Skoltech

Skolkovo Institute of Science and Technology

EDUCATIONAL MODEL, PROGRAM AND COURSE DESCRIPTIONS

ACADEMIC YEAR 2013/14

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Skolkovo Institute of Science and Technology

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Mats Hanson,
Dean of Education

Greetings!

I'd like to introduce you to Skoltech — a new model in the Russian higher education system, bridging science and innovation to impact our world. Within our international community of scholars and researchers, we are doing more than graduating leaders. We are preparing agents of change.

We have formulated our educational programs to foster students' interdisciplinary understanding and ability to solve open-ended problems. Unfettered by departmental barriers, students continually cross disciplinary boundaries during applied learning experiences. In team environments and project-based learning activities, they also build communication skills, learn how to work in teams and attain the confidence necessary to take risks and innovate.

We have formed these programs around the renowned CDIO Principles (Conceive – Design – Implement – Operate), and intentionally construct each course to instill students with specific learning outcomes. All educational activities are then systematically designed to teach those desired results.

International experience is also a central part of a Skoltech education.
We view our network of partner universities around the world as one of our most valuable assets. Through our Centers for Research, Education, and Innovation, students can travel to the Massachusetts Institute of Technology, University of Groningen and others to conduct research. Easing our graduates' mobility, we have also aligned the programs with the European Higher Education Area (the Bologna process).

We look forward to collaborating with you in the future, and hope you join us as we develop a new educational community from the ground up. Please read on to learn more about what makes me so excited to say I am a part of Skoltech!

About Skoltech

The Skolkovo Institute of Science and Technology is a private graduate research university in Skolkovo, Russia, a suburb of Moscow.

Established in October 2011 in partnership with the Massachusetts Institute of Technology (MIT), Skoltech educates global leaders in innovation, advances scientific knowledge, and fosters new technologies to address critical issues facing Russia and the world. Applying international research and educational models, the university integrates the best Russian scientific traditions with twenty-first century entrepreneurship and innovation.

Vision: bridges from science to innovation

- Expanding fundamental research with a consideration for innovation that bridges functions to bring ideas to impact
- Education for innovation that grounds students in fundamentals and the innovation process, so that they can be leaders in bringing ideas to impact

By 2020

203,000 **square-meter campus**

1,200 **students**

440 **postdoctoral associates**

200 **professors**

15 **Centers for Research, Education and Innovation**

Master's Program Concept

Education in the European Higher Education Area

- Skoltech education is aligned with the European Higher Education Area, created through the Bologna process of which Russia is a signatory.
- The degree awarded is Master of Science.
- Skoltech uses ECTS (European Credit Trasfer System).
- The Master programs are 120 ECTS units (two years).

Facts About ECTS

- A credit-bearing learning activity (course, project, thesis etc) is defined by its intended learning outcomes and its workload expressed in ECTS units.
- The workload is defined as the estimated average workload for students, including all scheduled activities, self-study and assessment. 1 week workload equals 1,5 credits.
- There are 60 ECTS units per academic year, corresponding to 40 weeks full time workload. A two-year program is 120 ECTS units.

Credit Transfer

- Credits earned at other institutions can be part of the degree, if and when Skoltech recognizes the credits and associated learning outcomes.
- To be eligible for a degree awarded by Skoltech, typically 96 of the total 120 credits must be earned at Skoltech. The credits earned at Skoltech will typically include the curricula elements defined in the minimum degree requirements.

Learning Outcomes Framework

Skoltech designs its education following the CDIO approach, an outcomes-based methodology developed in the CDIO Initiative.

Skoltech started by formulating a high-level vision of the graduates and translated this vision into learning outcomes. The Skoltech Learning Outcomes Framework* has been validated with stakeholders and used as an instrument for defining and declaring program and course learning outcomes. Each credit-bearing learning activity will specify its contribution towards these goals.

The next step was to design curriculum elements – courses, projects, or other credit bearing learning activities. Each curriculum element aims to achieve and assure students' attainment of the intended learning outcomes through appropriate teaching and learning activities and assessment procedures. In this manner, each course has a specific function in the program, making explicit contributions toward the overall learning outcomes.

The Learning Outcomes Framework states on a high level the vision of what our graduates should be abble to do as a result of a Master program. It is structured into four sections:

1. Disciplinary knowledge and Reasoning
2. Personal Attributes—Thinking, Beliefs and Values
3. Relating to Others—Communication and Collaboration
4. Leading the Innovation Process

** For more on the Skoltech Learning Outcomes Framework, see Appendix 1*

Streams through the curriculum

The curriculum elements (credit-bearing learning activities) are classified into categories, each with responsibility for developing certain graduate qualities.

Science, Technology and Engineering Learning Experiences
These courses provide the scientific and engineering fundamentals, including disciplinary and interdisciplinary structure of knowledge. Courses include learning activities for application and development of skills, and fostering a deep working understanding of the fundamentals. In early research experiences students will learn about the research process, and become junior researchers.

Sector Learning Experiences
Sector courses are related to the dynamics of a specific industrial sector ecosystem, including how the technical, social, political, economic and regulatory systems work. Through an early professional experience students will become a professional in the sector. The aim is to develop the knowledge and skills for making an impact in an industrial sector through engineering and innovation.

Innovation and Entrepreneurship Learning Experiences
Innovation and entrepreneurship courses are related to the full innovation process from first identification of needs and opportunities, until exploitation (commercialization and entrepreneurship), leading to economic or other impact. In early innovation experiences students will learn about the generic process of innovation, acquire the skills and self-confidence necessary for innovation, and become junior innovators.

Diploma Thesis
The thesis ties the learning together in a major project and is reported in writing and orally. Projects should draw on earlier science and technology, sector and/or innovation work, and connect research with innovation.

Degree Requirements

There is a distinction between the educational programs offered and the minimum requirements for awarding the associated degree.

Students can for instance opt to take courses originally designed for another program, or they can transfer credits from other institutions. To ensure that all graduates benefit from the distinguishing features of a Skoltech education, minimal levels for each category are specified in the general degree requirements. They state the minimum level of credits in the categories and apply to all students who want to graduate with a Master degree from Skoltech.

The Master of Science degree comprises 120 credits. On graduation all graduates will have done 120 credits, of which at least:

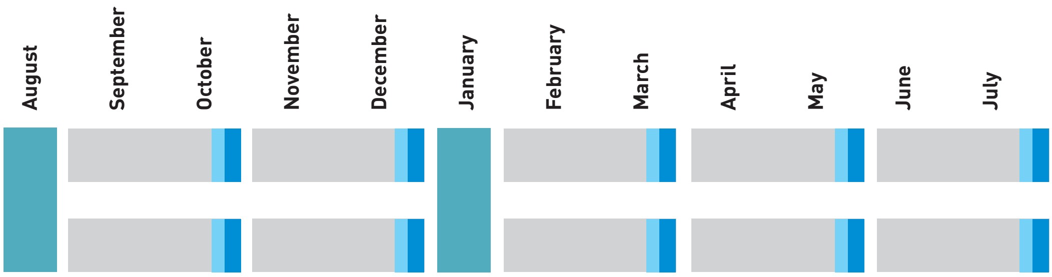
- 48 credits in Science, Technology and Engineering stream (coursework; research projects)
- 12 credits in Sector stream (coursework; professional projects in sector company or organisation)
- 12 credits in Innovation and Entrepreneurship stream (coursework; innovation projects)
- 24 credits for Thesis Project

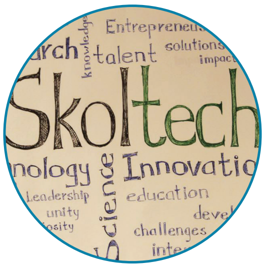
Structure of the academic year

Each academic year is divided into terms

1. August term, for 1st year students only (4 weeks full time, 6 ECTS)
2. September/October term (two activities of 6 ECTS running in parallel over 8 weeks)
3. November/December term (two activities of 6 ECTS running in parallel over 8 weeks)
4. January term (3 weeks full time) Independent Studies Period
5. February/March term (two activities running in parallel over 8 weeks, 6 ECTS each)
6. April/May term (two activities running in parallel over 8 weeks, 6 ECTS each)
7. June/July term (sector/research experience)

Students can also participate in credit-bearing activities in the summer between year 1 and 2.





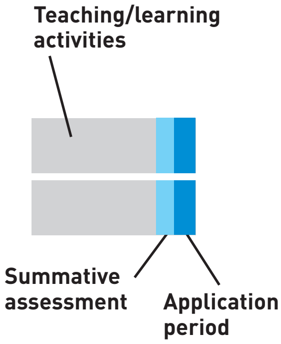
Structure of the term

The standard eight-week term long term is divided into an instruction period ending with assessment of student learning, seminars, lectures, projects, followed by an application period.

- **Teaching and learning activities**, including activities for assessment and feedback, are scheduled in week 1-6. All formal instruction must be finished before Friday of week 6, to give students time to study for examinations.

- **Summative assessment** takes place on week 7. The aim is to assess the factual understanding of the subject matter as well as the deeper conceptual understanding. Summative assessment can be written, oral, hands-on or a suitable combination.

- **Application period** starts on the final Friday of week 7. The purpose is to put the knowledge from the preceding subjects into practice in an experiential hands-on and/or innovation activity aimed toward solving a real-world problem while practicing personal and interpersonal skills such as communication and collaboration. Furthermore, through activity that is authentic and within the knowledge and skills of the learners, participants would likely improve their efficacy for entrepreneurial and innovative activities.



Program: Information Science and Technology

The Information Technology track focuses on data rich and computational approaches for science and technology problems: the formulation and implementation of new approaches that are more efficient and capable; and the informed application of existing approaches to important engineering questions. Our emphasis is on the development of the next generation of Data and Computation innovators. The Computational Mathematics track is an interdisciplinary program designed to prepare tomorrow's engineers and scientists in advanced data analysis and computational methods and applications. The program provides a strong foundation in data enabled and computational approaches to the understanding of complex data and to the design and operation of complex engineered and scientific systems. Through industry and research projects, students may develop or apply advanced methods to a diverse range of applications.

Two Tracks:

Information Technology (Big Data) Curriculum
Machine Learning, Databases, Networks, Computer Vision, Natural Language Processing

A Skoltech graduate will be able to:

- Analyze, distribute and access, and interpret enormous amounts of data
- Construct explanations and solutions to business/science/societal problems based on data analyses and interpretation
- Design statistical-based algorithms to solve information technology and data problems
- Explain economic impact of different design decisions in data storage and distribution
- Evaluate current and future business opportunities in data extraction

Computational Mathematics Curriculum
Algorithms, Optimization, Numerical PDEs, Cryptography/Cryptoanalysis, Multicore Techniques

A Skoltech graduate will be able to:

- Apply algorithms, optimization, and numerical techniques to solve new engineering design problems.
- Apply techniques of the computational mathematics field, use a repertoire of computational strategies or developing innovative approaches to analysis.
- Create combinations of problem formulation and computational techniques
- Design solutions by assembling techniques drawn from Theoretical computer science (TOCS), Optimization (Opt), and Physical Simulation (Phys)

Program:
Energy Science and Technology

The Skoltech Master of Science (M.Sc.) with an emphasis in Energy combines deep expertise with a broad understanding of the interlinked realms of science, technology, and social sciences as they relate to energy and associated environmental challenges. The program builds on Skoltech's core curriculum and is composed of an "Energy Commons" curriculum, at least one Industrial–Immersion experiences, a strategic set of classes in key energy specializations, and an array of elective classes.

The Energy Commons curriculum provides students fundamental tools in energy systems and prepares them for classes in one of three specialized tracks. Two extended assignments in energy–industry settings provide real–world problem-solving and team–management experience. The Industrial Immersion experiences are interspersed with Skoltech classes, so that students have the opportunity for applied learning on–site as well as discussion and reflection with peers and faculty. Host companies–both large, traditional energy companies and in early stage, growing companies–may be involved in energy production and conversion, transmission and distribution of energy, energy equipment manufacturers and process designers, and other aspects of energy systems.

In the second half of the program, students deepen their energy knowledge in one of three specialized Tracks, each of which delve into greater depth in a critical application area: **Upstream Oil & Gas, Energy/Power Systems, Materials for Energy**. These Tracks, as well as the master's program as a whole, are aligned with the context and associated needs of the Russian energy industry as well as with those of the Centers for Research, Energy and Innovation, so that students will emerge with a deep applied set of skills that are relevant to Russian industry.

A Skoltech Energy graduate will be able to:

- Explain traditional and emerging energy sources, resource extraction, conversion, and uses in all energy sectors, such as buildings, transportation, and manufacturing;
- Design energy systems to be economically and environmentally efficient;
- Analyze the relationships and interactions of energy system components;
- Explain the interlinked realms of science, technology, and social sciences as they relate to energy and associated environmental challenges;
- Apply fundamental tools to solve energy problems — design, optimize, troubleshoot, innovate;
- Demonstrate industrially driven problem–solving and teamwork/management capabilities;
- Explain how locational, institutional, and cultural attributes shape constraints and opportunities;
- Explain how structure and function shape spaces of strategic opportunity; and Synthesize Energy Program experiences and knowledge to pursue effective energy careers.

Course Number: MC0601
ECTS Credits: 6
Course Leader: Luis Perez Breva
Affiliation: MIT

Innovation Workshop

Description:
The purpose of this intensive workshop is threefold: to create a foundational experience in E&I for all, to empower participants to identify and solve real–world problems with technology, and to instill an entrepreneurial "can–do" attitude. Participants engage in experiential learning to prototype whole technology innovations. That is, they iterate all the components of an innovation: the problem to solve, the technology to solve it, the possibilities for impact, and the vehicle to bring the proposed innovation to life.

Learning Outcomes
Upon completion of this course the student will be able to:
- Engage in the joint optimization of the system–technology–problem–impact
- Demonstrate the ability to advocate for a technology innovation by translating uncertainty into actionable steps and milestones
- Prototype an innovation leveraging engineering principles and systems thinking
- Participate in imagining new visions for products, research, and/or organizations, including identifying issues, thinking creatively, defining problems and road–mapping solutions

Leverage interpersonal dynamics and leadership

Learning Activities
The four-week workshop contains a mix of learning activities:
- 4 categories of lectures — innovation prototyping, engineering leadership, impact series, "glue" series
- 2 types of hands–on project work — quick success series, capstone projects
- events and group building — networking, presentations, company visits, team–building
- social and observation skills — social events, activities to observe design, Energy, IT or other projects

Course Number: MC0602
ECTS Credits: 6
Course Leader: Violetta Gerasymenko, Rory O'Shea, Doug Hart
Affiliation: MIT

Ideas to Impact: Foundations for Commercializing Technological Advances

Description:
Technological Innovation is critical to the survival and competitiveness of emerging and existing organizations. This course lays the foundation to undertake a robust analysis and design of opportunities for technology-based commercialization. We introduce tools and frameworks that help isolate and control the factors shaping the identification, evaluation and development of commercial opportunities. Throughout the course we use technology examples originating from problem sets found in engineering and scientific education to develop the skills necessary to connect technology and impact.

The course is designed to help students develop the ability to find, evaluate, and develop technological ideas into commercially viable product and process concepts, and build those concepts into viable business propositions. The material covered is research and theory-based but the course is practice-oriented with much of the term spent on shaping technology-based opportunities. A central objective of this subject is to equip students with an understanding of the main issues involved in the commercialization of technological advances at both strategic and operational levels.

Learning outcomes
Upon completion of this course the student will be able to:

- Apply innovation theories and concepts to the rigorous identification and development of new opportunities for societal and commercial impact.
- Reconcile tools and methods learned in the context of an engineering education with the need to assess and design an opportunity that will bring them to use.
- Forge technology-based ideas into workable business concepts and learn how to test them in the marketplace.
- Differentiate and distinguish the different process activities associated with new product/process/service development, inside or outside an established firm.
- Explain the concepts of customer development and business model development.
- Critically assess and evaluate the resource assembly junctures in the development of new ventures (whether they be within established corporations or start-ups).

Course Number: MA0603
ECTS Credits: 6
Course Leader: Jacob White
Affiliation: MIT

Machine Learning

Description

Machine learning methods are commonly used across engineering and sciences, from computer systems to physics. Moreover, commercial sites such as search engines, recommender systems (e.g., Netflix, Amazon.com), advertisers, and financial institutions employ machine learning algorithms for content recommendation, predicting customer behavior, compliance, or risk. Why have these methods become so popular? As a discipline, machine learning tries to design and understand computer programs that learn from experience for the purpose of prediction or control. It is this focus on prediction – turning experience (data) into predictions– that has made machine learning so popular. Examples of machine learning problems include recommending products you might wish to purchase; recognizing faces from images or video; suggesting people to link to in a social networking site; predicting parts of computer code that might contain errors; deciding which data to cache for later utility; predicting properties of new materials. All of these questions involve predictions driven by data. It would be difficult for a human to specify or even know exactly how to solve each of these tasks. But it is relatively easy to provide a few examples or training data to illustrate correct and incorrect answers, as if grading possible answers to questions. In this course, you will learn about principles and algorithms for turning training data into effective automated predictions.

Learning Outcomes

Upon completion of this course the student will be able to:

- Design computer programs that learn from experience for the purpose of prediction or control
- Use algorithms to turn training data into effective automated predictions
- Implement, apply and test basic machine learning methods
- Apply machine learning concepts to new contexts
- Explain basic concepts, techniques, and algorithms in machine learning such as classification, linear regression, boosting, support vector machines, hidden Markov models, and Bayesian networks.
- Describe modern machine learning methods, including how, why, and when they work.
- Explain the principles, techniques, and algorithms in machine learning from the point of view of statistical inference, such as representation, generalization, and model selection; and methods such as linear/additive models, active learning, boosting, support vector machines, hidden Markov models, and Bayesian networks.

Course Number: MA0605
ECTS Credits: 6
Course Leader: Luca Daniel
Affiliation: MIT

Great Computational Methods

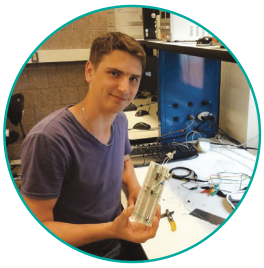
Description

This course is an introduction to computational techniques for the simulation of a large variety of engineering and physical systems. Applications are drawn from aerospace,mechanical, electrical, and chemicalengineering, biology, and materials science. Topics include mathematical formulations (techniques for Automatic assembly of mathematical problems from physics' principles); sparse, direct and iterative solution techniques for linear systems; Newton methods for nonlinear problems; discretization methods for ordinary, time-periodic and partial differential equations; accelerated methods for integral equations; techniques for automatic generation of compact dynamical system models.

Learning Outcomes

Upon completion of this course the student will be able to:

- Design innovative fast algorithms that are able to simulate large three-dimensional problems fast enough to be useful for design optimization
- Explain the fundamentals of modern numerical techniques for a wide range of linear and nonlinear elliptic, parabolic, and hyperbolic partial differential and integral equations.
- Discuss mathematical formulations; finite difference, Finite volume, finite element,and boundary element discretization methods; and direct and iterative solution techniques.
- Explain how methodologies form the foundation for Intended learning outcomes.



Course Number: MA0602
ECTS Credits: 6
Course Leader: Victor Lempitsky
Affiliation: Skoltech

Systems Optimization

Description

This course is a computational and application-oriented introduction to optimization modeling of large-scale systems in a wide variety of decision-making domains. We focus on using state-of-the-art optimization software to solve models and understand the limitations of the modeling and solution techniques. Application domains include transportation, logistics, and telecommunications system planning; pattern classification and artificial intelligence; structural and engineering design; and financial engineering.

Learning Outcomes

Upon completion of this course the student will be able to:

- Explain optimization modeling of large scale systems in a wide variety of decision making domains
- Solve models using state of the art optimization software
- Explain the limitations of modeling and solution techniques.
- Compare solutions for domains including transportation, logistics, and telecommunications system planning; pattern classification and artificial intelligence; structural and engineering design; and financial engineering.
- Apply model formulation techniques including linear optimization, non-linear convex and non convex optimization, as well as discrete optimization and conic semidefinite optimization.
- Explain solution techniques including decomposition methods, column and constraint generation, continuous mappings, stochastic programming, and conic optimization and solution methods via interior point methods.
- Formulate optimization problems and select from a catalog of computational strategies.

Energy Physics and Technology

Course Number: MA0601
ECTS Credits: 6
Course Leader: Konstantin Turitsyn
Affiliation: MIT

Description
This course will provide a graduate level overview of modern energy systems, covering generation, conversion, transportation and end-use energy technologies. For each set of technologies we will first review the fundamental physics principles that are already extensively covered in most of the Russian undergraduate technical department curriculums. Next, we will assess the engineering challenges associated with the technologies, and discuss how to do basic cost-benefit analysis of possible approaches. Each section will be concluded by the analysis of modern trends in the areas and discussion of possible innovation and research opportunities. The pedagogy will include overview lectures and homework covering the more fundamental part of the material, as well as individual projects focusing on the analysis of novel technologies proposed in academic papers or introduced by various innovative companies. Guest lectures of industry representatives will present the major industrial company's perspective on the key challenges and opportunities.

Learning Outcomes
Upon completion of this course the student will be able to:
- Explain global and regional energy flow diagrams, including characteristic scales, key technologies, and physical processes that are responsible for its structure.
- Explain the physics of main mechanisms of energy conversion and transport.
- Apply fundamental physics laws to describe the quantitative characterization of the main processes of energy conversion and transport.
- Describe the major technologies that form the foundation of modern energy systems.
- Discuss the key constraints and objectives that drive the innovation in the area.
- Describe recent innovations in the area.
- Critically assess innovation proposal feasibility using basic physics, technical, and economic analysis.

Course Number: MA0607
ECTS Credits: 6
Course Leader: Michael Chertkov
Affiliation: Skoltech

Introduction to Power Systems

Description

The course will provide a graduate level overview of modern power systems, with a major emphasis on the system aspects of power production, transmission, storage and delivery. All stages of the power energy technical chain will be thoroughly reviewed from a comprehensive engineering prospective but also from the standpoint of fundamental physics principles/equations. A special emphasis will be given to improving students' ability to extract well-formulated physics and mathematics problems from power engineering reality.

The course will rely on strong undergraduate math/physics background of the students, however no background in power systems will be assumed or required. In this course we will advance gradually through major principles of the power system design (with some history re-course), discussion of major elements of the power systems (generators, power lines, transformers), analyze state estimation, optimization, control and design practice, and will conclude with discussions of modern engineering, physics and mathematics challenges associated with the emergent smart/intelligent/resilient grid technologies.

Learning outcomes:

Upon completion of this course the student will be able to:

- Explain the general picture of the spatio-temporal scales and magnitude of energy production, transfer, storage and consumption in power systems at both transmission and distribution levels and related energy infrastructures.
- Explain basic operating principles and physics behind individual components and power system as the whole.
- Formulate optimization, control and planning problems in power systems.
- Select and apply the appropriate mathematical tools and algorithms to solve optimization, control and planning problems.
- Discuss major elements of the power systems (generators, power lines, transformers).
- Analyze state estimation, optimization, control and design practice.
- Discuss modern engineering, physics and mathematics challenges associated with the emergent smart/intelligent/ resilient grid technologies.

Course Number: MA0608
ECTS Credits: 6
Course Leader: Sergei Tretiak
Affiliation: Skoltech

Computational Chemistry and Materials Modeling

Description

The course will provide a graduate level overview of modern atomistic computer simulations used to model, understand and predict the properties of realistic technologically important materials. The class will emphasize use of practical techniques, algorithms and programs to bridge theory and applications, from the discovery of materials to their use in real-world technologies.

The lectures will start with an introduction of classical models, gradually moving on to increasingly more complex quantum mechanical and dynamical theories. In particular, the topics will include:

- energy models from classical potentials to first-principles approaches;
- density functional theory and wavefunction methods;
- errors and accuracy of quantitative predictions: thermodynamic ensembles, Monte Carlo sampling and molecular dynamics simulations;
- excited state and energy/charge transport properties; and
- coarse-graining approaches and mesoscale models.

Learning Outcomes

Upon completion of this course the student will be able to:

- Explain the fundamentals of the modern computational methods for molecular, nano- and meso-scale materials modeling that cover a wide time and length scales
- Compare and contrast topics in computational materials science in terms of similarities and differences among available methods as well as their strengths and limitations.
- Use commercial and free/copyleft (GNU) modeling and visualization software for materials science studies.
- Apply fundamental knowledge about materials modeling via computer simulations including terminology, key concepts, methods and topics of study.
- Select a computational method(s) appropriate for a given materials modeling study.
- Interpret the results of simulations
- Communicate, orally or through writing, the results of simulations to experimentalists and materials scientists.

Course Number: MA0610
ECTS Credits: 6
Course Leader:
Alessandro Golkar
Affiliation: Skoltech

Systems Architecture and Tradespace Exploration

Description

This course introduces students to formal methods of systems architecting and tradespace exploration for early conceptual design of engineering systems. The course reviews the theory of systems architecting and introduces students to quantitative tradespace exploration, with exposure to computational methods for architectural enumeration, evaluation, and downselection. Methods reviewed in this course include tools for creativity and conceptual design, formal systems design synthesis (UML, OPM), design of experiments techniques, correlation analysis, sensitivity analysis, systems modeling and simulation. Students will apply the theory discussed in the course to an individual design project of their choice. After successful completion of the course, students will acquire a toolkit of qualitative and quantitative methods to support the architecting process of new engineering systems in their domain of expertise (i.e. Space, Energy, IT, Nuclear, Biomed).

Learning outcomes:

Upon completion of this course the student will be able to:

- Structure and lead the early, conceptual phases of the design process of a complex engineering system
- Apply quantitative systems architecting tools for requirements definition, architecture enumeration, evaluation, and downselection;
- Apply tools for the identification of architectural tradeoffs;
- Develop systems architecting model and analyze results and formulate recommendations to decision-makers involved in the system development process;
- Discuss systems, systems thinking, value delivery to stakeholders, competitive advantage, and the role of the systems architect in system and product development;
- Analyze and critique the architecture of existing systems, and create the architecture of new or improved systems;
- Create functional and formal concepts of an engineering system, while performing comprehensive analysis of the underlying business case and value proposition;
- Manage complexity and interfaces in systems design, to ensure that system goals are met and function is delivered to stakeholders.
- Develop individual principles for successful systems architecting.
- Formulate project reports.
- Practice communications skills for effective technical presentations.

Course Number: MA0609
ECTS Credits: 6
Course Leader: Victor Lempitsky
Affiliation: Skoltech

Building a Large Scale Computer Vision System

Description
This project-based course will involve building a MATLAB system that can search by text query (a place, an object, a person name) in a large collection of untagged photographs. Building the system will use machine learning, computer vision, and data compression techniques, and will involve Yandex image search. The system will have several semi-independent modules, so that building the whole system will be divided among subgroups of students.

Learning outcomes:
Upon completion of this course the student will be able to:
- Evaluate machine learning, computer vision, and data compression techniques to build a module for a MATLAB text-query search system
- Select the appropriate techniques to build a module for a MATLAB text-query search system
- Use machine learning, computer vision, and data compression techniques to build a module for a MATLAB text-query search system
- Describe the use of Yandex image search
- Review research articles to evaluate relevance of information
- Present research analyses

Course Number: MA0604
ECTS Credits: 6
Course Leader: Ivan Oseledets
Affiliation: MIT

Fast Methods for Partial Differential and Integral Equations

Description

This course provides a unified introduction to the theory and practice of modern, near linear-time, numerical methods for large-scale partial-differential and integral equations.

Topics include preconditioned iterative methods; generalized Fast Fourier Transform and other butterfly-based methods; multiresolution approaches, such as multigrid algorithms and hierarchical low-rank matrix decompositions; and low and high frequency Fast Multipole Methods.

Example applications include aircraft design, cardiovascular system modeling, electronic structure computation, and tomographic imaging.

Learning outcomes:

Upon completion of this course, the students should be able to:

- Design innovative fast algorithms that are able to simulate large three-dimensional problems fast enough to be useful for design optimization
- Explain the fundamentals of modern numerical techniques for a wide range of linear and nonlinear elliptic, parabolic, and hyperbolic partial differential and integral equations.
- Discuss mathematical formulations; finite difference, finite volume, finite element, and boundary element discretization methods; and direct and iterative solution techniques.
- Explain how methodologies form the foundation for computational approaches to engineering systems involving heat transfer, solid mechanics, fluid dynamics, and electromagnetics.
- Explain the theory and practice of modern, near linear-time, numerical methods for large-scale partial-differential and integral equations
- Describe preconditioned iterative methods; generalized Fast Fourier Transform and other butterfly-based methods; multiresolution approaches, such as multigrid algorithms and hierarchical low-rank matrix decompositions; and low and high frequency Fast Multiple Methods as they apply to aircraft design, cardiovascular system modeling, electronic structure computation, and tomographic imaging.

Course Number: MA0611
ECTS Credits: 6
Course Leader: Jacob White, Brian Anthony
Affiliation: MIT

Computational Control

Description
This course will aim to introduce the learner to the programming and mechanical thinking and skills necessary for designing and developing robotic systems. As such, areas of study will include (1) Signals, Systems, and Inference; (2) Dynamics and Control; and the (3) Science and Systems of Robotics. In short, this course will widely cut across domains. Participants will learn about these areas and the methods for developing control systems through active participation in teamwork that includes software programming, conceptualization and building of specific task oriented machines, and technical report and presentation as found in industry. In addition, a central element of this course will be for students to practice problem solving by way of analysis, planning a solution, and selecting methods for achieving success. As a culminating project, participants will be presented a 'challenge' project by which they may attack a posed design problem. Through activities of designing system mechanics, selecting appropriate hardware, and writing new software, participants will demonstrate their collective knowledge while at the same time solving a real problem.

Learning outcomes:
Upon completion of this course the student will be able to:
- Practice communication techniques in written and presentation formats standard among professionals in the field of robotics.
- Discuss and make judgments about ethical and philosophical aspects related to the application of advanced technologies to assist and/or replace human effort.
- Create and assess the utility of lumped parameter models of simply dynamic systems in domains of electrical and mechanical engineering.
- Identify wide-sense stationary processes (WSS) and then compute and interpret its power spectral density (PSD).
- Generate a wide-sense stationary process (WSS) and examine how all-pass filtering leave power spectral density (PSD) unchanged.
- Identify state variables; write corresponding state-space equations; and compute equilibrium solutions.
- Design state feedback controls, observers for state estimation, and observer-based controls.
- Utilize feedback techniques in a design to compensate the transient response of dynamic systems.
- Design, implement, and assess an active control system for its achievement of intended performance.
- Compose technical reports related to design and development challenges associated with the robotics engineering.
- Identify and explain requirements for integrating hardware and software for implementing an autonomous system for performing a specific task.

Course Number: MA0612
ECTS Credits: 6
Course Leader: Alex Matveev
Affiliation: MIT

Multicore Algorithms

Description

Most engineers must learn the tricks of the trade by asking help from more experienced friends and through a laborious trial and error process. However, there are few reference books addressing how to program multiprocessors. This course aims to change this state of affairs, providing a comprehensive presentation of the principles and techniques available for programming multicore/multiprocessor machines.

The course will begin by covering the theoretical foundations of programming on multicore machines (we are strong believers that good practice requires understanding the theory). It will then move on to cover the real-world techniques used to program them. It will include a sequence of programming assignments of increasing difficulty, culminating with the design of a highly parallel "firewall" application, running on a state-of-the-art 80-way multicore machine.

Learning outcomes:

Upon completion of this course, the students should be able to:

- Analyze both the foundations and the practice of multiprocessor and multicore programming.
- Build intuition and confidence in reasoning about concurrency.
- Describe the fundamentals of the underlying architecture to reason effectively about the performance of a concurrent data structure.
- Interpret the fundamentals of concurrent data structure design.
- Design and implement his/her own concurrent data structures.

Course Number: MA0614
ECTS Credits: 6
Course Leader: Alessandro Golkar
Affiliation: Skoltech

Satellite Engineering and Space Mission Design

Description

This course introduces students to satellite engineering and provides theoretical fundamentals required for the design of a space mission. The course will teach design fundamentals of satellite subsystems, including payload, thermal, structures and configuration, communications, avionics, power, propulsion, ADCS, orbits, and ground systems. The theory is applied to a group design project of a space mission for novel terrestrial applications or space science purposes. After successful completion of this class, students will have acquired the body of knowledge required to design a space mission at the Preliminary Design Review (PDR) level.

Learning outcomes:

Upon completion of this course the student will be able to:

- Explain the function of spacecraft subsystems;
- Apply orbital mechanics formulas and tools to spacecraft mission design;
- Select appropriate launch systems and understand their effect on satellite and payload design and performance;
- Evaluate spacecraft tradeoffs in performance, cost, and risk;
- Estimate costs of a space mission;
- Trade spacecraft performance requirements to optimize higher-level system performance, cost, and mass;
- Define spacecraft mission objectives, formulate system requirements and analysis;
- Formulate project reports;
- Practice communications skills for effective technical presentations.

Course Number: MB0601
ECTS Credits: 6
Course Leader: Amy Glasmeier
Affiliation: MIT

Global Energy, Decisions, Markets and Policies

Description

This course provides students with the social science, management, and policy foundations necessary to understand why existing energy systems have developed as they have and what is required to change them, all in a global context. The global context will be provided by considering the geographic distribution of energy resources and the variation in patterns of energy capture, conversion and transmission, and end-use across Russia, the United States, and China.

Learning Outcomes

Upon completion of this course the student will be able to:

- Characterize the geographic distribution of energy resources and variation in energy development across Russia, China, US
- Analyze choices and constraints regarding sources and uses of energy
- Evaluate analysis and decision-making methods in complex energy contexts
- Explain the roles of markets and prices, government regulation, and other factors in energy systems
- Apply key analytical frameworks (e.g. economic, organizational, spatial, cultural) to describe and explain energy systems at various levels of aggregation (e.g. individuals, firms, governments)
- Integrate information into proposed policy alternatives.

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Course Number: ME0601
ECTS Credits: 6
Course Leader: Stass Shpanin
Affiliation: Skoltech

Art, Technology & Science

Description
In the 21 century, a lot of artwork is made not in the studio, but in a lab where artists and scientists work together. This is a survey course on the scientific and artistic collaborations of the last thirty years. We will study the most important intersections between science and art and the different cultural phenomena created.

The lecture part of this course is structured to provide students with comprehensive knowledge of major artistic and scientific collaborations, and to introduce different artistic practices connected to cutting-edge technology. There will be discussions of philosophical and social issues related to the subjects of contemporary art and science. Themes of the lectures relates to the five Skoltech M.Sc. programs and include, but are not limited to: Physics, Biology, Kinetics, and Robotics.

Lab is the most challenging and important part of the course. This is not the "arts and crafts" class, but on the other hand a challenging place where students could use their professional knowledge and skills to convey their ideas related to the global problems. This course consists of science and technology students working in teams with invited artists and curators to collaborate on projects related to their professional interests. Since in the spring of 2014 most of the students at the Skoltech are enrolled in the IT and Energy Science programs, it will be expected from them to create these projects using computer science programs and newfangled materials. By the end of the course, there will be an exhibit where Skoltech students will showcase their scientific and innovative projects to a wider audience.

Learning outcomes:
Upon completion of this course, the students should be able to:
- Examine their own scientific work from artistic, philosophical and cultural perspectives
- Explain and discuss main themes in science art
- Establish international collaboration with American specialists of the arts and sciences, and the engineering community to provide the exchange of ideas to stimulate innovative ideas in the science community
- Practice an ability to work in creative teams with students and specialists from different disciplines
- Gain experience in creating and presenting projects to a larger audience and, as a result, to showcase importance of science to a wider audience.

Course Number: MC0304
ECTS Credits: 3
Course Leader: Elena Silantieva
Affiliation: Skoltech

International Business Studies I

Description

Part 1 of a 3-semester series in the area of International Business Studies. Special attention is given to analysis and investigation of the Russian Federation context. Survey course in 8 main thematic areas.

Theme 1. The business world at the beginning of the XXI century
Theme 2. The system of international economic relations
Theme 3. The world market, global market conditions, and prices
Theme 4. International trade and trade policy
Theme 5. Foreign trade contracts
Theme 6. Russia's foreign trade in goods and its regulation
Theme 7. International trade in services and tourism
Theme 8. The international market of transport services

Learning outcomes:

Upon completion of this course the student will be able to:

- Set goals and make choice of ways to achieve it during business games;
- Increase the ability of logically true, clearly argued oral and written language;
- Collect, analyze and process the data necessary for solving the international economic problems;
- Analyze and interpret the data of domestic and foreign statistics on socio-economic processes and phenomena, identify trends in the socio-economic indicators;
- Use domestic and foreign financial data sources, to collect the necessary data to analyze and prepare a background review and / or evaluation report
- Cooperate with colleagues, work in teams
- Know systemic nature of modern international business relations, their main forms;
- Know main problems associated with the integration of the Russian economy in the world business;
- Be familiar with the contradictory nature of the modern system of world business relations, the complexity of finding new directions for reform in the context of globalization of the world economy;
- Be familiar with the interdependence and vulnerability of different areas and subjects of international business;
- Master the methods of finding and evaluating information about the world markets
- Master the methods of executing business cases from real events.
- Be able to carry out the selection of statistical data on the state of world business, using the publication of national and international economic organizations on various areas of international economic activity;
- Be able to use a system of knowledge about patterns and trends in international business for the analysis of the appropriateness and effectiveness of stakeholder participation in the world economy activities;
- Be able to analyze the state of international business relations for appropriate management decisions.

Course Number: MC0205
ECTS Credits: 2
Course Leader: Sergey Ulyakhin
Affiliation: Skoltech

Intellectual Property Management

Description
Intellectual property occupies a very important place among the most important assets of a successful enterprise. It includes technological and commercial solutions, which are protected by patents for inventions, utility models and industrial designs, certificates of trademark, copyright objects to computer programs, databases, topology circuits, and intellectual property rights received or transmitted on the basis of licenses.
The course reveals not only the theoretical and legislative basis for the creation of intellectual property, but also shows how to use this knowledge in practical activities to achieve maximum efficiency.
This course covers the an introduction to basic IP legislation as well as analysis and recommendations related to key practical aspects such as licensing, patent search and mapping, selection of optimal forms of IP protection, etc.

Topics covered:
- Legal basis of creation and use of the results of intellectual activity and means of individualization
- Primary approaches to intellectual property commercialization
- Methods of analysis of R&D projects and determination of patent strategy
- Patents, utility models, industrial samples
- Copyright
- Trademarks
- Protection against IP infringement
- Strategy of IP protection for start-up firms

Learning Outcomes
Upon completion of the course, students will be able to:
- Recognize and analyze basic kinds of intellectual property objects
- Set goals and formulate IP strategies to achieve them;
- Collect, analyze, and process information necessary for solving key tasks of IP protection of new business;
- Examine the prior art
- Use effective research and evaluation methods to evaluate patent landscape in certain technological areas;
- Use effective methods of intellectual property commercialization
- Know basic principles of patent and trademark protection
- Know and be able to implement in practice basic requirements to invention – novelty, inventive step and industrial applicability
- Determine patent strategy for reliable protection of R&D results
- Apply reasonable principles to select appropriate means of IP protection of brand
- Draft license agreements and assignment agreements
- Understand key aspects of collaboration with inventors and patent attorneys.

Course Number: MC0003
ECTS Credits: 3
Course Leader: : Vitaly Belik, Elena Silantieva
Affiliation: Skoltech

Venture Financing

Description

Basics of financial theory and some practical questions and issues related to funding of research in general and technology companies in particular are important for development of technology entrepreneurship. What are the financial options for the research projects and alternative funding options for start-ups? What are the financial models & projections and their use? How the funding deals are initiated, structured, negotiated and carried to closing? Some basics of M&A (including JVs) and valuation approaches. What are the main issues with controlling and management of research projects and startups? During the course, you will learn about principles and main terms for funding of projects and companies (startups), as well as get some practical experience of participating in real deal negotiations and/or considerations.

Learning outcomes:

Upon completion of this course the student will be able to:

- Explain basic concepts, techniques, and approaches in financial management, accounting and legal aspects for funding of projects and companies.
- Describe modern funding options and alternative approaches to funding deal structuring, including how, why, and when they work.
- Explain and have working knowledge of details related to funding processes from beginning to close of the deals and post-funding financial management.

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