Computer Science

Program Guide 2018-2019

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1. Aims and Scope

The Computer Science program educates students to become world-class researchers and thought leaders in the field of computer science. The program is designed to prepare the student for a career in academia, industrial research or advanced positions in industry.

The program offers two degrees: the Doctor of Philosophy (Ph.D.) degree and the M.S. degree The M.S. degree can be obtained by taking courses only or by a combination of courses and writing a thesis. Students who are interested in a research career are encouraged to apply directly to the Ph.D. program. An M.S. degree is not a pre-requisite to enroll in the Ph.D. program.

A student who completes the Ph.D. degree will have demonstrated original research that is published in world-class prestigious conferences, journals and other research forums. This degree is appropriate for those who want to pursue a career in research either in academia or industry. A student who completes the M.S. degree by taking courses and writing a thesis will have demonstrated ability to perform directed research and complete a research project. This degree is appropriate for students who wish to pursue a Ph.D. degree later.

A student who completes the M.S. degree by taking only courses will have demonstrated strong performance in graduate-level courses that prepare the student for a career of advanced research and development in industry.

The scope of research in the Computer Science program at KAUST includes the following areas:

- Artificial Intelligence and Machine Learning
- Computational Biosciences
- Computer Systems and Databases
- High Performance Computing
- Theoretical Computer Science
- Visual Computing

2. Assessment Test (If applicable)

Students are admitted to KAUST from a wide variety of programs and backgrounds. In order to facilitate the design of an appropriate study plan for each individual student, all admitted students without an MS are required to take a written assessment exam when they arrive on Campus. The purpose of the assessment is to determine whether students have mastered the prerequisites for undertaking graduate-level courses taught in the program. The Academic Advisor works with admitted students to develop a study plan if needed. Students are encouraged to prepare for the assessment by refreshing the general knowledge gained from their undergraduate education before arriving at KAUST. The remedial study plan requirements must be satisfactorily completed, in addition to the University degree requirements.

3. Master's Degree Requirements

It is the sole responsibility of the student to plan her/his graduate program in consultation with her/his advisor. Students are required to meet all deadlines. Students should be aware that most core courses are offered only once per year.

The Master's Degree (M.S.) is awarded upon successful completion of a minimum of 36 credit hours. A minimum GPA of 3.0 must be achieved to graduate. Individual courses require a minimum of a 'B-'for course credit. Students are expected to complete the M.S. degree in three semesters and one Summer Session. Satisfactory participation in every KAUST's Summer Session is mandatory. Summer Session courses are credit bearing and apply towards the degree.

The M.S. degree has the following components:

- Core Courses

- Elective Courses
- Research/Capstone Experience
- Graduate Seminar 298 (non-credit). All students are required to register and receive a Satisfactory grade for the first two semesters.

3.1 M.S. Course Requirements

3.1.1 Core Courses (nine credits)

CS 220 Data Analytics
CS 240 Computing Systems and Concurrency
CS 260 Design and Analysis of Algorithms

These core courses are designed to provide a student with the background needed to establish a solid foundation in the program area.

3.1.2 Elective Courses (fifteen credits)

The elective courses (which exclude research, internship credits, and IED courses) are designed to allow each student to tailor his/her educational experience to meet individual research and educational objectives, with the permission of the student's academic advisor.

3.1.3 Research/Capstone Experience

See sections for thesis and non-thesis options below.

3.1.4 Winter Enrichment Program

Students are required to satisfactorily complete at least one full Winter Enrichment Program (WEP).

3.2 M.S. Thesis Option

Students wishing to pursue the thesis option must apply by the ninth week of their second semester for a thesis and must have at least a 3.2 cumulative GPA.

The selected thesis advisor must be a fulltime program-affiliated Assistant, Associate or Full Professor at KAUST. This advisor can only become project affiliated for the specific thesis project upon program level approval. Project affiliation approval must be completed prior to commencing research.

3.2.1 M.S. Thesis Defense Requirements

An oral defense of the M.S. Thesis is required, although it may be waived by the Dean's Office under exceptional circumstances. A requirement of a public presentation and all other details are left to the discretion of the thesis committee.

A written thesis is required. It is advisable that the student submits a final copy of the thesis to the Thesis Committee Members at least two weeks prior to the defense date.

- Students are required to comply with the university formatting guidelines provided by the library **CLICK HERE**
- Students are responsible for scheduling the thesis defense date with his/her thesis committee.
- A pass is achieved when the committee agrees with no more than one dissenting vote, otherwise the student fails. The final approval must be submitted at the latest two weeks before the end of the semester.

3.2.2 M.S. Thesis Defense Committee

The M.S. Thesis Defense Committee, which must be approved by the student's Dean, must consist of at least three members and typically includes no more than four members. At least two of the required members must be KAUST Faculty. The Chair, plus one additional Faculty Member must be affiliated with the student's program. This membership can be summarized as:

Member Role Program Status

Member	Role	Program Status
1	Chair	Within Program
2	Faculty	Within Program
3	Faculty or Approved Research Scientist	Outside Program
4	Additional Faculty	Inside or Outside KAUST

Notes:

- Members 1-3 are required. Member 4 is optional.
- Co-Chairs may serve as Members 2, 3, or 4, but may not be a Research Scientist.
- Adjunct Professors and Professors Emeriti may retain their roles on current Committees, but may not serve as Chair on any new Committees.
- Professors of Practice and Research Professors may serve as Members 2, 3 or 4 depending upon their affiliation with the student's program. They may also serve as Co-Chairs.
  - Visiting Professors may serve as Member 4.

View a list of faculty and their affiliations: **CLICK HERE**

3.3 M.S. Non-Thesis Option

Students wishing to pursue the non-thesis option must complete a minimum of six credits of Directed Research (299). Summer internship credits may be used to fulfill the research requirements provided that the Summer internship is research-based. Summer internships are subject to approval by the student's academic advisor.

Students must complete the remaining credits through one or a combination of the options listed below:

- Broadening Experience Courses: Courses that broaden a student's M.S. experience.
- Internship: Research-based Summer Internship (295). Students are only allowed to take one internship.
- PhD Courses: Courses numbered at the 300 level.

4. Doctor of Philosophy

The Doctor of Philosophy (Ph.D.) Degree is designed to prepare students for research careers in academia and industry. It is offered exclusively as a fulltime program.

There is a minimum residency requirement at KAUST of three and a half years for students entering with a B.S. Degree and two and a half years for students entering with a M.S. Degree. A minimum GPA of 3.0 must be achieved on all doctoral coursework. Individual courses require a minimum of a 'B-' to earn course credit.

The Ph.D. Degree includes the following steps:

- Securing a Dissertation Advisor.
- Successful completion of Program Coursework.

- Passing the Qualifying Examination.
- Passing the Dissertation Proposal Defense to obtain candidacy status.
- Preparing, submitting and successfully defending a Doctoral Dissertation.

4.1 Ph.D. Course Requirements

The required coursework varies for students entering the Ph.D. Degree with a B.S. Degree or a relevant M.S. Degree. Students holding a B.S. Degree must complete all Program Core/Mandatory Courses and Elective Courses outlined in the M.S. Degree section and are also required to complete the Ph.D. courses below. Students entering with a B.S. Degree may also qualify to earn the M.S. Degree by satisfying the M.S. Degree requirements; however, it is the student's responsibility to declare their intentions to graduate with an M.S.

Students entering the Ph.D. Degree with a relevant M.S. Degree must complete the requirements below, though additional courses may be required by the Dissertation Advisor.

Ph.D. Courses

- At least two 300-level courses.
- Graduate Seminar 398 (non-credit): All students are required to register and receive a Satisfactory grade for the first two semesters.
- Winter Enrichment Program: Students are required to satisfactorily complete at least one full Winter Enrichment Program (WEP) as part of the degree requirements. Students who completed WEP requirements while earning the M.S. Degree are not required to enroll in a full WEP for a second time in the Ph.D. Degree.
- Satisfactory participation in every KAUST's Summer Session is mandatory. Summer Session courses are credit bearing and apply towards the degree.

4.2 Ph.D. Designation of Dissertation Advisor

The selected Dissertation Advisor must be a full time program-affiliated Professor at KAUST. The student may also select an advisor from another program at KAUST. This advisor can only become project affiliated for the specific thesis project with program level approval. Project affiliation approval must be completed prior to commencing research.

View a list of faculty and their affiliations: **CLICK HERE**

4.3 Ph.D. Candidacy

In addition to the coursework requirements, the student must successfully complete the required Ph.D. qualification milestones to progress towards Ph.D. candidacy status. These milestones consist of the subject-based qualifying examination and Ph.D. Proposal Defense.

4.3.1 Ph.D. Dissertation Proposal Defense Committee

The Ph.D. Dissertation Proposal Defense Committee, which must be approved by the student's Dean, must consist of at least three members and typically includes no more than six members. The Chair, plus one additional Faculty Member must be affiliated with the student's Program.

Member Role Program Status

Member	Role	Program Status
1	Chair	Within Program
2	Faculty	Within Program
3	Faculty	Outside Program

4	Approved Research Scientist	Inside KAUST

Notes:

- Members 1-3 are required. Member 4 is optional.
- Co-Chairs may serve as Members 2 or 3.
- Adjunct Professors and Professors Emeriti may retain their roles on current Committees, but may not serve as Chair on any new Committees.
- Professors of Practice and Research Professors may serve as Members 2 or 3 depending upon their affiliation with the student's program. They may also serve as Co-Chairs.

Once constituted, the composition of the Proposal Committee can only be changed with the approval of both the Dissertation Advisor and the Dean.

View a list of faculty and their affiliations: **CLICK HERE**

4.3.2 Ph.D. Dissertation Proposal Defense

The purpose of the Dissertation Proposal Defense is to demonstrate that the student has the ability and is adequately prepared to undertake Ph.D.-level research in the proposed area. This preparation includes necessary knowledge of the chosen subject, a review of the literature and preparatory theory or experiment as applicable.

The Dissertation Proposal Defense is the second part of the qualification milestones that must be completed to become a Ph.D. Candidate. Ph.D. students are required to complete the Dissertation Proposal Defense within the second year of doctoral studies. The Dissertation Proposal Defense includes two aspects: a written Research Proposal and an oral Research Proposal Defense. Ph.D. students must request to present the Dissertation Proposal Defense to the Proposal Dissertation Committee at the beginning of the Semester they will defend their proposal.

There are four possible outcomes from this Dissertation Proposal Defense:

- Pass
- Pass with conditions
- Fail with retake
- Fail without retake

A pass is achieved when the committee agrees with no more than one dissenting vote, otherwise the students fails.

In the instance of a Pass with Conditions, the entire committee must agree on the required conditions and if they cannot, the Dean decides. The deadline to complete the conditions is one month after the defense date, unless the committee unanimously agrees to change it.

In the instance of a Fail without Retake, the decision of the committee must be unanimous. The deadline to complete the retake is six months after the defense date, unless the committee unanimously agrees to reduce it. Students who fail the Dissertation Proposal Defense, or who fail the Retake will be dismissed from the University.

A student who successfully passes the Dissertation Proposal Defense is deemed a Ph.D. Candidate.

4.4 Ph.D. Defense

To graduate, a Ph.D. candidate has to form a Ph.D. Dissertation Defense Committee, finalize the Ph.D. dissertation and successfully defend his/her Ph.D. dissertation.

4.4.1 Ph.D. Dissertation Defense Committee

The Ph.D. Dissertation Defense Committee, which must be approved by the student's Dean, must consist of at least four members and typically includes no more than six members. At least three of the required members must be KAUST Faculty and one must be an Examiner who is external to KAUST. The Chair, plus one additional Faculty Member must be affiliated with the student's Program. The External Examiner is not required to attend the Defense, but must write a report on the dissertation and may attend the Dissertation Defense at the discretion of the Program.

Member Role Program Status

Member	Role	Program Status
1	Chair	Within Program
2	Faculty	Within Program
3	Faculty	Outside Program
4	External Examiner	Outside KAUST
5	Approved Research Scientist	Inside KAUST
6	Additional Faculty	Inside or outside KAUST

Notes:

- Members 1-4 are required. Members 5 and 6 are optional.
- Co-Chairs may serve as either members 2, 3 or 6.
- Adjunct Professors and Professors Emeriti may retain their roles on current Committees, but may not serve as Chair on any new Committees.
- Professors of Practice and Research Professors may serve as members 2, 3 or 6 depending upon their affiliation with the student's Program. They may also serve as Co-Chairs.
- Visiting Professors may serve as member 6, but not as the External Examiner.

The only requirement with commonality with the Proposal Committee is the Supervisor, although it is expected that other members will carry forward to this committee.

If the student has a co-supervisor, this person can be considered one of the above four members required, provided they come under the categories listed (i.e. meets the requirements of the position).

4.4.2 Ph.D. Dissertation Defense

The Ph.D. Degree requires the passing of the defense and acceptance of the dissertation. The final defense is a public presentation that consists of an oral defense followed by questions and may last a maximum of three hours.

The student must determine the defense date with agreement of all the members of the Dissertation Committee, meet deadlines for submitting graduation forms and inform the committee of his/her progress. It is the responsibility of the student to submit the required documents to the Graduate Program Coordinator at the beginning of the semester they intend to defend. It is also expected that the student submits their written dissertation to the committee at least two months prior to the defense date in order to receive feedback.

The written dissertation is required to comply with the University Formatting Guidelines which are on the library website: **CLICK HERE**

There are four possible outcomes from this Dissertation Final Defense:

- Pass
- Pass with conditions
- Fail with retake
- Fail without retake

A pass is achieved when the committee agrees with no more than one dissenting vote, otherwise the student fails. If more than one member casts a negative vote, one retake of the oral defense is permitted if the entire committee agrees. In the instance of a 'Pass with Conditions', the entire committee must agree on the required conditions and if they cannot, the Dean decides. The deadline to complete the revisions is up to one month after the defense date, unless the committee unanimously agrees to reduce it. The deadline to complete the retake is as decided by the defense committee with a maximum of six months after the defense date, unless the committee unanimously agrees to reduce it. Students who fail without retake the Dissertation Defense or who fail the retake will be dismissed from the University.

Evaluation of the Ph.D. Dissertation Defense is recorded by submitting the Result of Ph.D. Dissertation Defense Examination form within three days after the Defense to the Registrar's Office.

5. Program Courses and Descriptions

Course Notation:

Each course is listed prefaced with its unique number and post fixed with (L-C-R) where:

L = the lecture hours to count towards fulfilling the student workload during the semester.
C = the recitation or laboratory hours
R = the credit hours towards fulfilling a degree course requirement.

E.g. CS 220 Data Analytics (3-0-3) has a total of three hours of lectures per week, has no labs and earns three credits for the semester.
100-level courses are preparatory in nature and do not count towards the MS or PhD degrees.

CS 140 – Systems Programming and Architecture (3-0-0)

This course provides a comprehensive and unified introduction to operating systems and concurrency control topics. It emphasizes both design issues and fundamental principles in contemporary systems and gives students a solid understanding of the key structures and mechanisms of operating systems. It also prepares the students to master concurrent and parallel programming by exposing the concepts of parallelism, synchronization and mutual exclusion. The course discusses design trade-offs and the practical decisions affecting design, performance and security. The course illustrates and reinforces design concepts and ties them to real-world design choices through the use of case studies.

CS 160 – Data Structures and Algorithms (3-0-0)

This course teaches techniques for the design and analysis of efficient algorithms, emphasizing methods useful in practice. Topics covered include: sorting; search trees; heaps; hashing; divide-and-conquer; dynamic programming; amortized analysis; graph algorithms; shortest paths; network flow; computational geometry; number-theoretic algorithms; polynomial and matrix calculations; caching and parallel computing.

CS 161 – Theory of Computer Science (3-0-0)

The course will progress through finite automata, circuits and decision trees, Turing machines and computability, efficient algorithms, reducibility, the P versus NP problem, NP-completeness, the power of randomness, and computational learning theory. It examines the classes of problems that can and cannot be solved by various kinds of machines. It tries to explain the key differences between computational models that affect their power.

CS 199 – Directed Study in Computer Science (variable credit up to a maximum of 12 credits)
A course of self-study in a particular topic as directed by faculty and approved by the division.

CS 207 – Programming Methodology and Abstractions (3-0-3)
Computer programming and the use of abstractions. Object-oriented programming, fundamental data structures (such as stacks, queues, sets) and data-directed design. Recursion and recursive data structures (linked lists, trees, graphs). Introduction to basic time and space complexity analysis. The course teaches the mechanics of the C, C++ or Java language as well as an example of media library. No degree credits for CS majors.

CS 213 – Knowledge Representation and Reasoning (3-0-3)
The course covers basic concepts in knowledge representation, reasoning and its application in the Semantic Web. The aims of the course are to introduce key concepts of knowledge representation and its role in artificial intelligence, enable students to design knowledge-based systems and understand limitations and complexity of algorithms for representing knowledge.

CS 220 – Data Analytics (3-0-3)
Prerequisites: familiarity with algorithm runtime analysis (e.g., big O notations), probability theory (e.g. Gaussian distribution and conditional probability) and programming language (e.g., MATLAB or C++).
The course covers basic concepts and algorithms for artificial intelligence, data mining and machine learning. The main contents are: artificial intelligence (task environment, performance measure and problem solving by searching), data mining (data and patterns, summary statistics and visualization, unsupervised feature selection and supervised feature selection) and machine learning (cross validation and supervised learning).

CS 229 – Machine Learning (3-0-3)
Prerequisites: linear algebra and basic probability and statistics. Familiarity with artificial intelligence recommended.
Topics: linear and non-linear regression, nonparametric methods, Bayesian methods, support vector machines, kernel methods, Artificial Neural Networks, model selection, learning theory, VC dimension, clustering, EM, dimensionality reduction, PCA, SVD and reinforcement learning.

CS 240 – Computing Systems and Concurrency (3-0-3)
Prerequisite: solid computer programming skills. Operating systems design and implementation. Basic structure; synchronization and communication mechanisms; implementation of processes, process management, scheduling and protection; memory organization and management, including virtual memory; I/O device management, secondary storage and file systems. Concurrency at the hardware, programming language and operating system level.

CS 244 – Computer Networks (3-0-3)
Packet switching, Internet architecture, routing, router architecture, control algorithms, retransmission algorithms, congestion control, TCP/IP, detecting and recovering from errors, switching, Ethernet (wired and wireless) and local area networks, physical layers, clocking and synchronization. Assignments introduce network programming using NS-3, sockets, designing a router and implementing a transport layer. Also, advanced research papers on cloud computing, software define networking, and wireless sensor networks. The course consists of a final implementation project on a novel idea.

CS 245 – Databases (3-0-3)
Prerequisites: working knowledge of basic discrete mathematics (e.g., sets, functions and relations) and programming skills. Database design and use of database management systems for applications. The relational model, relational algebra and SQL, the standard language for creating, querying and modifying

relational and object-relational databases. XML data including the query languages XPath and XQuery. UML database design and relational design principles based on functional dependencies and normal forms. Other topics include indexes, views, transactions, authorization, integrity constraints and triggers. Advanced topics from data warehousing, data mining, Web data management, Datalog, data integration, data streams and continuous queries and data-intensive Web services.

CS 247 – Scientific Visualization (3-0-3)

Recommended prerequisites: Linear algebra, basic calculus, C/C++ programming experience. Recommended additional prerequisites: AMCS/CS 248 Computer Graphics, CS 380 GPU and GPGPU Programming, OpenGL programming experience.
This course covers the basics and applications of scientific visualization. It covers techniques for generating images and interactive visualizations of various types of experimentally measured, computer-generated (simulated) or gathered data. It covers grid structures, scalar field and volume visualization, vector field and flow visualization, and tensor field visualization. It covers applications in science, engineering and medicine.

CS 248 – Computer Graphics (3-0-3)

Prerequisites: solid programming skills and linear algebra.
Basic topics: linear algebra for computer graphics, 2D and 3D transformations, mesh data structures, viewing and camera models, local shading models, texturing, shader programming.
Advanced topics: color, radiometry, real-time rendering, bump mapping, environment mapping, bounding volumes, hierarchical data structures, collision detection, parametric curves, ray tracing, photon mapping, path tracing, anti-aliasing, reaction-diffusion, scanning, normal estimation, ransac, quaternions and displays.

CS 260 – Design and Analysis of Algorithms (3-0-3)

Prerequisites: computer programming skills, probability, basic data structures and algorithms, basic discrete mathematics.
The course covers main approaches to design and analysis of algorithms including important algorithms and data structures and results in complexity and computability. The main contents are: review of algorithm analysis (search in ordered array, binary insertion sort, merge sort, worst-case and average-case time complexity, minimum complexity of sorting n elements for small n, 2-3 trees, asymptotic notation); divide and conquer algorithms (master theorem, integer multiplication, matrix multiplication, fast Fourier transform); graphs (breadth-first search, connected components, topological ordering, depth-first search, way from planar graphs to Robertson-Seymour theorem);dynamic programming (chain matrix multiplication, shortest paths, edit distance, sequence alignment, extensions of dynamic programming); greedy algorithms (binary heaps, Dijkstra's algorithm, minimum spanning tree, Huffman codes, matroids); randomized algorithms (selection, quick sort, global minimum cut, hushing); P and NP (Cook's theorem, examples of NP-complete problems); approximate algorithms for NP- hard problems or polynomial algorithms for sub problems of NP-hard problems (set cover, vertex cover, maximum independent set, 2-SAT); partial recursive functions (theorem of Post, Diophantine equations); computations and undecidable problems (existence of complex problems, undecidability of halting problem, theorem of Rice, semantic and syntactical properties of programs).

CS 261 – Combinatorial Optimization (3-0-3)

Prerequisite: familiarity with discrete algorithms at the level of AMCS 260
Topics: Maximum flow, minimum cut. Polytopes, linear programming, LP-relaxation, rounding. Greedy algorithms, matroids. Approximation algorithms for NP-complete problems. Randomized algorithms. These techniques are applied to combinatorial optimization problems such as matching, scheduling, traveling salesman, set cover, maximum satisfiability.

CS 272 – Geometric Modeling (3-0-3)

Prerequisites: Advanced and multivariate calculus, and linear algebra, computer graphics and programming experience. Terminology, coordinate systems and implicit forms. Parametric and spline representations of curves and surfaces and their uses. Basic differential geometry of curves and surfaces. Subdivision surfaces.

Solid modeling paradigms and operations. Robustness and accuracy in geometric computations. Applications.

CS 291 – Scientific Software Engineering (3-0-3)

Prerequisites: programming experience and familiarity with basic discrete and numerical algorithms.
Practical aspects of application development for high performance computing. Programming language choice; compilers; compiler usage. Build management using make and other tools. Library development and usage. Portability and the GNU auto-configure system. Correctness and performance debugging, performance analysis. Group development practices and version control. Use of third-party libraries and software licensing.

CS 292 – Parallel Programming Paradigms (3-0-3)

Prerequisites: programming experience and familiarity with basic discrete and numerical algorithms.
Distributed and shared memory programming models and frameworks. Thread programming and OpenMP. Message passing and MPI. Parallel Global Address Space (PGAS) languages. Emerging languages for many core programming. Elements to be covered will include syntax and semantics, performance issues, thread safety and hybrid programming paradigms.

CS 294 – Contemporary Topics in Computer Science (3-0-0)

A course of current interest. Topics are not permanent and the content of the course will change to reflect recurring themes and topical interest. The content will be approved by the division.

CS 295 – Internship

Master-level supervised research.

CS 297 – Master Thesis Research (variable credit)

Master-level supervised research.

CS 298 – Master Graduate Seminar (non-credit)

Master-level seminar focusing on special topics within the field.

CS 299 – Master Directed Research (variable credit)

Directed research under the supervision of a faculty member.

CS 308 – Stochastic Methods in Engineering (3-0-3)

Prerequisite: CS 241.
Review of basic probability; Monte Carlo simulation; state space models and time series; parameter estimation, prediction and filtering; Markov chains and processes; stochastic control and stochastic differential equations. Examples from various engineering disciplines.

CS 320 – Probabilistic Graphical Models (3-0-3)

Prerequisite: Students are expected to be familiar with probability theory, algorithms, machine learning and programming language.
This is a research-oriented graduate-level course on PGMs. The course will cover two main types of PGMs, i.e., directed PGMs and undirected PGMs. For directed PGMs we will cover Bayesian networks with one of its most important variants, hidden Markov models. For undirected PGMs, we will cover Markov networks (or Markov random fields) with one of its most important variants, conditional random fields. Therefore, the course contains four (4) parts: Bayesian networks, hidden Markov models, Markov networks and conditional random fields.
In each part, motivations, ideas, definitions, examples, properties, representations, inference algorithms, and applications for the corresponding PGM will be introduced. This is done through lectures by the instructor. In the next two lectures, the students will present recommended research papers and lead in-class discussions. The last lecture of each part will be an in-class quiz, the purpose of which is not to judge their ability of calculation or memorization, but to push them to think more and deeper about the contents

introduced in lectures. The course will finish by a final exam lecture and two project presentation lectures. The projects are expected to be a real application or a serious theoretical work of PGMs on real research problems.

CS 321 – Applications of AI in Bioinformatics (3-0-3)

Prerequisite: C/C++, HPC (parallel computing) programming experience
Recommended additional prerequisites: Course consists of selected projects. These projects cover application of AI to some of the relevant problems of analysis of large biological data and generally deal with complex information. Each year problems change. Students get assigned one project and they work either alone or in groups of 2. Students in the interactive discussions with the whole class and the instructor solve the project problems. Students regularly present their progress and defend their approach and results in front of the whole class. During one semester several types of topics are dealt with. Students get direct experience in research methodology, report writing, presentations and most importantly, different ways of approaching solving AI problems

CS 322 – Applied Ontology

Prerequisite: CS 213.
The course covers advanced topics in conceptual modelling, data management, integration and analysis, all of which have applications in data-intensive disciplines such as biology, biomedicine and others. The aims of the course is to provide an in-depth understanding of the state of the art in formal ontologies, including their role in integrating and analyzing data. While Knowledge Representation and Reasoning (CS 213) introduced basic logic formalisms that can be used to express knowledge. Examples include the theories for mereological (parthood) relations, or theories of space and time and the consequences of selecting a particular theory in formalized knowledge bases. The Course is split in two parts, the first focusing on concrete applications with examples taken from the biomedical domain, the second focusing on the theoretical framework underlying formal ontologies and their role in information systems.

CS 337 – Information Networks (3-0-3)

Prerequisite: probability, stochastic systems, network architecture of the Internet and the systems performance
Modeling, experimental design, performance measurement, model development, analytic modeling, single queue facility, networks of queues, stochastic systems, deterministic systems, birth-death model analysis, closed network model, bottleneck, interactive networks, M/M/m queues, M/G/1 priority queues, Markovian queuing model, random numbers, discrete event simulation, verification and validation of simulation models, workload characterization and benchmarks. Also, advanced research papers on using queuing theory for networking systems. The course consists of a final modeling and simulation project on a novel idea that leads to publication

CS 340 – Computational Methods in Data Mining

Prerequisites: Probability and Statistics, Linear Algebra, Artificial Intelligence.
Focus is on both classical and new emerging techniques in data mining. Topics include computational methods in supervised and unsupervised learning, association mining, collaborative filtering and graph mining. Individual or group applications-oriented programming project is required.

CS 341 – Advanced Topics in Data Management (3-0-3)

Prerequisites: CS 245.
Topics in Data Management will be analyzed and discussed. Students will engage in research and project presentations. Topics will vary by semester.

CS 343 – Advanced Distributed and Networked System (3-0-3)

Prerequisites: CS 240
This class is a graduate seminar that covers design and implementation concepts in distributed systems and networked systems by reviewing a selection of classical and contemporary papers. We will study efficient system design and evaluation as well as learn high-level system issues with a focus on exciting

topics in distributed and networked systems. Research in these areas also tends to be scattered across disjoint sets of researchers and conferences and the course attempts to study commonalities. The syllabus for this course will vary from year to year so as to cover a mixture of older and more contemporary systems papers. Contemporary papers will be generally selected from the past 5 years, primarily drawn from high quality conferences such as SOSP, SIGCOMM, OSDI, NSDI and EuroSys. On completion of this module, students should have a broad understanding of some key papers and concepts in computer systems research as well as an appreciation of how to argue for or against any particular idea. There is no textbook for this course.

CS 344 – Advanced Topics in Computer Networks (3-0-3)

Prerequisites: solid computer networking background or CS 244 computer networks, excellent skills in programming using C/C++, using network simulators such as NS-3, working with Linux systems.
Topics in Computer Networks will be analyzed and discussed. Topics will vary by a semester

CS 345 – Advanced Topics in Distributed and Networked Systems (3-0-3)

This course is a graduate seminar that covers design and implementation concepts in distributed systems and networked systems by reviewing a selection of classical and contemporary papers. We will study efficient system design and evaluation as well as learn high-level system issues with a focus on exciting topics in distributed and networked systems. Research in these areas also tends to be scattered across disjoint sets of researchers and conferences and the course attempts to study commonalities.
The syllabus for this course will vary from year to years so as to cover a mixture of older and more contemporary systems papers. Contemporary papers will be generally selected from the past 5 years, primarily drawn from high quality conferences such as SOSP, SIGCOMM, OSDI, NSDI and EuroSys.
On completion of this module students should have a broad understanding of some key papers and concepts in computer systems research, as well as an appreciation of how to argue for or against any particular idea. There is no textbook for this course.

CS 346 – Advanced Topics in Operating Systems (3-0-3)

Prerequisites: Solid computer programming skills (at least at the level of CS 207) and solid background in at least one operating systems (CS 240) or computer architecture (at least at the level of CS 209 or CS 280), or permission of instructor.
Topics in Operating Systems will be analyzed and discussed. Topics will vary by semester.

CS 360 – Computational Complexity (3-0-3)

Prerequisites: CS 260.
This course covers the main complexity classes, as well as selected advanced topics in computational complexity. Topics: Hardness of Computational problems, models of computations including Turing machines (universal, probabilistic), Boolean Circuits. Complexity classes (P, NP, coNP, PSPACE, NL, P/poly, BPP) and their relations. Diagonalization, space complexity, randomized computation. Selection of topics such as interactive proofs, cryptography, quantum computation, hardness of approximation, decision trees, or algebraic computational models.

CS 361 – Combinatorial Machine Learning (3-0-3)

Prerequisites: CS 260 Design and Analysis of Algorithms, CS 220 Data Analytics.
The course covers tools for design and analysis of decision trees, decision rules and tests, their applications to supervised machine learning and related topics including current results of research. The main contents are: introduction (basic notions and examples from applications); tools (relationships among decision trees, rules and tests, bounds on complexity of tests, decision rules and trees, algorithms for construction of tests, decision rules and trees); applications (supervised machine learning); some of the additional topics (decision tables with many-valued decisions, approximate decision trees, rules and tests, global and local approaches to the study of problems over infinite sets of attributes, applications to combinatorial optimization, fault diagnosis, pattern recognition, analysis of acyclic programs, data mining and knowledge representation); current results of research.

CS 372 – Computational Geometry (3-0-3)

Prerequisites: CS 260. This course presents worst-case efficient algorithms for geometric problems.
The main topics are: Notions of discrete geometry (convex hulls, planar graphs, triangulations, Delaunay graphs, Voronoi diagrams, arrangements of lines, point-line duality).
Geometric algorithms design techniques (plane sweep, randomized incremental construction, bucketing, divide and conquer).
Geometric data structures (doubly-connected edge list, history graphs, range trees, segment trees, and interval trees)
Low-dimensional linear programming. Topological lower bounds. Implementation issues.
These theoretical results are presented in connection with applications to computer graphics, robotics, databases, and geographic information systems.

CS 380 – GPU and GPGPU Programming (3-0-3)

Prerequisites: Good C/C++ programming skills, or other strong programming background. Understanding of basic computer architecture.
Recommended optional prerequisites: CS 248, CS 280, and CS 292. The course covers the architecture and programming of GPUs (Graphics Processing Units). It covers both the traditional use of GPUs for graphics and visualization, as well as their use for general purpose computations (GPGPU, GPU Computing). The main contents are: GPU many-core hardware architecture, shading and GPU programming languages and APIs, programming vertex, geometry and fragment shaders, programming with CUDA, Brook, OpenCL, stream computing, approaches to massively parallel computations, memory subsystems and caches, rasterization, texture mapping, linear algebra computations, alternative and future architectures.

CS 390D – Special Topics: Computational Imaging and Display (3-0-3)

Prerequisites: AMCS 251
This course provides an introduction to computational imaging and display. Starting from image formation models for conventional and unconventional camera designs we derive inverse problems for image reconstruction in 2D and 3D. Specific applications include standard camera imaging pipelines, light field and high dynamic range cameras, 3D imaging using conventional cameras as well as transient and time-of-flight approaches. Finally we will discuss how to apply the same techniques to the design of computational displays with extended capabilities.

CS 390H – Big Data Optimization

Prerequisite: Linear algebra, multivariate calculus, probability theory and programming. Ability to understand mathematical proofs. Experience with a high level computer language (e.g. Matlab, Julia, Python, and C++)
Mathematically rigorous introduction into the field of big data optimization. Randomized algorithms in numerical linear algebra, convex optimization and machine learning.

CS 390I – Integrating Symbolic and Statistical AI

The course covers advanced topics in Artificial Intelligence. Symbolic approaches to artificial intelligence represent entities within a domain of knowledge through physical symbols, combine symbols into symbol expressions and structures and manipulate symbols and symbol expressions and structures through inference processes. Statistical approaches to AI include many machine learning, data mining and optimization methods in which target functions are approximated. Statistical approaches are useful in learning patterns and regularities, while symbolic approaches are useful in representing knowledge and manipulating symbols to infer new knowledge. The aim of the course is to explore combinations of statistical and symbolic approaches to AI. In particular, the course will focus on interfaces between learning, representation and inference.

CS 394 – Contemporary Topics in Computer Science (3-0-0)

A course of current interest. Topics are not permanent and the content of the course will change to reflect recurring themes and topical interest. The content will be approved by the division.

CS 395 – Internship (variable credit) (Summer semester)
Doctoral-level supervised research.

CS 397 – Doctoral Dissertation Research (variable credit)
Doctoral-level supervised research.

CS 398 – Doctoral Graduate Seminar (non-credit)
Doctoral-level seminar focusing on special topics within the field.

CS 399 – Doctoral Directed Research (variable credit)
Doctoral-level supervised research.

6. University Wide Courses
University wide courses are courses in areas not tied to any specific degree program. They are designed to meet institutional requirements, provide broadening experience or to provide supplemental preparation to support students in their degree.

These are listed below:

6.1 English as a Second Language
These courses are designed to provide English language training for students who do not fully meet the University's English language entrance requirements. Students will be assigned courses based on their level of English or proficiency.

ESL 101 English as a Second Language I (6-0-0)
ESL 101 is a foundational English skills course for reading, listening, speaking and writing.
The course has a strong focus on teaching students the basics of academic writing and grammar structures in preparation for thesis work. Course materials are typically A2 level to help students acquire basic academic English skills required for graduate coursework.

ESL 102 English as a Second Language II (3-0-0)
ESL 102 is a pre- English skills course for reading, listening, speaking and writing. The course continues to focus on building academic writing and grammar skills and also have more emphasis on reading for academic purposes. Course materials are typically B1 level to help students further develop pre-intermediate English skills required for graduate coursework.

ESL 103 English as a Second Language III (3-0-0)
ESL 103 is an upper-intermediate English skills course for reading, listening, speaking and writing. The course helps to further develop academic English skills necessary to successfully complete research and thesis work. Course materials are typically B2 level to help students refine upper-intermediate English skills required for graduate coursework.

6.2 Enrichment Program – WEP Courses
The Winter Enrichment Program (WEP) takes place in January each year and is designed to broaden students' horizon.WEP is an essential and core requirement of the degree programs at KAUST. Satisfactory completion of at least one WEP is required of all M.S. students as part of the completion of the degree requirements. Ph.D. students who did not receive their M.S. Degree at KAUST are also required to satisfactorily complete at least one WEP. To satisfy this mandatory requirement, full participation must occur within a single WEP period.

6.3 Innovation and Economic Development

Innovation and Economic Development (IED) courses are meant as a broadening experience and are not technical electives. Students should consult with their program to ensure credits can be applied toward their degree.

6.3.1 IED 210 – Technology Innovation and Entrepreneurship (3-0-3)

This course introduces students to using an entrepreneurial and design thinking view to solving real-world challenges including the pathway to commercializing research. It is about changing methods of thinking and equipping graduate students to be able to understand and manage innovation in the corporate world. This course is open to all M.S. students as an elective and to Ph.D. students with permission of their academic advisors.

6.3.2 IED 220 – New Venture and Product Innovation Challenge (6-0-6)

This intensive 8 week module will give a small select group of students, the opportunity and time to develop a detailed value proposition for a product based on an existing piece of intellectual property. This technology may be from the KAUST IP portfolio or potentially from a corporate partner. As part of the program, students will be provided with an overview of key creative subjects related to new product development including; key aspects of intra/entrepreneurship, innovation management including new product development, Go-to-Market strategies as part of commercialization roadmaps, as well as general knowledge on relevant creativity and design thinking. It will also enable students to develop these skills in a full time, heavily mentor-led and experiential learning environment that includes regular pitches and feedback from a wide range of pre-selected mentors from both inside and outside KAUST including international experts.

7. Grading

The KAUST grading system is a 4.0 scale utilizing letter grades and these are the only grades that will be assigned:

A	=	4.00	C	=	2.00
A-	=	3.67	C-	=	1.67
B+	=	3.33	D+	=	1.33
B	=	3.00	D	=	1.00
B-	=	2.67	D-	=	0.67
C+	=	2.33	F	=	0.00
I	=	Incomplete			
IP	=	In-Progress			
W	=	Withdrew			
S	=	Satisfactory			
U	=	Unsatisfactory			
WF	=	Withdrew-Failed			

7.1 Incomplete Grades

Students who complete the majority of the requirements for a course but are unable to finish the course may receive an Incomplete (I) grade. A grade of Incomplete will be assigned only with the consent of the instructor of the course after the instructor and the student have agreed on the academic work that needs to be completed and the date it is due (but no later than the end of the second week of the following semester or session). When the requirements for the course are completed, the instructor will submit a grade that will replace the Incomplete grade on the student's academic record. 'Incompletes' not completed by the end of the second week of the following semester or session will be changed to Failing (F) grades.

Grades for students that are due to Graduate

Note that any Incomplete grades (as well as Fail grades) will mean a student will not graduate or receive a diploma during the Commencement Ceremony.

Incomplete grades are granted to individual students on a case-by-case basis. Incomplete grades should not be used as a mechanism to extend the course past the end of the Semester. Students are allowed only one Incomplete grade while in a degree program at KAUST.

7.2 In-Progress Grades

Thesis Research (297) or Dissertation Research (397) should be graded as In-Progress (IP) or Unsatisfactory (U) for each semester. These 'IP' Grades will be converted by the Registrar's Office to 'S' Grades for all semesters once the office has been notified that the thesis or dissertation has been submitted to the library.

7.3 Research and Seminar Courses

297 =	Thesis Research	-Either 'IP' or 'U'
397 =	Dissertation Research	-Either 'IP' or 'U'
295/395 =	Summer Internship	-Either 'S' or 'U'
298/398 =	Seminar	-Either 'S' or 'U'
299/399 =	Directed Research	-Either 'S' or 'U'

8. Academic Standing

A student's academic standing is based on his/her cumulative performance assessment and a semester performance based on the number of credits earned and GPA during the most recently completed semester.

Academic Standing classifications are divided into four categories of decreasing levels of Academic Performance:

- Good Standing
- Academic Notice
- Academic Probation
- Academic Dismissal

Cumulative Grade Point Average

- A minimum GPA of 3.0 must be achieved in all coursework.
- Individual courses require a minimum of a B- for Course credit.

Cumulative Assessment

GPA	Academic Standing
3.00-4.00	Good Standing
2.67-2.99	Academic Notice
2.33-2.66	Academic Probation
Below 2.33	Academic Dismissal

S/U Performance	Academic Standing
0-2 Credits	GPA Standing
3-5 Credits	GPA Standing less one category
6-8 Credits	GPA Standing less two categories
9+ Credits	Academic Dismissal

Semester Assessment (Registered in 12 Credits)

Credits Earned	Academic Standing
12+ Credits	GPA Standing
9-11 Credits	GPA Standing less one category

6-8 Credits	GPA Standing less two categories
0-5 Credits	Academic Dismissal

Semester Assessment (Registered in 9 Credits)

Credits Earned	**Academic Standing**
9+ Credits	GPA Standing
6-8 Credits	GPA Standing less one category
3-5 Credits	GPA Standing less two categories
0-2 Credits	Academic Dismissal

Summer Session Assessment

Credits Earned	**Academic Standing**
6 Credits	GPA Standing
3-5 Credits	GPA Standing less one category
0-2 Credits	GPA Standing less two categories

Definitions:

Good Standing

Student is making satisfactory academic progress towards the degree.

Academic Notice

Student is not making satisfactory progress towards the degree. A student placed on Academic Notice will be monitored in subsequent semesters to ensure satisfactory progress towards the degree (see Good Standing). If the student's performance does not improve in the following semester, the student will be placed on Academic Probation.

Academic Probation

Student is not making satisfactory progress towards the degree. A student placed on Academic Probation will be monitored in subsequent semesters to ensure satisfactory progress towards the degree (see Good Standing). If the student's performance does not improve in the following semester, the student will be academically dismissed.

Academic Dismissal

Student is not making satisfactory progress towards the degree and is unlikely to meet degree requirements. Dismissed students will be required to leave the University. If deemed eligible, dismissed students will have one week from receiving Notice of Dismissal to file an Appeal.

Appeal Process for Students Academically Dismissed

If the student is eligible to appeal, he/she must submit a written explanation why the dismissal should be rescinded along with any supporting documentation. The Committee on Academic Performance will hear the appeal and make a decision to grant or deny the appeal based on the appeal and documentation, the student's past performance and the likelihood that the student is capable of successfully completing his/her academic program. If the appeal is denied, the student will be required to leave the University. The decision of the committee is final – no additional appeals are permitted.

S/U Protection

Due to the significant impact of Unsatisfactory (U) Grades, a Faculty Member giving a 'U' Grade for a course involving six or more credits must obtain concurrency of the Dean prior to submitting the grade. If the grade is given for only a single class (including Research Credit), the number of credits will be capped at six when using the Academic Standing Table displayed above.

Returning to Good Standing

A student not in Good Standing due to a GPA deficiency may return to Good Standing by improving his/her cumulative GPA such that it meets or exceeds 3.0. A student not in Good Standing due to 'U' Grades may return to Good Standing by completing at least twelve credits during the subsequent semester with no 'U' grades and a semester GPA of at least 3.0 in traditionally graded courses.

9. Transferring Credits

A student may petition to transfer graduate credits from KAUST or another University upon approval of the Program Director and the Registrar.

Each student's application will be reviewed on a case-by-case basis.

The following rules apply:

- Students entering the program with an M.S. Degree from KAUST may transfer unused coursework toward the Ph.D. program requirements subject to program level approval.
- Up to three graduate-level courses not to exceed nine credits may be transferred for credit. Courses already used for another degree cannot be used as transferred credits.
- The course grade for any course to be transferred must be a 'B' or above.
- Courses transferred for degree credit must have been taken within three years prior to admission to KAUST.
- The student must submit a completed KAUST Transfer of Credit Form and include the Course Syllabus and Course Description.
- The student is responsible for supplying an official transcript:
- The transcript may be no more than three months old.
- The transcript must be in English or accompanied by a certified English translation.
- The Grading Key must be included with the transcript.
- The Transcript must include the course name, level, grade and credit value.
- The credit value of the course must be equivalent to a minimum of three KAUST credit hours.

Course Transfer and Equivalency

Graduate credit hours taken from any KAUST program may be applied to other KAUST graduate programs under the guidelines of the degree program to which the student is admitted. Graduate courses taken from another University or KAUST program that are equivalent in level and content to the designated courses in a major track may be counted towards meeting the major track requirement if their equivalence is confirmed by the Program Director.

Students transferring from other Ph.D. programs may receive some Dissertation Research and Coursework credit units on a case-by-case basis for related work performed at their original Institution. However, such students must satisfy the written and oral requirements for a research proposal (if the proposal had been submitted and approved at the original Institution, the proposal may be the same, if approved by the research advisor). The minimum residency requirement for enrolment of such students at KAUST is two years.

10. Policy for Adding and Dropping Courses

A course may be added during the first week of the semester. Students may add courses after the first week with the permission of the instructor. Instructors have the right to refuse admission to a student if the instructor feels that the student will not have the time to sufficiently master the material due to adding the course late. A course may be dropped without penalty at any time during the first two weeks of the semester. Between the second and ninth week, students can drop a course but the course will appear on the student's transcript with the grade of Withdraw (W). After the ninth week of a full semester, courses may be dropped only under exceptional circumstances and with the approval of the Course Instructor, the Program Director and the Registrar.

11. Program Planning

It is the sole responsibility of the student to plan her/his graduate program in consultation with her/his advisor. Students are required to meet all deadlines. Students should be aware that most core courses are offered only once per year.