thrasos Pappas (Chair), Matthew Grayson, Ming Kao, Hai Zhou, Ying Wu, Yehea Ismail, Selim Shahriar, Peter Scheuermann (co-chair), Larry Birnbaum, Dongning Guo, Jack Tumblin, and Morteza Dehghani

Undergraduate Recruiting

Allen Taflove (Chair), Manijeh Razeghi, Russ Joseph, Peter Dinda, Bryan Pardo, Robert Dick, Fabian Bustamante, Seda Memik, and Xu Li

Secretary of the Faculty

Randy Freeman

Associate Chair for the Graduate Program

Chris Riesbeck

Associate Chair for the Undergraduate Program

Alan Sahakian

2. M.S. Program

2.1 Course Requirements

At least twelve units of graduate study are required for the M.S. degree. Typically, one unit of credit corresponds to a one-quarter course. With the exception of EECS 590, all courses must be taken for a grade. All course work for the M.S. degree must be taken within the Northwestern University Graduate School, and must be completed within a period of five years. To assure depth, every M.S. student is required to take at least three relevant courses at the 400 level. Not all course work must be taken in EECS; exceptions are allowed based on the recommendation of the student's advisor and the approval of the Graduate Committee. The EECS 590 research units do not count towards 400 level course credits. Courses completed for undergraduate credit at Northwestern or elsewhere cannot be repeated for graduate credit.

EECS 499 is for projects not directly related to the thesis or project required for the degree, or for readings in specific subjects for which we have no regular courses. EECS 499 Independent Study is not intended to replace or augment required units of EECS 590 for either the M.S. or Ph.D. degrees.

The Graduate School policy specifies that students who have undertaken graduate study elsewhere cannot transfer credit for those courses towards the Master's degree program. .

2.2 Thesis or Project Requirement

In addition to the course work, each student working toward an M.S. degree in Electrical and Computer Engineering or Computer Science must choose one of the following plans to be approved by the student's advisor. (These options may not be available to all Programs of Study. See Section 5 for details.)

Plan A (Thesis M.S.): The student must write an M.S. thesis for which he or she may receive two or three units of research credit 590. This can be counted toward the 12 unit requirement for the M.S. degree. The thesis must be approved by the student's M.S. Examination Committee. Upon completion and approval, one unbound and corrected copy is to be brought to the Department Graduate Coordinators office, to be forwarded to the university library.

Plan B (Project M.S.): The student must complete a project and write a project report for which he or she will receive one or two units of research 590, which can be counted toward the 12 unit requirement for the M.S. degree. The main difference between an M.S. thesis and an M.S. project is that the thesis normally has substantial original research results, while a project contains results based on existing theory or techniques. The project report must be approved by the student's M.S. Examination Committee. One copy of the approved final project report must be spiral bound and archived in the Department after the M.S. Final Examination.

Plan C (Course M.S.): The student must take 12 courses approved by the student's advisor. The choice of courses must represent a coherent program of study which prepares the student for advanced work in a specific field. Students are strongly encouraged to follow the Programs of Study (POS) described in the Ph.D. program (See Section 4.). The student's performance in the coursework will be evaluated by an M.S. Examination Committee. Not all Programs of Study allow this option.

2.3 Residency Requirements

According to The Graduate School, the minimum residency requirement for the M.S. degree is the equivalent of three quarters of full-time registration in graduate courses. Full-time registration is defined as three or four course units per quarter. Refer to The Graduate School website for details about residency requirements:

http://www.tgs.northwestern.edu/studentsvcs/requirements/masters/residency/

2.4 Resident Master's Study (TGS 588)

Registration for TGS 588 is open to those Master's students who wish to devote their time to full-time research for one quarter. TGS 588 provides no accumulation of credit toward residency. TGS 588 is appropriate for students who have completed the 12-unit requirement for the M.S. degree, but have not completed the required project or thesis, and wish to maintain full-time enrollment status. Students may register for TGS 588 in more than one quarter, but the Dean of The Graduate School will review each TGS 588 registration beyond the first to determine that the student is making reasonable progress toward completion of the M.S. degree.

2.5 Graduation Requirements

In order to receive the master's degree, the student must also complete the Application for a Degree Form by the date specified in the Academic Calendar.

To do this, take the following steps:

- Go to CAESAR online and click on Self Service. Click on the Application for a Degree tab and provide the requested information. **Before clicking the SUBMIT button, print the page** (to bring to the EECS Department Graduate Coordinator). When the form is complete, click Submit. Bring the page you printed to the EECS Department Graduate Coordinator, Tech Room L351.

To be eligible to receive the master's degree, students must have at least a B average and no X or Y grades. No more than one-third of the total units presented for the master's degree may be EECS 499; EECS 590 Research is the only course for which the P/N option is acceptable in a master's degree program.

2.6 Final Examination

Students prepared to take their MS Final Examination need to take the following steps at **least one week prior to the exam**:

- Go to CAESAR online and click on Self Service. Click on the M.S. Final Exam tab and provide the requested information. **Before clicking the SUBMIT button**, print the page (to bring to the EECS Department Graduate Coordinator). When the form is complete, click Submit. Bring the page you printed to the EECS Department Graduate Coordinator, Tech Room L351.
- Obtain and complete the EECS Examination Request form, available from the EECS Department Graduate Coordinator. Follow the instructions on the form and obtain the required signatures. To reserve an examination room, bring the departmental form to the Department Chair's assistant who will fill in and initial the required room reservation information. Be sure to verify your proposed committee is available on the date of your exam, and you have met all degree requirements of the EECS Department and The Graduate School, as detailed in this manual.
- Return the form to the Department Graduate Coordinator at least one week prior to the exam date.

If the exam is open to the public, an announcement of the exam will be posted in the Department. Your file will be checked for any missing documents, grades, etc. The file and the EECS Examination Request form will be given to your advisor prior to the exam, and must be in the exam room for reference. After the exam, the form must be signed by all committee members. Your advisor is t return the completed signed paperwork and your file to the Graduate Coordinator's office immediately upon completion of the final exam.

2.7 Part-time Graduate Program

Graduate students may pursue their M.S. studies in the Department on a part-time basis. For this purpose, the Department schedules certain courses in the late afternoon. However, all of the M.S. degree requirements must be fulfilled, and it may not be possible to take all required courses at these late-afternoon time slots. For further information, contact the Associate Chair for Graduate Affairs.

3 Ph.D. Program

The following new unit and course requirements were approved by the faculty on Feb. 17, 1999, for students entering the Ph.D. program in Fall 1999. Students who entered the Ph.D. program prior to Fall 1999, may choose to adopt these requirements instead of the program requirements in place in the 1998-99 Graduate Programs Manual.

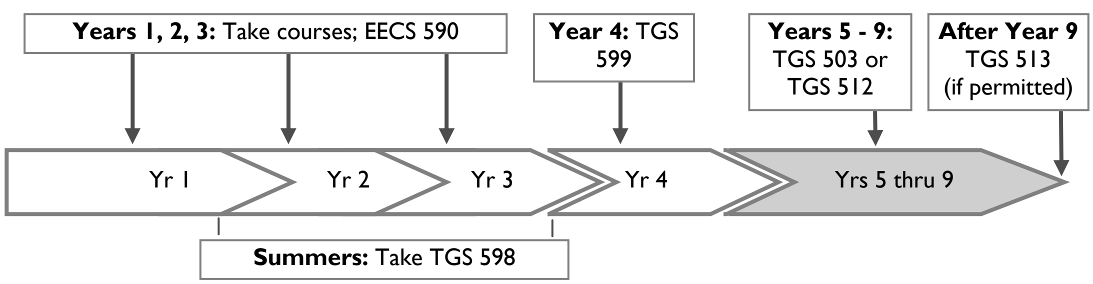
> Note: In addition to the requirements outlined below, each program of study (POS) may have additional requirements. See Section 5 for details.

This section is divided into two parallel and complementary streams: the official **Milestones** in a graduate career, and the **Registration** requirements mandated by the university and department for each year.

3.1 Milestones

Any student not meeting the milestones listed below will be considered not in good standing and therefore will be ineligible for fellowships, traineeships, teaching or research assistantships, and scholarships. Students who do not meet published requirements of satisfactory academic progress may be excluded from TGS. Students who have taken time off for family or other approved leave will have appropriate accommodations made to adjust their milestones.

a. Selection of Research Topic for the Ph.D. Dissertation
b. Ph.D. Qualifier Examination
c. Admission to Candidacy
d. Prospectus (Dissertation Proposal)
e. Ph.D. Final Examination
f. Dissertation
g. Teaching Trainee requirement



3.1.a Selection of a Research Topic for the Ph.D. Dissertation

The purpose of a Ph.D. dissertation is to train the student in the methods of research, that is, in how to formulate a research problem and how to proceed in a logical and systematic way to its solution. It is expected that the results be publishable in a technical journal.

After starting the graduate program, students are urged to select their research topics as soon as possible. Identifying a research advisor is essential for academic progress. Failure to do so often results in a delay in completing the degree requirements. Full-time Ph.D. students should identify a research advisor no later than the end of the first academic quarter of enrollment, and a research topic soon thereafter. The student will select their subject of research with their advisor.

3.1.b **PhD Qualifier Examination**

When you are ready for the PhD Qualifier Examination, go to CAESAR, and click on Self-Service. Click on PhD Qualifier Exam tab and provide the requested information. **Before clicking the SUBMIT button, print the page** (to bring to the EECS Department Graduate Coordinator). When the form is complete, click Submit.

Bring the page you printed to the Department Graduate Coordinator's office (Tech Room L351). While there, obtain the EECS Examination Request Form.

Note that you are responsible for reserving a room via the Department Chair's assistant, who must initial the form. Obtain all required signatures; verify the availability of your proposed committee on the date shown for your exam. When the EECS Examination Request Form is complete, return it to the same office.

3.1.c **Admission to Candidacy**

A Ph.D. student receiving financial aid must be admitted to candidacy within three academic years following completion of the B.S. degree, or two academic years following completion of the M.S. degree.

Admission to candidacy requires meeting the academic requirements of one of the EECS programs of study, and passing a qualifying exam for that program. Details of these requirements and the nature of the qualifying exam appear in Section 5. The student notifies The Graduate School of intent to take a qualifying exam via the Self-Service system. See The Graduate School "deadlines" web page for when this must be done:

http://www.tgs.northwestern.edu/deadlines/

3.1.d **Ph.D. Prospectus**

Students must have a prospectus (dissertation proposal) approved by their committee no later than the beginning of the fifth year of study to remain in good academic standing. The prospectus must be approved by a faculty committee. A minimum of three individuals must serve on the prospectus committee. At least three members of this committee, including the chair, must be members of the Northwestern University Graduate Faculty. Upon formation of the prospectus committee, the student should submit the Prospectus Committee form through TGS Self-Service in CAESAR.

3.1.e **Ph.D. Final Examination**

When you are ready for the PhD Final Examination, go to CAESAR, and click on Self-Service. Click on PhD Final Exam tab and provide the requested information. **Before clicking the SUBMIT button, print the page** (to bring to the EECS Department Graduate Coordinator). When the form is complete, click Submit.

Bring the page you printed to the Department Graduate Coordinator's office (Tech Room L351), and while there obtain the EECS Examination Request Form.

Note that you are responsible for reserving a room via the Department Chair's assistant, who must initial the form. Obtain all required signatures; verify the availability of your proposed committee on the date shown for your exam, meet all degree requirements of the EECS Department and The Graduate School as detailed online and in this Manual. When the EECS Examination Request Form is complete return it to the same office.

This form must be submitted four weeks before your PhD examination date.

In addition to your final examination, you also need to submit your dissertation electronically to The Graduate School. Instructions on how to do this, and a handy checklist, can be found at:

http://www.tgs.northwestern.edu/studentsvcs/requirements/doctoral/completion/

An announcement of your exam will be posted in the Department. The student's file will be checked for any missing documents, grades, etc., that need to be completed for the exam and awarding of the degree. The file, and the Report of Committee on Examination of Candidate form, will be given to your advisor prior to the exam, and should be in the exam room for reference. After the exam, the Report must be signed by all committee members. Your advisor will return the completed signed paperwork and file it with the Graduate Coordinator's office immediately upon completion of the final exam.

3.1.f **Dissertation**

Every candidate is required to present a dissertation indicating evidence of original and significant research. A copy of *Instructions for the Preparation of Dissertations* may be obtained from The Graduate School.

3.1.g **Teaching Trainee Requirement**

The Teaching Trainee (TT) requirement for full-time EECS doctoral students was approved by the EECS faculty in Fall 2007, and became effective in Winter 2007. It replaces the Teaching Associate requirement for ECE students and the annual teaching requirement for CS students. Although any student can choose to stay with the previous requirements, the new requirement is much less onerous for both groups. We will therefore assume the TT requirement for all EECS students, unless notified otherwise.

All full-time doctoral students in EECS, whether pursuing a CS or ECE Ph.D., over the course of their career must serve as either

- a Teaching Assistant (TA) for at least 3 quarters, or
- a TA for 2 quarters and a Teaching Trainee (TT) for 1 quarter, or
- a TT for 2 quarters
- an instructor for an EECS course or approved McCormick course for 1 quarter

One quarter of service as a McCormick Graduate Tech Tutor may be substituted for one quarter of TT.

TT duties are equivalent to those of a half-time TA, i.e., 10 hours per week. In addition, to make the experience most beneficial, it is recommended that TT's have the opportunity to prepare and present a class lecture, and/or design a homework assignment, and otherwise be actively involved as more than just a grader or help desk.

First-time TT students should register for EECS 545 (Teaching Experience) to receive one credit for their effort. Second-time TT students should register for EECS 546, which is zero credit, but does place on their transcript recognition of their contribution.

Note: you can't be a TA and TT in the same quarter. Also, EECS 545 and EECS 546 are only for TT students.

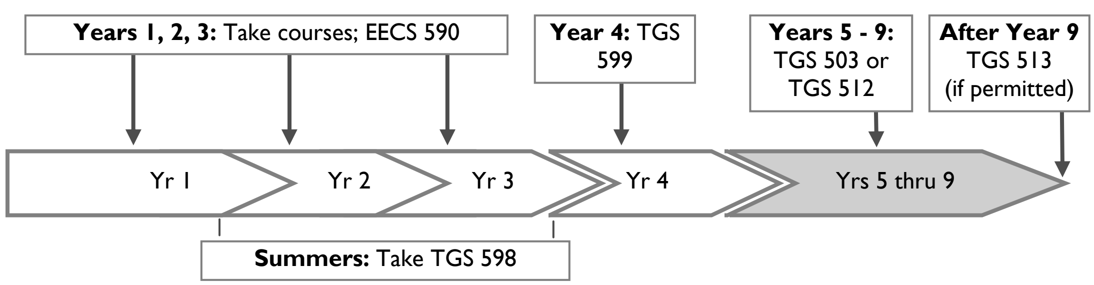
Deadline for Fulfillment of Teaching Training Requirement

The requirement must be fulfilled before graduation. A student will not be able to graduate until one of the TT/TA requirements listed above is fulfilled.

When a student files his or her thesis proposal, the student will also file a form listing what part of the requirement has been fulfilled so far, and what, if any, teaching requirement has yet to be fulfilled.

3.2 Registration Requirements

a. Unit Requirements
b. Course Requirements
c. Residency Requirements
d. Continuous Registration following Admission to PhD Candidacy (TGS 503, TGS 512, TGS 599)
e. Resident Doctoral Study (TGS 598)
f. The Crown Family Graduate Internship Program



3.2.a Unit Requirements

The total number of quarters required for a Ph.D. from The Graduate School is nine (9). A student who receives an M.S. degree from Northwestern, or a student entering with an M.S. degree from another university in an area relevant to the Ph.D. degree pursued in our department, can be granted up to 9 units of credit, if approved by the advisor, department, and Graduate School.

3.2.b Course Requirements

Typically students take three courses per quarter, or 27 units total. Of those units, a minimum of 15 are required to be coursework. These fifteen (15) units may include EECS 499 units, EECS 510 units, and one EECS 545 unit.

The student must take at least 6 units of course work at the 400 or 500 levels, excluding the unit for EECS 545.

A student granted 9 units of credit for an M.S. degree, either from Northwestern or from another school, must take at least 6 additional units of coursework, at least 3 of which are at the 400 or 500 level, excluding EECS 545.

EECS 590 research units make up the remainder of the units beyond the courses taken by the student and credit given for prior coursework.

A Ph.D. student's division, research group or research advisor may require more than the minimum number of courses. In such cases, the number of EECS 590 research units will be reduced correspondingly.

EECS 499 is for projects not directly related to the research required for the Ph.D. thesis, or for readings in specific subjects for which we have no regular courses. The course EECS 499 is not intended to replace or augment the required units of research (EECS 590) for either the M.S. or Ph.D. degrees. ECE students are limited to two units of EECS 499.

3.2.c Residency Requirements

Regular

The minimum residency requirement is nine academic quarters of full-time registration (three course units per academic quarter) in courses authorized by the Graduate Faculty for graduate credit. Following the first three academic quarters of full-time study, or its equivalent, three consecutive academic quarters of full-time registration must be completed. Registration in the Summer Session is not required to fulfill the continuous residency requirement. With the exception of the requirement of three consecutive quarters, a student may meet the residency requirement on a part-time basis. Review the Doctoral Residency requirements specified on The Graduate School web pages:

http://www.tgs.northwestern.edu/studentsvcs/requirements/doctoral/residency/

Registration for two units in one academic quarter and four units in another does not equate to two full academic quarters of residency, but rather one and two-third academic quarters of residency.

Modification of the Continuous Residence Requirement

The consecutive three academic quarters of full-time residence required of doctoral students beyond the first-year level may be fulfilled by five consecutive academic quarters at the two-thirds load level. Exceptions are only intended for students who can demonstrate compelling reasons, such as commitments at home, or the necessity of part-time employment to finance graduate study.

Employed persons who can demonstrate to the Department and The Graduate School that they have been relieved from approximately one-third of the responsibilities of full-time employment may be allowed to meet the continuous residence requirement by registering for five consecutive quarters at the two-thirds level.

Persons who wish to satisfy the continuous residence requirement as a part-time student at the two-thirds level must submit a petition to The Graduate School through the Department **in advance** of the period of study. A statement from the employer must be included with the petition, indicating the number of hours or days each week the part-time student will be relieved from full-time duties of employment.

Transfer Credit

A student with a Master's degree in electrical engineering, computer engineering, computer science, or another relevant field from a recognized institution may be granted up to three quarters of transfer credit toward the nine academic quarter residency requirement, upon approval by the advisor, department, and Graduate School.

Special Note for Students Receiving Financial Aid

Students receiving financial support (assistantships or fellowships) must be registered as full-time students, including during the summer quarter. For details, see

http://www.tgs.northwestern.edu/studentsvcs/information/registration/

Such students must also maintain satisfactory academic progress, as defined here:

http://www.tgs.northwestern.edu/financialaid/

3.2.d **Continuous Registration Following Admission to Ph.D. Candidacy (TGS 599, TGS 503, TGS 512)**

Following admission to candidacy, the student is informed of unfulfilled residency and course requirements, and a degree deadline date is set.

A student admitted to candidacy for the Ph.D. and having completed residency must register for at least three quarters of TGS *599 Post Candidacy Research* by the time the dissertation is submitted. If a student completes the degree requirements in less than three quarters after the completion of residency, he or she needs only to be registered for 599 in those quarters which intervene between the completion of residency and the submission of the dissertation. For this purpose, the Summer Session is considered a regular academic quarter.

TGS 599 carries full-time status without accumulation of credit. This registration does not need to be consecutive and applies whether or not a student is in residence. A person not registered loses student status.

This registration requirement does not apply to a student with a baccalaureate degree who completed all the requirements for the Ph.D. within three calendar years after initial registration or a student with the equivalent of a Master's degree who completes all the requirements for the Ph.D. within two calendar years.

Students receiving financial aid must be registered full-time. Students who do not receive financial aid, and have completed three quarters of TGS 599 after the admission to candidacy, may register for TGS *503 Resident Research Continuation* if they need or intend to use University facilities.

TGS *512 Continuous Registration* is appropriate for students who must be away from campus or on leave for any reason (medical, family, research, etc.) and students who are unfunded (without any stipend or tuition scholarship), in order to maintain university status and benefits. Students in terminal master's degree programs and PhD students who have not yet reached candidacy **must** meet with their advisor before registering for TGS 512. Read further details on The Graduate School web page: http://www.tgs.northwestern.edu/studentsvcs/requirements/allstudents/continuousreg/

In general, The Graduate School will not approve registration for courses after the student has been admitted to candidacy. Therefore, the student should plan on having all required courses completed before taking the oral qualifying exam.

3.2.e **Resident Doctoral Study (TGS 598)**

TGS *598 Resident Doctoral Study* is open to doctoral students who have completed at least three full-time academic quarters of registration at Northwestern, and who have not been admitted to candidacy. This category of registration, at reduced tuition, certifies full-time status, but does not allow the accumulation of credit toward residency.

TGS 598 is appropriate for full-time doctoral students receiving financial aid during any quarter who do not need formal course work. TGS598 is also appropriate occasionally for doctoral students who need freedom from formal course work for a quarter without jeopardizing their status as full-time students during the academic year.

3.2.f **The Crown Family Graduate Internship Program**

Ph.D. candidates may elect to participate in the Crown Family Graduate Internship Program. This opportunity permits the doctoral candidate to gain practical experience in industry or in national research laboratories in areas closely related to his or her research. The internship can provide significant positive impetus to the thesis effort and may provide a basis for future employment. The program’s intention is to promote continuing collaboration between Northwestern University and the participating organization.

Students elect the graduate internship option in the latter stages (e.g., third year) of the Ph.D. study. The student is generally paid by the participating sponsor and works full-time for either three, six, or nine months with that sponsor. An appropriate position is located with the help of the student's Ph.D. advisor and the associate deans of Graduate Studies and Research and Industry/Academic Affairs.

Students who wish to take advantage of this internship opportunity and earn academic credit need to sign up for The Graduate School General Curriculum *799-510 Crown Family Graduate Internship* course for 0 units. A prerequisite for this course is a written approval of the Ph.D. advisor. Students may register for this course for no more than three academic quarters, and no more than two consecutive academic quarters.

Foreign students can participate in this internship program as part of their Curricular Practical Training (CPT) without it counting towards their quota of 12 months of Practical Training for F-1 or J-1 visas. They may register for this course during the summer quarter in which they spend their summer internship. At the end of the summer internship they must present their advisor with a written report.

For details about the Crown Family Graduate Internship Program, contact the Associate Dean for Graduate Studies and Research of the McCormick School of Engineering or visit the following URL:

http://www.tgs.northwestern.edu/academics/schooloverview/mccormick/

4. Departmental Divisions

Currently the department offers six programs of study:

Solid-State & Photonics – SSP; Computer Engineering & Systems – CES; Computing, Algorithms, & Applications – CAA; Cognitive System – CSDs; Signals & Systems – SSD; Graphics & Interactive Media – GIM

Solid State and Photonics – SSP

Faculty: Prem Kumar (Division Head), Matthew Grayson, Seng-Tiong Ho, Xu Li, Chang Liu, Hooman Mohseni, Martin Plonus, Manijeh Razeghi, Selim Shahriar, Bruce Wessels, Horace Yuen

Solid state engineering focuses primarily on the science and technology of semiconductors for quantum structures and devices operating from the ultraviolet up to far infrared. Quantum devices are fabricated using the most advanced semiconductor synthesis technologies (MOCVD, MBE, gas source MBE, etc.), as well as micro-fabrication techniques (high-precision photolithography, e-beam evaporation, RTA, reactive-ion-etching, etc.). The quantum devices are fully tested at each step in the fabrication process using advanced characterization techniques (diffraction, SEM, TEM, photoluminescence, Hall, etc.) Most of the research is performed within the Center for Quantum Devices, in a 'clean room' environment similar to what is found in industry. These quantum devices are in high demand by today's applications. Ultraviolet lasers and photodetectors are needed for astronomy, space communications and the monitoring of engines and heat sources. Red, green and blue (RGB) solid-state lasers are needed for high brightness full-color displays and optical data storage (CD, DVD). High power 0.808 μm, 0.98 μm, 1.3 μm, and 1.5 μm lasers and VCSELs are needed for medical applications and fiber optical communications. Infrared lasers (e.g. Quantum Cascade lasers), photodetectors (e.g. QWIP) and focal-plane-arrays (FPA) are needed for chemical analysis and night vision.

Optical systems and technology focuses on micro-cavity lasers, nano-stuctures, quantum and nonlinear optics, integrated optics, fiber-optic and infrared waveguide devices, fiber-optic communications, computational electromagnetics, and imaging through turbulence. Special emphases include: applications of novel quantum amplifiers in optical communications, imaging, and cryptography; devices for tera-bit per second WDM and TDM optical networks; and, applications of computational techniques in integrated and nonlinear optics.

Computer Engineering & Systems – CES

Faculty: Alok Choudhary (Division Head), Fabian Bustamante, Yan Chen, Robert Dick, Peter Dinda, Larry Henschen, Yehea Ismail, Russ Joseph, Aleksandar Kuzmanovic, Wei-Chung Lin, Gokhan Memik, Seda Memik, Alan Sahakian, Peter Scheuermann, Chi-Haur Wu, Hai Zhou

Areas of study in the Computer Engineering and Systems Division fall into seven main categories: analysis and design of integrated circuits, computer architecture, high-performance and parallel computing, embedded systems, data management and analysis, security, as well as distributed systems and networks. Example subtopics within each category follow.

Analysis and design of integrated circuits: design verification; integrated circuit synthesis; model order reduction; and physical design of integrated circuits.

Computer architecture: application-specific programmable processors; power-aware microarchitectures; reconfigurable architectures; and, reliable high-performance processor design.

High-performance and parallel computing: compilers and applications; high-performance storage and parallel I/O; and, ultra-scale architectures and software.

Embedded systems: embedded system synthesis; mobile, wireless, and ubiquitous computing; operating systems; and, power optimization.

Data management and analysis: data mining and knowledge discovery; moving objects databases; parallel and distributed database systems; and, physical database design.

Security: network security; secure architectures; and secure software.

Distributed systems and networks: autonomic computing; network measurement and performance analysis; network protocols and security; peer-to-peer and overlay networks; resource virtualization; ubiquitous computing and journalism; as well as wireless, ad-hoc, and sensor networks.

Computing, Algorithms, & Applications - CAA

Faculty: Ming Kao (Division Head), Yan Chen, Lance Fortnow (arriving January 2008), Jason Hartline (arriving January 2008), Nicole Immorlica (arriving Fall 2008), Jorge Nocedal, Peter Scheuermann, Allen Taflove, Hai Zhou

The research of this division focuses on algorithms, theory, applications, and software and hardware implementations.

Current research areas include bioinformatics, computational economics and finance, continuous and discrete optimization, database algorithms, formal methods, networking algorithms, security algorithms, self-assembly, and VLSI CAD algorithms.

Cognitive Systems – CSD

Faculty: Ken Forbus (Division Head), Larry Birnbaum, Justine Cassell, Daniel Edelson, Louis Gomez, Kristian Hammond, Larry Henschen, Ian Horswill, Don Norman, Bryan Pardo, Christopher Riesbeck, Uri Wilensky

This Division conducts research focused on understanding how the mind works (with a computational focus) and on creating systems for education, performance support, and entertainment that exploit principles of cognitive science and artificial intelligence.

Signals & Systems – S&S

Faculty: Alan Sahakian (Division Head), Randy Berry, Arthur Butz, Robert Dick, Randy Freeman, Dongning Guo, Abraham Haddad, Michael Honig, Yehea Ismail, Aggelos

Katsaggelos, CC Lee, Wei-Chung Lin, Thrasos Pappas, Jack Tumblin, Chi-Haur Wu, Ying Wu, Horace Yuen

Networks, Communication and Control focuses on communications, telecommunications and communication networks, and control theory. Specific areas of study include: mobile wireless multi-user communication, estimation and detection, wireless networks, resource allocation in communication networks, data network protocol design, network performance modeling and analysis, nonlinear and robust control, and, stochastic hybrid systems.

Signal Processing focuses on the digital representation and algorithmic manipulation of speech, audio, image and video signals. Specific topics within this general area include: image and video processing; recovery and compression; multimedia signal processing; filter design and rank-order operators; image and video transmission; medical and biomedical signal processing; medical imaging; and, algorithms for medical instrumentation.

Graphics & Interactive Media – GIM

Faculty: Ian Horswill (Division Head), Justine Cassell, Daniel Edelson, Louis Gomez, Kristian Hammond, Don Norman, Andrew Ortony, Bryan Pardo, Jack Tumblin, Uri Wilensky

The Division of Graphics and Interactive Media focuses on the human-centered design of computational media systems. This means we study not only the machine itself, but the human user and their closed-loop interactions. Students in GIM combine computer science with theoretical and experimental techniques from the behavioral sciences and the arts to build systems with more effective closed-loop behavior. This includes questions such as:

How can we use theories of human vision to build better cameras?

Or theories of hearing to let us edit sounds out of a recording?

Or studies of human gesture to build engaging artificial characters?

Or theories of human learning to build better educational software?

Research Centers

Additionally, many EECS faculty are involved in research in various interdisciplinary research Centers:

- Optimization Technology Center
- Center for Quantum Devices
- Motorola Center for Telecommunications Research
- Center for Photonic Communication and Computing
- Center for Ultra-scale Computing and Information Security
- Council on Dynamic Systems and Control
- Center for Connected Learning and Computer Based Modeling
- Northwestern Institute on Complex Systems

5. Divisional Programs of Study

Upon receiving their Ph.D., each candidate should have a solid background in their field as preparation for a career in research or teaching. To ensure that each of our students receives this background, we require them to choose, and complete the Program of Study (POS) corresponding to their intended field of inquiry. Students entering without the prerequisite knowledge to enroll in the POS courses will be required to take additional preparatory coursework. Currently the department offers six programs of study:

Solid-State & Photonics

Computer Engineering & Systems

Computing, Algorithms, & Applications

Cognitive Systems

Signals & Systems

Graphics & Interactive Media

Each program of study is represented by a committee of faculty who teach the courses in that program. The names of the faculty who represent various POS committees are listed below, along with the detailed descriptions of each POS.

With the consent of their advisor and the relevant POS committee, students may petition to the Graduate Committee (specifically, Prof. Christopher Riesbeck, Associate Chair for Graduate Affairs) to take alternate classes. The petition should include a brief letter of justification, the list of courses which the student intends to take to complete his/her POS, and any relevant information (such as a description of a similar course the student has already taken, including course title, text, instructor, university, and grade received). All courses in the Ph.D. program must be selected in consultation with, and with the consent of, the student's advisor.

The Programs of Study for each Division are described below.
(Note: Not all listed courses are offered every year. The list of courses outlined below is subject to change. Refer to the Department website for the latest course schedule)

5.1 Solid-State and Photonics – SSP

Faculty: Prem Kumar (Division Head), Matthew Grayson, Seng-Tiong Ho, Xu Li, Chang Liu, Hooman Mohseni, Martin Plonus, Manijeh Razeghi, Selim Shahriar, Allen Taflove, Bruce Wessels, Horace Yuen

The courses in this area are divided into Core Courses and Area Specific Courses as follows:

Core Courses (Group A)

Each student is required to take **five** of the following **ten** core courses:

EECS 382	Photonic Information Processing
EECS 383	Fiber-Optic Communication
EECS 388	Microelectronic Technology
EECS 401	Fundamentals of Electronic Devices

EECS 402	Advanced Electronic Devices
EECS 403	Quantum Semiconductors
EECS 404	Quantum Electronics
EECS 405	Advanced Photonics
EECS 406	Nonlinear Optics
EECS 408-1	Classical Electrodynamics

Area Specific Courses (Group B)

Elective courses in Solid-State and Photonics include:

EECS 333	Introduction to Communication Networks
EECS 381	Electronic Properties of Materials
EECS 384	Solid-state Electronic Devices
EECS 385	Optoelectronics
EECS 386	Computational Electromagnetics and Photonics
EECS 407	Quantum Optics
EECS 408-2	Computational Electrodynamics
EECS 409	Semiconductor Lasers
EECS 422	Random Processes in Communications and Control I
EECS 423	Random Processes in Communications and Control II
EECS 424	Noise and Fluctuation in Physical/ Engineering Systems
EECS 425	Quantum Electronics II–Noise, Modulation, and Quantum Properties of Laser Emissions
EECS 427	Optical Communications
EECS 428	Information Theory
EECS 429	Selected Topics in Quantum Information Science and Technology
EECS 454	Advanced Communications Networks
ESAM 411	Differential Equations of Mathematical Physics

In consultation with their advisors, students can also take advanced courses (400-level) in Applied Mathematics, Physics and Astronomy, and Materials Science and Engineering, to fulfill the requirements of the Area Specific Courses.

Course Requirements for Ph.D. Degree Students with M.S. Degree or equivalent

A student granted 9 units of credit for an M.S. degree must take at least 6 units of coursework from the above lists, at least 5 of which are from the Core Courses, and 4 should be at the 400- or 500-level, excluding 545 and 546.

Course Requirements for Ph.D. Degree Students without M.S. Degree or equivalent

Typically students take three courses per quarter, or 27 units total. Of those units, a minimum of 15 are required to be coursework. These fifteen (15) units may include EECS 499 units, EECS 510 units, and one EECS 545 unit. The student must take at least 8 units of coursework at the 400- or 500-level excluding 545 and 546.

Ph.D. Program of Study (POS) Evaluation

For PhD students in Photonics subgroup, POS evaluation will be made by the Solid-State and Photonics POS Committee, appointed by the division director, on the basis of the following criteria: (1) the student's performance in coursework, (2) the student's performance in research, and (3) an oral exam. The oral examination requirement can be bypassed if so deemed by the student's advisor. The oral examination is conducted by a team selected by the POS committee and consists of at least three faculty members with expertise in the examination area. Some of the committee members can be faculty members from outside the EECS Department. The exam is offered once a year and students must sign up for the exam with the director of the POS committee. A student will be given two attempts to pass the POS Evaluation. However, each student must get the POS Evaluation done by the end of the student's second year in order to continue in the Ph.D. program. Extension of this deadline for up to one year will be granted by the division director if requested by the student's adviser. In addition to the POS evaluation, the student must get a thesis prospectus approved by the end of the fourth year. The procedure for this approval is as follows. The student will select three faculty members, one of which must be his/her adviser, for the thesis committee. The student will produce a written proposal, and make a presentation to this committee. Following an evaluation of the written proposal and the performance of the student during the presentation, the committee will decide on approving the prospectus. A student will be given two attempts to receive the approval.

SSE Option

POS evaluation for the PhD students in the Solid-State subgroup will be a part of the qualifying exam. The student's advisor approves the exam and selects the qualifying exam committee members from the experts in the field. At least three committee members are from the EECS department. The committee evaluation is based on the student's performance in coursework, the oral presentation, and a written proposal detailing the future research plans. The qualifying exam must be approved no later than the beginning of the fifth year of study.

5.2 Computer Engineering & Systems – CES

Faculty: Alok Choudhary (Division Head), Fabian Bustamante, Yan Chen, Robert Dick, Peter Dinda, Larry Henschen, Yehea Ismail, Russ Joseph, Aleksandar Kuzmanovic, Wei-Chung Lin, Gokhan Memik, Seda Ogrenci Memik, Alan Sahakian, Peter Scheuermann, Chi-Haur Wu, Hai Zhou

Computer engineering and systems research is a broad area with the essential goal of discovering the principles, methods, and abstractions needed to understand, construct, and enhance software/hardware systems. These systems are simultaneously the key enablers of the modern world and among the most complex artifacts created by man. Specific current areas of interest at Northwestern include: computer architecture, operating systems, high performance I/O, compilers, embedded systems, databases, VLSI design and CAD, networking, reconfigurable systems, distributed systems, robotics, parallel systems, computer vision, performance analysis, and security.

The division offers a Ph.D. in ECE and a Ph.D. in CS, with differing requirements, which are presented below. Students should speak with their advisor about which course of study is most appropriate for their interests and goals. This document covers the ECE degree first and then the CS degree.

Program of Study for ECE

The following is a summary of the ECE program of study.

You should be involved in directed research with your advisor from your first quarter. The bulk of your training consists of "learning by doing." The following describes coursework that you should do beyond this core training.

You must take the following two core courses:

EECS 361: Computer Architecture

EECS 336: Design and Analysis of Algorithms

In addition, you must choose three of the following six tracks and take at least two courses from each chosen track. EECS 361 and EECS 336 can help fulfill the track requirement. A course that is listed in two different tracks can fulfill both track requirements.

A. Digital Design & VLSI

- EECS 303 Advanced Digital Logic Design
- EECS 357: Introduction to VLSI CAD
- EECS 391: VLSI Systems Design
- EECS 346: Microprocessor System Design
- EECS 459: VLSI Algorithmics
- EECS 393/493: High Performance Issues in VLSI Circuits

B. Architecture

- EECS 361: Computer Architecture
- EECS 452: Advanced Computer Architecture
- EECS 453 Advanced Computer Architecture II

C. Software and Data Engineering

- EECS 351: Introduction to Computer Graphics
- EECS 322-1: Compiler Construction I
- EECS 339: Introduction to Database Systems
- EECS 343: Operating Systems
- EECS 455: Distributed Computing Systems
- EECS 467 Parallel and Distributed Database Systems

Other 300- and 400- level courses from the EECS department in the software area can fulfill software track requirements (with the consent of the advisor).

D. Parallel and Distributed Computing

EECS 356:	Introduction to Formal Specification and Verification
EECS 358:	Introduction to Parallel Computing
EECS 455:	Distributed Computing Systems
EECS 333:	Introduction to Communication Networks
EECS 467	Parallel and Distributed Database Systems
EECS 453	Advanced Computer Architecture II

E. Numerical Computing

EECS 328:	Numerical Methods for Engineers
EECS 479-1,2:	Nonlinear Optimization
ESAM 446-1,2,3:	Numerical Solution of Partial Differential Equations

F. Algorithms

EECS 459:	VLSI Algorithmics
EECS 457	Advanced Algorithms
IEMS 452:	Combinatorial Optimization
IEMS 457:	Integer Programming
EECS 336:	Design and Analysis of Algorithms
EECS 332:	Digital Image Analysis
EECS 390:	Introduction to Robotics
EECS 435:	Neural Networks

Qualifying Examination for Admission to Candidacy and Thesis Process in ECE

The Ph.D. Qualifying Exam is taken after all course work is completed and preliminary results have been obtained, in agreement with the student's advisor. This examination may cover courses taken both in and out of the Department, though emphasis is normally on the student's specialty area and the proposed thesis research. The examiners must receive the thesis proposal at least seven days prior to the Qualifying Examination.

The student's oral Qualifying Examination Committee is appointed by the Dean of the Graduate School upon the recommendation of the Department Chair and shall be composed as follows:

1. There will be at least three members who currently have full-time faculty appointments at Northwestern University. At least two of these must be faculty members of the EECS Department. At least two (including the chair) must be members of the Graduate Faculty of Northwestern.

2. With the approval of the Department Chair, there may be one additional voting member of the committee from outside the University. This person should be an expert in

the area of the student's research. The Department Chair may request a resume from this outside member before the appointment.

3. Others may be invited to attend the examinations as non-voting members of the committee.

If a Ph.D. candidate changes his/her advisor and/or research topic after taking the Ph.D. Oral Qualifying Examination, the student may be required to take another oral examination on the new research topic.

Admission to Candidacy (ECE)

Admission to candidacy for PhD students in Computer Engineering is determined during the quarter following the fourth quarter of course registration. Students who have taken at least six graded coursed by the end of their fourth quarter may request an examination of academic record to decide admission to candidacy. If the GPA for all graded courses is 3.5 or higher, the student will be admitted to candidacy. If the GPA is less than 3.5, the student may request an oral exam conducted by a committee of three professors associated with the Computer Engineering program. This exam must be held during the quarter following the student's fourth quarter of registration. Students who pass this oral exam will be admitted to candidacy; students who fail will be excluded from the PhD program in Computer Engineering.

Approval of Prospectus (ECE)

By the end of their fourth year of study, Ph.D. students must propose a topic of doctoral study. A committee of three or more, three of whom are members of the Northwestern University Graduate Faculty, will evaluate the proposal. The proposal consists of an open public presentation and a written proposal. If requested by the committee, it will also contain a closed oral exam held after the presentation. At least three of the committee members must attend the presentation. Related previous work by the student and other researchers should be presented. The presentation should also describe topics for future work that is expected to culminate in a Ph.D. Thesis. A week before the presentation, the committee members must be provided with a written proposal corresponding to the presentation.

Students may petition for exceptions to the above deadlines if there are extenuating circumstances.

Process and Requirements for Computer Science Systems Ph.D. Students[1]

The purpose of this document is to outline the process and requirements for earning a Northwestern Computer Science (CS) Ph.D. in Systems in the Computer Engineering and Systems (CES) division of the Electrical Engineering and Computer Science (EECS)

[1] This is a living document and is subject to change. The latest version is available on http://nsrg.cs.northwestern.edu.

Department, and to demystify elements of graduate student life within the group and the department. Please consult your advisor if you don't understand anything here.

Overall Process and Model (CS)

After being admitted to the program, you may visit Northwestern to get a sense of the possibilities here. It is very important that you find at least one faculty member with whom you would like to work.

The first thing that you should do after you arrive is to start looking for an advisor. ***Your advisor is of critical importance***. He or she will guide you, help you, fund you, and defend you. We believe in the ***apprenticeship model*** of Ph.D. education. How you learn to do research and your style and taste in problems will be formed in large measure by your advisor. Choose wisely. Although it is always possible to change your advisor later, you can lose valuable time in doing so. Advisors have different styles, but it is common to meet once a week with your advisor to talk about research.

In choosing an advisor, you should talk to any faculty member who interests you. The Department typically runs a "Meet the Faculty" series that is helpful. However, you should take the initiative right away. Generally, you should find an advisor by the end of the fall quarter (your first quarter). The remainder of this document assumes you have chosen a faculty member in the Systems Group[2] as your advisor.

By the beginning of your second quarter, you should be starting to engage in research. In your first year or two, you will also be taking classes, but ***doing research is the critical to your success as a graduate student***. Throughout your graduate student years, at least 50% of your time should be spent on research. ***The whole point of a Ph.D. in CS is to become a good, independent researcher***. The only way to learn how to do research is to do research under the guidance of your advisor and other faculty members. You also want to determine very quickly whether research is for you. Remember, you are not in graduate school to take classes.

At the end of your first or second year, you will take the systems qualifying exam, which is described in detail below. The next step after the qualifying exam is to find a thesis topic. This can take some time and it is easy to get lost during the process. This makes it all the more important to work with your advisor. One you have a good topic, you will embark on the thesis process as described below.

It is important to note that the Department and the Graduate School also have requirements that need to be abided by. Here is a summary of how certain milestones map:

- The qualifying exam maps to "Admission to Candidacy." Either an "unqualified pass" or a "qualified pass" on the exam is immediately reported to the Graduate school so that the student is immediately admitted into Ph.D. candidacy.

[2] Broadly defined, this is the group of faculty who advise students for a Ph.D. according to this document. This currently includes Bustamante, Chen, Dinda, Kuzmanovic, and, for some students, Horswill and Dennis.

- The thesis proposal defense maps to “Approval of Prospectus.” A successful thesis proposal defense is immediately reported to the Graduate School as an approved prospectus.
- The thesis defense maps one-to-one. A successful defense is reported as such, and the student is allowed to file his dissertation with the Graduate School (and as a departmental technical report).

The target duration for the Ph.D. process is five years.

Importance of self-motivation and initiative

A Ph.D. student is expected to be strongly self-motivated. Unlike undergraduate school or a masters program, Ph.D. level study involves long periods where the primary driver is the student himself. The search for the thesis topic is the most critical of these periods.

A Ph.D. student is also expected to increasingly take the initiative in research as he or she progresses in the program. By the thesis proposal, and ideally well before, the student should feel comfortable suggesting research directions, disagreeing with literature, and taking on side projects.

Lab expectations

Systems research necessarily involves computers and networks, often many of them. This research infrastructure does not manage or configure itself, nor does the systems support group support all aspects of research computing. Systems students are expected to help in configuring, updating, and maintaining the infrastructure for the Systems group’s overall benefit.

Understanding funding

Students in the Northwestern EECS Department are funded during the academic year through university fellowships, external fellowships, teaching assistantships (TA), and research assistantships (RA). ***Funding depends on adequate progress toward the Ph.D. and available funding sources. It is not guaranteed.***

University fellowships, such as Murphy and Cabell, typically apply only to first year students. These funds are generally provided, in a department-level competition, on the basis of the perceived quality of the incoming students and the policies of the Graduate School. After the thesis proposal, the Dissertation Year Fellowship and other fellowships may apply. External fellowships, such as the NSF, NASA, and DOD Graduate Fellowships and others, are awarded directly to students and provide the maximum flexibility. ***We highly recommend that students take the initiative in seeking external funding.*** It provides maximum flexibility to the student and will also be rewarded by the systems group.

Teaching assistantships can fund students at any stage in the career. TAships are distributed according to a department-level competition and generally require that the student teach. The time involved in TAing a course should not exceed 20 hours a week on average.

Note on teaching requirements and time: Independent of funding, all EECS Ph.D. students are expected to be involved in teaching to some extent. In addition to TAing a course, a student can also be a Teaching Trainee (TT). A student must be a TA for 3 quarters, a TA for 2 quarters and a TT for 1 quarter, or a TT for two quarters. Teaching can become a time sink, but it should not be. ***If you find that you are spending more than 15 hours per week on average TAing or TTing a course, immediately inform your advisor so that he or she can help you fix the situation.***

Research assistantships are funding that is provided as part of a research grant, generally your advisor's grant, and generally a grant from the federal government. If you are funded from an RAship, the expectation is that ***you will do, in part, research and development related to the grant,*** as determined by your advisor. There is generally a very workable situation as you hopefully share at least some of your advisor's interests and those interests are partially reflected in the grant and its work. Many advisors are extremely happy when students take the initiative in suggesting work to be done while funded on an RAship.

New faculty members generally have some degree of student support as a part of their startup packages. This takes the form of some combination of RAships, Fellowships, and TAships.

There are no fellowships (other than perhaps external fellowships) or TAships during the summer months. ***Summer funding derives almost entirely from RAship funding and is not guaranteed. The expectation is that students funded during the summer will work full time on the research of the underlying grant.***

Students are encouraged to seek out summer funding of their own in the form of internships at quality research laboratories. Students who are interested in doing a summer internship must take the initiative in finding appropriate opportunities. Generally, this must be done in January.

Acquiring Breadth in Computer Science beyond Systems

Good systems researchers understand the big picture of computer science and related fields such as electrical and computer engineering. You should not embarrass yourself or Northwestern by lack of this basic knowledge. Before taking qualifiers, you should have taken at least one course in each of the following areas. We list here courses from the EECS department. We also strongly suggest that you examine the department's undergraduate computer science curriculum document for a deeper explanation of what we mean by breadth and depth in computer science. With the consent of your advisor, you may substitute other courses, including 495s and 499s.

- Theory: EECS 310, 328, 336, 356, 357, 457, 459, 495(Current Topics), 495 (Bioinformatics), 495 (e-Commerce); MATH 374. We strongly recommend that students become familiar with algorithms at least to the level of EECS 336.

- Artificial Intelligence: EECS 325, 337, 344, 348, 349, 360, 495 (AI for interactive entertainment,) 495 (Knowledge Representation). We strongly recommend that students become familiar with core AI and machine learning topics as described in 348 and 349.

- Interfaces: EECS 330, 332, 351, 352, 370, 395 (Intermediate computer graphics), 395 (Advanced computer graphics), 495 (Computer animation), 495 (Graphics and perception), 495 (Image-based modeling and rendering), 495 (Human-centered product design)

A student may already have satisfactory background in these areas, either through general knowledge or having taken similar courses at other universities. If the student feels he has satisfied any of these areas, he is encouraged to approach the relevant course coordinator for an assessment, or his advisor if the coordinator is unable to provide an assessment.

Acquiring Breadth in Computer Systems

A systems researcher in some specific area should be familiar with work in other areas of computer systems. The expectation for students is that they have deeper knowledge of systems in general than of computer science as a whole. Each area is listed with appropriate corresponding Northwestern introductory and advanced courses. All EECS systems courses have online syllabi and the advanced courses have online reading lists. You should familiarize yourself with their contents. You need not have taken these specific courses, but you should be familiar with their concepts and content.

We expect that you will take at least six courses in the following areas. You must take at least one course in each of Operating Systems, Networking, and Compilers, unless, for some reason, appropriate courses are not offered. You may already have satisfactory background in these areas, either through general knowledge or having taken similar courses at other universities. If you feel you have satisfied any of these areas, you are encouraged to approach the relevant course coordinator for an assessment, or your advisor if the coordinator is unable to provide an assessment.

Architecture: EECS 361 (452, 453)

Operating Systems: EECS 343 (441, 443)

Distributed Systems: EECS 345 ()

Parallel Systems: EECS 358 ()

Real-time Systems: EECS 397 ()

Compilers: EECS 322 ()

Languages: (no current courses)

Networking: EECS 340 (440)

Performance Analysis: (EECS 410, 442, 486)

Databases: EECS 339 (464)

Security: EECS 350 (450)

Note that there are typically also several additional 395 and 495 courses that may be appropriate for systems depth. Additionally, 499 courses may be used with advisor approval.

Depth in Systems

How to acquire depth in your area will be determined by your advisor. Generally, it takes the form of taking additional graduate level courses and doing guided research and reading. By the end of your second year, we expect that you will have made research contributions.

Qualifiers

The purpose of the systems qualifying exam is to determine whether you have the essential prerequisites of being a doctoral level researcher, namely:

Have you acquired a breadth of knowledge in computer science and computer systems?

Do you have a depth of knowledge in your research area?

Can you do research?

Can you present your research well, both in written form and orally?

Can you defend your research?

Can you think and discuss research extemporaneously? In other words, can you think on your feet?

If you do not meet these prerequisites, you will not pass the exam. In some cases, such as if you fail due to insufficient breadth or depth, a student may be able to retake the exam. The exam can be retaken only once.

What You Should Expect

You should ask your advisor if you are prepared to take the systems qualifying exam. If he or she agrees, you should form a committee consisting of your advisor and at least two other systems faculty members. Non-systems faculty are also appropriate in some situations: you should ask your advisor. It is your responsibility to schedule the exam and reserve a conference room for it. Exams have no set length, but past exams have taken from 2 hours to 6 hours. Exams are private: only your committee and you are in the room.

The exam will begin with your presentation of a significant piece of research that you have done. *One week before the exam, you must supply the committee with a paper about the work.* A conference or workshop talk/paper is ideal. The committee will ask you tough questions about the content of the presentation and the work. The purpose of this part of the exam is to determine whether you are capable of doing research, presenting it, and defending it well.

In the next stage of the exam, each of your committee members will have the opportunity to ask you questions. Any technical question related to computer science is fair, however the focus will be on systems. Many faculty members prefer to start with a question designed to test your breadth or depth of knowledge in computer science. The committee may follow up on such questions, probing to find out what you know and what you don't know. The committee is particularly interested in how you respond to questions in areas you don't know or that you don't know the answer to. This is a common situation in doing research and the committee wants to know how you respond to it. It is appropriate and encouraged to ask questions of the committee. The committee also wants to see how you respond in an intellectual dialog.

After the exam, the committee will deliberate and write you a formal letter. Four outcomes are possible:

- **Pass.** You did great.
- **Conditional Pass**. You did OK. The letter will explain what you need to do to improve and the process by which you and your advisor will make it happen.
- **Fail With Possibility Of Retake**. You failed, but the committee thinks there is hope for you. The letter will outline what you need to do before you retake the exam.
- **Fail Without Possibility of Retake.** You failed and the committee does not believe you will ever pass.

All members of the committee will receive a copy of the letter.

If the outcome is Pass or Conditional Pass, we will immediately tell the graduate school that you should be "admitted into candidacy".

What You Should Know

Breadth of Knowledge in Computer Science. This is described above.

Breadth of Knowledge in Computer Systems. This is described above.

Depth of Knowledge in Systems. This is described above.

Programming. Good systems researchers build systems; they don't just talk about or simulate them. You must know at least one low-level systems programming language such as C or C++. You must know at least one high-level application programming language such as Java, Perl, Python, Scheme, Lisp, ML, or Matlab. If you haven't written a 1000+ line program in the language, you don't know it. If you haven't programmed on a multi-person project, you haven't programmed. You should look at the web sites of the various labs that comprise the systems group to get a sense of the level of programming you should be up to.

Thesis Process

The point of the thesis process is to demonstrate that you can independently come up with a significant new research question, do the research necessary to answer it, write compellingly about the question, your research, and the answer, and defend it all. Successfully completing the thesis process earns you the Ph.D. and hence establishes you as a person who can successfully conduct independent research.

The thesis process generally takes from one to two years to complete.

Committee

The thesis is judged by a committee that is chosen by the student in consultation with the student's advisor. The committee commits to reading and commenting on the thesis proposal, attending the thesis proposal defense, providing guidance and advice as the thesis work progresses, reading and commenting on the dissertation, and attending the thesis defense.

The committee must consist of at least three faculty members in the EECS Department that are also faculty in the Graduate School and at least one external committee member. The committee must include the student's advisor, who is generally the chair of the committee. In most cases, the faculty member should be drawn from the systems group, although exceptions can be made. The external committee member should be from outside Northwestern and should hold a Ph.D. Exceptions can be made in consultation with the student's advisor, but a member external to the EECS Department is required.

It is the responsibility of the student to form the committee and to schedule it for the proposal and dissertation defenses.

Proposal

The thesis proposal is a document written by the student that describes the proposed thesis. It must contain:

- Thesis statement. What is the specific research problem being addressed and what is the proposed solution?
- Related work. What have other people done in this area and why is the proposed solution new?
- Prior work. What work has the student done already that suggests that he is capable of addressing the problem?
- Work plan. What the student proposes to do. Of course, research often takes one in unplanned directions. The point of the work plan (and schedule) is to describe what path is currently expected.
- Expected contributions. What artifacts and results are expected?
- Schedule. When will the major elements of the work plan be completed? Notice that writing the dissertation is an important task.

A thesis proposal is generally 10-15 pages long and prepared in consultation with the advisor.

The proposal must be given to the members of the committee and posted in written form in a public place in the department at least one week before the proposal defense. It is not necessary to make the proposal available online.

Proposal Defense

The proposal defense is a open, advertised, public talk, given in front of the committee and any members of the EECS department who care to attend. The open segment of the proposal defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all his committee members are there physically or via phone conference. The student must assure that the proposal defense is advertised to the EECS department at least one week before it occurs. It will specifically be posted as a thesis proposal talk.

The talk is a summary of the thesis proposal and a defense of its ideas. It's the final sanity check before the thesis work begins and is very important.

Generally, a proposal talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished with public questions, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions, or raise other private concerns.

The student will then leave the room and the committee will determine whether the student as passed or failed the proposal defense. The student will be informed whether he has passed or failed on the day of the proposal defense. In either case, the chair of the committee will write a formal letter to the student describing the results and what additional work, if any, is to be done. All members of the committee will be given a copy of the letter.

If the student passes the thesis proposal defense, we will immediately inform the Graduate School that the student's "thesis prospectus has been approved".

All But Dissertation

After a successful proposal, the student will carry out the work described in the proposal, modifying his research plan in consultation with the committee, and, most importantly, his advisor.

Dissertation

A dissertation is a book describing the work carried out during the thesis process and its questions and results. It must be well written and stand on its own.

The dissertation document must be complete, in draft form, before the dissertation defense can take place. It must be provided to the members of the committee at least one week before the defense is to take place. Generally, the student will have his advisor read and comment on the draft well before then.

A summary of the dissertation (generally 10-15 pages) must be posted in a public place in the department at least one week before the defense is to take place.

Dissertation Defense

The procedures for the dissertation defense are similar to those of the proposal defense. The defense is an open, advertised, public talk, given in front of the committee and any members of the EECS department who care to attend. The open segment of the defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all his committee members are there physically or via phone conference. The student must assure that the defense is advertised to the EECS department at least one week before it occurs. It will specifically be posted as a thesis defense talk.

The talk is a summary of the thesis work and a defense of its ideas and results.

Generally, a defense talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished with public questions, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions, or raise other private concerns.

The student will then leave the room and the committee will determine whether the student as passed or failed the dissertation defense. In either case, the chair of the committee will write a formal letter to the student describing the results and what additional work, if any, is to be done. All members of the committee will be given a copy of the letter.

If the student passes the thesis defense, we will immediately report this to the Graduate School. At this point, the student needs only to deliver the final version of his dissertation in order to graduate.

Wrap Up

After a successful defense, the committee will, within 2 weeks, send comments on the dissertation draft to the student. The student will then complete any additional work and make the necessary changes to his dissertation. The student must deliver his final dissertation in two ways. First, he must turn it in to the library. Second, he must publish it as a EECS department technical report.

The purpose of publishing the dissertation as a technical report is to make it widely available to the public.

5.3 Computing, Algorithms, & Applications – CAA

Faculty: Ming Kao (Division Head), Yan Chen, Lance Fortnow (arriving January 2008), Jason Hartline (arriving January 2008), Nicole Immorlica (arriving Fall 2008), Jorge Nocedal, Peter Scheuermann, Allen Taflove, Hai Zhou

Research Scope and Opportunities in the Division

Research in this division focuses on computation theory and algorithms, and their implementations and applications.

Current research areas include: bioinformatics, computational economics and finance, continuous and discrete optimization, database algorithms, formal methods, networking algorithms, security algorithms, self-assembly, and VLSI CAD algorithms.

Overall Schedule and Model of the Ph.D. Study Process

You are generally expected to finish your Ph.D. study in 4 years. Generally, you should make every effort to follow the following schedule:

1. find a faculty member to be your Ph.D. advisor no later than the end of the spring quarter of your 1st year, but preferably by the end of the fall quarter of the 1st year;
2. take courses during the first two years;
3. pass the qualifying exam by the end of the 2nd year;
4. pass the Ph.D. thesis proposal defense by the fall quarter of the 3rd year;
5. complete the writing of your Ph.D. thesis by the end of the winter quarter of the 4th year; and
6. defend your Ph.D. thesis during the spring of the 4th year.

The choice of an advisor is of critical importance. Your research career will be greatly influenced by your advisor. In choosing an advisor, you should take the initiative to discuss with any faculty member who interests you upon your joining Northwestern or even before then. Generally, you should find an advisor by the end of the fall quarter (your 1st quarter). The remainder of this section assumes you have chosen a faculty member in the CAA Division as your advisor.

Preferably by the beginning of your 2nd quarter, you should proactively engage in research. In your first year or two, you will also be taking classes, but doing research will determine your success as a graduate student. Throughout your graduate student years, two thirds of your time should be spent on research. The objective of Ph.D. study is to become a good independent researcher. Except in extremely rare cases, the most effective way to learn how to do research is to do research under the guidance of your advisor and other faculty members.

By the end of your 2^{nd} year, you will take the CAA Division qualifying exam, which is described in detail below. The next step after the qualifying exam is to find a Ph.D. thesis topic. This can take some time and it is easy to get lost during the process. This makes it all the more important to work with your advisor. Once you have a good topic, you will embark on the Ph.D. thesis process as described below.

Acquiring Breadth in Computer Science

Good researchers understand the big picture of not only their own research areas but also related fields. Before taking the CAA qualifying exam, you should have taken at least two courses in the following three areas in Computer Science:

- at least one from Computer Engineering and Systems, and
- at least one from Cognitive Systems or Graphics and Interactive Media.

With the consent of your advisor, you may substitute other courses. You may also be able to “test out” of areas; see the course coordinator if you are interested. You must submit a computer science breadth requirements form to the graduate coordinator to document your fulfillment of these requirements.

- Cognitive Systems: EECS 325, EECS 337, EECS 344, EECS 348, EECS 366, EECS 430**.**
- Computer Engineering and Systems: EECS 322, EECS 339, EECS 340, EECS 343, EECS 344, EECS 350, EECS 440, EECS 441, EECS 442, EECS 443, EECS 450, EECS 464, EECS 510-4**.**
- Graphics and Interactive Media: EECS 330, EECS 351.

Acquiring Breadth in Computing, Algorithms, and Applications

The expectation for CAA students is that they have deeper knowledge of computation theory and algorithms than that of EECS as a whole. Each area below is listed with appropriate corresponding Northwestern introductory and advanced courses. These courses have online syllabi, and some have online reading lists. You should familiarize yourself with the contents of those syllabi and reading lists.

You must take at least 6 courses in the following areas. You also must take at least one course in each of Computational Complexity, Continuous Optimization, and Discrete Algorithms. You may be able to “test out” of areas; see the course coordinator if you are interested. You must submit the CAA breadth requirements form to the graduate coordinator to document your fulfillment of these requirements.

- Computational Complexity
- Continuous Optimization:

    EECS 479 Nonlinear Optimization

- Discrete Algorithms:

    EECS 336 Design and Analysis of Algorithms

    EECS 457 Advanced Algorithms

- Databases:
  - EECS 339 Introduction to Database Systems
  - EECS 467 Parallel and Distributed Database Systems
- Networking and Security:
  - EECS 340 Introduction to Computer Networking
  - EECS 440 Advanced Computer Networking
  - EECS 350 Introduction to Computer Security
  - EECS 450 Internet Security
- Scientific Computing:
  - EECS 328 Numerical Methods
  - ESAM 446 Partial Differential Equations (Parts 1 and 2)
- VLSI CAD:
  - EECS 357 Introduction to VLSI CAD
  - EECS 459 VLSI Algorithmics
  - EECS 356 Introduction to Formal Specification and Verification
- Mathematics, Probability, and Statistics:
  - IEMS 303 and 304 Statistics 1 and 2

Acquiring Depth in Computing, Algorithms, and Applications

How to acquire depth in your research area will be determined by your advisor. Generally, it takes the form of taking additional graduate courses and doing guided research and reading. By the end of your 2nd year, we expect that you will have made research contributions.

Qualifying Exam

The purpose of the CAA Division Qualifying Exam is to determine whether you have the essential prerequisites of being a doctoral-level researcher, namely:

> *Have you acquired a breadth of knowledge in computer science and computing, algorithms, and applications?*
>
> *Do you have a depth of knowledge in your research area?*
>
> *Can you do research?*
>
> *Can you present your research well, both in written form and orally?*

If you do not meet these prerequisites, you will not pass the exam. In some cases, such as if you fail due to insufficient breadth or depth, you may be able to retake the exam. The exam can be retaken only once.

You should ask your advisor if you are ready to take the CAA Division Qualifying Exam. If your advisor agrees, you should form a Qualifying Exam Committee consisting of your advisor and at least two other CAA faculty members. Non-CAA committee members from outside the CAA Division, the EECS Department, or the University are also appropriate in some situations with consent by your advisor. Exams will typically take two hours. Exams are private. Only your committee and you are in the room.

The exam will begin with your presentation of a significant piece of research you have done. Fourteen days before the exam, you must supply the committee with a paper about the work. A workshop, conference, or journal paper is ideal. The committee will ask you tough questions about the content of the presentation and the work. The purpose of this part of the exam is to determine whether you are capable of doing research, presenting it, and defending it.

In the next stage of the exam, each of your committee members will have the opportunity to ask you questions. Any technical question related to computer science is fair; however the focus will be on CAA areas. Many faculty members prefer to start with a question designed to test your breadth or depth of knowledge in computer science. The committee may follow up on such questions, probing to find out what you know and what you do not know. It is appropriate and encouraged to ask questions of the committee. The committee also wants to see how you respond in an intellectual dialog.

After the exam, the committee will deliberate and write you a formal letter. Four outcomes are possible:

- **Pass**. You have done great.
- **Pass with conditions**. You did OK. The letter will explain what you need to do to improve. Satisfying the conditions remains required for satisfactory academic progress.
- **Fail with Possibility of Retake.** You failed, but the committee thinks there is hope for you. The letter will outline what you need to do before you retake the exam.
- **Fail without Possibility of Retake**. You failed and the committee does not believe you will ever pass.

All members of the committee will receive a copy of the letter.

If a student changes his/her advisor after passing the qualifying exam, the new advisor may require the student to take another qualifying exam. Similarly, if a student changes his/her research topic after passing the qualifying exam, the advisor may require the student to take another qualifying exam on the new topic.

Thesis Research Process

The objective of the Ph.D. thesis research process is to demonstrate that you can independently formulate a significant new research question, conduct the research necessary to answer it, and compellingly defend, promote, and publish your results. Successfully completing the Ph.D. thesis earns you a Ph.D. degree and hence establishes you as a person who has accomplished the above objective.

Thesis Committee

The Ph.D. thesis is judged by a committee chosen by the student and the student's advisor. The committee commits to reading and commenting on the Ph.D. thesis proposal, attending the Ph.D. thesis proposal defense, providing guidance and advice as the Ph.D. thesis work progresses, reading and commenting on the Ph.D. thesis, and attending the Ph.D. thesis defense.

The committee is chaired by the student's advisor and must consist of at least three internal members from the tenured or tenure-track faculty of the EECS Department and at least one external member from outside the EECS Department or the University. The internal committee members are usually, but not always, drawn from the CAA Division.

Thesis Proposal, aka Prospectus

The Ph.D. thesis proposal is a document written by the student that describes the proposed Ph.D. thesis. It must contain:

- Thesis statement. What is the specific research problem being addressed and what is the proposed solution?
- Related work. What have other people done in this area and why is the proposed solution new?
- Prior work. What work has the student done already that suggests that she or he is capable of addressing the problem?
- Expected contributions. What artifacts and results are expected?
- Work plan and schedule. What major tasks does the student plan to do? When will they be completed? Of course, research often takes one in unplanned directions. The point of the work plan and schedule is to describe what path is currently expected. Also, notice that writing the thesis itself is the most important task of Ph.D. study, is highly time-intensive and energy-intensive, and should be explicitly discussed in the work plan and schedule.

A Ph.D. thesis proposal is generally 10-15 pages long and prepared in consultation with the advisor. The proposal must be given to the Ph.D. thesis committee, and posted in written form in a public place in the Department at least 14 days before the proposal defense.

Thesis Proposal Defense

The proposal defense is an open public talk, given in front of the Ph.D. Thesis Committee and any members of the EECS Department who care to attend. The open segment of the proposal defense is followed by a closed segment attended only by the Committee and the student.

The student must schedule the defense, making sure all committee members are physically present or via phone conference. The student must assure that the proposal defense is advertised to the EECS department at least 14 days before it occurs. It will specifically be posted as a Ph.D. thesis proposal talk.

The talk is a summary of the Ph.D. thesis proposal and a defense of its ideas. It's the final sanity check before the Ph.D. thesis work begins and is very important.

Generally, a Ph.D. thesis proposal talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the Committee, in an order determined by the committee chair, will ask in-depth questions. Once the Committee is finished with public questions, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions, or raise other private concerns.

The student will then leave the room and the Committee will determine whether the student has passed or failed the proposal defense. The student will be informed whether she or he has passed or failed on the day of the proposal defense. In either case, the Chair of the Committee will write a formal letter to the student describing the results and what additional work, if any, is to be done. All members of the committee will be given a copy of the letter.

All But Thesis

After a successful proposal defense, the student will carry out the work described in the proposal, modifying her or his research plan in consultation with the committee, and, most importantly, the student's advisor.

Ph.D. Thesis

A Ph.D. thesis is a book describing the work carried out during the Ph.D. thesis process and its questions and results. It must be well written and be sufficiently self-contained.

The Ph.D. thesis document must be complete, in draft form, before the Ph.D. thesis defense can take place. It must be provided to the members of the committee at least 30 days before the defense is to take place.

A summary of the Ph.D. thesis (generally 10-15 pages) must be posted in a public place in the Department at least 14 days before the defense is to take place.

Thesis Defense

The procedures for the Ph.D. thesis defense are similar to those of the proposal defense. The defense is an open public talk, given in front of the Committee and any members of the EECS Department who care to attend. The open segment of the defense is followed by a closed segment with only the Committee and the student.

The student must schedule the defense, making sure all her or his committee members are present physically or via phone conference. The student must assure the defense is advertised to the EECS department at least 14 day before it occurs. It will specifically be posted as a Ph.D. thesis defense talk.

The talk is a summary of the Ph.D. thesis work and a defense of its ideas and results.

Generally, a defense talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the Committee Chair, will ask in-depth questions. Once the Committee is finished with public questions, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions, or raise other private concerns.

The student will then leave the room and the Committee will determine whether the student as passed or failed the Ph.D. thesis defense. In either case, the Chair of the Committee will write a formal letter to the student describing the results and what additional work, if any, is to be done. All committee members will be given a copy of the letter.

Final Step of the Ph.D. Study Process

After a successful thesis defense, your committee will, within 14 days, send comments on the thesis draft to you. You will then complete any additional work and make the necessary changes to the thesis. You must deliver the finalized thesis by both submitting it to the University Library and publishing it as a departmental technical report. After you have delivered your thesis, congratulations to you and your advisor!

5.4 Cognitive Systems – CSD

Faculty: Ken Forbus (Division Head), Larry Birnbaum, Justine Cassell, Daniel Edelson, Louis Gomez, Kristian Hammond, Larry Henschen, Ian Horswill, Don Norman, Bryan Pardo, Christopher Riesbeck, Uri Wilensky

Students in this category are interested in:

- Understanding how minds work, from a computational perspective
- Creating systems for helping people learn better and perform better, using principles of Cognitive Science.
- Using Artificial Intelligence techniques to create new forms of interactive entertainment.

Courses serve two purposes. The first is to fill any gaps in your Computer Science background, if necessary. (If your undergraduate major was something other than Computer Science, or had significant gaps, C-level courses provide a means of catching up.) The other purpose of courses is to help you explore new areas. Your course work will vary depending on your exact interests and your background. Someone deeply interested in Cognitive Science might take a number of courses in Psychology. Someone interested in creating new kinds of educational software might take some of their courses in the School of Education and Social Policy. Someone interested in more applied AI might take some of their courses in human-computer interaction and interface design.

By the time of the qualifying exam, you should be conversant with the material in the following courses:

EECS 325 Artificial Intelligence Programming

EECS 337 Introduction to Semantic Information Processing

EECS 338 Practicum in Intelligent Information Systems

EECS 344 Design of Computer Problem Solvers

EECS 348 Introduction to Artificial Intelligence

EECS 395 Situated Information Retrieval

EECS 395 Knowledge Representation

If you believe you have had equivalent courses before, that is fine, but do not rely on the course titles; please check the specifics of the syllabi and talk to your advisor.

It is crucial to realize that, unlike undergraduate study, graduate school is primarily about research, not courses. We expect you to do well in your courses, naturally. However, we expect you to become involved in research starting in your first year. Independent study projects are a good way to explore what kind of work you want to become involved in, or just to wrap your head around something different if you are already involved in a project. Instead of a Master's thesis, we encourage students to publish research in conferences and journals, starting early in their career.

Qualifying Exam and Admission to Candidacy

The Cognitive Systems qualifying exam is a one-day written exam, traditionally the Monday or Tuesday after Finals week of Spring Quarter. The exam is open-book, open-notes, and graded anonymously. Graduate students must take the exam at the end of their second year. The committee for a student's qualifying exam is determined by the student's advisor and division faculty.

Admission to candidacy is determined by the examination committee, based on the results of the qualifying exam and a review of the student's academic and research progress so far. The result will be either pass or fail. In some cases, a pass will be accompanied by additional requirements for satisfactory academic progress that the student must meet within the following academic year.

Approval of Thesis Prospectus

All graduate students will write a thesis proposal before undertaking serious work on their Ph.D. thesis. The written proposal must be approved by a division-approved thesis committee. After approval, the student must give a public presentation of the thesis proposal.

Final PhD Thesis Defense

Two presentations are required. The actual defense of the thesis is an oral presentation, open only to faculty and other members of the university with PhD degrees. A public presentation of the thesis is required after the defense is passed.

5.5 Signals & Systems – SSD

Faculty: Alan Sahakian (Division Head), Randy Berry, Arthur Butz, Robert Dick, Randy Freeman, Dongning Guo, Abraham Haddad, Michael Honig, Yehea Ismail, Aggelos Katsaggelos, CC Lee, Wei-Chung Lin, Thrasos Pappas, Jack Tumblin, Chi-Haur Wu, Ying Wu, Horace Yuen

Core Courses

All students must take the following four core courses:

EECS 307	Communications Systems
EECS 359	Digital Signal Processing
EECS 410	System Theory
EECS 422	Random Processes in Communication and Control I

Elective Courses

Each student must select three from the following list of seven courses:

EECS 332	Digital Image Analysis
EECS 333	Introduction to Communication Networks
EECS 360	Introduction to Feedback Systems
EECS 378	Digital Communications
EECS 420	Digital Image Processing
BME 383	Cardiovascular Instrumentation
BME 402	Advanced Systems Physiology

Area Specific Courses

In addition, each student must complete a sequence of courses in an area of specialization according to the recommendation of the advisor. These courses may be in Signals & Systems, and other areas. Elective courses in Signals & Systems may include:

EECS 363	Digital Filtering
EECS 374	Introduction to Digital Control
EECS 380	Wireless Communication
EECS 418	Advanced Digital Signal Processing
EECS 420	Digital Image Processing
EECS 421	Multimedia Signal Processing
EECS 423	Random Processes in Communications and Control II
EECS 426	Signal Detection and Estimation
EECS 427	Optical Communications
EECS 428	Information Theory
EECS 432	Advanced Computer Vision
EECS 435	Neural Networks
EECS 454	Advanced Communication Networks
EECS 478	Advanced Digital Communications
EECS 485	Local Area Networks
BME 384	Biomedical Computing
BME 402	Systems Physiology

Ph.D. Program of Study Evaluation

The Signals & Systems Ph.D. program of study evaluation involves a written exam which consists of two parts. The first part of the exam covers Communication Systems (EECS 222 and EECS 307), Signal Processing (EECS 359), Linear Systems (EECS 410), and Probability and Random Processes (Math 310 and EECS 422). All students are responsible for all materials in the first part of the exam. The second part of the exam covers Digital Image Analysis (EECS 332), Communication Networks (EECS 333), Control (EECS 360), Digital Communications (EECS 378), Image Processing (EECS 420), and Instrumentation (BME 383). Each student is responsible for three of the five areas in the second part of the exam.

The Signals & Systems POS evaluation will be done by the Signals & Systems POS Committee on the basis of a student's performance in coursework, research, and the Signals & Systems POS written exam. The exam and corresponding evaluation are offered twice per year, towards the end of the Fall and Spring quarters. Students must sign up for the exam with the EECS Graduate Office. Students can choose between the Fall and Spring exams and they will be given two attempts to pass the evaluation. However, each full-time student must pass the Evaluation by the end of the student's second year to continue in the Ph.D. program. Part time students must pass the exam by the end of their third year.

Prospectus

In the Signals and Systems Division the prospectus is the student's proposal defense. The proposal is a written document describing the student's Ph.D. research topic, with background and prior work and proposed work. The proposal defense is an event during which the student presents the proposal to their Ph.D. committee who then decide whether or not to pass the student either conditionally or unconditionally. Upon passing the prospectus the student then completes the research and writes and eventually defends the Ph.D. thesis.

5.6 Graphics & Interactive Media – GIM

Faculty: Ian Horswill (Division Head), Justine Cassell, Daniel Edelson, Darren Gergle, Louis Gomez, Kristian Hammond, Don Norman, Andrew Ortony, Bryan Pardo, Jack Tumblin, Uri Wilensky

There are no specific required courses for GIM students. However, all GIM students are required to demonstrate proficiency in computer science and other core fields of GIM, specifically:

- Programming (knowledge of programming comparable to CS 111+211+311)
- Theory
    - Fundamental algorithms
    - Computing and complexity theory
- Systems (2 of the following)

    - Operating systems
    - Computer architecture
    - Networking
    - Programming languages
- Graphics or media (e.g. sound processing, games, etc.)
- Cognitive and social systems
  (any course in AI, cognitive science, social science, or learning sciences)
- Experimental methods

Concretely, proficiency means showing knowledge comparable to getting an A in an undergraduate course on the topic at a peer institution, so you will probably be able to pass most or all of it on the strength of your undergraduate transcript. However, you will review your transcript with your advisor to determine if there are any areas in which you haven't already demonstrated proficiency, and if so, identify appropriate courses for you to take. If you entered with an undergraduate degree in computer science, you should complete this work in your first year, otherwise within two years.

Qualifying Exam

Admission to Ph.D. candidacy consists of presenting the results of a small-to-medium-sized, completed research project to an examination committee of three faculty. Although the project may be a component of a larger group project, the work reported on should be yours, not joint work with other students.

You may take it any time you and your examination committee agree on, but it's best to take the exam near the end of your second year. However, the Graduate School requires you pass the exam before the end of your third year.

Paper

For the written component of the qualifying exam, you will submit a mock (or real) conference paper on the project. Although the project need not be published work, you should identify a conference in which the project could plausibly be published and write the paper to be consistent with the submission requirements (length etc) for that conference. The paper submitted to the committee should be a final version that both you and your advisor are happy with. In certain cases, a committee may agree to accept a dissertation proposal in lieu of a completed project. You should submit the paper at least two weeks before the presentation to allow the committee time to read and critique it.

Presentation

The oral component of the qualifying exam consists of a formal presentation of the project, as one might give at a departmental colloquium. You should plan the presentation for 45 minutes, with another 15-45 minutes for questions. The purpose of the oral exam is to probe your analytical and research skills, although the committee may ask whatever questions it feels are appropriate.

Thesis Proposal, aka Prospectus

The next step is to choose a dissertation topic and committee. As a beginning step in writing the thesis, you should write a proposal specifying:

- The topic you wish to address
- Why it's important
- The relevant work that has been done before on the topic
- How you expect your work to improve upon it
- A schedule for the work to be done. This is intended as a planning tool for you to help you make sure your plans are practical. So try to be as realistic as possible. Also, if you intend to work with human subjects, remember to schedule time for the IRB approval process.

Submit the written thesis proposal to your committee. The committee will either approve the proposal or provide feedback on what needs to be modified. There is no oral defense of the proposal. In general, you should start working on your proposal as soon as you identify a good dissertation topic. However, the Graduate School requires that you submit and approved proposal by the beginning of your 5^{th} year.

6. Student Related Activities and Organizations

Institute of Electrical and Electronics Engineers (IEEE)
Faculty Counselor: Professor A. V. Sahakian

The Institute of Electrical and Electronics Engineers (IEEE) is the principal professional society in the electrical engineering profession. It has over 300,000 members, including 38,000 student members. It publishes more than 40 technical journals and sponsors or co-sponsors more than 1,000 scientific conferences and meetings around the world covering all aspects of electrical engineering and related fields. It has a student branch in every major university in the free world that offers an electrical engineering curriculum. The student Branch at Northwestern University is well established and sponsors a number of technical meetings every year. The Department provides an office for the Student Branch. Student members are entitled to receive the monthly publication, Spectrum; subscribe to the special publications of the IEEE technical societies (there are 35); and attend any of the IEEE-sponsored or co-sponsored conferences at substantially reduced rates. Students are encouraged to join the organization. Application forms can be obtained at the Student Branch office, the Department Office, or from Professor Sahakian. (Current basic dues are $30/year.)

Optical Society of America (OSA)
Faculty Advisor: Professor Prem Kumar

The Optical Society of America was founded in 1916 with the mission to increase and diffuse the knowledge of optics and to promote the common interests of and encourage cooperation among scientists, designers, and users of optical apparatus of all kinds. Today there are over 12,500 members worldwide representing 50 countries. Through its sponsorship of conferences, peer-reviewed journals and a monthly optics and photonics news magazine, OSA has emerged as one of the leading and most prestigious organizations serving the optics and photonics community. Northwestern is very active in the OSA with four professors (Ho, Kumar, Razeghi, and Wessels) who are Fellows of the society. The Student Chapter hosts regular meetings with invited speakers, participates in community outreach activities, and sponsors social gatherings for its members. Students are encouraged to join the Student Chapter to become involved with the exciting research activities of the optics and photonics community at Northwestern University.

Beta Tau Chapter of Eta Kappa Nu
Faculty Advisors: Professors A. Taflove and A. V. Sahakian

Eta Kappa Nu is the national electrical engineering honor society. It was founded in 1904 at the University of Illinois and now includes more than one-hundred collegiate and alumnus chapters. Our chapter at Northwestern, Beta Tau, was installed on January 24, 1948. Membership is by invitation to electrical engineering students in the Junior and Senior years of study who show strong promise of success in their chosen field as evidenced by excellence of scholarship and character.

Tau Beta Pi
Faculty Advisor: Professor A. Taflove

Tau Beta Pi is a national scholastic honorary engineering fraternity which recognizes scholastic achievement and character among engineering students. Membership is by invitation to students in their Junior and Senior year of study in the McCormick School. ***http://msgroups.tech.northwestern.edu/tbp/***

Northwestern University Amateur Radio Society (W9BGX)
Faculty Advisors: Professors A. V. Sahakian and A. Taflove

NUARS was formed in 1949 under the auspices of what is today known as the IEEE. In 2003, the club station was upgraded, including erecting a new H.F. seven-element beam antenna. The primary purpose of the club is to give members of the Northwestern community the opportunity to operate an amateur radio while at school. There are also many opportunities for experimental work (including circuit design and fabrication), message handling, working DX (amateurs in distant lands around the globe), award chasing, and antenna experimentation. Facilities are available for transmitting CW, SSB, AM, FM, and digital packet on various amateur frequencies available between 3 and 450 MHz. Membership is open to all Northwestern students, faculty, and staff, although only licensed members may operate the transmitting equipment. Electrical Engineering students with an interest in communications and experimentation are especially encouraged to join.

Female Researchers in EECS (FREECS)
Faculty Advisor: Professor Justine Cassell

The mission of FREECS is to engage in activities and projects that aim to improve the working and learning environments for women in EECS at Northwestern. This includes promoting activities that result in more equal representation of women in EECS such as mentoring, serving as a repository of information about programs, documents and policies of concern to women in EECS, and organizing events that benefit the EECS community as a whole. For more information and to get involved, email the executive board at **nufreecs@gmail.com**.

Graduate Electrical Engineering and Computer Science Society (GEECS)
Faculty Advisor: Professor Alan Sahakian
Graduate Student Liaison: Grace Nijm

GEECS is a graduate student-run organization founded in January 1997. The goal of GEECS is to help foster a sense of community and to provide a venue for social interaction between graduate students and faculty members of the many groups within our department.

Association for Computing Machinery (ACM)
Faculty Advisor: Professor Peter Dinda

The ACM (acm.org) is the oldest society for computer science, having been founded in 1947. It publishes over 40 journals as well as the proceedings of innumerable conferences and workshops. ACM provides steep discounts for student members, allowing them ready access to the state of the art in the field, both in research and practice, through print and the award-winning ACM Digital Library. The Northwestern ACM student chapter (acm.cs.northwestern.edu) was founded in 1996. It provides technical learning opportunities, social activities, and long-term projects. It also has a range of equipment and services available for use in student projects. All of its activities are open to all Northwestern students. ***http://acm.cs.northwestern.edu/***

Systems Reading Group

The Systems Reading Group is an informal group that meets to read and discuss two to three systems research papers every week. We construe "systems" fairly broadly. Anyone involved with Northwestern's computer science and computer engineering areas are welcome to attend. We generally talk for 1-1.5 hours, but people are welcome to come and go as they please. The general protocol is that we round-robin among the people in the group to choose the "paper dictator" of the week. The paper dictator chooses the papers for the week, tells everyone where to find them, and is responsible for leading the discussion of the papers when we meet. No formal presentation of the paper is required. Faculty and systems graduate students can recommend papers if you're not comfortable picking them yourself. Every week, each member of the group should send a short (a paragraph at most) comment/summary of each paper to the mailing list, systems-reading-group-list@cs.northwestern.edu.

Society of Women Engineers (SWE)

The Society of Women Engineers is a national organization dedicated to promoting interest and encouraging women to pursue the fields of science and engineering. SWE gives support, guidance and recognition to women engineers and other engineering students. Today, SWE is a nationally recognized professional, educational, non-profit, service organization. Its student section membership includes graduate and undergraduate female and male engineers. The Northwestern SWE chapter was founded in 1976. The Society of Women Engineers encourages women in engineering and science fields. We work to increase awareness of the opportunities for women in engineering, to help overcome challenges that are encountered, and to increase communication, teamwork and leadership. SWE provides an environment of personal and professional growth to compliment the academic experience. SWE members work on improving their skills in leadership, problem solving and interpersonal relationships. Along with responsibilities come the rewards of accomplishing goals, making a difference in the lives of others, affecting policy at the university and building a network of professional friends. The SWE experience prepares its members to be successful professionals. In addition to building upon previous programs, SWE tries to discover new methods of encouraging and supporting women in engineering. SWE has many activities to help you develop the skills to succeed. ***http://msgroups.tech.northwestern.edu/swe/***

National Society of Black Engineers (NSBE)

The National Society of Black Engineers is a 501(C)(3) non-profit association that is owned and managed by its members. The organization is dedicated to the academic and professional success of African-American engineering students and professionals. NSBE offers its members leadership training, professional development, mentoring opportunities, career placement services and more! NSBE is comprised of more than 300 collegiate, 75 professional and 75 pre-college chapters nationwide and overseas. NSBE is governed by an executive board of college students and engineering professionals and is operated by a professional staff in our World Headquarters located in Alexandria, VA. NSBE with its unique characteristics has accomplished more for Black engineering students than any other organization in the world. The same light that NSBE spreads to students and professionals in the United States is also relevant in African, European, South American, Asian, Caribbean, Canadian, Australian, and Pacific Islander countries for people of color. It is the NSBE leadership's vision that the organization will replicate itself in countries around the world, creating a world network of Black engineers, scientists, and technologists through its international operations. ***http://www.nsbe.org/***

The Graduate Research Seminar in Computer Science and Engineering
Faculty Advisor: Prof. Peter Dinda

The Graduate Thesis Seminar is a place where graduate students in Northwestern's EECS Department can talk about their work and learn how to give good presentations through gentle feedback from faculty and fellow students. Talking about your work can provide a useful forcing function to advance research and giving good talks is a critical skill for computer scientists and engineers. There is also free lunch! Undergraduates are welcome. GRS meets each Wednesday during the school year at noon in Ford’s ITW classroom.
http://geecs.eecs.northwestern.edu/GRS/GRS

7. Laboratory and Computer Facilities

The EECS Department has well-equipped instruction and research laboratories for electronic circuits, digital circuits, solid-state electronics, biomedical electronics, communications, microwave techniques, real-time control systems, holography, fiber-optics, coherent light optics, digital systems design, computer systems (including distributed and parallel systems), security, networking, computer graphics, artificial intelligence, computer vision, and robotics.

In addition, the Department has excellent computing facilities, with most of its computers upgraded in the last three years, and all of its computers linked to Northwestern's ever-evolving high-speed backbone network connection to the internet. Specifically, the Center for Ultra-scale Computing and Information Security has: several Sun Solaris and Red Hat Enterprise Linux workstations: a Sun Enterprise 250 fileserver: a 16-processor IBM SP-2 distributed-memory message-passing multicomputer: an 8-processor IBM J-40 shared-memory multiprocessor: an 8-processor SGI Origin 2000 distributed shared-memory multiprocessor: and, several PCs. These are connected via a high-speed fast Ethernet network.

The Wilkinson Computing Lab includes several powerful Sun and Red Hat Enterprise Linux servers, 28 high-performance Sun Solaris workstations, and 16 Windows XP PCs. A wide variety of graphics, CAD, circuit design/simulation, database, and other software packages are available on these machines.

The TLab ("Teaching Lab") consists of 16 high-end PCs connected to a storage server on a private network. The PCs include powerful graphics cards attached to large LCD displays, dual boot Linux and Windows XP, and are on a private network. They have a wide range of software installed and are used in numerous courses. The TLab can be used for studio instruction. As an adjunct to the TLab, WiFi and camera-enabled Pocket PC handheld computers are available for students to check out for project use with faculty approval.

The Prescience Lab has an IBM e1350 cluster, consisting of 33 dual Xeon nodes on a gigabit interconnect, access to the DOT optical research network via a smaller local e1350 cluster and metro edge router, significant amounts of RAID storage, and a machine/equipment pool for research projects. The Aqua Lab has a 20 node Sun Sparc-based cluster and a 20 node dual Opteron cluster. Collaborations among the Prescience, Aqua, and LIST labs also provide the Northwestern Netbase, a significant router/server infrastructure for high-throughput wide-area network monitoring, trace storage, and analysis. The collaboration also equipment and access to the PlanetLab worldwide distributed systems testbed. The Qualitative Reasoning Group has a very large cluster, the "symbolic supercomputer".

The VLab (“Virtual Lab”) consists of 11 powerful dual Xeon 64 bit server computers, 2 TB of storage, and a private gigabit network. Students and faculty can create their own virtual computers on this hardware. Their virtual computers can run any operating system and they have root access.

The Ford Motor Company Engineering Design Center is our new state-of-the-art teaching facility. New designs will come to life at the center. Presented with real-world problems from clients, students can work their ideas out in the CADD (computer-aided drafting and design) lab and rapid prototyping area located on the sub-basement level, and then move those plans up to the basement-level “factory floor.” The large flexible, barrier-free workspace with its concrete floor is where designs actually get built. Students can use the design prototyping lab and fabrication facilities, which include machinery such as lathes, milling machines and large saws, to build design projects both large and small.

The Ford building also features a vehicle testing area, a mechatronics lab for building circuit boards, a 60-seat classroom, a conference room, research labs, group study rooms, project display areas and a student commons area. Faculty and graduate students from the department of Electrical Engineering and Computer Science have offices on the second and third floors, and labs in the subbasement.

8. Department Faculty

ACADEMIC FACULTY

Randall A. Berry, Associate Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Wireless communication, data networking, and information theory

Larry Birnbaum, Associate Professor; Ph.D., Yale University
Research Interests: systems, artificial intelligence, human-computer interaction, natural language processing, semantics

Fabian Bustamante, Assistant Professor; Ph.D., Georgia Institute of Technology
Research Interests: Experimental systems, with a focus on operating systems, distributed and parallel computing

Arthur R. Butz, Associate Professor; Ph.D., University of Minnesota
Research Interests: Digital signal processing, median and related filtering

Justine Cassell, Professor, joint appointment with the School of Communication; Director, Center for Technology and Social Behavior; Ph.D. University of Chicago
Research Interests: Discourse and dialogue, nonverbal behavior generation and understanding, natural language generation, human-computer interaction, interactive technology for young children, embodied conversational agents

Yan Chen, Assistant Professor; Ph.D., University of California at Berkeley
Research Interests: Computer networking and large-scale distributed systems, network measurement, diagnosis, and security, overlay and peer-to-peer systems

Alok Choudhary, Professor; Director, Center for Ultra-scale Computing and Information Security; Ph.D., University of Illinois at Urbana-Champaign
Research Interests: High-performance computing and storage, compiler and runtime systems for HPC and embedded power-aware systems, parallel data mining and databases

Robert P. Dick, Assistant Professor; Ph.D., Princeton University
Research Interests: Embedded systems, design automation, probabilistic optimization algorithms, ad-hoc wireless networks

Peter Dinda, Associate Professor; Ph.D., Carnegie Mellon University
Research Interests: Distributed systems, distributed interactive applications, networking, resource demand and availability prediction, performance analysis, statistical analysis and prediction

Daniel Edelson, Associate Professor, joint appointment with the School of Education and Social Policy; Ph.D., Northwestern University
Research Interests: Design of educational software; data visualization and analysis software for learners; inquiry-support environments for learners; motivation and learning

Kenneth Forbus, Professor, joint appointment with School of Education and Social Policy; Ph.D., Massachusetts Institute of Technology
Research Interests: Qualitative physics, analogical reasoning and learning, cognitive simulation, sketching as an interface modality, AI-based articulate virtual laboratories and modeling environments for education, computer game design

Lance Fortnow, Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Computational complexity, theoretical computer science

Randy Freeman, Associate Professor; Ph.D., University of California, Santa Barbara
Research Interests: Nonlinear control systems, robust control, adaptive control, optimal control, game theory

Louis Gomez, Professor, joint appointment with the School of Education and Social Policy; Ph.D., University of California, Berkeley
Research Interests: Human-computer interfacing, application of computing and networking to learning

Matthew Grayson, Assistant Professor; Ph.D. Princeton University
Research Interests: Spintronics with GaAs holes, manipulation of the valley index in AlAs nanodevices, and one-dimensional transport in novel quantum wires

Dongning Guo, Assistant Professor; Ph.D., Princeton University
Research Interests: Wireless communications, information theory, communication networks, signal processing

Abraham H. Haddad, Henry and Isabelle Dever Professor; Director, M.S. in Information Technology; Director, Council on Dynamic Systems and Control; Ph.D., Princeton University
Research Interests: Stochastic systems, modeling, estimation, detection, nonlinear filtering, singular perturbation, applications to communications and control

Kristian Hammond, Professor; Ph.D., Yale University
Research Interests: Science of case-based reasoning - understanding the role of examples and experience in reasoning; how encapsulated experience, or cases, can be used to inform planning, problem solving, and the control of action; how examples can be used in information retrieval and in communicating preferences to a machine

Jason D. Hartline, Assistant Professor; Ph.D., University of Washington
Research Interests: Algorithmic mechanism design, algorithmic game theory, distributed algorithms, randomized algorithms, competitive analysis, data structures, machine learning theory, auction theory, microeconomics, economic theory

Lawrence J. Henschen, Professor; Ph.D., University of Illinois at Urbana-Champaign
Research Interests: Automated reasoning, theorem proving, meta-reasoning, deductive databases, heterogeneous/distributed database systems, visual aids for programming

Seng-Tiong Ho, Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Photonic device integration, DWDM chip technology, IV-V device modeling, nanoscale photonic device technology, micro-optics technology, organics and inorganics electro-optic modulators, quantum and non-linear optics

Michael Honig, Professor; Ph.D., University of California, Berkeley
Research Interests: Digital communications, wireless communications, networks, signal processing

Ian Horswill, Associate Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Autonomous agents, robotics and computer vision, cognitive architecture and situated agency and biological modeling

Nicole Immorlica, Assistant Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Game theory and algorithms, design of ad auctions for search engines, approximation algorithms, network design and clustering *(starting Fall 2008)*

Yehea Ismail, Associate Professor; Ph.D., University of Rochester
Research Interests: High performance VLSI circuits, simulation and analysis techniques for VLSI design, deep-submicron VLSI design, inductance modeling

Russ Joseph, Assistant Professor; Ph.D., Princeton University
Research Interests: Computer architecture and power-aware computer systems including techniques for monitoring, characterizing, and optimizing performance and power consumption

Ming-Yang Kao, Professor; Ph.D., Yale University
Research Interests: Design, analysis, applications and implementation of algorithms, specific application areas include: computational biology, computational finance, and e-commerce. Specific algorithm areas include: combinatorial optimization, online computing, and parallel computing

Aggelos K. Katsaggelos, Ameritech Professor; Director, Motorola Center for Seamless Communications; Ph.D., Georgia Institute of Technology
Research Interests: Image and video recovery and compression, multimedia signal processing, computational vision, image and video restoration

Prem Kumar, AT&T Professor of Information Technology, joint appointment with the Department of Physics and Astronomy; Director, Center for Photonic Communication and Computing; Ph.D., State University of New York, Buffalo
Research Interests: Quantum and nonlinear optics, laser and atomic physics, fiber-optic communications, networks

Aleksandar Kuzmanovic, Assistant Professor, Ph.D., Rice University
Research Interests: High-speed networks, network security, multimedia communication, resource management and control in large-scale networks, network measurement and analysis

Chung-Chieh Lee, Professor; Ph.D., Princeton University
Research Interests: Digital communications, communication network performance modeling and analysis, distributed multi-sensor detection and estimation

Xu Li, Assistant Professor, joint appointment with the Department of Biomedical Engineering; Ph.D., University of Wisconsin-Madison
Research Interests: computational and experimental electromagnetics, microwave imaging and sensing techniques for biomedical applications, optical imaging and diagnosis techniques for biomedical applications, propagation and scattering of electromagnetic waves in random media, especially in biological tissues, nanophotonic devices, ultrawideband antennas, image reconstruction and signal processing algorithms

Wei-Chung Lin, Associate Professor; Ph.D., Purdue University
Research Interests: Computer vision, pattern recognition, neural networks, and computer graphics

Chang Liu, Professor, joint appointment with Mechanical Engineering; Ph.D., California Institute of Technology
Research Interests: Sensors and sensing technology, micro and nanofabrication

Gokhan Memik, Assistant Professor, Lisa Wissner-Slivka and Benjamin Slivka Chair in Computer Science; Ph.D., University of California, Los Angeles
Research Interests: Computer Architecture, embedded systems, compilers, design automation

Seda Ogrenci Memik, Assistant Professor; Ph.D., University of California, Los Angeles
Research Interests: Computer-aided design for VLSI, reconfigurable computing, synthesis for programmable systems

Hooman Mohseni, Assistant Professor; Ph.D., Northwestern University
Research Interests: Low-dimensional devices, quantum dots, nano-photonics, novel opto-electronic devices, novel integration methods for photonic integration circuits (PIC), advanced optical modulators

Jorge Nocedal, Professor; Director, Optimization Technology Center; Ph.D., Rice University
Research Interests: Nonlinear optimization, applied linear algebra, numerical analysis, software development for numerical computations

Don Norman, Allen K. and Johnnie Cordell Breed Senior Professor in Design; Ph.D., University of Pennsylvania
Research Interests: The human side of computer science, products, the human-centered design process, society and technology, using technology to make the world more humane; whether in education, business, entertainment, or the home, design; especially of physical objects with embedded computation and telecommunication

Thrasos Pappas, Associate Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Image processing, multi-dimensional signal processing

Bryan Pardo, Assistant Professor; Ph.D., University of Michigan
Research Interests: Application of machine learning, probabilistic natural language processing, computer music, and search techniques to auditory user interfaces for HCI

Martin A. Plonus, Professor; Ph.D., University of Michigan
Research Interests: Electromagnetic theory, propagation and scattering of electromagnetic waves, optical communication through the turbulent atmosphere, consumer electronics

Manijeh Razeghi, Walter P. Murphy Professor; Director, Center for Quantum Devices; Ph.D. and ES-Science Doctorate, University of Paris
Research Interests: Compound semiconductor science and technology; theory, epitaxy, characterization, modeling and fabrication of quantum structures and devices operating from ultraviolet (200 nm) up to terahertz (100 micron)

Christopher Riesbeck, Associate Professor; Ph.D., Stanford University
Research Interests: Educational change through the development of tools for authoring and delivering interactive learning scenarios, and tools for asynchronous efficient high-quality mentoring

Alan V. Sahakian, Professor, joint appointment with the Department of Biomedical Engineering; Ph.D., University of Wisconsin
Research Interests: Instrumentation, signal and image processing for medical and aerospace applications, automatic detection and treatment of atrial cardiac arrhythmias by implanted devices

Peter Scheuermann, Professor; Ph.D., State University of New York, Stony Brook
Research Interests: Physical database design, pictorial databases, parallel I/O systems, parallel algorithms for data-intensive applications, distributed database systems

Selim M. Shahriar, Associate Professor; Ph.D., Massachusetts Institute of Technology
Research Interests: Applications of optically induced spin transitions, nanolithography, optical data storage, and optical phase conjugation

Allen Taflove, Professor; Ph.D., Northwestern University
Research Interests: Theory and applications of computational electrodynamics, especially finite-difference time-domain (FDTD) solutions of Maxwell's equations

Jack Tumblin, Associate Professor; Ph.D., Georgia Institute of Technology
Research Interests: Human visual perception of intensity, movement, form and color; computer graphics; visual appearance; surface modeling; computational geometry; image-based rendering; image processing; and computer vision

Bruce Wessels, Walter P. Murphy Professor and EECS Chair, joint appointment with the Department of Materials Science and Engineering; Ph.D., Massachusetts Institute of Technology
Research Interests: Opto-electronic integrated circuits, Compound semiconductors, electro-optic thin films and devices, MOCVD processing of ceramic superconductors and ferro-electrics

Uri Wilensky, Associate Professor, joint appointment with the School of Education and Social Policy; Ph.D., Massachusetts Institute of Technology
Research Interests: Multi-agent modeling, modeling and simulation, networked simulation environments, parallel algorithms

Chi-haur Wu, Associate Professor; Ph.D., Purdue University
Research Interests: Robotics, CAD/CAM, industrial control applications, automated manufacturing, neural networks, computer graphics and images, automated medical instrumentations, surgical robot systems

Ying Wu, Associate Professor; Ph.D., University of Illinois, Urbana-Champaign
Research Interests: Computer vision and graphics, image and video processing, vision-based human-computer interaction, machine learning and pattern recognition, multimedia, multimodal human-computer interactions, virtual environments, robotics

Horace P. Yuen, Professor, joint appointment with the Department of Physics and Astronomy; Ph.D., Massachusetts Institute of Technology
Research Interests: Optical communication, theoretical quantum optics, measurement theory, physical cryptography

Hai Zhou, Associate Professor; Ph.D., University of Texas at Austin
Research Interests: VLSI design automation including physical design, logic synthesis, and formal verification

RESEARCH FACULTY

Thomas Hinrichs, Research Associate Professor; Ph.D., Georgia Institute of Technology
Research Interests: Analogical and case-based reasoning, qualitative reasoning, performance support for engineering design

Kemi Jona, Research Associate Professor; Ph.D. Northwestern University
Research Interests: Online learning, virtual schools, technologies to support online learning and collaboration, online laboratory science course design, corporate e-learning strategy and design

Wei-Keng Liao, Research Associate Professor; Ph.D., Syracuse University
Research Interests: High-performance computing systems, parallel input/output system design, implementation and evaluation of radar signal processing applications on HPC systems

Ryan McClintock, Research Assistant Professor; Ph.D. Northwestern University
Research Interests: Wide Band-Gap III-Nitride Semiconductors, Solar-Blind Photodetectors and UV Avalanche Photodiodes, Focal Plane Array Imaging Technology, Deep UV LEDs and UV Lasers

Steven Slivken, Research Assistant Professor; Ph.D., Northwestern University
Research Interests: Growth and fabrication of III-V semiconductors for use in optoelectronic devices, including quantum cascade lasers, QWIPs, type-II InAs/GaSb lasers/detectors, and quantum dot lasers/detectors

Goce Trajcevski, Research Assistant Professor; Ph.D., University of Illinois at Chicago
Research Interests: Mobile Data Management and Moving Objects Databases (MOD), Data Management in Sensor Networks, and Reactive Behavior in Dynamic and Distributed Environments

Sotirios Tsaftaris, Research Assistant Professor; Ph.D., Northwestern University
Research Interests: DNA-Based Digital Signal Processing, DNA-based Storage of Signals, DNA Microarray Imaging, Molecular Computing for Biotechnology

Yajun Wei, Research Assistant Professor; Ph.D., Northwestern University
Research Interests: Computer engineering, theoretical modeling; growth, fabrication, material characterization, and device testing techniques, design

ADJUNCT FACULTY

Prithviraj Banerjee, Adjunct Professor; Senior Vice President and Director, HP Labs; Ph.D., University of Illinois at Urbana-Champaign

Geraldo Barbosa, Adjunct Professor, Ph.D., University of Southern California

Gail Brown, Adjunct Professor; U.S. Air Force Research Laboratory; Ph.D., University of Dayton

Brian Dennis, Adjunct Assistant Professor; Assistant Professor, Medill School of Journalism; Ph.D., University of California, Berkeley

Bruce Gooch, Adjunct Assistant Professor; Assistant Professor, University of Victoria, British Columbia, Canada; Ph.D., University of Utah

Patrick Kung, Adjunct Assistant Professor; Ph.D., Northwestern University

Sven Leyffer, Adjunct Professor; Argonne National Laboratory

Joel Mambretti, Adjunct Professor; Director, International Center for Advanced Internet Research

Antoni Rogalski, Adjunct Professor; Professor, Institute of Physics, Military University of Technology; Ph.D., Military University of Technology

Steven Swiryn, Adjunct Professor; Professor, Division of Cardiology, Northwestern University

Rajeev Thakur, Adjunct Associate Professor; Argonne National Laboratory; Ph.D., Syracuse University

George Thiruvathukal, Adjunct Professor; Associate Professor of Computer Science, Loyola University Chicago; Ph.D., Illinois Institute of Technology

FACULTY WITH COURTESY APPOINTMENTS

Alvin Bayliss, Professor; joint with Engineering Sciences and Applied Math

Robert Chang, Professor; joint with Material Sciences and Engineering

Darren Gergle, Assistant Professor; joint with the School of Communication

Andrew E. Kertesz, Professor; joint with Biomedical Engineering

John Ketterson, Fayerweather Professor; joint with Physics and Astronomy

Andrew Larson, Assistant Professor; Department of Radiology

Samuel A. Musa, Professor and Associate Vice President for Strategic Initiatives

Andrew Ortony, Professor; Education and Social Policy & Psychology Departments

Morteza Rahimi, Professor and Vice President; Northwestern University Information Technology and Chief Technology Officer (NUIT)

Rakesh Vohra, J. L. and Helen Kellogg Professor of Managerial Economics and Decision Sciences; Kellogg School of Management

EMERITUS FACULTY

James A. Aagaard, Emeritus Professor; Ph.D., Northwestern University

Morris E. Brodwin, Emeritus Professor; Ph.D., Johns Hopkins University

Max Epstein, Emeritus Professor; Ph.D., Illinois Institute of Technology

John E. Jacobs, Emeritus Professor; Ph.D., Northwestern University

Carl R. Kannewurf, Emeritus Professor; Ph.D., Northwestern University

Gilbert K. Krulee, Emeritus Professor; Ph.D., Massachusetts Institute of Technology

Gordon J. Murphy, Emeritus Professor; Ph.D., University of Minnesota

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