COMPUTER SCIENCE DEPARTMENT
BOSTON UNIVERSITY

The Departmental Graduate Bulletin 2012/2013

This document describes the graduate program of the Computer Science Department of Boston University, including procedures and requirements specific to the Computer Science Department. It does not list all procedures and requirements of Boston University's Graduate School. For those, the latest edition of the bulletin of the Graduate School must be consulted (in case of contradictions, it takes precedence).

Please read relevant parts of this booklet and the Bulletin of the Graduate School before you seek the advice of a faculty member. If you still have questions request an appointment with the departmental Director of Graduate Studies.

1. INTRODUCTION

You do not need a degree in computer science nowadays to be able to "work with computers": computers are becoming ever more user-friendly. Computer professionals are needed at many points where a better understanding of information processing principles is needed: from the design of faster hardware or more "intelligent" programs to adjusting programs to meet clients' special needs. With an undergraduate degree in computer science, you become a good programmer with a grasp of the basic structural features of computers, operating systems, languages and major application areas, able to mediate efficiently at the large interface between computer systems and their users in business, engineering and other fields.

With a Master's degree you become a professional with knowledge of the underlying principles of the main areas of information processing, and enough hands-on experience in at least one area to participate in development of new systems. Confronted with a new problem at work, you will have sufficient facility with basic terms and methods to be able to peruse the technical literature in search of a solution.

By the time you obtain a Ph.D. degree you will have become familiar with (and have contributed to) the state of the art in some research area of computer science represented in our department. This kind of professional is needed for determining the future directions of the development of computer systems, for teaching or for finding new scientific concepts and facts in the area of information processing.

The Computer Science Department of Boston University offers a rigorous program providing basic competence in the central areas of computer science. On this foundation, you build expertise in one among a number of practical and theoretical subjects, working toward a deeper understanding under the guidance of a faculty member with an international reputation. The physical facilities and intellectual assets of our department are greatly enhanced by those of Boston in general and Boston University in particular. Students have taken advantage of common points of interests, among others, with the Department of Mathematics, the Department of Cognitive and Neural Sciences, the College of Engineering, the Departments of Biomedical Engineering and Bioinformatics, and the Department of Physics. In the metropolitan Boston area, there are several major universities with active computer science research programs. Contacts with these schools, as well as with nearby computer companies expose our students to the atmosphere of one of the world's major centers of computer research.

The requirements and course offerings listed in this brochure should aid prospective students in matching our program to their interests. Compared to the Electrical and Computer Engineering program of the College of Engineering, our program is less hardware-oriented. Compared to the computer science program of the Metropolitan College (B.U.'s continuing education college), our program offers a PhD program with more full-time faculty and students.

2. THE DEPARTMENT

Location. The Department is located at 111 Cummington Street. The Department Office is on the first floor, in room 138. The telephone number is (617) 353-8919.

The department administrator in charge of the graduate student affairs is Jennifer Streubel (room 140F, `jenn4@cs.bu.edu`). In administrative matters, she must be consulted first. Problems requiring Departmental decision must be brought to the student's advisor, the Director of Graduate Studies, or the Chair.

Housing. Boston University's Charles River Campus is located centrally in the urban Boston area. Local newspaper (*The Boston Globe* and *The Boston Herald*) rental property sections can be consulted as well as local roommate services. More information about graduate housing options is available: `http://www.bu.edu/cas/students/graduate/graduate-housing/`.

Financial Aid. The main sources of financial assistance are teaching fellowships, research assistantships and university graduate fellowships. U.S. students may be eligible for financial aid through Graduate Assistantships in Areas of National Need (GAANN) program,

as well as various student loans and work study grants. Applications for federally funded programs are available in major university financial aid offices or the Financial Aid Office of the Graduate School of Arts and Sciences of Boston University (617-353-2696, 705 Commonwealth Ave., Boston, MA 02215).

Research assistants are supported by research grants of one or more faculty members. Research assistant duties are determined by the faculty member(s) providing the fellowship (normally the student's advisor).

Exceptionally well qualified applicants may be nominated by the Department for the Boston University Presidential Fellowships. These fellowships are available to Ph.D. students entering in the Fall term; they include full-tuition benefits and a generous nine-month stipend for the first two years.

Financial aid must be applied for annually. The deadline to apply for Fall financial aid is January 1. Students may also be awarded aid "off-cycle" with departmental approval.

Faculty.

Jonathan Appavoo. Assistant Professor (PhD 2005, U Toronto). Research areas: operating systems, parallel architecture and software, cloud computing, and exploratory hybrid systems.

Azer Bestavros. Professor (PhD 1992, Harvard U). Research areas: networking, internet/web systems, and real-time systems.

Margrit Betke. Professor (PhD 1995, MIT). Research areas: computer vision, human computer interfaces, and object recognition.

John Byers. Associate Professor (PhD 1997, UC Berkeley). Research areas: networking, content delivery, and analysis of algorithms.

Mark Crovella. Professor (PhD 1994, U Rochester). Research areas: networking, internet characterization, and performance evaluation.

Joyce Friedman. Professor Emerita (PhD 1965, Harvard U). Research areas: mathematical and computational logic and linguistics.

Peter Gács. Professor (PhD 1978, Frankfurt U). Research areas: cellular automata, fault-tolerant computing, and algorithmic information theory.

Sharon Goldberg. Assistant Professor (PhD 2009, Princeton U). Research areas: network security, cryptography, game theory, and networking.

Steve Homer. Professor (PhD 1978, MIT). Research areas: complexity theory, learning theory, parallel and probabilistic algorithms.

Assaf Kfoury. Professor (PhD 1973, MIT). Reseach areas: programming languages and type theory.

George Kollios. Associate Professor (PhD 2000, Polytechnic University). Research areas: database systems, indexing for non-textual information, and data mining.

Leonid Levin. Professor (PhD, Moscow U and MIT). Research area: theory of computation.

Ibrahim Matta. Professor (PhD 1995, U Maryland at College Park). Research areas: networking, performance evaluation, and quality of service management.

Leonid Reyzin. Associate Professor (PhD 2001, MIT). Research areas: Security, cryptography and theory of computation.

Stan Sclaroff. Professor (PhD 1995, MIT). Research areas: computer vision, computer graphics, and pattern recognition.

Wayne Snyder. Associate Professor (PhD 1988, U Pennsylvania). Research areas: automated theorem proving, unification, and rewriting systems.

Evimaria Terzi. Assistant Professor (PhD 2007, U Helsinki). Research areas: data mining, social networks, sequence analysis.

Richard West. Associate Professor (PhD 2000, Georgia Tech). Research areas: operating systems, real-time systems, and quality of service management.

Hongwei Xi. Associate Professor (PhD 1998, Carnegie-Mellon U). Research areas: Software systems and programming languages.

Detailed descriptions of faculty research interests and research groups can be found on the departmental WWW site: `http://www.cs.bu.edu/`.

Advisor. Every graduate student has a faculty advisor. Each graduate student must consult with his/her faculty advisor when planning their program of study. The advisor is assigned by the Department when the student enters the program. However, students are encouraged to find a faculty member who they feel can help them most in their chosen area of study. Upon mutual agreement between the faculty member and the student, the faculty member will be assigned as advisor.

3. Admission

Formalities. A copy of the application package can be obtained from the Graduate Admissions Office web page: `http://www.bu.edu/cas/`. You may also obtain a printed copy of the application package from the Graduate School Admissions Office, 705 Commonwealth Ave., Boston, MA 02215.

Make sure that all supporting materials (GRE and TOEFL records, recommendations) will be sent to the Graduate Admissions Office, and not to the Department. Please note that a delay of several months can result when these materials are sent to the wrong place

(e.g., to the Engineering School's program in Electrical Computer Engineering, which is different from Computer Science), since your application will not be forwarded to us until all the credentials are collected in your file. We regret that the Graduate School cannot forward applications to the Department that do not include payment of the application fee.

To be admitted to the Master's program, you must have approximately the equivalent of an undergraduate degree in computer science from a program comparable to the one at Boston University. Otherwise, even with, say, a Master's in Electrical Engineering and years of experience in the computer industry, you may need to take some computer science foundation courses prior to commencing graduate study in computer science.

A Ph.D. applicant must have completed, or must complete, the requirements for a Master's degree in computer science or the equivalent. Unusually well qualified candidates may be accepted as Ph.D. candidates directly after earning a Bachelor's degree. In general, applicants who are admitted to the Ph.D. program are those who show evidence of ability to perform original research in one of the fields of current interest in the Department.

Courses in the undergraduate program. A complete description of requirements for the undergraduate computer science major, as well as the course descriptions can be found in the College of Arts and Sciences Undergraduate Bulletin: `http://www.bu.edu/academics/cas/`. Fifteen courses are required for the undergraduate concentration in computer science: seven CS Background Courses, four CS Required Courses, and four must be CS Elective Courses. CS Background Courses are non-CS courses listed as prerequisites or corequisites of CS Required Courses and CS courses designated as such in their bulletin description.

Background Courses.

CS 111	Intro. to CS I (JAVA programming)
CS 112	Intro. to CS II (Data Structures)
CS 131	Combinatoric Structures
CS 132	Geometric Algorithms
CS 210	Computer Systems
CS 235	Algebraic Algorithms
CS 237	Probability in Computing
MA 242	Linear Algebra
MA 293	Discrete Math I
MA 294	Discrete Math II

Required Courses.

CS320	Concepts of Programming Languages
CS330	Intro. to Analysis of Algorithms
CS332	Theory of Computation
CS350	Fundamentals of Computing Systems

Electives. At least four computer science Courses with numbers 400 and above.

Filling the gaps in your background. We want to be reasonably certain that a student can succeed in our graduate courses, therefore we require applicants to have completed an undergraduate program comparable to ours. When you apply to the graduate program, your transcript will be reviewed to identify any gaps (if any) in your background. If you are offered admission, any undergraduate prerequisite or corequisite courses will be listed in your admission letter.

Applicants with years of experience in the computer industry often feel that they know much more about computers than a typical B.A. in computer science. However, many graduate courses have a theoretical character and require abstract knowledge and mathematical skills difficult to obtain from industrial experience. Such applicants may be required to take undergraduate foundation courses in theoretical computer science.

Many of our applicants hold undergraduate degrees in areas different from computer science, or have an undergraduate degree in a computer science program that is difficult to compare with ours. In that case, to make sure that they will succeed in our graduate courses, we have to ascertain that they have studied most of the material in our B.A. program. If they have not, we advise them to take some undergraduate courses either from our department, or from the Computer Science Department at Metropolitan College of Boston University (Evening College), or from some comparable institution. The advantage of taking these courses in our department is that we know what a B grade or an instructor's recommendation from these courses mean.

Taking graduate courses before enrolling. Many prospective graduate students are well enough prepared to take some graduate courses even if, on the whole, they do not meet our admission requirements. If you enroll in graduate courses at Boston University before entering the degree program, then upon entering the program, credits for up to two of these courses can be counted toward your degree. Another advantage of this procedure is that good achievement in these courses and possible recommendations from our instructors may convince the Admissions Committee that the student will succeed in our graduate program.

If you want to take graduate courses but do not know which, our recommendation is to take one of the computer science graduate *breadth* courses. These are the courses from which you will have to select five to satisfy the course requirements for the Master's Degree, as described later in this document.

Non-degree applicants. A person who does not wish to or is not yet qualified to enter the degree program may apply for admission as a *special student* with non-degree status. International special students are eligible for a student visa if they pursue their study full-time. Application for a change from non-degree to degree status may be made any time via the normal admissions process. Financial assistance is not available for non-degree students.

Admissions procedure. The Admissions Committee bases its recommendation on:

Your background. as it can be determined from official transcripts or records of each university or college attended.

Graduate Record Examination (GRE) official test results. We do not insist on the Advanced Computer Science GRE, since it requires very specialized knowledge. We *require* the Verbal, Quantitative, and Analytical GRE scores.

Letters of recommendation. from at least two faculty members in the proposed field of study. We value letters given by your former professors more than those of your colleagues or supervisors.

Test of English as a Foreign Language (TOEFL). Foreign students from non-anglophone countries must submit the results of the Test of English as a Foreign Language (TOEFL). *The Department cannot waive this requirement*.

4. General academic requirements

Undergraduate prerequisite courses. If in your admission letter, you are required to take some undergraduate course in addition to the standard graduate requirements then this will not be waived even if you manage to take some graduate course for which this was a prerequisite. The only way to avoid taking this course is by convincing your advisor that you have actually covered the material in some other undergraduate course. In this case, you may be allowed to take just some of the examinations of the prerequisite course instead of actually enrolling in it.

Courses approved for graduate credit. All College Arts and Sciences(CAS) or Graduate School of Arts and Sciences (GRS) computer science courses with a course number 500 or higher may be taken for graduate credit. A course list can be found at the end of this document.

Courses offered outside the Department (mainly offered by the Department of Mathematics, the Department of Electrical and Computer Engineering in the College of Engineering, and the Dept. of Cognitive and Neural Sciences), need individual approval by the student's advisor and the departmental Director of Graduate Studies. Approval will rarely, if ever, be given for a course offered by the Metropolitan College.

Transfer of credit. The possibility for transfer of credit is limited by the rules given in the Graduate Bulletin of the university and by the standards of the department. Consult the GRS Graduate Bulletin for details: `http://www.bu.edu/academics/bulletin/`.

The *number* of transferred credits will be determined by the Graduate School administration on a case-by-case basis, and the criteria are different from the Department's ones. Therefore we also strongly urge students to determine the number of transferable credits for each course in advance of matriculation at Boston University.

Transfer of breadth courses taken while a BU undergraduate. If a student obtained a grade B or higher as a BU undergraduate in a breadth graduate course then the course will fulfill the breadth requirement; however, since it was counted toward the undergraduate degree, it cannot be counted toward the course credits required for a graduate degree.

Courses taken at other universities or other departments of BU. Such transfer is rarely approved (even from the computer science program of the Metropolitan College). We strongly urge students to ask for prior approval from the students advisor before taking the course. The burden of the proof that the course is up to the standards of our department lies with the student.

To gain approval for a course take elsewhere, the student must complete a *Petition for Approval of Course Transfer and/or Equivalency* form: `http://www.bu.edu/cs/graduate/`. The completed form is then submitted to the Director of Graduate Studies who circulates it among the appropriate faculty members for consideration. If after review of the form the faculty recommend approval of the petition, final approval is required from the Graduate School.

Courses completed prior to enrollment into the Graduate Program. No more than two courses for the eight-semester-course MA degree program or four courses for a sixteen-semester-course post-BA PhD degree program may be credited toward a degree, and only if the grades were B-minus or higher. No transfer of credit is allowed into the post-masters (eight-course) Ph.D. program.

Language requirement. There is no foreign language requirement.

Academic standards.

Failing grade. A graduate student who earns less than a B-minus in more than two courses in the degree program will be terminated. This applies not only to courses taken for graduate credit, but also to undergraduate courses taken to remedy deficiencies in a student's background.

Incomplete grades. The Department discourages graduate students from taking Incompletes. An Incomplete requires a written agreement between a student and the instructor specifying both the work to be done and the time limit within which the work will be completed. An Incomplete that is not made up within the time limit specified by an instructor becomes a permanent 'I' and is considered a failing grade. Incompletes may make students ineligible for financial aid.

Intensity. Graduate students are expected to pass at least two courses each academic semester in the Department, until their course requirements are met. Failure to do so may entail termination. These courses must be approved graduate courses, except in those cases where a student's advisor has recommended an undergraduate course to remedy deficiencies in the student's background.

Colloquia. Graduate students are required to attend departmental colloquia regularly.

Teaching fellow duties. These take up about 20 hours per week and include meetings with the instructor, attending lectures, office hours, tutoring hours, grading of homework assignments, teaching of discussion classes and overseeing the work of graders.

5. Requirements for the Master of Arts degree

Courses, grade minimum. Eight one-semester courses (32 credits) approved for graduate study are required. Ordinarily, all courses are in computer science and related areas.

Five of these eight courses must be from designated M.A. breadth courses. The remaining course work may include directed study (research) courses, as determined in consultation with the student's faculty advisor. An "average" grade B is enforced on the breadth courses in the following sense: the number of breadth courses in which the student receives the grade B-minus must not be greater than the number of those with B-plus or higher.

The breadth courses in the Masters curriculum are divided into four areas: Theory, Systems, Software, and Applications. Of the five breadth courses the student must take, at least one is required from each area. Here is the list of breadth courses.

Theory. Algorithms (530), Complexity Theory (535), Probability in Computing (537).

Software. Object-Oriented Software Principles (511), Programming Languages (520), Compilers (525).

Systems. Architecture (550), Operating Systems (552), Adv. Operating Systems (553), Adv. Computer Networks (556), Computer Networks (655), Distributed Systems (651), Performance Analysis of Computer Systems (670).

Applications. Cryptography (538), Machine Learning (542), Adv. Cryptography (548), Network Security (558), Algorithmic Aspects of Computer Networks (559), Adv. Databases (562), Data Mining (565), Adv. Computer Graphics (580), Image and Video Computing (585), Artificial Intelligence (640), Databases (660), Intro. to Comp. Graphics (680).

Master's Project, Master's Thesis. Students in the M.A. program must prepare a Master's Project or Master's Thesis in addition to the course requirements. Students in the M.A./Ph.D. program have to complete a Master's Thesis to get a Master's degree. The Department will not approve a program change from M.A./Ph.D. to M.A. in order to convert the thesis requirement to a project requirement.

A project does not have the scope of a thesis. It typically consists of one semester of advanced work in a specific area, under the direction of a faculty supervisor, culminating in a written report explaining what was achieved. Normally the project is carried out as part of a graduate advanced course, or as part of a Directed Study with a faculty supervisor. Faculty are responsible for supervising these projects and judging their acceptability.

In the case of a student with outstanding academic performance, a project can be expanded to a Masters Thesis. In this case two semesters of work are usually necessary, as well as the selection of a thesis committee of two faculty members who will judge a written thesis and a public presentation of the results. The distinction will be reflected in the student's official record.

6. Requirements for the Ph.D. degree

The requirements are satisfied by course work (16 courses for a student admitted with a bachelor's degree, eight courses for a student admitted with a master's degree), by passing two exams (an area subject and an oral), and by successfully defending a thesis. These Ph.D. requirements are organized in two stages: a Qualification Stage and a Thesis Stage, which are further detailed below.

Qualification Stage.

Breadth requirement. This is satisfied by completing six graduate courses from designated Ph.D. breadth courses. Two of these courses must be in theoretical computer science (the first subject area listed below) and four must be in applied computer science (the other areas), with at least one course in each of the Systems, Software, and Applications tracks of the curriculum. Each of the courses must be passed with a grade of B-minus or higher, with an average of at least 3.5 for all six courses. Note that the course lists in these four areas are similar but not identical to the core course lists in the Masters program.

The 6-course breadth requirement should be finished within two years for both post-BA and post-MA students. The remaining course work may include directed study (research) courses, as determined in consultation with the student's faculty advisor.

- ***Theory.*** Algorithms (530), Complexity Theory (535), Probability in Computing (537).
- ***Software.*** Object-Oriented Software Principles (511), Programming Languages (520), Compilers (525).
- ***Systems.*** Architecture (550), Operating Systems (552,553), Computer Networks (556,655).
- ***Applications.*** Cryptography (538), Machine Learning (542), Adv. Cryptography (548), Network Security (558), Algorithmic Aspects of Computer Networks (559), Databases (562,660), Data Mining (565), Computer Graphics (580,680), Image and Video Computing (585), Artificial Intelligence (640).

Depth requirement. This is satisfied by passing an in-depth subject exam in one of the four areas listed above. One or more subject exams are offered in each area. Syllabi for subject exams are available from web page `http://www.bu.edu/cs/graduate/`. The subject exam format may vary from area to area. Students must register to take an area's subject exam by October 15th of each academic year. Subject exams are typically held within six weeks of that date and their results made available by the end of the Fall semester.

A Ph.D. student is expected to complete the depth requirement within the first three years of graduate studies (two years for post-master's students).

Thesis Stage. In preparation for the Thesis Stage, the student is expected to approach a faculty member for guidance in a research topic; this faculty member becomes the *advisor* of the student. The advisor will assign reading, problems and projects deemed necessary to prepare the student for the original research called for in a Ph.D. thesis. Each Ph.D. student must have a faculty member within the Department as the main advisor, who will eventually be the first reader of the Ph.D. thesis.

Oral examination. The purpose of this requirement is to demonstrate ability to conduct research on a topic chosen by the student and approved by the student's advisor. An oral exam requires the formation of an *oral exam committee*, consisting of the advisor and two other faculty members, which is a precursor of a *thesis committee*. A Ph.D. student is expected to pass the oral exam within the first four years (three years for post-master's students).

Thesis proposal. The purpose of this requirement is to provide students with early feedback on their proposed thesis research. The thesis proposal must be approved by a thesis committee of three readers, normally after an oral defense of the proposal. The first reader is the student's advisor and must be a faculty member of the Department. The thesis proposal should be completed within the first five years (four years for post-master's students).

Thesis defense. The culmination of the Ph.D. program is the successful defense of a doctoral thesis. A Ph.D. student is normally expected to satisfy this final requirement within 6 years of graduate studies (5 years for post-master's students).

Progress Assessment Session (PAS). Every year, in January, each Ph.D. student's progress is evaluated by all the faculty, in a meeting dedicated to this purpose. This evaluation is based on:

- Satisfaction of course and exam requirements.
- Progress towards defining and solving a research problem.

A *progress report*, filed by each student, is commented on by the student's academic advisor and by other faculty involved in research with the student. The report must point to progress judged adequate by the advisor and the faculty.

The faculty replies to the student's report with an evaluation of his/her progress, and suggestions or requirements for future steps the student should take. If necessary, the student's case is reviewed within a half year. After appropriate warning and advice, the student's support may be terminated for lack of progress or failure to meet requirements.

Special graduate courses for PhD students. CS-697 (Graduate Initiation) is a 2-credit seminar designed to introduce graduate students embarking on a research career in computer science to various dimensions of academic life. All PhD students are required to pass

the CS-697 seminar, preferably during their first year in the program.

CS-698 (Teaching Initiation) is a 2-credit pass/fail seminar designed to prepare graduate students in computer science to be effective teachers and communicators. All PhD students are required to pass the CS-698 seminar, preferably during their first year in the program. Students who fail CS-698 must take it again and pass it before being eligible to serve as Teaching Fellows.

CS-699 (CS Teaching College) is a 2-credit pass/fail course that reflects the performance of Teaching Fellows in classes they have been assigned to teach. CS-698 is a co-requisite of CS-699. All students assigned as Teaching Fellows in a given semester are automatically enrolled in CS-699. Students who fail CS-699 will not be eligible to serve as TFs.

7. Graduate Courses

The real course numbers are either of the form "CAS CS xxx", if xxx $<$ 600, or "GRS CS xxx" if xxx $\geq$ 600, where xxx is the course number.

511 Object-Oriented Software Principles
520 Programming Languages
525 Compiler Design Theory
530 Analysis of Algorithms
532 Computational Geometry
535 Complexity Theory
537 Probability in Computing
538 Fundamentals of Cryptography
539 Methods of Scientific Computing
542 Machine Learning
548 Advanced Cryptography
550 Computer Architecture II
552 Introduction to Operating Systems
553 Advanced Operating Systems
556 Advanced Computer Networks
558 Network Security
559 Algorithmic Aspects of Computer Networks
562 Advanced Database Applications
565 Data Mining
580 Advanced Computer Graphics
585 Image and Video Computing
591 Topics in Computer Science
640 Artificial Intelligence
651 Distributed Systems
655 Computer Networks
660 Introduction to Database Systems
670 Performance Analysis of Computer Systems
680 Graduate Introduction to Computer Graphics
720 Advanced Programming Languages
791 Advanced Topics in Computer Science

8. Additional Information

Note that additional information can be found on the web at `http://www.bu.edu/cs/graduate/`. In case of any discrepancy, students are responsible for satisfying the official requirements as specified in this CS graduate bulletin.