THE ROBOTICS GRADUATE PROGRAMS AT CARNEGIE MELLON UNIVERSITY

2008

Robotics Institute
Carnegie Mellon University
Pittsburgh, PA 15213

INTRODUCTION

Carnegie Mellon's Robotics Institute graduate programs aim to produce well-educated researchers and future leaders in Robotics. The graduate degree is a certification by the faculty that the student has a broad education in Robotics and has performed original research in the area.

This document is an informal description of the Robotics graduate programs; herein "we" refers to all faculty and staff involved in the graduate programs. Currently, the Director is Matthew Mason; the Ph.D. Program Chair and Associate Director for Education is Reid Simmons; the M.S. Program Chair is Illah Nourbakhsh; Professor and the Associate Director of Faculty is Jessica Hodgins; and the Associate Director for Finance and Administration is Cheryl Wehrer.

To complete the Ph.D. degree, we require that each student

- Participate in directed research
- Pass 96 university units worth of graduate courses, with certain distribution requirements
- Serve as a teaching assistant at least once
- Demonstrate research, writing, and speaking skills
- Write and orally defend a thesis, a significant piece of original research in a specialized area of Robotics

To complete the M.S. degree, we require that each student

- Participate in directed research
- Pass 96 university units worth of graduate courses, with certain distribution requirements
- Write results in a technical paper and give an oral presentation

We are committed to the principle that students may achieve competence through a variety of methods, including courses, seminars, projects, and independent study. We consider each student's individual strengths, weaknesses, and interests in designing the best method for the student to fulfill these requirements. Our program is unique in that we encourage and expect students to engage in research from their first day in the Institute.

To help students fulfill these requirements, we provide these educational opportunities:

- An active research environment
- The Immigration Course, intended to give an overview of the research interests of the faculty and to familiarize new students with the people and facilities of the Institute
- A large number of graduate courses: regularly offered core courses in perception, cognition, action, math foundations; advanced graduate area courses; special topics courses; and practicum courses—together covering a broad range of areas in Robotics
- Teaching support for Ph.D. students

.

OVERVIEW OF THE GRADUATE PROGRAMS

Ph.D. Program

Carnegie Mellon's Ph.D. in Robotics is, above all, a research degree. When the faculty award a Ph.D., they certify that the student has a broad foundation in Robotics, has advanced the field by performing significant original research, and has reported that work in a scholarly fashion.

Before embarking on original research, we expect students to acquire a body of technical knowledge that includes a familiarity with the breadth of Robotics as well as a deep understanding of a specialized area. The Immigration Course is the first step in this process, exposing the student to the many ongoing research activities and projects in the Institute and School. Next, through structured coursework the student gains a broad understanding of the fundamental research issues in major areas of Robotics, and has the opportunity to gain a deep understanding in the student's area of specialization. Finally, the thesis work itself guarantees that the student understands the area well enough to advance the state of knowledge in the field.

Below we sketch the progress of a typical student through the program. Since the Ph.D. program is flexible, the careers of some students depart from this script at one or more points.

Toward the end of September of the first year, each Ph.D. student is matched with a suitable advisor, who helps the student pursue directed research in an area of mutual interest. If the student's research interests change, he or she is free to change advisors at any time.

During the first two years of the program, the student begins to gain the foundation of knowledge that will allow him or her to go on and become an expert researcher in Robotics, primarily through the following two ways:

- By mastering a body of graduate material, achieved by passing 96 university units worth of graduate courses. Ninety-six units are equivalent to eight full-time (12-unit) courses.
- By learning how to organize and begin to carry out original research, achieved by participating in directed research. What constitutes directed research is decided individually between the student and his or her advisor.

Once, usually during the first two or three years, the student serves as a teaching assistant. While teaching or taking courses, we expect students to spend at least half their time doing directed research.

Our environment provides a myriad of opportunities for students to hone their writing and speaking abilities and to maintain their programming finesse. We expect students to satisfy their research qualifier requirements within their first two to three years.

Each 12-unit course should require no more than a quarter of the student's time during any one semester. So, typically a student tries to complete all coursework by the end of two years, at which point the student becomes involved in full-time research and starts thinking about research directions for a thesis. As the student's thesis research direction becomes clear, the student writes a thesis proposal and assembles a thesis committee with help from the student's advisor. The student then completes and defends the thesis, and graduates.

All requirements in the Ph.D. program must be fulfilled by work actually carried out at Carnegie Mellon University. Work done elsewhere cannot be accepted for satisfying Robotics Institute requirements; rare exceptions must be approved by the Director and Ph.D. Program Chair.

The entire faculty meet twice a year to evaluate each Ph.D. student's progress. A student demonstrates progress by passing courses, doing directed research, teaching, fulfilling the skills requirements, and doing thesis work. While students are encouraged to shape an educational program to suit their needs, financial support and/or

permission to continue in the Ph.D. program depends on satisfactory progress each semester along at least some of these dimensions.

M.S. Program

Carnegie Mellon's M.S. in Robotics reflects both the breadth and the hands-on nature of Robotics. The Master's degree is designed both as a terminal degree, for those who want professional qualifications, and as an introduction to research, for those who want to pursue the Ph.D. Accordingly, the degree requirements are designed to be flexible, so individual students can tailor the coursework and laboratory work to best meet their own needs.

The degree requirements for students in the Robotics Master's Program at Carnegie Mellon consist of core courses, electives, and supervised research culminating in a public oral presentation and a written report regarding the supervised research in which he or she is the sole or primary author.

The Master's Degree Program is designed to be completed in 12-16 months for those who are full-time students. There are also a limited number of research assistantships available. For students holding assistantships, the program is designed to take two academic years. RA's are often expected to remain on campus during the summer between their first and second year of the program, in order to make significant contributions to their research projects.

Since the bulk of the M.S. curriculum is course work, there is no formal review of the student by the entire faculty. Satisfactory progress in coursework will be assessed by the student keeping up with the course schedule and passing the courses. All courses must be passed with a grade of B- or better. The advisor will assign a pass / fail grade every semester for the supervised research. To oversee completion of the M.S. requirements the student will form a Masters Committee that will verify the final presentation of the supervised research in oral and written forms.

All requirements in the M.S. program must be fulfilled by work actually carried out at Carnegie Mellon University. Work done elsewhere cannot be accepted for satisfying Robotics Institute requirements; rare exceptions must be approved by the Director and M.S. Program Chair.

THE IMMIGRATION COURSE

The Immigration Course (IC) is intended to provide a common starting point for the entering graduate students. It is organized as a short, intensive one-week session one week prior to the beginning of the semester. The IC's goals are

- To orient new students to the Institute, through introductions to people (faculty, staff, other students) and through social activities
- To introduce students to various research and educational topics of current interest to the faculty
- To give students an opportunity to find a suitable research advisor
- To familiarize students with the computing facilities and environment at Carnegie Mellon

These goals are fulfilled through a program of research talks, demonstrations, and tours of laboratories. Enough open hours are scheduled to allow students to meet with faculty individually to learn more about their research. All first-year graduate students are required to attend the IC.

STUDENT ADVISORS

Ph.D. Program

Except during their first month in the program, each student has a faculty advisor charged with guiding the education and monitoring the progress of the student through the program. This personal student-advisor relationship ensures that every student receives the necessary faculty mentoring. Throughout the program, the advisor is responsible for guiding the student's research and education. Early in the program, the advisor guides the student along some research initiative and helps with strategic planning for courses and other educational activities. Later, the advisor helps to focus the student's research interests towards a thesis topic. Toward the end of the program, the advisor chairs the student's thesis committee, and helps to select the other members of the committee. The advisor also provides the student with career advice.

How are advisors initially chosen? Near the end of their first month, entering students are matched with faculty advisors by the “marriage” process. Students list faculty preferences and faculty list student preferences; a marriage committee then matches each student with a faculty member, taking into consideration each of their preferences. Students base their faculty preferences on research interests. They can learn about an individual faculty member's research interests by attending the faculty's research presentation during the IC, by reading the Institute’s Faculty Research Guide, and from meeting individually with different faculty members during their first month here.

There is flexibility in the kind of relationship a student has with his or her advisor. Some students work more closely with their advisors than any other faculty member, and some students work more closely with another faculty member on a particular research project. A few students have two advisors. It is possible for a student to change advisors with approval of the Ph.D. Program Chair. A student may request to switch to a new advisor, to add an additional “co-advisor”, or to remove a co-advisor. In this way, the student’s changing perspectives and research focus can be accommodated by the program.

A graduate student may be advised by any SCS teaching or research faculty member.

M.S. Program

A student's advisor serves as a mentor and research supervisor. If the student is a Research Assistant, the advisor is also the student's funder and work supervisor.

A graduate student may be advised by any SCS teaching or research faculty member.

Ph.D. DIRECTED RESEARCH

During a student's first two years, he or she should be doing directed research at least half time; once all coursework is completed and before doing thesis research, full time (except when teaching). Different students, and different advisors, have different ideas of what directed research means and how progress can be demonstrated. It is the responsibility of both the student and his or her advisor to formulate for each semester a set of reasonable goals, plans, and criteria for success in conducting directed research.

At each semi-annual faculty meeting, the faculty review the student's previous semester's research progress and the student's next semester's research plans to ensure that the student is making satisfactory progress. The evaluation of a student's progress in directed research often depends on the student having produced some tangible result; examples include a written report on research explorations, an annotated bibliography in a major area, or, as part of preparation for doing research, a passing grade in a graduate course (beyond the required 96 required units).

Advisors are individually responsible for adequately supervising this portion of the Ph.D. program.

COURSE REQUIREMENTS

Ph.D. Program

The purpose of completing 96 university units worth of graduate courses is to cover breadth across many areas in and beyond Robotics. By taking five core courses, at least one per core area, students acquire breadth through exposure to basic knowledge, concepts, and skills in four different areas in Robotics. Through the equivalent of three elective courses, students typically choose to gain more depth in the student's particular area of research. Some students use electives to gain more breadth by specialized exposure to an area outside of the student's research area and even outside of Robotics.

Core Courses

Students must pass a total of four Core Courses with a grade of B-, or better. Students must pass at least one course from each of the following four Core Areas:

- **Perception**: vision, image sensors, range data interpretation, tactile and force sensors, inertial guidance, and other sensors. Core courses in Perception are 16-720 Computer Vision and 16-722 Sensing and Sensors.

- **Cognition**: artificial intelligence for robotics, knowledge, representation, planning, task scheduling, and learning. Core courses in Cognition are 15-780 Advanced AI Concepts, and 10-701 Machine Learning.

- **Action**: kinematics, dynamics, control, manipulation, and locomotion. Core courses in Action are 16-741 Mechanics of Manipulation, and 16-711 Kinematics, Dynamic Systems, and Control.

- **Math Foundations**: optimal estimation, differential geometry, computational geometry, and operations research. There is one core course in the area which is 16-811 Math Fundamentals for Robotics.

Specialized Qualifier

The specialized qualifier is a sequence of courses chosen by the student to enhance the Core Course subject matter. These courses must total at least 48 units of graduate coursework (the equivalent of four full-semester courses). In this way, the basic science component of the program is complemented by studies in engineering and other areas that keep pace with new developments in the area of robotics. The courses should have coherence in subject matter, and should be chosen to enhance, or be complementary to, the Core Course subject matter. The subject matter of the Specialized Qualifier may be directly related to the student's thesis research, but is not restricted to that topic.

The Specialized Qualifier must be approved by the Program Committee Chairperson prior to registering for the courses. An exception can be made for courses taken in the first semester. Approval forms are available from the Program Coordinator's office. It is recommended that the Specialized Qualifier be designed in conjunction with the student's advisor.

Waivers

On the basis of previous related course work, students may apply to waive any course by completing a Waiver Request form available from the Program Coordinator. The Program Chair will then assign a suitable faculty member to handle the request, typically the course instructor. In some cases, the faculty may determine that a student has demonstrated significant knowledge of the research area, but not quite sufficient enough to waive the course requirement entirely. In such cases, the faculty may grant a conditional waiver, contingent upon additional work, such as successfully TAing the course, or completing some designated project. If a student disagrees with the outcome, he or she may petition the Ph.D. Program Chair or the Program Committee, through the Program Committee Chair, to review the case.

Research Qualifier
The Research Qualifier consists primarily of the student's research, approximately the first two years, and is normally done while the student is completing the Course Qualifiers. The primary component of the Research Qualifier is supervised research under the guidance of a faculty member who serves as the student's advisor. In addition, the research qualification process includes serving as a teaching assistant, writing a research paper, and presenting a technical talk.

To oversee this process, the student forms a Research Qualifier Committee consisting of three faculty members and one Robotics Ph.D. student who has completed his or her second year of study. The faculty members should include the student's advisor, one faculty member from the student's research area, and one faculty member from outside the area. Typically, the student's advisor will be the,chairperson of the committee. Forms to verify completion of the parts of the Research Qualifier are available from the Program Coordinator, and must be filled out by the Research Qualifying Committee (with the exception of the Teaching Requirement, which must be filled out by the instructor of the course).

The total time required for a student to accomplish the research qualifier is expected to be approximately 50% effort for two years. Any student who does not complete the entire Research Qualifier by the end of the third year of study will no longer be in good standing in the Program, subject to the judgement of the faculty.

The Research Qualifier comprises four components:

- **Research Skills:** The ability to create, explore, refine, and test new ideas in robotics. Students are expected to demonstrate awareness of previous work in their area of research, depth of insight into the problem, creativity in approaching the problem, and substance of results obtained.

- **Speaking:** The ability to communicate in oral presentation. Students are expected to demonstrate the ability to present technical material to a technical audience clearly and succinctly. The presentation must be made at a venue open to the public. Ideally, the Research Qualifying Committee will be in attendance, but committee members may designate proxies to evaluate the presentation.

- **Writing:** The ability to communicate in technical writing. A student is expected to produce a conference-length, or longer paper, in which he/she is the sole, or the primary author plus a one page executive summary in which he/she is the sole author. The paper should demonstrate a style, organization and clarity that enables researchers in the field to comprehend the problem, method, and results of the research being written about. Students who have written papers prior to entering the Robotics Program may submit them for evaluation, provided they meet the above criteria.

- **Teaching:** The experience of teaching in a classroom environment. This includes demonstration of as many as possible of the following: lecturing, recitation instruction, homework and exam design, grading, office hours, curriculum design. Each student must serve as a teaching assistant (TA) in one course relevant to the Robotics Program. Allowable courses will be defined by the Chair of the Program. Students may arrange to serve as TA by contacting the Program Coordinator at the beginning of the semester before the semester in which the student will act as a TA. The student is not required to spend more than twenty hours, but is not prohibited from doing so. The instructor should provide feedback to the student concerning the quality of the student's teaching. The instructor should report to the Program Coordinator his or her evaluation of whether the student has carried out the TA activities successfully.

The Thesis Process
The thesis must describe a significant piece of original research work. It is evidence of proficiency, high attainment, and ability to do research in a specialized area of Robotics.

Researching, writing and presenting a thesis is intended to occupy approximately two to three years of activity, with these specific parts:

- The Thesis Proposal
- The Dissertation
- The Oral Defense of the Dissertation

The evaluation of all three of these steps must be performed by the Program faculty, as represented by the student's Thesis Committee. The committee will consist of at least four members: a minimum of three from Carnegie Mellon, at least two of whom must be faculty members in the Robotics Institute, and at least one qualified researcher who is external to Carnegie Mellon. The student's advisor is the chairperson of the Thesis Committee.. The entire composition of the committee must be approved by the Chair of the Program before the Thesis Proposal is presented.

It is expected that the Thesis Proposal will require about half a year of productive research for its preparation. In the Thesis Proposal, the student is formally asking the faculty for permission to pursue a line of research leading to the Dissertation. To do this, the student must do the following:

- Describe a problem and its importance;
- Summarize and evaluate what previous work has been done by others to solve this problem;
- State what has been accomplished so far by the student and how and why it will lead to the solution, or partial solution, of the problem;
- Describe and state what the student intends to do to complete the dissertation and how long it is expected to take; and
- Tell what contributions it will make to the field of Robotics that merit awarding the degree of Ph.D.

The oral presentation of the proposal is made to the entire research community, including particularly the Thesis Committee. The Thesis Committee must then express approval to the Chair of the Program if the proposal is to be accepted.

The Dissertation itself is normally preceded by a year or more of research and writing after the proposal. The Dissertation is a scholarly document describing the problem, related work, the student's approach, the results and insights achieved, and the significance of the work. The written dissertation must be presented to the Thesis Committee for approval. When the committee gives preliminary approval, the Oral Defense can take place. At the Oral Defense, the committee and the entire community will have the opportunity to question the work critically. Finally, the Thesis Committee must decide whether to approve the thesis.

The faculty of the Robotics program and the local community must receive notice of all thesis presentations at least one week in advance. Therefore, students are required to provide the Program Coordinator with complete information, no less than ten days before the scheduled presentation, including: title, abstract, committee members, online location of thesis document and/or hard copy. The Program Coordinator will advertise theses presentations on appropriate on-line and physical venues.

Master's Degree for Ph.D. students

The Robotics Doctoral Program at Carnegie Mellon is principally a Ph.D. program. However a student who is working towards a Ph.D. may receive the degree of M.S. in Robotics upon request by the student and upon completion of the following requirements:

- Four Core Courses from the Course Qualifiers, and
- 24 units of coursework from the student's approved Specialized Qualifier
- The Writing and Speaking portions of the Research Qualifier.

Thus a student will generally become eligible for the Master's degree only after two to three years of dedicated study. A Master's degree will be awarded to students following completion of all the requirements.

M.S. Program
The Master's Degree curriculum is designed to be a subset of the Ph.D. curriculum. Each M.S. student must complete 96 credits, equivalent to eight 12-unit courses.

Core Courses

Students must pass a total of four Core Courses with a grade of B-, or better. Students must pass at least one course from each of the following four Core Areas:

- **Perception**: vision, image sensors, range data interpretation, tactile and force sensors, inertial guidance, and other sensors. Core courses in Perception are 16-720 Computer Vision and 16-722 Sensing and Sensors.

- **Cognition**: artificial intelligence for robotics, knowledge, representation, planning, task scheduling, and learning. Core courses in Cognition are 15-780 Advanced AI Concepts, and 10-701 Machine Learning.

- **Action**: kinematics, dynamics, control, manipulation, and locomotion. Core courses in Action are 16-741 Mechanics of Manipulation, and 16-711 Kinematics, Dynamic Systems, and Control.

- **Math Foundations**: optimal estimation, differential geometry, computational geometry, and operations research. There is one core course in the area which is 16-811 Math Fundamentals for Robotics.

Elective Courses

The student should take 24-36 units of elective courses. These can be drawn from one of the approved advanced sequences for the Ph.D. curriculum, or can be additional core courses. Electives need to be approved by the Chair of the Master's Program prior to taking the courses. The Elective Course Approval form can be obtained from the Program Coordinator.

Supervised Research

The balance of the units, to a total of 96, will come from supervised research, (16-997), which will normally be conducted in a faculty's laboratory, working with that faculty on one of the on-going projects of the laboratory. Supervised research is graded pass/fail, based on the advisor's assessment that the student has learned how to contribute to an original research project. Those students who receive research assistantships are expected to satisfy their supervised research requirement by working on the project from which they receive their funding.

Masters Committee

To complete the M.S. curriculum the student will form a Masters Committee consisting of two faculty members and one Robotics Ph.D. student who has completed his or her second year of study. The committee should include the student's advisor and a second faculty member from a different research group or project than that of the student. The Masters Committee must be formed by the end of the student's first semester. A form to verify completion of the speaking and writing presentation of the supervised research is available from the Program Coordinator, and must be filled out by the Masters Committee.

Final Presentation

The student is expected to give an oral presentation regarding the supervised research in a public venue. The student is expected to demonstrate the ability to present technical material to a technical audience that is not presumed to have specific expertise in the research area. Ideally, the Masters Committee will be in attendance,

but committee members may designate proxies to evaluate the presentation. The student is also expected to deliver a written report regarding the supervised research in which he or she is the sole or primary author. The report should demonstrate a style, organization and clarity that enables researchers in the field to comprehend the problem, method, and results of the research. Typically the written report will be archived as a technical report.

Waivers

On the basis of previous related course work, students may apply to waive any course by completing a Waiver Request form available from the Program Coordinator. The Program Chair will then assign a suitable faculty member to handle the request, typically the course instructor. In some cases, the faculty may determine that a student has demonstrated significant knowledge of the research area, but not quite sufficient enough to waive the course requirement entirely. In such cases, the faculty may grant a conditional waiver, contingent upon additional work. If a student disagrees with the outcome, he or she may petition the M.S. Program Chair or the Program Committee, through the Program Committee Chair, to review the case.

GRADUATION CERTIFICATION

The Program Coordinator maintains a checklist of procedures for scheduling the thesis oral presentation and completing the other requirements for graduation. The Program Coordinator certifies fulfillment of requirements for graduation only when the final version of the thesis

1. has been approved by the thesis committee, the Department Head, and the Dean, and

2. is submitted to the Program Coordinator at which time the student will be awarded the degree of Doctorate of Philosophy in the field of Robotics.

Students are not allowed to participate in commencement exercises unless final certification has been made.

If the final copy of the thesis is not submitted within one year of the thesis defense, the faculty may require a second defense before making a final certification.

COMMUNITY SPIRIT

Our sense of community is well-known as a distinguishing aspect of doing robotics at Carnegie Mellon. It is one of the reasons many students choose to come here. The Robotics Institute is proud of our strong community spirit, which we foster through close working relationships between students and advisors, among faculty, and among students. Many working relationships turn into friendships for life.

Luckily, our community works. People volunteer their time, energy, intellect, talent, and other skills to do many of the things that keep our environment running smoothly. These efforts include organizing seminars, serving on departmental committees, being a host during Open House, planning and running social activities, and giving tours.

STUDENT SUPPORT

Academic Year Support for Ph.D. students

The Department aims to allow students as much freedom as is possible in choosing research directions, subject to the interests and expertise of the faculty who are available to oversee the work. Thus, the Ph.D. program generally decides which funding source to use to support a student *after* the student has chosen an advisor or research area.

On occasion, the Ph.D. program is able to obtain an individual fellowship for a student through external sources.

We also encourage students to seek their own external funding since often the award is prestigious (e.g., NSF or Hertz) or the source provides an opportunity to make professional connections. The Robotics Institute supplements the stipends of students with an outside fellowship to meet (and usually exceed) the stipends of students with internal funding.

Academic Year Support for M.S. students

Students in the Master's degree program are expected to be self-supporting, either on their own or through their employer. Research Assistantships may also be available for some students. These pay for all tuition and fees, and carry a supplemental stipend.

Summer Stipend

Summer stipend after the first full year is available for most Ph.D. students, particularly for those working on their dissertation. Please note that all financial support is subject to continued satisfactory progress toward your degree.

We believe it is also good for Ph.D. students to gain experience in industry for one or two summers during their career here at Carnegie Mellon. Faculty and staff will provide help in finding suitable summer employment.

Travel Support

The department encourages students to travel to conferences and workshops to enhance their professional and career development.

Policy: If a student wants to attend a conference or workshop, the student's advisor or research sponsor should support the trip through either a research contract or a discretionary account.

If no such funding is available to the student, then limited departmental funds may be available upon request from the Ph.D. Program Chair. Since departmental funds are limited, some requests may not be approved, and some may not receive full funding; however, the department will try to support a student's travel as much as possible. Funding is usually available to a student for no more than one departmentally-sponsored trip per year.

Process: To obtain travel support, the student and his or her faculty advisor/research sponsor must first agree that the student should take the trip. Then *in advance of the trip* the student should get a Student Travel Authorization Form from the Program Coordinator, and then the advisor/research sponsor's signature. The faculty member must either (i) indicate the amount of support the student may receive and its source, or (ii) state that no funds are available from any research or discretionary account.

If no faculty support is available, the student should submit the signed form to the Ph.D. Program Chair for approval of departmental sponsorship. The maximum to be reimbursed will be $200 plus the registration fee, if only attending the conference or workshop; $600 plus registration fee, if presenting a paper.

CONSULTING AND OUTSIDE EMPLOYMENT

Consulting is a privilege, not a right. We grant this privilege for one of two reasons:

- The consulting task is relevant to the student's thesis work or a Carnegie Mellon research project.
- The student has exceptional financial obligations.

Consulting is normally limited to a maximum of one day per week.

A student who wishes to consult should obtain permission from his or her advisor and the Ph.D. Program Chair, and fill out an approval form, available from the Program Coordinator.

We may require that students limit outside employment in order to be in compliance with university rules.

LEAVE OF ABSENCE

Students who wish to leave the program temporarily may request a leave of absence by submitting a request to the Program Coordinator. Leaves are initially granted for a period of no more than one year, but an extension of up to one additional year may be granted under exceptional circumstances. When an extension is granted, the conditions for return must be negotiated with the advisor and the Ph.D. Program Chair prior to returning to the program.

Students on leave of absence should contact the Program Coordinator two months prior to the end of the leave to indicate their plans for the next year.

Ph.D. EVALUATION OF STUDENTS' PROGRESS

Evaluation and feedback on a student's progress are important both to the student and to the faculty. Students need information on their overall progress to make long range plans. The faculty need to make evaluations to advise students, to make support decisions, and to write recommendations to potential employers.

The faculty meet at the end of each semester to make a formal evaluation of each student in the Ph.D. program. For historical reasons this meeting is called "Black Friday." The purpose of having all the faculty meet together to discuss all the students is to ensure uniformity and consistency in evaluating across all the different areas, by all the different advisors, throughout the years of the Ph.D. program in Robotics as it inevitably changes.

The faculty measure each student's progress against the goal of completing the Ph.D. program in a reasonable period of time. The evaluation considers all components of the program using indicators and information sources described below. Through a Black Friday letter the faculty inform students of the results of this evaluation, which may include specific recommendations for future work or requirements that must be met for continued participation in the program.

Components and Indicators In their evaluation, the faculty consider the following components, though naturally only some these components will be applicable in any given semester; they are not equally important at every stage of a student's career.

- Courses taken: Evaluated by the course instructor--brief prose evaluation/summary grade.
- Directed research: Evaluated by research supervisor.
- Teaching: Evaluated by the course instructor.
- Skills: Research, writing, and speaking, by relevant faculty and forms.
- Thesis: Status summarized by the thesis advisor.
- Other: Lectures given, papers written, etc. Evaluated by cognizant faculty.

The faculty's primary source of information about the student is the student's advisor. The advisor is responsible for assembling the above information and presenting it at the faculty meeting. The student should make sure the advisor is informed about participation in activities and research progress made during the semester. Each student is asked to submit a summary of this information to the advisor at the end of each semester--the *Student Statement for Black Friday*. This statement is used as student input to the evaluation process and as factual information on activities. It is strongly recommended that the student and advisor meet prior to the faculty meeting to review the information provided in this statement.

Recommendations Based on the above information, the faculty decide whether a student is making satisfactory progress in the Ph.D. program. If so, the faculty usually suggest goals for the student to achieve over the next semester. If not, the faculty make more rigid demands of the student; these may be long-term (e.g., finish your thesis within 1-1/2 years) or short-term (e.g., select and complete one or more specific courses next semester; prepare a thesis proposal by next Black Friday).

Ultimately, permission to continue in the Ph.D. program is contingent on whether or not the student continues to make satisfactory progress toward the degree. If a student is not making satisfactory progress, the faculty may choose to drop the student from the program.

The faculty also decide whether support should be continued for each student. Termination of support does not always mean termination from the program.

Grades Since the Ph.D. program is not based solely on conventional academic courses, it is difficult to associate grades with a student's accomplishments. Also, for students who complete the program, grades are

largely irrelevant; graduates are judged primarily on their professional achievements and the experience they have gained during the program, and on the basis of recommendations from members of the faculty.

The Ph.D. program keeps an internal record of various information about a student's performance, such as final grades given in graduate courses. This information is used at the Black Friday meeting. This information does not go on the student's university transcript.

Once the required coursework is completed, students register only for a blanket course (e.g., “Reading and Research”) covering all their program activities for that semester, for which they receive a Pass/No Pass grade.

Robotics Ph.D. students may formally register for graduate or undergraduate courses in other departments, in which case they are subject to the grading policies of the University and the department offering the course. The Robotics faculty may on occasion require that a student take a course for a grade.

Students enrolled in other programs, but taking courses in Robotics, are assigned either a letter grade or a “Pass/Fail/No Grade,” at the option of the instructor. When a letter grade is required by the student's home department in order to receive credit toward the degree, the policy of the home department will be respected.

UNIVERSITY POLICIES

All policies not explicitly covered in this document adhere to university policies as stated in the Graduate Student Handbook. These policies include the status of All But Dissertation and In Absentia students, academic disciplinary actions, and grievance procedures.

PREREQUISITES TO THE CORE COURSES

It is each student's personal responsibility to arrive with, or to acquire rapidly thereafter, basic understanding (at the level of an introductory undergraduate course) in the following areas:

- Mathematics: calculus, linear algebra, numerical analysis, probability and statistics
- Computer Science: programming, data structures, algorithms
- Physics and Engineering: mechanics, dynamics, electricity and magnetism, optics

On request, the faculty will advise incoming students about individually appropriate alternative ways to satisfy these requirements, e.g., taking an undergraduate course, serving as a TA in an undergraduate course, or self-study by guided reading and discussion.

ESTIMATES OF THE TIME ALLOCATED TO EACH COMPONENT OF THE PH.D. PROGRAM

The following table indicates estimates for an appropriate distribution of effort in the Ph.D. program. It is based on actual student performance over the past few years; it also corresponds to the faculty's judgment of realistic estimates of the time required by various components of the program.

These figures are meant to be suggestive, not prescriptive. We present them so that all faculty and students can develop a shared image of the expectations of the program.

COMPONENT	INTENSITY	DURATION	TOTAL TIME
Immigration Course	full-time	one week	one week
Courses	1/4 time	1 sem each	3-4 sem
Teaching	1/2 time	1 sem	1 sem
Skills	variable	variable	variable
Directed Research	1/2 time	*	3-5 sem
Thesis Proposal	1/2 time	2 sem	1 sem
Thesis	full-time	until done	2-3 sem
Good Works	variable	often	--

* Always, except during the IC and when writing a thesis.

ESTIMATES OF THE TIME ALLOCATED TO EACH COMPONENT OF THE M.S. PROGRAM

The following table indicates estimates for an appropriate distribution of effort in the M.S. program. It is based on actual student performance over the past few years; it also corresponds to the faculty's judgment of realistic estimates of the time required by various components of the program.

These figures are meant to be suggestive, not prescriptive and are based on a self-supporting student. We present them so that all faculty and students can develop a shared image of the expectations of the program.

COMPONENT	INTENSITY	DURATION	TOTAL TIME
Immigration Course	full-time	one week	one week
Courses	3/4 time**	1 sem each	2-3 sem**
Skills	variable	variable	variable
Directed Research	1/4 time**	*	2-3 sem**

* Always, except during the IC.
** Based on self-supporting student

Ph.D. SPECIALIZATIONS

Students admitted to the Ph.D. Program in Robotics may choose to further specialize in one of two tracks; M.D. / Ph.D. Program with the University of Pittsburgh Medical Center; Center for the Neural Basis of Cognition (CNBC). These students must also be separately admitted to those programs; they fulfill the same basic requirements as regular Ph.D. students in Robotics but have additional requirements to fulfill. Brochures and catalogs for both specialized programs are available as separate documents from the Program Coordinator.

NEURAL BASIS OF COGNITION TRAINING PROGRAM

The Center for the Neural Basis of Cognition offers an interdisciplinary training program operated jointly with affiliated doctoral programs at Carnegie Mellon University and the University of Pittsburgh. The affiliated programs include Robotics, Computer Science, Psychology, and Statistics at Carnegie Mellon, and Mathematics, Psychology, and the Program in Neuroscience at the University of Pittsburgh.

The CNBC option for Robotics Ph.D. students allows them to combine intensive training in RI with a broad exposure to cognitive science, neural computation, and other disciplines that touch on problems of higher brain function.

Course of Study: RI/CNBC students are admitted through their home department (Robotics Institute) and fulfill the normal RI Ph.D. program requirements. In addition, they take a sequence of CNBC core courses in neurophysiology, systems neuroscience, computational neuroscience, and cognitive neuroscience. The CNBC core courses take the place of the three elective course unit requirements in RI. RI/CNBC students also participate in a research seminar series and experience a lab rotation.

Completion of all degree requirements earns the student a Ph.D. in Robotics plus an additional certificate in the "Neural Basis of Cognition." More information about the CNBC option is available at http://www.cnbc.cmu.edu/

M.D. / Ph.D. PROGRAM OVERVIEW

Students are first accepted into the M.D. / Ph.D. Program at the University of Pittsburgh Medical Center (UPMC), a major medical research institution located within walking distance of the Robotics Institute. After two years of medical school, students enter the Ph.D. portion of their program, which typically lasts from 3 - 5 years, before returning to finish medical school. At the Robotics Institute, a number of faculty are involved in medically related research and may serve as the primary Ph.D. advisor. During their first two years of medical school, students normally work for a 10-week period in one or more laboratories, to determine their choice of Ph.D. advisor. Students apply for admissions to the Robotics Institute during the fall term of their second year in medical school.

AFFILIATED PH.D. AND MASTER'S PROGRAMS

There are many Ph.D. and Master's programs that are affiliated with the School of Computer Science.

Other Related Ph.D. Programs

- Ph.D. Program in Computer Science
- Ph.D. in Human-Computer Interaction: offered by the Human-Computer Interaction Institute.
- Ph.D. in Language and Information Technology: offered by the Language Technology Institute.
- Ph.D. in Software Engineering: offered by the Institute for Software Research, International
- Ph.D. in Computational and Statistical Learning: offered by the Center for Automated Learning and Discovery.

Related Master's Programs

- Master of Computer-Aided Language Learning; offered jointly by the Language Technologies Institute and the Modern Languages Department.
- Master of Electronic Commerce: joint with the Graduate School of Industrial Administration; administered through the Institute for Software Research, International.
- Master of Entertainment Technology: offered by the Entertainment Technology Center.
- Master of Human-Computer Interaction: offered by the Human-Computer Interaction Institute.
- Master of Information Technology: offered by the Institute for Software Research, International.
- Master of Science in Language Technologies: offered by the Language Technologies Institute.
- Master of Software Engineering: offered by the Institute for Software Research, International.