

# School of Computing Graduate Handbook 2019-2020

This is the official handbook for the Computer Science program at the School of Computing, University of Utah. This handbook covers both MS and PhD programs under various tracks. Requirements stated in this handbook are kept track of on our gradtracker system situated at <https://gradtrack.cs.utah.edu> . All questions concerning our graduate program should be directed to [grad-advisors@cs.utah.edu](mailto:grad-advisors@cs.utah.edu) .

**History:** This handbook evolved from the 2018 version, and has these features: (1) cuts out all PR-related stuff, which does not belong in a handbook (2) removes info on faculty and research areas (these keep changing too fast; refer to [www.cs.utah.edu](http://www.cs.utah.edu) for this info). (3) the previous document proved unmaintainable in its old typesetting system; this document is in Google Docs, hence searchable/commentable while revising, and a PDF is the official copy which is better. More formatting changes slated for 2020.

## **TABLE OF CONTENTS (clickable headings below)**

<b>Administration</b>	<b>6</b>
<b>Overall Master's Degree Guidelines</b>	<b>10</b>
REGISTRATION REQUIREMENTS	11
COURSE REQUIREMENTS	11
COURSE WAIVERS	12
MS SUPERVISORY COMMITTEE	12
MS COMPREHENSIVE EXAM	12
MS TRANSFER CREDIT	13
MS THESIS DEFENSE AND THESIS DOCUMENT (Thesis Option)	13
RESIDENCY	14
LEAVE OF ABSENCE	14
STUDENT RESPONSIBILITIES, MONITORING OF PROGRESS	14
GRADUATE STUDENT PROGRESS GUIDELINES FOR THE MS THESIS (Our GradTrack system is the official place for recording progress)	15
<b>MS in Computer Science</b>	<b>15</b>
<b>MS in Computing: Computer Engineering</b>	<b>17</b>
Course-only Option:	19
Thesis Option:	19
Project Option:	19
<b>MS in Computing: Data Management and Analysis</b>	<b>19</b>
<b>MS in Computing: Graphics and Visualization</b>	<b>22</b>
COURSE-ONLY OPTION	24
PROJECT OPTION	25
<b>MS in Computing: Human-Centered Computing</b>	<b>27</b>
<b>MS in Computing: Image Analysis</b>	<b>30</b>
<b>MS in Computing: Robotics</b>	<b>32</b>
<b>MS Computing: Scientific Computing</b>	<b>34</b>
<b>Overall PhD Degree Guidelines</b>	<b>37</b>
PHD DEGREES OPTIONS	37
REGISTRATION REQUIREMENTS	38

COURSE REQUIREMENTS	38
RESIDENCY	39
CREDIT FOR PREVIOUS COURSES	39
RESEARCH ENGAGEMENT REQUIREMENT FOR FELLOWSHIP STUDENTS ONLY	40
TEACHING MENTORSHIP	41
PhD QUALIFYING EXAMINATION	41
PhD DISSERTATION	43
STUDENT RESPONSIBILITIES, MONITORING OF PROGRESS	44
	44
GRADUATE STUDENT PROGRESS GUIDELINES FOR THE PhD program (Our GradTrack system is the official place for recording progress)	45
<b>PhD in Computer Science</b>	<b>46</b>
<b>PhD in Computing: Computer Engineering</b>	<b>47</b>
<b>PhD in Computing: Data Management and Analysis</b>	<b>48</b>
<b>PhD in Computing: Graphics and Visualization</b>	<b>49</b>
<b>PhD in Computing: Human-Centered Computing</b>	<b>51</b>
<b>PhD in Computing: Image Analysis</b>	<b>54</b>
<b>PhD in Computing: Robotics</b>	<b>56</b>
<b>PhD in Computing: Scientific Computing</b>	<b>58</b>

# 1. Administration

<p><b>PROGRAM DIRECTORS</b></p> <p><b>DIRECTOR</b> Ross Whitaker Professor</p> <p><b>ASSOCIATE DIRECTOR</b> Mike Kirby Professor</p> <p><b>DIRECTOR OF GRADUATE STUDIES (DGS)</b> Ganesh Gopalakrishnan Professor</p> <p><b>DIRECTOR OF GRADUATE ADMISSIONS</b> Ladislav Kavan Associate Professor</p> <p><b>DIRECTOR OF BS/MS PROGRAM</b> Jason Wiese Assistant Professor</p> <p><b>DIRECTOR OF UNDERGRADUATE STUDIES</b> Jim de St. Germain Associate Professor, Career-Line</p>	<p><b>TRACK DIRECTORS</b></p> <p><b>COMPUTER ENGINEERING</b> Mahdi Bojnordi Assistant Professor</p> <p><b>COMPUTER SCIENCE PROGRAM</b> Jacobus Van der Merwe Associate Professor</p> <p><b>DATA MANAGEMENT &amp; ANALYSIS</b> Aditya Bhaskara Assistant Professor</p> <p><b>GRAPHICS &amp; VISUALIZATION</b> Cem Yuksel and Ladislav Kavan Associate Professors</p> <p><b>HUMAN-CENTERED COMPUTING</b> Jason Wiese Assistant Professor</p> <p><b>IMAGE ANALYSIS</b> Ross Whitaker Professor</p> <p><b>ROBOTICS</b> John Hollerbach Professor</p> <p><b>SCIENTIFIC COMPUTING</b> Hari Sundar Assistant Professor</p>
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# Master's Program

MS in Computer Science

MS in Computing

## 2. Overall Master's Degree Guidelines

**Important:** See individual track guidelines coming later for

1. MS in Computer Science
2. MS in Computing Tracks
  - Computer Engineering
  - Data Management and Analysis
  - Graphics and Visualization
  - Human-Centered Computing
  - Image Analysis
  - Robotics
  - Scientific Computing

### MS DEGREES OPTIONS

There are two Master's degree programs within the School of Computing (SoC) at the University of Utah:

- MS in Computer Science
- MS in Computing

Degree programs may contain a thesis, a project, or a course-only option as specified. Transfers between degree programs will be considered between semesters and will occur only once per academic year.

An MS in Computing is earned within a particular track. Students are, in part, admitted based upon the track that they have selected during the admissions process. If students wish to switch tracks, they should seek approval from DGS and from the track director of the track to which they wish to enter.

The Program of Study form must be submitted through Grad Tracker no later than two weeks after the first day of classes in your final semester.

The Director of Graduate Studies (DGS) is the responsible entity for all graduate degree related issues. He/she will act in consultation with the track directors for the administration of the Computer Science program and the Computing Degree programs. In the information that follows: statements indicating that something will be done/approved by DGS should be understood to mean "DGS and/or the track directors".



## REGISTRATION REQUIREMENTS

Full-time graduate students in the School of Computing are required to register for 9 hours, which includes regular courses, seminars, and research credits as appropriate. This is especially the case for students being supported via research or teaching assistantships. Students who are not being supported by the school are required to take nine hours to be classified as full-time by the graduate school.

Graduate School policy dictates that a graduate student who receives tuition benefit during any semester in which he or she holds an assistantship, fellowship, or traineeship, is required to register for at least nine semester hours, including thesis research and seminars. Tuition benefit details are described at <https://gradschool.utah.edu/tbp/tuition-benefit-program-guidelines/> .

Students must be registered for at least three hours per semester, exclusive of summer semester, to remain in a graduate degree program. Students who do not maintain continuous registration and who have not been granted a leave of absence by the Graduate School are subject to being discharged from their degree program. Please consult <https://gradschool.utah.edu/graduate-catalog/registration/> for full details on continuous registration.

Students choosing the thesis option must be registered for at least three semester hours during the semester of their thesis defense. Once a student has passed the thesis defense, the student does not have to register during the next term. The student needs to turn in the final thesis draft to the thesis office within 90 days.

## COURSE REQUIREMENTS

All degree programs have certain course requirements. To graduate, this coursework must appear on a student's approved program of study, a customized course plan developed by the student in conjunction with their committee. Courses that count toward graduation must be on the program of study. The following default restrictions apply to these courses:

- CS courses must have a course number of 6000 or above
- Be directly related to the student's degree
- A grade of at least a C must be earned
- The GPA over all courses in the program of study must be at least 3.0

In the subsequent pages of this document, each degree program and/or track may specify modifications and/or additions to these restrictions. Students should also consult the Graduate School Handbook concerning any university requirements.

A student may register for CS 6020 if that student writes and publishes a peer-reviewed article based on research performed in the School of Computing at the University of Utah. Registration must be after the article has been accepted for publication. The contribution of the student to the article should be equivalent to that conferred by first authorship. The paper should be published in a respectable outlet. It is the responsibility of the student's advisor and the DGS to determine whether the student has made such a contribution, and whether the outlet is of sufficient quality. This paper must be accepted for publication prior to the end of the second year of study.

## **COURSE WAIVERS**

A student may obtain a waiver for any of the required courses by demonstrating prior knowledge (e.g., successful completion of a similar course taken at another recognized University). This waiver is obtained by petitioning the DGS. The waiver procedure should be initiated by first contacting the Graduate Advisor. Waiving a required course does not reduce the 30 graduate credit-hour requirement.

## **MS SUPERVISORY COMMITTEE**

The MS Supervisory Committee consists of three members. The following two policies are in place:

1. The chair of the Supervisory Committee must be a regular faculty member (tenured/tenure track) from the SoC.
2. The majority of the Supervisory Committee must be regular faculty members (tenured/tenure track) within the SoC

Research or adjunct faculty may chair or may be members of supervisory committees if accorded that privilege by the SoC faculty and the Graduate School. However, exception to only one of the two policies listed above but not both simultaneously will be allowed.

## **MS COMPREHENSIVE EXAM**

For the project and thesis options of the MS, the MS comprehensive exam will be administered by the student's supervisory committee and can be coupled with (i.e., satisfied by) a project or thesis proposal defense, and/or meeting a specified level of performance on a set of classes.

For students not opting for a project or thesis, the comprehensive exam will typically be passed by meeting the grade requirements in the courses required for completing

their degree/track, but this can be modified at the discretion of the student's committee.

### **MS TRANSFER CREDIT**

A student may only count up to nine semester hours of non-matriculated graduate work at the University of Utah toward any graduate degree unless the student's registration for more than nine semester hours is specifically approved in advance by the SoC Director and the Dean of the Graduate School. Graduate courses taken as an undergraduate at the University of Utah cannot be counted towards a degree program unless a petition for graduate credit was filed with the University's Registrar at the time the course was taken.

Students who have done graduate study at other recognized institutions may transfer up to six semester hours to the University of Utah. The courses must be bona fide graduate-level classwork (e.g., independent study is excluded), with a grade of at least a C. Students must be able to show that the course work was not used toward any other degree.

Approval of each course is granted by the student's supervisory committee and the DGS. Course appropriateness is determined by consideration of course content and the student's declared research area. Approved courses are certified by a transfer credit form. Approval of a course taken elsewhere for transfer credit does not necessarily imply fulfillment of any specific course requirement.

### **MS PROJECT DOCUMENT (Project Option)**

The project is done through an independent study (often formally as an independent study course) with a professor in the School of Computing. The parameters for the scope of the project is set forth at the onset of the independent study, and the defense of the project will be done before the student's entire committee plus the professor in charge of the independent study (normally with the chairperson of the committee being the professor with whom the independent study is done). The student is responsible for arranging a time and place for the defense together with the committee.

### **MS THESIS DEFENSE AND THESIS DOCUMENT (Thesis Option)**

The supervisory committee must give preliminary approval of the thesis prior to the defense. The defense can be scheduled after this approval. To schedule the defense, contact the Graduate Advisor at least two weeks prior to the defense date agreed upon by the supervisory committee. A verification notice will be sent to all committee members asking if the student is ready to defend. Once positive responses are received, and no later than one week prior to defense, the defense will be announced to all students and faculty in the School of Computing.

The student must provide one copy of the thesis to the chair of the supervisory committee at least three weeks before the defense, and one copy to each of the other committee members at least two weeks prior to the defense.

After successfully defending the thesis, the student must obtain approval that the thesis is satisfactory by obtaining signatures from their committee members and the chair of the department (who will be approached by the Grad Advisors) by using the Final Reading Approval form, and Supervisory Committee Approval form. These forms will be submitted along with the final draft of the thesis manuscript to the thesis office. The majority of the signatures of the committee members are required for the thesis editors to start the format approval and the editing process. A student can defend a thesis until the day before the subsequent semester starts.

However, in order to graduate in a certain semester, please consult the thesis calendar for submission deadlines on the Graduate School's website <https://gradschool.utah.edu/>.

Students should also read the document regarding copyright notices provided by the School and declare their intentions regarding granting the School the right to photocopy the thesis before notifying the Graduate Advisor of completion of the defense.

The student has one month after the defense to make any revisions prior to submitting the thesis to the Graduate School Thesis Editor. There will be at most two additional months to complete any changes required by the Thesis Editor before final acceptance. If either of these deadlines are not met, the candidate must redo the oral defense. The final thesis must be filed one week before the end of the semester of graduation.

## **RESIDENCY**

At least 24 hours of the 30 MS course and thesis hours must be in resident study at the University of Utah. This does not refer to, or fulfill, State Residency Requirements. A full-time student working on an MS program is expected to complete the degree requirements within two calendar years. The Graduate School limits MS programs to four years.

## **LEAVE OF ABSENCE**

If a student does not plan to take classes during a Fall or Spring semester, a leave of absence must be requested. Contact your Graduate Advisor for the proper procedures to follow, including form(s) to use. Barring unforeseen circumstances, the leave application must be in place by August 1st (for Fall semester leave) and December 1st (for Spring semester leave).

## **STUDENT RESPONSIBILITIES, MONITORING OF PROGRESS**

All students are expected to be reading their UNID-based email (UNID @ utah.edu, where UNID begins with a 'u') regularly to keep track of all official email correspondence directed at

them. Each semester students must update their progress at the website <https://gradtrack.cs.utah.edu> where the progress guidelines shown below (plus newly added ones) will be offered as fillable entries.

**Actions by the DGS and the School:** In the event that a student is found not to be in good standing (a decision made by the DGS based on reports from the advisory committee) one or more actions may be taken. For example, the School may assign the DGS to counsel the student, deny opportunities to serve as departmentally funded TA, discontinue tuition benefit, or remove the student from the program.

**GRADUATE STUDENT PROGRESS GUIDELINES FOR THE MS THESIS (Our GradTrack system is the official place for recording progress)**

Milestone	Good Progress	Acceptable Progress	Comments
Choose advisor	1 Semester	2 Semesters	
Ethics Training	1 Semester	2 Semesters	Only if funded as a Research Assistant
Full committee formed	2 Semesters	3 Semesters	
Program of study	2 Semesters	3 Semesters	
Complete required courses	3 Semesters	4 Semesters	Program requirement within three semesters
Defend proposal	3 Semesters	4 Semesters	
Thesis defense	4 Semesters	5 Semesters	U. requirement document finalized within three months of the defense
Final document			

### 3. MS in Computer Science

A student may pursue an MS with (1) a thesis option, or (2) a project option, or (3) a course-only option, or (4) an MS/MBA option. The MS program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option). All students must take the following three required courses (for all options).

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6150	Advanced Algorithms
CS 6460	Operating Systems
CS 6810	Computer Architecture

Students must show proficiency in the three fundamental categories: theory, systems and hardware. Students can request approval from the Track director to substitute the required courses with other electives, or more advanced courses offered by the School of Computing in the same or related subject areas. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes. Each advanced course can be employed as a substitute for only one required course. **Allowable substitutions include the following.**

- **For CS 6150 (Advanced Algorithms):** CS 6100 (Theory of Computation), CS 6160 (Computational Geometry).
- **For CS 6460 (Operating Systems):** CS 6450 (Distributed Systems), CS 6465 (Advanced Operating System Implementation), CS 6480 (Advanced Computer Networks), CS 6490 (Network Security), CS 6530 (Advanced Database Systems), CS 6780 (Embedded System Design)
- **For CS 6810 (Computer Architecture):** CS 6710 (Digital VLSI Design), CS 6740 (Computer-Aided Design of Digital Circuits), CS 6745 (Testing and Verification of Digital Circuits), CS 6750 (Synthesis and Verification of Asynchronous VLSI Systems), CS 6770 (Advanced Digital VLSI Systems Design), CS 6830 (VLSI Architecture), CS 7810 (Advanced Computer Architecture).

Up to six semester hours of graduate-level course may be taken outside of the School of Computing. In general, seminars cannot be used as part of the required 30 hours.

### **THESIS OPTION**

A minimum of six thesis research credits (CS 6970) are required for the thesis option, and a maximum of 10 thesis research credits can be used on the Program of Study. At least one additional CS 6000-level or higher course is required (excluding independent study, and seminars). Additional 6000-level courses may be needed to reach the 30 credit minimum. At most three independent study (CS 6950) credit hours may be used to fulfill the required 30 semester hours, but only when the project is self-contained and independent of thesis research.

### PROJECT OPTION

A minimum of three Independent Study credits (CS 6950) are needed for the project option, and a maximum of six Independent Study credits can be used on the Program of Study. At least four additional CS courses must be taken excluding independent study, seminars, or thesis research credit (CS 6970). Additional 6000-level courses may be required to reach the 30 credit minimum.

### COURSE-ONLY OPTION

At least six additional CS courses must be taken excluding seminars, or thesis research credit (CS 6970). Additional 6000-level courses may be required to reach the 30 credit minimum. At most three independent study (CS 6950) credit hours may be used to fulfill the required 30 semester hours.

### MS/MBA OPTION

At least four additional CS courses must be taken excluding independent study, seminars, or thesis research credit (CS 6970). One independent study must be taken. The remaining courses needed for this option are specified by the Business School as part of the joint MS/MBA Program.

## 4. MS in Computing: Computer Engineering

A student may pursue an MS with (1) a thesis option, or (2) a project option, or (3) a course-only option. The MS program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option).

<b>COURSE REQUIREMENTS</b>
Required courses:
CS/ ECE 6810 Computer Architecture
CS/ ECE 6710 Digital VLSI Design

**Thesis option:** 2 required, 2 electives

**Project option:** 2 required, 3 electives

**Course-only option:** 2 required, 4 electives

\* Additional courses on the program of study must be approved by the student's committee.

## **ELECTIVES**

Two courses must be taken by students doing the thesis option, three courses must be taken by students doing the project option, and four courses must be taken by students doing the coursework option, and Courses selected should be in an area of specialization selected by the student. This is a list of suggested/ recommended elective courses. Courses taken as electives should be 6000 and above in CS or ECE and are approved by the student's committee.

CS 6110	Software Verification and Analysis
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CS 6150	Advanced Algorithms
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CS 6235	Parallel Programming for GPUs/Many Cores/Multi-Cores
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CS 6460	Operating Systems
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CS 6470	Compiler Principles and Techniques
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CS 6475	Advanced Compilers
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CS 6480	Advanced Computer Networks
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CS 6490	Network Security
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ECE 5325	Wireless Communications Systems
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ECE 5520	Digital Communications Systems
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Computer Engineering Track Elective courses: Continued	
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ECE 6530	Digital Signal Processing
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CS/ ECE 6720	Analog Integrated Circuit Design
CS/ ECE 6740	Computer-Aided design of Digital Circuits
CS/ ECE 6745	Testing and Verification of Digital Circuits
CS/ ECE 6750	Synthesis and Verification of Async VLSI Systems
ECE 6755	Relative Timed Asynchronous Circuit Design
CS / ECE 6770	Advanced Digital VLSI Systems Design
ECE 6775	Advanced VLSI Memory Design
CS/ ECE 6780	Embedded Systems Design
CS/ ECE 6785	Advanced Embedded Software
CS/ ECE 7810	Advanced Architecture
CS/ ECE 7820	Parallel Architecture

**Course-only Option:**

In this option all the course requirements are fulfilled through graduate courses (no thesis hours). No more than three hours can be Independent Study (CS/ECE 6950).

**Thesis Option:**

This option involves research on a thesis area and a written thesis submitted to the graduate school. A minimum of six thesis hours are required, and there must be at least 20 classroom hours in the program of study. A maximum of three hours of Independent Study (CS/ECE 6950) is permitted only when it is self-contained and not related to the thesis.

**Project Option:**

Similar to the coursework option with an independent/special study on a project topic required with a project report submitted to the independent/special study advisor. A minimum of three hours and a maximum of six hours of Independent Study (CS/ECE 6950) are allowed.

***A maximum of two seminar hours will be permitted for any of the three options.***

## 5. MS in Computing: Data Management and Analysis

A student may pursue an MS with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of the three options is 30 from graduate level classes. A maximum of 6 project hours or 9 thesis hours is allowed to be included in the program of study for students in the project or the thesis option. A minimum of 6 hours of thesis research is required for the thesis option.

<b>CORE CLASSES</b> - Must take 4 core classes, at least one from each line.	
CS 6140	Data Mining <u>or</u> CS 6350 Machine Learning
CS 6150	Advanced Algorithms
CS 6530	Advanced Database Systems
CS 6630	Visualization for Data Science (CS 6635 Visualization for Scientific Data may be taken as a substitute)

An average grade of at least a B is required for core classes.

<b>ELECTIVES:</b> Three courses from the following list are required: (or CS 6140/CS 6350 if not counted above) Students may also substitute most graduate classes taught by track faculty.
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**ALGORITHMICS**

CS 6160	Computational Geometry
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CS 6170	Computational Topology
CS 6180	Clustering
CS 6966	Theory of Machine Learning

### **ANALYTICS**

CS 6190	Probabilistic Modeling
CS 6210	Advanced Scientific Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6355	Structured Prediction

### **MANAGEMENT**

CS 6230	High-Performance Computing and Parallelization
CS 6235	Parallel Programming for GPUs/Many Course/Multi-Cores
CS 6480	Advanced Computer Networks
CS 6490	Network Security
CS 6963	Distributed Systems

Students may substitute other SoC graduate-level courses for elective requirements with approval of the Track Director (especially those taught by track faculty). With approval of the supervisory committee, a student may take two elective courses (6 credit hours) at the graduate level or higher from other departments, excluding independent study, seminars and research credit. Students may place out of the above requirements by substituting or transferring courses from other institutions at the discretion of the Track Director.

In all three options, seminar hours cannot be included to fulfill the 30 graduate level credits requirement. Independent study credit hours can only be used on the Program of Study for students who pursue the project-based degree. However, once a student enters the project or the thesis option, his/her prior independent study or thesis research hours can be converted into project or thesis hours whichever is applicable, if the student's advisor deems these hours relevant to the student's project or thesis.

A student may pursue an MS with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of the three options is 30 from graduate level classes. A maximum of 6 project hours or 9 thesis hours is allowed to be included in the program of study for students in the project or the thesis option. A minimum of 6 hours of thesis research is required for the thesis option.

## DATA SCIENCE OPTION

CORE CLASSES	
CS 5530	Database Systems <u>or</u> CS 6965 Big Data Computer Systems
CS 6140	Data Mining
CS 6190	Probabilistic Modeling
CS 6350	Machine Learning
CS 6630	Visualization for Data Science (CS 6635 Visualization for Scientific Data may be taken as a substitute)
MATH 5080	Statistical Inference I
MATH 6010	Linear Models

SUGGESTED ELECTIVES	
CS 6150	Advanced Algorithms
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6530	Database Systems

CS 6961	Structured Prediction
MATH 5770	Introduction to Optimization
MATH 6030	Multivariate Models
MATH 6070	Mathematical Statistics

An average grade of at least a B is required for core classes.

Students may place out of the above requirements by substituting or transferring courses from other institutions at the discretion of the Track Director. Students may complete the required 30 credits with SoC graduate-level courses or Math graduate-level courses, or from other departments with the approval of the Track Director.

In all three options, seminar hours cannot be included to fulfill the 30 graduate level credits requirement. Independent study credit hours can only be used on the Program of Study for students who pursue the project based degree. However, once a student enters the project or the thesis option, his/her prior independent study or thesis research hours can be converted into project or thesis hours whichever is applicable, if the student's advisor deems these hours relevant to the student's project or thesis.

## 6. MS in Computing: Graphics and Visualization

A student may pursue an MS with (1) a course-only option, (2) a project option, or (3) a thesis option. The minimum number of credits for any option is 31 with 30 from graduate level (6000 level for CS courses) and 1 hour of either CS 7942 Visualization Seminar or CS 7933 Graphics Seminar. Seminars may not replace required or elective courses.

<p><b>COURSE REQUIREMENTS</b>  <b>(COURSE ONLY OPTION)</b> Four of the following regular courses are required in addition to the seminar.</p>	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science

CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
A minimum of a B- or greater is required for any of the required courses.	

Three courses from the following list are required:	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
Elective courses (to equal 30 total credit hours):	

Graduate level CS courses and independent study (a maximum of three hours of independent study is allowed). Thesis research hours are not counted toward the degree in the course-only option.

**COURSE-ONLY OPTION**

With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments including 5000 or 6000 level courses, excluding independent study, seminars and research credit.

<b>COURSE REQUIREMENTS</b> <b>(PROJECT OPTION)</b> Four of the following regular courses are required in addition to the seminar.	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
A grade of at <u>least a B-</u> is required for any of the required courses.	

Three courses from the following list are required:	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6320	3D Computer Vision
CS 6360	Virtual Reality

CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
Elective courses (to equal 30 total credit hours):	
Students must take at least 3 and up to 6 credits (no more than 6 credits) of independent study for their MS project. Thesis research hours are not counted toward the degree in the project option.	

## PROJECT OPTION

<p><b>COURSE REQUIREMENTS</b></p> <p><b>(THESIS OPTION)</b></p> <p>Minimum 21 hours classroom courses and six hours of thesis research are required. Three of the following regular courses are required in addition to the seminar:</p>	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design



CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)

A grade of at least a B- is required for any of the required courses.

Three courses from the following list are required:

CS 6160	Computational Geometry
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CS 6170	Computational Topology
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CS 6320	3D Computer Vision
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CS 6360	Virtual Reality
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CS 6540	Human/ Computer Interaction
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CS 6600	Mathematics of Computer Graphics
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CS 6620	Ray Tracing for Graphics
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CS 6650	Perception for Graphics
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CS 6660	Physics-based Animation
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CS 6665	Character Animation
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CS 6680	Computer-Aided Geometric Design II
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Elective courses (to equal 30 total credit hours):

For the thesis option, students can take up to 9 thesis hours and no independent study.

A minimum of six hours of thesis research (CS 6970) is required.

## THESIS OPTION

With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments including 5000 or 6000 level courses, excluding independent study, seminars, research credit.

# 7. MS in Computing: Human-Centered Computing

In human-centered computing (HCC) the design and development of technology is motivated by the needs of people. HCC focuses on understanding how people use technology, creating new and accessible technology that enables novel interactions, and evaluating how technology impacts and supports people in the world. The core methods and techniques in HCC are grounded in computer science, but are also draw on social science and design. Current HCC focus areas in the School of Computing include personal informatics, mobile interaction, visualization, games, and privacy.

A student may pursue an MS with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of the three options is 30 from graduate level classes. A maximum of 6 project hours or 9 thesis hours is allowed to be included in the program of study for students in the project or the thesis option. A minimum of 6 hours of thesis research is required for the thesis option.

<b>CORE CLASSES:</b> Required courses:	
CS 6540	HCI
CS 6963	Advanced HCI
CS 6630	Visualization for Data Science
ED PS 6010	Introduction to Statistics and Research Design

<b>ELECTIVES:</b> 6 electives in total. Up to 3 electives can be taken from outside of CS. Courses not on the pre-approved list require approval of the Track Director.
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## PRE-APPROVED CS ELECTIVES

### Data Science

CS 6140	Data Mining
CS 6160	Computational Geometry
CS 6190	Probabilistic Modeling
CS 6340	Natural Language Processing
CS 6350	Machine Learning
CS 6530	Database Systems

### **Visualization**

CS 6635	Visualization for Scientific Data
CS 6965	Advanced Data Visualization

### **Robotics**

CS 6300	Artificial Intelligence
CS 6310	Robotics
CS 6320	Computer Vision

### **Computer Graphics and Interaction**

CS 6360	Virtual Reality
CS 6610	Interactive Computer Graphics
CS 6640	Introduction to Digital Imaging
CS 6955	Science of Game Design
CS 6964	Computational Models of Interactive Narrative

### **PRE-APPROVED NON-CS ELECTIVES**

Courses taught outside of the College of Engineering may require differential tuition.

### **Embedded Systems**

CS 6780	Embedded System Design
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CS 6785	Advanced Embedded Software
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### **Design**

DES 5320	Typographic Communication
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DES 5370	Digital Fabrication
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DES 5710	Product Design and Development
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### **Ed Psychology**

ED PSY 6030	Introduction to Research Design
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### **Psychology**

PSY 6120	Advanced Human Cognition
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PSY 6140	Cognitive Neuroscience Approaches to Research
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PSY 6420	Methods in Social Psychology
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PSY 6700	Neuropsychology
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### **Nursing**

NURS 7107*	Principles of Qualitative Inquiry I
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NURS 7203	Principles of Qualitative Inquiry II
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NURS 7209	Research Interviews and Focus Groups
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\*This course must be taken as a sequence with NURS 7203.

### **Sociology**

SOC 6110	Methods of Social Research
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### **Entertainment Arts and Engineering**

EAE 6900	Games User Research
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EAE 6900	A.I. For Games
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### **Mechanical Engineering**

## 8. MS in Computing: Image Analysis

A student may pursue an MS with (1) a thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of three options is 30 from graduate level classes. A maximum of 6 project hours or 9 thesis hours is allowed to be included in the program of study for students in the project or the thesis option. A minimum of 6 hours of thesis research is required for the thesis option.

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6640	Image Processing
CS 7640	Advanced Image Processing and/or Mathematics of Imaging
Students are also required to complete two out of the following three courses. The third can be taken as an elective.	
CS 6150	Advanced Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

The Program of Study must be courses at the 6000 level or above and research credits. Of the required 30 semester hours, up to 24 credit hours must be graduate courses within the SoC or on the following list of recommended electives.

### **ELECTIVES**

Recommended elective courses within the School of Computing and other departments are listed below:

### **IMAGING, VISUALIZATION & GRAPHICS**

CS 6630	Scientific Visualization
CS 6650	Perception for Graphics
CS 6670	Computer-Aided Geometric Design I
BIOEN 6330	Principles of Magnetic Resonance Imaging
BIOEN 6500	Mathematics of Imaging
<b>COMPUTATIONAL METHODS</b>	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
<b>STATISTICS &amp; LEARNING</b>	
CS 6190	Probabilistic Learning
CS 6300	Artificial Intelligence
CS 6560	Computational Statistics
ECE 6540	Estimation Theory

Students may place out of required courses or electives by substituting or transferring courses from other institutions. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes, and they must be approved by the Track Director.

## 9. MS in Computing: Robotics

A student may pursue an MS with a thesis option, a project option, or a course-only option. The minimum number of credits is 30. Three courses are required, plus an additional three courses must also be taken from a restricted selection as described in Robotics Track Courses.

Two additional elective courses, directly related to the student's degree, at the 6000-level or higher (not including independent study, seminars, or thesis research hours) from any department are required. Depending on whether a student is pursuing a thesis MS, a project MS, a course-only MS or additional 6000-level or higher courses can be chosen, this time including independent study, seminars, and research credit, in order to reach a 30-credit minimum.

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6310	Introduction to Robotics
CS 6330	Introduction to Robot Control
CS 7939	Robotics Seminar (1 fall and 1 spring semester)
CS 6300 CS 6370	Artificial Intelligence <u>or</u> Motion Planning
CS 6640 CS 6320	Image Processing <u>or</u> Computer Vision
Pre-approved robotics electives: Choose 3 electives from at least 2 of 5 different areas.	
<b>1. Action/Control</b>	
ME EN 6200	Classical Control
ME EN 6210	State Space Control
ME EN 7200	Nonlinear Controls
ME EN 7210	Optimal Controls
CS 7310	Robot Mobility and Manipulation

ECE 6570	Adaptive Control
<b>2. Cognition</b>	
CS 6300	Artificial Intelligence <u>or</u> CS 6370 Motion Planning (if not taken above)
CS 6350	Machine Learning
CS 7320	System Identification for Robotics
<b>3. Perception</b>	
CS 6640	Image processing <u>or</u> CS 6320 3D Computer Vision (if not taken above)
CS 7640	Advanced Image Processing
ECE 6960-13	Deep Learning for Image Analysis
<b>4. Human-Robot Interaction</b>	
CS 6540	Human-Computer Interaction
CS 6360	Virtual Reality
ME EN 7960-07	Haptics
<b>5. Robot Design</b>	
ME EN 6240	Advanced Mechatronics
ME EN 7960	Wearable Robotics
ECE 6670	Control of Electric Motors



## 10. MS Computing: Scientific Computing

A student may pursue an MS in Scientific Computing with a thesis option or a project-based option. A minimum of 30 credit hours is required for either option. In addition to six required courses, students must take two elective courses that involve the themes of Scientific Computing or are directly applicable to the student's dissertation research. Students are also required to take two courses of independent study (for projects) or MS thesis hours (for thesis) for a total of six hours.

<b>COURSE REQUIREMENTS</b>	
The following six courses are required:	
CS 6150	Advanced Algorithms
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230 CS 6235	High-Performance Computing and Parallelization and/or Parallel Programming for GPUs/Many Cores/Multi-Cores
CS 6630	Visualization
MATH 6870	Math Modeling

Two additional elective courses must be selected from the following list. Students can possibly take other 6000-level and above courses within the School of Computing as electives; permission of the track director (the student's committee) is necessary in such cases.	
CS 6100	Foundations of Computer Science

CS 6530	Database Systems
CS 6610	Interactive Computer Graphics
CS 6650	Image Synthesis
CS 6810	Advanced Computer Architecture
CS 7210	Advanced Topics in Scientific Computing
CS 7450	Simulation Methods
Additional 6000-level and above courses may be required to reach a 30-credit minimum (excluding independent study, seminars, or thesis research credit hours).	

# PhD Program

PhD in Computer Science

PhD in Computing

# 11. Overall PhD Degree Guidelines

**Important: See individual track guidelines coming later for**

1. PhD in Computer Science
2. PhD in Computing Tracks:
  - Computer Engineering
  - Data Management and Analysis
  - Graphics and Visualization
  - Human-centered Computing
  - Image Analysis
  - Robotics
  - Scientific Computing

## **PHD DEGREES OPTIONS**

There are two PhD degree programs within the School of Computing (SoC) at the University of Utah:

- PhD in Computer Science
- PhD in Computing

Transfers between degree programs will be considered between semesters and will occur only once per academic year.

A PhD in Computing is earned within a particular track. Students are, in part, admitted based upon the track that they have selected during the admissions process. If students wish to switch tracks, they should seek approval from DGS and from the track director of the track to which they wish to enter. They should also maintain good Due Progress milestones as specified.

The Director of Graduate Studies (DGS) is the responsible entity for all graduate degree related issues. He/she will act in consultation with the track directors for administration of the Computing Degree program. In the information that follows: statements indicating that something will be done/approved by the DGS should be understood to mean “DGS and/or the track directors”.

## REGISTRATION REQUIREMENTS

Full-time graduate students in the School of Computing are required to register for 9 hours, which includes regular courses, seminars, and research credits as appropriate. This is especially the case for students being supported via research or teaching assistantships. Students who are not being supported by the school are also required to take nine hours to be classified as full-time by the graduate school.

Graduate School policy dictates that a graduate student who receives tuition benefit during any semester in which he or she holds an assistantship, fellowship or traineeship is required to register for at least nine semester hours, including dissertation research and seminars. Please read through the Tuition Benefit Program Guidelines <https://gradschool.utah.edu/tbp/tuition-benefit-program-guidelines/> for additional details.

Students must be registered for at least three hours per semester, exclusive of summer semester, to remain in a graduate degree program. Students who do not maintain continuous registration and who have not been granted a leave of absence by the Graduate School are subject to being discharged from the degree program. Please consult <https://gradschool.utah.edu/graduate-catalog/registration/> for full details on continuous registration.

Students doing dissertations must be registered for at least three semester hours during the semester of the student’s dissertation defense. Once a student has passed the dissertation defense, the student does not have to register during the next term, but the final dissertation should be turned in within 90 days.

## COURSE REQUIREMENTS

All degree programs have certain course requirements. However, these represent a necessary, rather than sufficient, set of courses for graduation. To graduate, this coursework must appear on a student’s approved program of study, a customized course plan developed by the student in conjunction with their committee.

Courses that count toward graduation must be on the program of study. The following default restrictions apply to these courses:

- CS courses must have a course number of 6000 or above

- Non-CS courses must be a graduate level course having a course number of 5000 or above, and should be directly related to student's degree
- A grade of at least a B
- The GPA for all required courses must be at least 3.5

In the subsequent pages of this document, each degree program and/or track may specify modifications and/or additions to these restrictions. Students should also consult the Graduate School Handbook concerning any University requirements.

A student may register for CS 6020 if that student writes and publishes a peer-reviewed article based on research performed in the School of Computing at the University of Utah. Registration must be after the article has been accepted for publication. The contribution of the student to the article should be equivalent to that conferred by first authorship. The paper should be published in a respectable outlet. It is the responsibility of the student's advisor and the DGS to determine whether the student has made such a contribution, and whether the outlet is of sufficient quality. This paper must be accepted for publication prior to the end of the second year of study.

## **RESIDENCY**

At least one year (i.e., two consecutive semesters) of the doctoral program must be spent in full-time academic work at the University of Utah. When a student proceeds directly from an MS degree to a PhD degree with no break in the program of study (except for authorized leaves of absence), the residency requirement may be fulfilled at any time during the course of study.

## **CREDIT FOR PREVIOUS COURSES**

PhD students may count some hours of coursework from other graduate degrees toward the coursework requirements associated with the program of study. Unlike for the MS programs, credit for previous courses for PhD students is administered by the DGS so these courses do not need to be officially transferred to the University. The number of hours is specified on a track / program basis. Each track / program determines the number of hours allowed that may count. Approved courses are certified by inclusion of the appropriate SoC form in the student's file. All coursework in the program of study is subject to approval by the student's supervisory committee, the track director, and the DGS.

PhD students with a masters-level degree in a closely related discipline should work with their initial committee to create a program of study that can include graduate courses taken as part of their previous degree program. Unless explicitly specified by a degree/track, the program of study can include up to 21 hours to be counted toward their PhD requirements, and can be used to satisfy some or all of the PhD required courses. Like all programs of study, it must then be approved by the DGS and the graduate school.

A student who has been accepted by the Graduate School is formally admitted to candidacy for the PhD by the University at the recommendation of the student's supervisory committee. Admission to candidacy occurs after the student:

- forms a supervisory committee,
- files an approved Program of Study form,
- completes the course requirements,
- passes the written portion of the qualifying examination, and
- passes the oral portion of the qualifying examination (i.e. proposal defense).

An application for candidacy must be submitted to the Graduate School no later than two months prior to the semester of graduation. For the degree to be conferred, the approved Program of Study form must be completed and the dissertation completed and publicly defended.

A PhD Supervisory Committee conducts the student's written qualifying examination, oral qualifying examination, and dissertation defense. This committee consists of five faculty members, at least one member must be from outside the SoC. The following two policies are in place:

1. The chair of the Supervisory Committee must be a regular faculty member (tenured/tenure track) from the SoC.
2. The majority of the Supervisory Committee must be regular faculty members (tenured/tenure track) within the SoC.

Research or adjunct faculty may chair or may be members of supervisory committees if accorded that privilege by the SoC faculty and the Graduate School. However, exception to only one of the two policies listed above but not both simultaneously will be allowed. For Computing degrees, further restrictions on committee makeup may apply. All official decisions of the committee are decided by a majority vote.

## **RESEARCH ENGAGEMENT REQUIREMENT FOR FELLOWSHIP STUDENTS ONLY**

All fellowship students are required to take a total of 4 credit hours during their first year enrolled in the PhD.

- **CS 7930 - Intro to Computing PhD - 1 credit (required in earliest semester offered during your PhD studies (i.e. first Fall typically))**
- **Seminars and/or Independent Study - total of 3 credits**

*(Students must engage in seminars from different research areas in order to qualify for this requirement.)*

The research engagement requirement can be waived by the DGS or the Director of SoC if a student can demonstrate some other “significant research activity”, such as working as an RA in a research group.

## **TEACHING MENTORSHIP**

All PhD students will be required to complete 4 credit hours of Teaching Mentorship with a “Pass” grade. Teaching mentorship will involve working with one or more faculty members (Teaching mentors) on tasks including but not limited to the following:

- Holding student contact hours
- Developing teaching resources (e.g., web pages)
- Lecturing
- Developing and grading assignments

The Teaching Mentorship must be spread across two semesters (2 credit hours each semester). The required tasks will be laid out by the Teaching Mentors before the start of the mentorship each semester. A Pass/Fail grade will be assigned for each semester by the Teaching Mentors based on how well the mentee performs the required tasks. The Teaching Mentorship must be completed before the written qualifying examination (described below). The Teaching Mentorship hours cannot be used to replace course requirements.

The mentorship assignment will be made in conjunction with your advisor and the Undergraduate Faculty Advisor (Jim de St. Germain). The mentorship should be fulfilled by the end of the 4th semester to meet the stipulated good progress criteria.

## **PHD QUALIFYING EXAMINATION**

All PhD students must pass a Qualifying Examination, as specified by the Graduate School. The Qualifying Exam consists of two parts, a written examination covering the candidate’s chosen area of specialization and an oral examination involving a defense of the candidate’s written thesis proposal.

The written portion of the Qualifying Examination will cover the candidate’s general area of specialization in sufficient depth to demonstrate his/her preparation for conducting PhD level research. Each member of the student’s supervisory committee will contribute one or more questions to this exam. The supervisory committee will provide a written evaluation of this portion of the exam, including an indication of whether or not the student will be allowed to proceed to the oral portion of the Qualifying Examination. Specific details of the written qualifying exam procedures appear below.

The oral portion of the Qualifying Exam involves a defense of the candidate’s dissertation proposal. At the supervisory committee’s option, it may also include follow



up questions relating to the written portion of the exam. All members of the candidate's committee should certify that the proposal is ready to be defended prior to conducting the oral portion of the Qualifying Exam.

There are two forms required to be filled out; these forms are available on-line or from the Graduate Coordinator. The first is a report on the written portion of the Qualifying Exam. The second is a report for the complete Qualifying Exam, both written and oral. These forms plus the written examination questions and student answers, will be retained in the student's School of Computing file. Consistent with the requirements of the Graduate School, the Qualifying Examination must be completed at least one semester prior to defense of the thesis.

### **Guidelines on PhD Written Qualifying Exams Question Submission**

Each member of the student's supervisory committee who holds a faculty rank in the University of Utah School of Computing must submit at least one question. Other committee members may each submit a question at their option.

### **Question Format**

The format of each question can be chosen by the committee member posing the question. Possibilities include (but are not limited to):

- "Take home" question, to be researched by the student using library, web, and other publicly available resources;
- A "closed book sit down" examination, to be written during a fixed period without use of background materials;
- An "open book sit down" examination, similar to (2), but permitting use of reference materials.

**Note that in all cases, the examination will be written, not oral.**

### **Exam Administration and Grading**

The entire exam should be completed in no more than seven days from initial question assignment to the submission of answers. Grading should be completed within seven days after the student delivers his/her answers. Each committee member contributing a question will grade that question and provide a specific, written evaluation of the quality and correctness of the answer. Allowable grades on individual questions are:

- HP - High-Pass
- P - Pass
- F - Fail

A grade of P signifies the minimal acceptable performance expected from a PhD student. An F grade indicates an answer that is partially correct, but not up to the standards we expect from our PhD students.

The members contributing questions will each cast a Pass/Fail vote on the examination as a whole. An overall passing grade should be given to candidates who, through their answers, demonstrate that they are well prepared to conduct PhD level research in their specialty area of computer science. The overall exam High-Pass / Pass / Fail grade will be determined by a majority vote of those contributing questions. In the event of equal numbers of Pass and Fail votes, the deciding vote will be cast by the Director of Graduate Studies.

### **Repeating the Exam**

A student who fails his/her first attempt may retake the exam once. No conditional pass grades will be given. However, the supervisory committee can at their discretion include fewer questions on repeated exams.

### **PhD DISSERTATION**

The supervisory committee must give preliminary approval of the dissertation prior to the defense. The defense can be scheduled after this approval. To schedule the defense, contact the Graduate Advisor.

The student must provide one copy of the dissertation to the chair of the supervisory committee at least three weeks before the defense, and one copy to each of the other committee members at least two weeks prior to the defense.

After successfully defending the dissertation, the student must obtain approval that the thesis is satisfactory by obtaining signatures from their committee members and the chair of the department by using the Final Reading Approval form, and the Supervisory Committee Approval Form. These forms will be submitted with the final draft of the thesis manuscript to the thesis office. The majority of the signatures of the committee members are required for the thesis editors to start the format approval and the editing process. The Dean of the Graduate School signs the Final Reading Approval form after all editing is completed and before the thesis release. While a student can defend a thesis until the day before the following semester starts, in order to graduate in a certain semester, please see the thesis calendar for submission deadlines on the Graduate School's website <https://gradschool.utah.edu/> .

Students should also read the document regarding copyright notices provided by the School and declare their intentions regarding granting the School the right to photocopy the dissertation before notifying the Graduate Advisor of completion of the defense.

The student has one month after the defense to make any revisions prior to submitting the dissertation to the Graduate School Thesis Editor. There will be at most two additional months to complete any changes required by the Thesis Editor before final acceptance. If either of these deadlines are not met, the candidate must redo the oral defense. The final dissertation must be filed one week before the end of the semester of graduation.

Students are expected to offer each committee member a bound copy of the dissertation once it is completed, and one to the School of Computing library. Detailed policies and procedures concerning the dissertation are contained in "A Handbook for Theses and Dissertations" published by the Graduate School.

The completed dissertation must be published either in its entirety (through a legitimate publisher of the student's choice or through University Microfilms) or as one or more articles accepted for publication in approved scholarly journals. An abstract of each dissertation must be published in University Microfilms' Dissertation Abstracts International.

## **STUDENT RESPONSIBILITIES, MONITORING OF PROGRESS**

All students are expected to be reading their UNID-based email ([UNID@utah.edu](mailto:UNID@utah.edu) where UNID begins with a 'u') regularly to keep track of all official email correspondence directed at them. Each semester students must update their progress at the website <https://gradtrack.cs.utah.edu> where the progress guidelines shown below (plus newly added ones) will be offered as fillable entries.

**Initial committee:** This consists of two University of Utah faculty members and an advisor, who must meet the School of Computing requirements for advising. The initial committee is different from the full committee, who will ultimately administer the qualifier and evaluate the dissertation. The full committee must be chosen to conform to program requirements. The initial committee is automatically dissolved when the student forms a full committee, however, the full committee may consist of the same faculty members as the initial committee.

**Good versus acceptable progress:** Students completing milestones within the time frame denoted as "good" are generally considered to be in good standing in the program. Students completing milestones within the time frame denoted as "acceptable" are considered to be making acceptable progress in the program and are encouraged to continue on and attempt to meet successive milestones within the time frames denoted as "good."

Students may or may not be considered in good standing, depending upon evaluation of the director of graduate studies (DGS) with input from their advisor and advisory committee. Students not completing milestones within the time frame denoted as "acceptable" are not considered in good standing. Students not in good standing can face consequences including loss of funding or expulsion from the PhD program.

**All PhD students are required to submit (online, on the GradTrack system) a due progress form in the Fall semester every year by October 15th. Those students who fail to submit their due progress forms by this deadline can face consequences including loss of funding or expulsion from the PhD program.**

The faculty as a whole conducts a Graduate Student Progress Review meeting every Fall semester (typically in November) to review and monitor graduate student progress. Advice generated during this meeting and other monitoring activities will be suitably conveyed to the student (typically via email from their advisor(s) and/or Graduate Advisors).

**All PhD students who are found lagging in any of their progress categories are additionally required to update their information on the GradTrack system by April 15th. By this date, they must also inform their advisor(s) how they have responded to comments (if any) passed on to them. Failure to do so can result in consequences similar to those noted above.**

**The School of Computing will make all reasonable attempts to support students and help them make progress in their studies, and convey their advice. They will also point the students to our Campus Help Resources as necessary. The School of Computing reserves the rights to follow prescribed Dismissal Policies if a student does not meet the stipulated progress guidelines.**

**GRADUATE STUDENT PROGRESS GUIDELINES FOR THE PhD program (Our GradTrack system is the official place for recording progress)**

<b>Milestone</b>	<b>Good Progress</b>	<b>Acceptable Progress</b>	<b>Comments</b>
Choose advisor and initial committee	1 Semester	2 Semesters	
Ethics Training	1 Semester	2 Semesters	
Program of study approved by advisor and initial committee	4 Semesters	5 Semesters	
Complete Teaching Mentorship	4 Semesters	4 Semesters	
Complete required courses	5 Semesters	6 Semesters	
Written qualifier	5 Semesters	6 Semesters	U requirement: one semester before defense
Full committee formed	6 Semesters	7 Semesters	U requirement: After written qualifier and one semester

			before defense.
Program of study approved by committee	6 Semesters	7 Semesters	
Oral Qualifier (proposal)	7 Semesters	8 Semesters	
Dissertation defense	10 Semesters	12 Semesters	
Final document			U requirement: Document finalized within three months of the defense

*All students are strongly advised to plan their own customized schedule for completing the required courses in frequent consultation with their advisor, as they may run the risk of lagging in publications if they do not start on research early.*

## 12. PhD in Computer Science

At least 50 hours of graduate coursework is required for the PhD degree in computer science. This must be composed of at least 27 hours of regular graduate coursework, and at least 14 semester hours of dissertation research. Independent study and seminars cannot be used as part of the required 50 hours. Of the required 27 semester hours of regular courses, up to six hours may be graduate-level courses outside of the School of Computing. Up to 20 hours of coursework taken elsewhere or counted toward previous degrees can be counted toward the 27 hour regular course requirement with the approval of the Track director. PhD students must demonstrate core knowledge in computer science by fulfilling the following requirements:

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6150	Advanced Algorithms
CS 6460	Operating Systems
CS 6810	Computer Architecture

Students must show proficiency in the three fundamental categories: theory, systems and hardware. Students can request approval from the Track director to substitute the required courses with other electives, or more advanced courses offered by the School of Computing in the same or related subject areas. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes. Each advanced course can be offered as a substitute for only one required course. Additional 6000-level courses and above may be required to reach a 50-credit hour minimum (excluding independent study, seminars, or dissertation research credit hours).

**Allowable substitutions include the following.**

- **For CS 6150 (Advanced Algorithms):** CS 6100 (Theory of Computation), CS 6160 (Computational Geometry).
- **For CS 6460 (Operating Systems):** CS 6450 (Distributed Systems), CS 6465 (Advanced Operating System Implementation), CS 6480 (Advanced Computer Networks), CS 6490 (Network Security), CS 6530 (Advanced Database Systems), CS 6780 (Embedded System Design)
- **For CS 6810 (Computer Architecture):** CS 6710 (Digital VLSI Design), CS 6740 (Computer-Aided Design of Digital Circuits), CS 6745 (Testing and Verification of Digital Circuits), CS 6750 (Synthesis and Verification of Asynchronous VLSI Systems), CS 6770 (Advanced Digital VLSI Systems Design), CS 6830 (VLSI Architecture), CS 7810 (Advanced Computer Architecture)

## 13. PhD in Computing: Computer Engineering

A PhD student must either already have an MS degree or complete all of the requirements for a course, project, or thesis-based MS degree in CE. The supervisory committees may require additional coursework hours above that required for the MS degree. Also, all students must complete at least 7 hours of coursework at the University of Utah. All students must complete at least 14 hours of dissertation research (CS 7970).

**COURSE REQUIREMENTS**

**Required courses for students not already having an MS degree:**  
Same as the requirements for the M.S. in Computer Engineering listed on Page 11 of this handbook.

**Required courses for students who already have an MS degree:**  
At least 7 hours of coursework at the University of Utah determined in consultation with the student's committee.

Each CE graduate student must form a supervisory committee whose members approve the student's program of study and guides the student's research program. A PhD committee consists of five members. The majority of the committee must consist of CE faculty from either SoC or ECE. PhD students are strongly encouraged to have a member of the committee who is outside the University of Utah whenever it is feasible. The committee should be formed by the end of the second semester of enrollment in the graduate program, although a committee may be revised later by petition to the CE committee.

Any SoC or ECE regular faculty member may serve as a supervisory committee chair. Auxiliary faculty may chair supervisory committees if accorded that privilege by the regular faculty and the Dean of the Graduate School. Individuals who are not faculty members may serve on supervisory committees if nominated by the regular faculty on the committee, and endorsed by the CE Committee. The Dean of the Graduate School must grant final approval of all supervisory committees. **A maximum of two seminars hours will be permitted.**

## 14. PhD in Computing: Data Management and Analysis

Course work listed on the approved Program of Study form must comprise at least 50 semester hours of graduate course-work and dissertation research, exclusive of independent study. At least 14 semester hours of dissertation research (CS 7970) and 24 semester hours of graduate course-work must be included. Up to 12 hours of graduate level course-work already applied to other degrees may be used in the program of study as approved by the track director. Students may place out of the following requirements by substituting or transferring courses from other institutions at the discretion of the track director.

**CORE CLASSES:** Must take 4 core classes, at least one from each line.

CS 6140	Data Mining <u>or</u> CS 6350	Machine Learning
CS 6150	Advanced Algorithms	

CS 6530	Advanced Database Systems
CS 6630	Visualization for Data Science (CS 6635 Visualization for Scientific Data) may be taken as a substitute)

A student must take four elective courses (twelve hours) which involve the areas related to data, or are directly applicable to the student's dissertation research. Up to three courses (nine hours) may be taken from other departments at the University of Utah. All elective courses on the Program of Study must be taught at the graduate level. For those classes taken within the School of Computing, the student needs to take 6000 level courses and above when available/appropriate. In addition to the following electives, other 6000 level and above classes taught by track faculty are also typically allowed as electives. All courses taken by a track student to fulfill the elective requirements must be approved by the student's committee and the track director.

**ELECTIVES**  
 Three courses from the following list are required: (or CS 6140/CS 6350 if not counted above.)  
 Students may also substitute most graduate courses taught by track faculty.

**ALGORITHMICS**

CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6180	Clustering
CS 6966	Theory of Machine Learning

**ANALYTICS**

CS 6190	Probabilistic Modeling
CS 6210	Advanced Scientific Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6355	Structured Prediction

**MANAGEMENT**

CS 6230	High-Performance Computing and Parallelization
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CS 6235	Parallel Programming for GPUs/Many Course/Multi-Cores
CS 6480	Advanced Computer Networks
CS 6490	Network Security
CS 6963	Distributed Systems

## 15. PhD in Computing: Graphics and Visualization

Course work listed on the approved Program of Study form must comprise at least 50 semester hours of graduate course-work and dissertation research, exclusive of independent study. Graduate course-work applied toward an MS degree may be included. At least 14 semester hours of dissertation research (CS 7970) and 27 semester hours of graduate course-work must be included. Up to 20 hours of graduate level course-work already applied to other degrees may be used in the program of study.

PhD students must demonstrate core knowledge in computer graphics and visualization by passing three required courses, prior to the start of their fifth semester of study, with grades of at least a B in each course and an overall GPA in the required courses greater than 3.5.

<b>COURSE REQUIREMENTS</b>	
Three of the following five courses are required:	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design

## **ELECTIVE COURSES**

The School of Computing Computer Science courses on the Program of Study must be at the 6000 level or above, excluding independent study, and research credits. Of the required 27 semester hours, up to nine credit hours may be graduate courses outside of the School of Computing. Admissible elective courses within the School of Computing are as follow:

CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-Based Animation
CS 6680	Computer-Aided Geometric Design II
CS 7650	Realistic Image Synthesis

Courses not on the list above must be approved by the student's committee to count toward the elective requirements. Independent study (CS 6950 and CS 7950) can not be included in the Program of Study for the PhD degree.

## 16. PhD in Computing: Human-Centered Computing

In human-centered computing (HCC) the design and development of technology is motivated by the needs of people. HCC focuses on understanding how people use technology, creating new and accessible technology that enables novel interactions, and evaluating how technology impacts and supports people in the world. The core methods and techniques in HCC are grounded in computer science, but also draw on social science and design. Current HCC focus areas in the School of Computing include personal informatics, mobile interaction, visualization, games, and privacy.

Course work listed on the approved Program of Study form must comprise at least 50 hours of graduate coursework and dissertation research. At least 14 semester hours of dissertation research (CS 7970) and 27 hours of graduate coursework must be included. Up to 12 hours of graduate coursework taken elsewhere or counted toward previous degrees can be counted toward the graduate coursework requirement with the approval of the track director.

### **CORE CLASSES:** Required courses:

CS 6540

HCI

CS 6963

Advanced HCI

CS 6630

Visualization for Data Science

ED PS 6010

Introduction to Statistics and Research Design

### **ELECTIVES:** 5 electives in total

Up to 3 electives can be taken from outside of CS. Courses not on the pre-approved list require approval of the Track Director.

### **PRE-APPROVED CS ELECTIVES**

#### **Data Science**

CS 6140

Data Mining

CS 6160	Computational Geometry
CS 6190	Probabilistic Modeling
CS 6340	Natural Language Processing
CS 6350	Machine Learning
CS 6530	Database Systems

### **Visualization**

CS 6635	Visualization for Scientific Data
CS 6965	Advanced Data Visualization

### **Robotics**

CS 6300	Artificial Intelligence
CS 6310	Robotics
CS 6320	Computer Vision

### **Computer Graphics**

CS 6610	Interactive Computer Graphics
CS 6640	Introduction to Digital Imaging

### **Embedded Systems**

CS 6780	Embedded System Design
CS 6785	Advanced Embedded Software

### **PRE-APPROVED NON-CS ELECTIVES**

Courses taught outside of the College of Engineering may require differential tuition.

### **Design**

DES 5320	Typographic Communication
DES 5370	Digital Fabrication
DES 5710	Product Design and Development

### **Ed Psychology**

ED PSY 6030	Introduction to Research Design
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### **Psychology**

PSY 6120	Advanced Human Cognition
PSY 6140	Cognitive Neuroscience Approaches to Research
PSY 6420	Methods in Social Psychology
PSY 6700	Neuropsychology

### **Nursing**

NURS 7107*	Principles of Qualitative Inquiry I
NURS 7203	Principles of Qualitative Inquiry II
NURS 7209	Research Interviews and Focus Groups

\* This course must be taken as a sequence with NURS 7203

### **Sociology**

SOC 6110	Methods of Social Research
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### **Entertainment Arts and Engineering**

EAE 6900	Games User Research
EAE 6900	A.I. For Games

### **Mechanical Engineering**

ME EN 7240	Haptics for Virtual Reality, Teleoperation, and Physical Human-Robot Interaction
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## 17. PhD in Computing: Image Analysis

A minimum of 50 credits is required, of which at least 27 credits must be graduate course work, and at least 14 credits must be dissertation research (CS 7970). Graduate course-work applied toward an MS degree may be included. **Seminars may be used as part of the required 50 hours, but independent study cannot.**

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6640	Image Processing
CS 7640	Advanced Image Processing and/or BIOEN 6500 Mathematics of Imaging
Students are also required to complete two out of the following three courses: The third can be taken as an elective.	
CS 6150	Advanced Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

<b>ELECTIVES</b>	
Computer Science courses on the Program of Study must be courses at the 6000 level or above and research credits. Of the required 27 semester hours, up to 12 credit hours may be graduate courses outside of the School of Computing. Recommended elective courses:	
<b>IMAGING, VISUALIZATION &amp; GRAPHICS</b>	
CS 6630	Scientific Visualization
CS 6650	Perception for Graphics
CS 6670	Computer-Aided Geometric Design I
BIOEN 6330	Principles of Magnetic Resonance Imaging

BIOEN 6500	Mathematics of Imaging
<b>COMPUTATIONAL METHODS</b>	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
<b>STATISTICS &amp; LEARNING</b>	
CS 6190	Probabilistic Learning
CS 6300	Artificial Intelligence
CS 6560	Computational Statistics
ECE 6540	Estimation Theory

Students may place out of required courses or electives by substituting or transferring courses from other institutions. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes, and they must be approved by the Track Director. Up to 12 approved credit hours may be transferred from other institutions, and up to 20 credit hours may be used from a previous MS degree at the University of Utah.

## 18. PhD in Computing: Robotics

A minimum of 50 credits is required, of which at least 27 credits must be graduate course work, and at least 14 credits must be dissertation research. Of the graduate course-work, three are required courses, plus an additional three courses must be taken from the restricted electives as described in Robotics Track Courses.

Two additional elective courses at the 6000-level or above (not including independent study, seminars, or thesis) from any department are required. Remaining credits to fill

the 50-credit minimum may be chosen from other 6000-level or higher courses or from seminars or dissertation research, but not independent study.

<b>COURSE REQUIREMENTS</b>	
Required courses:	
CS 6310	Introduction to Robotics
CS 6330	Introduction to Robot Control
CS 7939	Robotics Seminar (1 fall and 1 spring semester)
CS 6300 CS 6370	Artificial Intelligence <u>or</u> Motion Planning
CS 6640 CS 6320	Image Processing <u>or</u> Computer Vision
Pre-approved robotics electives: Choose 3 electives from at least 2 of 5 different areas.	
<b>6. Action/Control</b>	
ME EN 6200	Classical Control
ME EN 6210	State Space Control
ME EN 7200	Nonlinear Controls
ME EN 7210	Optimal Controls
CS 7310	Robot Mobility and Manipulation
ECE 6570	Adaptive Control
<b>7. COGNITION</b>	



CS 6300	Artificial Intelligence <u>or</u> CS 6370 Motion Planning (if not taken above)
CS 6350	Machine Learning
CS 7320	System Identification for Robotics
<b>8. Perception</b>	
CS 6640	Image processing <u>or</u> CS 6320 3D Computer Vision (if not taken above)
CS 7640	Advanced Image Processing
ECE 6960-13	Deep Learning for Image Analysis
<b>9. Human-Robot Interaction</b>	
CS 6340	Human-Computer Interaction
CS 6360	Virtual Reality
ME EN 7960-07	Haptics
<b>10. Robot Design</b>	
ME EN 6240	Advanced Mechatronics
ME EN 7960	Wearable Robotics
ECE 6670	Control of Electric Motors

## 19. PhD in Computing: Scientific Computing

50 hours of graduate coursework is required, composed of at least 24 hours of regular graduate coursework, and at least 14 semester hours of dissertation research. Of the required 24 semester hours of regular courses, up to six hours may be graduate

courses outside of CS. Up to 12 hours of coursework taken elsewhere or counted toward previous degrees can be counted toward the 24-hour regular course requirement with the approval of the track director.

<b>COURSE REQUIREMENTS</b>	
The following four courses are required:	
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230 CS 6235	High-Performance Computing and Parallelization and/or Parallel Programming for GPUs/Many Cores/Multi-Cores
CS 6630	Scientific Visualization
<p>In addition, a student must take four elective courses that involve the themes of scientific computing or are directly applicable to the student's dissertation research. The following is the list of those classes which will apply. Students can possibly take other 6000-level and above courses within the School of Computing as electives; advising and permission of the track director (or mentor and committee) is necessary in such cases.</p>	
CS 6100	Foundations of Computer Science
CS 6530	Database Systems
CS 6610	Interactive Computer Graphics
CS 6650	Image Synthesis
CS 6810	Advanced Computer Architecture
CS 7210	Advanced Topics in Scientific Computing

CS 7450

Simulation Methods

Additional 6000-level and above courses may be required to reach a 50-credit minimum (excluding independent study, seminars, or dissertation research credit hours).

**(Last page of  
Handbook)**

