NAZARBAYEV UNIVERSITY
SCHOOL OF ENGINEERING AND DIGITAL SCIENCES

Department of Robotics and Mechatronics

Program Handbook

Master of Science in Robotics

Academic year 2020-21 and onwards

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Robotics and Mechatronics Department Faculty

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Almas Shintemirov	Associate Professor
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Ton Do Duc	Assistant Professor
Tohid Alizadeh	Assistant Professor
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Zhanat Kappassov	Assistant Professor
Altay Zhakatayev	Instructor
Iliyas Tursynbek	Instructor
Aibek Niyetkaliyev	Postdoctoral researcher

Program Overview

The Master of Science in Robotics degree program is a specialized degree program offered by School of Engineering and Digital Sciences (SEDS) at Nazarbayev University (NU). Students are required to complete 120 ECTS credits, in 4 semesters, which satisfies requirements stipulated by the Bologna Process and the European Credit Transfer and Accumulation System (ECTS) for Master's Degrees. The program is focusing on research and has been designed to provide advanced skills and a detailed knowledge base at the graduate level for individuals working in academia, industry, or research settings in Kazakhstan or throughout the world.

The Robotics MSc provides a comprehensive technologic and scientific preparation for engineers in the areas of robotics and related engineering disciplines, in alignment with today´s technological challenges. A set of mandatory core courses guarantees competence in advanced mathematics, classic and novel research methods and effective oral and written communication in the science and technology domain.

By delivering an MSc at an international standard level, we are offering our master's students future opportunities in terms of PhD and positions in research centers, locally or abroad.

Aims and Objectives

The mission of the School of Engineering and Digital Sciences at Nazarbayev University is to contribute to the development of Kazakhstan in terms of:

- Educating students with engineering expertise to lead organizations and provide innovative solutions for complex technical issues of enterprises.
- Conducting innovative and pioneering basics of applied research that evolve the body of knowledge in Engineering through interdisciplinary collaboration with other schools and research centers at Nazarbayev University and leading universities worldwide.
- Advancing the professional development in engineering through our service to the professional community and providing lifelong learning opportunities for practitioners.

The Robotics program aims to reflect the mission of the School of Engineering and Digital Sciences and accomplishes this by aiming to prepare:

- Robotics specialists in (national and multinational) industry and academia in Kazakhstan, in neighboring countries and internationally.
- Entrepreneurs who will be able to promote advanced and innovative science-rich technologies anywhere in the world, in the field of robotics and related areas.
- Researchers capable of conducting high quality robotics research and development using their intellectual, analytical, and critical thinking abilities in solving complex problems.

Graduate Attributes

The Robotics program immerses the student within a scientific and technological ecosystem to favor their professional growth according to NU Graduate Attributes, which are very well aligned with the vision and mission of NU. These attributes are listed as:

1. Possess an in-depth and sophisticated understanding of their domain of study;
2. Be intellectually agile, curious, creative, and open-minded;
3. Be thoughtful decision makers who know how to involve others;
4. Be entrepreneurial, self-propelling and able to create new opportunities;
5. Be fluent and nuanced communicators across languages and cultures;
6. Be cultured and tolerant citizens of the world;
7. Demonstrate high personal integrity;
8. Be prepared to take a leading role in the development of their country.

The MSc program delivers these attributes by providing the students opportunities to be involved in: (a) working on individual and group assignments; (b) team-building exercises for developing decision-making skills; (c) designing tasks for developing creativity; (d) delivering and attending project-research presentations to polish their communication skills; and (e) engaging on group discussions among students and faculty in order to develop personal integrity and cultural tolerance. The same attributes are also addressed by the program learning outcomes that follow.

Program Learning Outcomes

On successful completion of the program, graduates of the MSc program in Robotics will be able to:

1. Demonstrate basic training in research methodology.
2. Have a good understanding of the contemporary research literature in their field of study.
3. Develop a strong understanding of the fundamentals of robotics engineering, electrical and computer engineering, software engineering, and control systems in a synergistic framework at the postgraduate level.
4. Show the capacity to take part in the design of a research project.
5. Acquire insight into robotic devices and systems requirements for current scientific and commercial applications.
6. Select and provide a rationale for the selection of particular paradigms and specialist analytical techniques.
7. Demonstrate the ability to explain scientific concepts and research findings, using various modalities of communication, with particular emphasis on tertiary education instruction.
8. Use robotics principles to envisage and devise novel applications, particularly for emerging real-world applications.

These Program Learning Outcomes can be mapped onto the NU graduate attributes as follows:

		Program Learning Outcomes							
		1	2	3	4	5	6	7	8
NU Graduate Attributes	1		☑	☑				☑	☑
	2		☑		☑		☑		☑
	3	☑			☑				
	4				☑	☑			☑
	5	☑						☑	
	6	☑	☑						
	7				☑			☑	
	8	☑	☑		☑		☑	☑	☑

Program Duration

The nominal MSc program duration is **two years**, while the maximum allowable duration can be extended up to **two and half years** (excluding leave of absence and deferment of admission; see "*ACADEMIC POLICIES AND PROCEDURES FOR GRADUATE PROGRAMS OF THE AUTONOMOUS ORGANIZATION OF EDUCATION 'NAZARBAYEV UNIVERSITY'*" for further details).

Assessment

The students in the MSc Program in Robotics are expected to take increased responsibility and involvement for learning activities within the coursework and research components of the program. In addition, they are expected to be effective communicators and instructors of the pertinent scientific methodologies. Unlike in the undergraduate program, MSc students will have priority in the selection of electives and research topic in consultation with the allocated supervisor. The student is required to complete a total 120 ECTS required by the MSc program. The following learning methods are the most likely to be utilized in the MSc level courses:

1) Lectures
2) Laboratory classes
3) Reflective Assignments
4) Literature Reviews
5) Research Paper Writing
6) Guided-research projects
7) Creation of Research Posters
8) Oral presentation
9) Teaching and Laboratory Practicums

These teaching methods and strategies will map onto the learning outcomes of the MSc program as follows:

Program Learning Outcomes	Where addressed	Teaching Methods and Strategies
Demonstrate basic training in research methodology	SEDS 591 Research Methods	Lectures Reflective Assignments Oral presentation
Have a good understanding of the contemporary research literature in their field	ROBT 592 Research Seminar ROBT 691 Thesis Proposal	Lectures Literature Reviews
Develop a strong understanding of the fundamentals of robotics engineering, electrical and computer engineering, software engineering, and control systems in a synergistic framework at the postgraduate level;	CSCI 501 Software Principles and Practice ROBT 501 Robot Manipulation and Mobility ROBT 503 Dynamic Systems and Control CSCI 502 Hardware Software Co-Design ROBT 502 Robot Perception and Vision All elective courses	Lectures Laboratory classes Reflective Assignments
Show the capacity to take part in the design of a research project	ROBT 691 Thesis Proposal ROBT 692 Thesis	Research Paper Writing Guided-research projects Creation of Research Posters Oral presentation

Acquire insight into robotic devices and systems requirements for current scientific and commercial applications	ROBT 501 Robot Manipulation and Mobility CSCI 502 Hardware Software Co-Design ROBT 502 Robot Perception and Vision	Lectures Laboratory classes
Select and provide a rationale for the selection of particular paradigms and specialist analytical techniques	MSC 601 Technical Communication SEDS 591 Research Methods ROBT 592 Research Seminar	Lectures Reflective Assignments
Demonstrate the ability to explain scientific concepts and research findings, using various modalities of communication, with particular emphasis on tertiary education instruction	MSC 601 Technical Communication SEDS 591 Research Methods SEDS 502 Teaching Practicum SEDS 503 Laboratory Practicum	Lectures Reflective Assignments Teaching and Laboratory Practicums
Use robotics principles to envisage and devise novel applications, particularly for emerging real-world applications	ROBT 501 Robot Manipulation and Mobility CSCI 502 Hardware Software Co-Design ROBT 502 Robot Perception and Vision Robotics elective courses	Lectures Laboratory classes

MASTER OF SCIENCE - PROGRAM CALENDAR YEAR-1

SEMESTER 1	FALL	August – December
TYPE	**COURSE CODE & TITLE**	**ECTS**
Program Core	CSCI 501 Software Principles and Practice	6
Program Core	ROBT 501 Robot Manipulation and Mobility	6
Program Core	ROBT 503 Dynamic Systems and Control	6
Program Core	MSC 601 Technical Communication	6
Program Core	SEDS 591 Research Methods	6

SEMESTER 2	SPRING	January – May
TYPE	**COURSE CODE & TITLE**	**ECTS**
Program Core	CSCI 502 Hardware Software Co-Design	6
Program Core	ROBT 502 Robot Perception and Vision	6
Program Core	ROBT 592 Research Seminar	6
Program Core	SEDS 502 Teaching Practicum	6
Elective	SEDS Technical Elective	6

MASTER OF SCIENCE - PROGRAM CALENDAR YEAR-2

SEMESTER 3	FALL	August – December
TYPE	**COURSE CODE & TITLE**	**ECTS**
Elective	ROBOTICS ELECTIVE I	6
Elective	ROBOTICS ELECTIVE II	6
Program Core	SEDS 503 LABORATORY PRACTICUM	6
Program Core	ROBT 691 THESIS PROPOSAL	12

SEMESTER 4	SPRING	January-May
TYPE	**COURSE CODE & TITLE**	**ECTS**
Program core	ROBT 692 THESIS	30

Academic Policies and Procedures

All academic policies and procedures that are not explicitly covered in this handbook are conformant with the corresponding items described in "*SCHOOL OF ENGINEERING AND DIGITAL SCIENCES MASTERS STUDENT HANDBOOK",* which covers School of Engineering and Digital Sciences Master Programs, and the "*ACADEMIC POLICIES AND PROCEDURES FOR GRADUATE PROGRAMS OF THE AUTONOMOUS ORGANIZATION OF EDUCATION "NAZARBAYEV UNIVERSITY" (APP-Graduate Programs-NU)"*, which covers all graduate programs in Nazarbayev University. These policies and procedures include, among others, the following:

1. Admissions
2. Registration
3. Credits (Requirements, awarding & transfers)
4. Grading issues such as: administrative grades, grade appeals
5. Course re-takes
6. Degree withdrawals
7. Academic code of behavior
8. Leaves of absence, including medical reasons, immediate family member issues and others
9. Dismissal & voluntary withdrawal.

Every student participating in the Robotics program is expected to have read and understood all the policies, rules, procedures, and guidelines described in this program specific handbook, school's MSc handbook and the general APP for graduate programs in NU.

Grading System

Letter graded courses

Letter Grade	Grade Points	Percentage
A	4.00	95-100%
A-	3.67	90-94.9%
B+	3.33	85-89.9%
B	3.00	80-84.9%
B-	2.67	75-79.9%
C+	2.33	70-74.9%
C	2.00	65-69.9%
C-	1.67	60-64.9%
D+	1.33	55-59.9%
D	1.00	50-54.9%
F	0.00	0-49.9%

PASS/FAIL courses

In the case of a non-graded course, the following assessment percentages apply

Description	Percentage
Pass	59% or Above
Fail	Below 59%

Program Completion Requirements

Satisfactory completion of the MSc program requires that the student progress through a number of distinct stages, each of which is characterized by a key evaluation point. The necessary stages are:

1) Satisfactory application to the program.
2) Completing all required coursework in the program.
3) Satisfactory completion of the master thesis.
4) Satisfactory achievement of minimum GPA for continuation through semesters and graduation.

Continuation / normal progress

To continue in the Robotics graduate program at SEDS, NU, a student must maintain a minimum CGPA of no less than a **B- (2.67 on a 4-point scale)** after each grading period and conform to all program rules and policies to maintain normal progress toward degree. A student who fails to satisfy the continuation requirement for the program is subject to dismissal.

Plagiarism

In any coursework or thesis assessment, unacknowledged copying or plagiarism is not acceptable. Plagiarism can result in extremely serious academic actions including cancellation of any or all results, suspension from the program, or even expulsion. Plagiarism means using the work of others in preparing an assignment and presenting it as your own without explicitly acknowledging or referencing where it came from. Plagiarism can also mean not acknowledging the full extent of indebtedness to a source. Work can be plagiarized from many sources including books, articles, the internet, and other media. Plagiarism can also occur unconsciously or inadvertently. Direct copying is plagiarism. Paraphrasing of another's work without acknowledgment is also plagiarism. Submitting someone else's work or ideas without attribution is not evidence of your own grasp of the material and cannot earn you marks.

Nazarbayev University's policy on plagiarism sets out student responsibilities in regard to copying. Students are responsible for ensuring that:

- They are familiar with the expected conventions of authorship and the appropriate use and acknowledgement of all forms of intellectual material relevant to their discipline.
- The work submitted for assessment is their own.
- They take all reasonable steps to ensure their work cannot be accessed by others who might seek to submit it, in whole or in part, as their own.

Whenever you refer to another person's research or ideas -either by directly quoting or by paraphrasing them-, you must acknowledge your source by proper referencing. Turnitin is a useful web-based originality checking service that can help in assessing the originality of submitted work. More information on Turnitin can be found via http://turnitin.com/ website.

Description of Courses

Note: In future, minor changes in courses and/or program, subject to approval by SEDS Teaching and Learning Committee, may not be reflected in this document, however, these would be reflected in the corresponding Course Specification Forms.

Program Core Courses

CSCI 501 Software Principles and Practice

This is an accelerated course in the evolution and design of imperative programming languages, and modern software development techniques. In the first part of the course, we will use the C language to review the fundamentals of programming, and progress on to the concepts of data types, encapsulation, and reusability. Algorithms and performance will also be topics of discussion. While investigating the advantages and drawbacks of C, we will motivate some of the key features of object-oriented languages, such as inheritance and polymorphism, as well as generics. We will then look at the Java language as an instance of the object-oriented paradigm, and discuss good object-oriented design principles. In the second part of the course, we will pull several of these threads together with a project.

CLOs

By the end of this course, students will be able to:

1. Effectively utilize modern software development tools and methods;
2. be proficient in understanding, explaining, and developing mid-scale software programs and systems;
3. Apply the concepts of encapsulation, data abstraction, inheritance, and polymorphism in software they construct;
4. Examine the relative performance of algorithms and data structures, and to justify the selection of one over another;
5. Apply core software engineering and OO principles to software systems that they develop.

MSC 601, Technical Communication

This graduate level course combines the application of rhetorical analysis to stylistic conventions of writing in engineering, with a focus on clarity, conciseness, and coherence. Students will employ process writing to produce genre specific writing familiar to Engineers, including research reports scientific papers designed for specific audiences. This course also trains students to deliver effective and appealing professional and scientific presentations, with attention to best practices in the use of technical English and oral communication.

CLOs

By the end of the course, students will be able to:

1. Understand technical communication along a continuum, identifying appropriate writing and speaking strategies for intra-disciplinary, inter-disciplinary, business and public audiences;
2. Determine audience needs and expectations as they pertain to writing and presentation in engineering genres;
3. Organize and prepare coherent and effective scientific texts and presentations for academic, professional, and public audiences;
4. Communicate effectively and efficiently the process of developing, implementing, and evaluating research;
5. Refine writing style for clarity, concision, coherence, and emphasis;
6. Practice the ethical use of sources and appropriate citation conventions;
7. Work with peers to provide written and oral feedback of student work.

ROBT 501 Robot Manipulation and Mobility

This course covers classical and advanced topics in robotics with particular emphasis on the dynamics and control of serial and parallel manipulators. Analysis of velocities, static forces, and kinematic singular configurations is carried out by means of differential kinematics, conventional Jacobian and screw-based Jacobian matrixes. Motion control is introduced in the joint and task space by using tracking and computed-torque techniques. Mobile and legged robotic systems with a high level of kinematic redundancy (e.g. humanoid robots, exoskeletons for tele-manipulation applications) are presented together with classical and state-of-the-art control algorithms targeted at solving the direct and inverse kinematic/dynamic problem, the spatial mapping, and the motion and path planning. Other topics covered in this course are: tendon-driven manipulators,

synthesis and design of manipulators and mobile robots, biological mapping, the subsumption and other bio-inspired control architectures.

CLOs

By the end of this course, students will be able to:

1. Formalize the direct kinematic model of serial and parallel manipulators.
2. Find the inverse kinematics solutions for open and closed kinematic chains.
3. Able to derive the differential kinematics of serial and parallel manipulators
4. Design and implement control algorithms for mobile robots.

ROBT 503 Dynamic Systems and Control

The course aims to introduce the students to the state-of-the-art analytical tools and methods used for control system design. The course will start with the modeling of physical systems in the frequency and state space domains. The student will master analytical tools such as Bode plots, root locus diagrams, and phase plots. The second part of the course includes frequency domain-based control design (mainly focused on PID controllers) and then covers control system design in state space (linear quadratic regulators, servo-controllers, etc.). In the last part, students will review different advanced control algorithms such as model predictive control, adaptive control and soft computing based control.

CLOs

By the end of this course, students will be able to:

1. Describe the fundamental concepts of physical system modeling.
2. Apply fundamental frequency and state-space domain techniques in the analysis and design of linear feedback control systems.
3. Analyze and synthesize advanced control algorithms.
4. Implement control algorithms to simulation and real-world systems using software packages, toolboxes, and relevant hardware.

SEDS 591 Research Methods

This course aims to provide the students with a set of principles and skills that will be of paramount importance for conducting their research and disseminating the corresponding results. The course provides an overview of the scientific method and its application, project planning, working in teams, interaction with sources, and assessment of research results. Students are also taught the fundamental principles necessary for writing technical reports, scientific papers, and research proposals, and for preparing and delivering presentations: the focus of this part is on the connection between the employed research methods and the way in which the results are presented, rather than on the writing/presentation style in itself. Finally, students are exposed to a general introduction on moral reasoning, with subsequent focus on ethics in professional practice and research activity. The latter topic will focus on data management and intellectual property rights, and on the description of phenomena such as plagiarism and data fabrication.

CLOs

By the end of this course, students will be able to:

1. Asses a research plan and its rationale, including application of the scientific method, interaction with sources, and critical evaluation of research results.

2. Discuss the principles behind the production of reports, papers, proposals, and scientific presentations.
3. Argue on ethical principles and their application to professional practice and research.

CSCI 502 Hardware Software Co-Design

The Hardware/Software Co-Design course introduces underlying scientific and engineering principles of embedded real-time systems for hardware data processing for computer science and robotics applications. Any system that responds at the pace of relevant events has real-time requirements and constraints whether the timescale is short like the airbag controls for an automobile or longer like the flight scheduling system for an airline. The course covers the software aspects of embedded processor architectures and elements of Linux operating systems for hardware control. Students can expect to learn how to apply off-shelf hardware components to design embedded sensor data processing systems that can be used in the Internet-of-Things, robotics and other applications. Topics covered include embedded processor architectures, concurrency principles, real-time principles (multi-tasking, process synchronization and scheduling), mechatronics design basics, sensor fusion and system state estimation (optional) algorithms, etc. Through a series of practical projects assignments using a state-of-the-art ARM based BeagleBone Black system-in-chip board and popular Robot Operating System (ROS) students will acquire skills in the design/implementation of core hardware control functionality using Linux based C/C++ programming tools and libraries.

CLOs

By the end of the course the student will be expected to be able to:

1. Describe embedded microprocessor architecture, peripheral interfacing and embedded operating system principles.
2. Work in a Linux operating system running on a personal computer PC and an embedded ARM based microprocessor board and program multitasking applications in C/C++ language.
3. Interface analog and/or digital sensors/peripherals to a system-on-chip microprocessor board via various communication protocols.
4. Work in a part of the team on embedded system design for engineering problems developing creative thinking and communicative skills.

ROBT 502 Robot Perception and Vision

The course aims to introduce the principles, models and applications of robot vision and perception. Some covered topics are image structure, projection, stereo vision, and the interpretation of visual motion. The practical applicability of the 2-D and 3-D vision algorithms to the robotic problems will also be discussed as case studies such as visual navigation of autonomous robots, robot hand-eye coordination and novel man-machine interfaces.

CLOs

On successful completion of the course students will be able to:

1. Evaluate the state-of-the-art tools commonly used for developing robot perception applications.
2. Experimentally analyze and test robot perception sensors using the latest benchmark suites.
3. Evaluate mathematical and machine learning tools for robot perception.

SEDS 502 Teaching Practicum

The course introduces students to the pedagogical structures and methods of teaching and learning, beginning with program structure and curricula requirements to the elucidation of learning objective and learning outcomes, the selection of student assessment methods, and the quality assurance life cycle processes.

CLOs

By the end of this course, students will be able to:

1. Recognize high-level program and curricular structure & purpose;
2. Identify and describe a variety of pedagogical methods;
3. Specify specific learning objectives and outcomes for a given topic;
4. Utilize Bloom's Taxonomy in the articulation of learning objectives;
5. Select appropriate assessment methodologies suitable to determine student achievement of stated learning objectives;
6. Conduct the reflective exercises necessary to implement ongoing quality enhancement processes.

ROBT 592 Research Seminar

The course requires students to select a topic, identify authoritative sources, generate an annotated bibliography, and compose a survey paper representing the current state-of-the-art in the selected topic area, and prepare a presentation based on the survey paper. The course includes a series of research presentations, presented by domain experts, to expose students to current research programs, and facilitate the thesis topic selection by students.

CLOs

By the end of this course, students will be able to:

1. Identify authoritative sources;
2. Conduct a literature search;
3. Prepare a detailed bibliography;
4. Analyze current research and critically review for strengths and weaknesses;
5. Recognize and extract relevant information from scientific papers, seminars, and presentations;
6. Prepare a survey paper representing the state-of-the art in the topic area;
7. Present the results to both technical and non-technical audiences.

SEDS 503 Laboratory Practicum

Students will apply educational and instructional methodologies in laboratory and practical sessions of their respective disciplines under the supervision of an experienced faculty member. They will summarize their observations and experience in a final report.

CLOs

By the end of this course, students will be able to:

1. Identify pedagogical methods for laboratory sessions.
2. Select appropriate assessment methodologies for evaluate the level of achievement of learning outcomes of the specific lab activity.

3. Conduct reflective exercises to assess the effectiveness of the laboratory learning experience, and implement modifications aimed at quality enhancement.

ROBT 691 Thesis Proposal

Students are led through the processes required to plan and initiate an independent research project that will make an original contribution to engineering knowledge. Students are required develop a research proposal based on literature analysis, and begin to execute the proposal.

CLOs

By the end of this course, students will be able to:

1. Critically review and evaluate relevant research literature using a thematic approach to identify knowledge gaps that could be addressed through a research project.
2. Define the scope of a research project to address one or more identified gaps in existing knowledge in terms of achievable aims and an appropriate methodology.
3. Present a coherent written proposal for a research study that describes the background, aims, rationale, methodology, and anticipated outcomes for the proposed study.
4. Demonstrate an ability to initiate a research project by sourcing necessary resources.

ROBT 692 Thesis

The student will conduct independent work under the direction of a supervisor on a research problem in the student's designated area of research. The project will involve a substantial amount of work in one of the NU research laboratories. For students who aim to pursue a career in research, the thesis represents an excellent opportunity to develop the skills necessary to work within a research group. On the other hand, for students who wish to pursue their careers in industry, it constitutes an important introduction to practical research and development work.

CLOs

By the end of this course, students will be able to:

1. Execute a previously developed research plan, adapting the plan if necessary as the research proceeds, and working within the available time and resource constraints.
2. Collect, arrange and critically analyze results at a standard expected for publishable research.
3. Critically evaluate research results in the context of existing knowledge.
4. Communicate research outcomes through an original thesis document, and through an oral presentation.

Program Elective Courses

In the second semester of Year 1, students will take one elective course within SEDS MSc courses, in line with their interests, for example to strengthen their knowledge of applied mathematics, electrical engineering, mechanical engineering, or computer science. The list of offered courses can be different for each academic year: as a consequence, the list is not provided in this document.

Two more elective courses in the third semester will be taken by students to further specialize in their thesis research direction. Available robotics elective courses are listed below. Students can take one of these electives outside of the Robotics courses to strengthen their background for their thesis work with the consent of their advisors.

ROBT 611 Industrial Robotics

The Industrial Robotics course builds upon the Robot Manipulation and Mobility course offered in the first year of the master program and introduces underlining principles behind industrial robot-manipulators. The course covers the theoretical aspects of robot-manipulator kinematic and dynamic modeling and control system design. Students can expect to learn how to simulate the robots using MATLAB and dedicated robotics software and state-of-the-art industrial robot-manipulators. At the end of the course students are expected to know basic robotic technologies and be able to master modelling and advanced control aspects of robots used in industrial and research settings.

CLOs

By the end of this course, students will be able to:

1. Derive forward and inverse kinematics of robot-manipulators
2. Derive dynamic models of robot-manipulators
3. Design robot control architectures and test them in popular robot modeling software.

ROBT 613 Brain Machine Interfaces

Brain-Machine Interface (BMI) systems are an emerging interdisciplinary field at the intersection of engineering, neuroscience, and medicine. It has brought promising new perspectives to human-machine interaction using brain activity. It provides users the capability to control applications such as assistive robotic technologies directly. This course is an introduction to the fundamentals of BMI technology and discusses its applications including both invasive and non-invasive BMI systems for controlling user interfaces, prosthetic arms, wheelchairs, and robotic exoskeletons. The course will also introduce other clinical applications of BMI technology for patients with locked-in syndrome and its utility in restoring movement and mobility in severely paralyzed persons. Also, other nonclinical use of BMI technology will be studied with hands-on experiments/projects for applications such as security, alertness monitoring, entertainment, gaming, and education or human augmentation.

CLOs

By the end of this course, students will be able to:

1. Plan and carry out BMI experiments;
2. Obtain programming skills required to design interfaces with human and machines;
3. Acquire physiological data;
4. Analyze the data and interpret their findings and present them scientifically;
5. Develop advanced medical systems for human and brain-machine interfaces.

ROBT 615 Optimal Control and Planning

This course aims to provide the state-of-the-art concepts relative to optimal control, in particular with application to robot motion planning. After introducing the definition and applications of the robot motion planning problem, a basic treatment of different motion planning algorithms, such as search-based

planning, virtual potential fields, visibility maps and sampling-based methods, is provided. Then, the course focuses on optimal control and planning algorithms, which are based on numerical methods that can be deployed in practical robotics applications. The course covers both offline motion planning problems and online motion planning via model predictive control.

CLOs

By the end of this course, students will be able to:

1. Discuss and synthesize motion planning algorithms for simple applications.
2. Classify and compare the most common numerical optimization methods.
3. Design optimal control schemes for robotic applications.

Master Thesis Guidelines

The guidelines presented here form a manual designed to provide you with a quick reference for planning, preparation, and compilation of your thesis project.

Aims and Objectives

The Master's thesis constitutes a piece of applied research and in this context, your primary goal is to analyze, solve and present your research findings for a problem relevant to your field of study. This process should be based on existing scientific and engineering knowledge and follow the principles of responsible research conduct.

The topic of your thesis should be related to your degree program and should be decided in agreement with your thesis supervisor and approved by the MSc program coordinator.

The primary focus of your research project is usually expressed in terms of **aims** and **objectives**. Your aims should comprise aspirations and/or intentions defined in broad terms which essentially describe what you are hoping to achieve. These aims set out what you targeting to deliver at the end of the project. Objectives, on the other hand, are specific statements that define measurable outcomes and comprise specific goals and steps that must be followed for achieving your aims. Your objectives should be:

Specific; provide precise descriptions of what you are going to do.
Measurable; be able to provide concrete evidence when reaching a goal.
Achievable; avoid setting infeasible goals.
Realistic; plan your steps and goals based on the available resources (time, equipment, skills, etc.)
Timely delivered; create a timetable, know when each stage needs to be completed, allow extra time for unexpected delays

Thesis Content

You should consider the following when conducting research and compiling your thesis manuscript:

- Always include a detailed literature review. The literature review should describe the existing theory and research in your thesis area and provide a context for your work. Reference all sources mentioned in the review and give full citation in thesis's Reference List.
- Explain the methods used in researching and developing your work. It is important to explain what research methods you used to acquire data.
- Discuss with your thesis supervisor the extent and level of detail required; different levels of research depth will obviously require different levels of detail.
- Clearly present your findings and describe what have been discovered. Include tables, graphs, illustrations etc., so that it is easier for the reader to understand your results.
- Always, include a discussion of your findings. Use a discursive and evaluative writing approach and fully present your interpretations and judgements of your results. Contextualize your ideas in relation to other theories and with similar research, particularly in reference to the works mentioned in your literature review.

Stages and Procedures

Students should follow the roadmap described in five stages to accomplish the MSc thesis:

STAGE 1: Identify Thesis Supervisor (Thesis Committee)

Students are expected to choose their MSc thesis supervisor before the end of the second semester of the first year, and spend the summer conducting preliminary work on their thesis project. Constructive supervision is a significant component aiming in the success of your thesis work and requires the vivid interaction between you and your supervisors. Your Supervisor is responsible for ensuring that the Master's thesis meets the goals and requirements set by SEDS.

Furthermore, the thesis committee must have at least three members. One of these can be assigned as the Co-Supervisor of the student. The thesis committee should include an external committee member who is external to the department and can be an academic from another NU department, university or, alternatively, an expert from the industry holding an appropriate academic degree and specializing in your thesis's scientific field.

STAGE 2: Thesis Topic Selection

Supervisors are in position to suggest appropriate MSc thesis's topics. These may stem from research work being conducted at the school/department or may arise from material covered during your coursework. Furthermore, thesis topics may be also related to work carried out in the context of research projects involving industrial partners. The topic of the thesis is decided in discussions between you and your chosen supervisors; however, the final choice is always made by you. In this regard, it is customary for faculty members to announce topics in helping you choose your thesis topic.

STAGE 3: Submission of Thesis Proposal

The MSc proposal should be submitted by the end of the third semester and approved by the thesis supervisor. Your thesis proposal should clearly address the following items:

- Outline of the problem/area of application
    - Explain why you think it is worth investigating
    - Set your ideas into a theoretical/academic context
- Aims and Objectives
    - Describe what you are aiming to achieve
    - Present the steps and approaches you will employ for reaching your goals
- Methodology
    - Explain what methods you intend to use when researching and developing your work
    - Use a descriptive writing approach corresponding to the detail required for the panel's comprehension of your approach.
- Scope and constraints
    - Clearly set your scope and anticipated constraints:
        - Your selected topic may be vast with numerous applications and thus, you might want to limit your work in an area of application
        - You may not be able to conduct some research due to constraints on time, cost, or availability of resources
- Discuss requirements on resources
    - Do you need any special lab equipment?
    - Is literature review possible with library's resources?
    - Are any materials and/or consumables required in your research?
- Propose a draft timetable for your thesis

STAGE 4: Carrying out Research and Thesis Manuscript Preparation

Once your proposal has been officially approved, the actual work may begin. It is crucial that you are always well-prepared in meetings with your supervisor. In this context, it is a good practice to always keep minutes of your meetings and circulate agendas with clearly outlined discussion points and expected results prior to your meetings. This makes it easier for the supervisor to focus on significant issues, leading to a better response for you. If you feel that you may have misunderstood a concept, or you are not certain of the steps required for performing a task, ask your supervisor for clarifications or further guidance. The supervisors should always guide you with advices on the topics and tasks you should put emphasis on and at the same time turn you away of tasks that may waste your time.

Finally, you must keep in mind that writing a thesis takes significant time and effort. You should keep track of your work, make notes, write intermediate reports so that when your work has approached a certain maturity, you will be able to compile a successful thesis's manuscript.

STAGE 5: Thesis Submission and Defense

Before submitting your manuscript, your supervisor will check it thoroughly and give you feedback on corrections and changes that need to be made.

When you have prepared the revised document, you submit to your supervisory committee and external examiner for evaluation. Keep also in mind that you should aim at meticulously following your supervisor's comment and corrections so that a series of multiple revisions can be avoided. When your supervisory committee & the external examiner approve the final document, your Lead supervisor will get permission to submit your final thesis report for evaluation.

Thesis Grading

The MSc. Thesis must be compiled in a report (manuscript) according to the specification provided by the course instructor of the ROBT 692 Thesis course and defended in front of the MSc. Thesis committee, which comprises of the supervisor and committee members (including the external committee member). The MSc. Thesis manuscript and MSc Defense Oral presentation will be evaluated according to the following assessment criteria.

MSc Thesis Assessment

- ***Presentation of the research problem and thesis's objectives***
  - Is the research problem clearly specified and contextualized?
  - Are the research questions and hypotheses clearly formulated?
  - Does the thesis capture the relevance, rationale, and objectives of the proposed research?
- ***Literature review***
  - Does the thesis include a comprehensive review and critical discussion of the relevant literature and/or technological developments?
  - Is there a description on how the conducted research positions itself within the generic context of works which have been published in the area?
  - Is the relevant background theory covered? Are the presentation, discussion and explanation provided, adequate? Has the theory been contextualized appropriately within the framework of the research problem being investigated?
  - Have the latest theoretical developments in the area been presented and described?
  - Does the student demonstrate a systematic understanding of the relevant background material and knowledge?
- ***Methodology, design and implementation***
  - Are the adopted methodologies and/or design approaches clearly justified and described?

- Is the implementation well explained?
- Is there a clear identification of any limitations, assumptions and constraints which affect the application of the employed methodology, design approach and implementation?

- ***Testing, results, analysis, evaluation concluding remarks & future work***
  - Are the test procedures sound and objective?
  - Do the proposed tests address the research problem being investigated?
  - Are the test conditions, assumptions, constraints, and limitations clearly identified?
  - Are the results clearly presented, analyzed objectively and critically evaluated?
  - Do the concluding remarks summarize the work done? Are there suggestions for any future development and/or enhancements?
- ***Structure and presentation of thesis***
  - Are the thesis contents well structured, focused, and easy to follow?
  - Are the student's contributions and assumptions clearly communicated to the reader?
  - Is it in compliance with the given guidelines?
  - Is it clearly presented and organized? Is the grammar and usage of English of an appropriate level?

Oral Presentation Assessment (MSc Thesis Defense)

PRESENTATION:

- ***Speech & Style***
  - Clear and easily understood. Correct use of terms.
  - Easy-to-understand sequence. Professional appearance. Use of good English.
- ***Structure of the Presentation***
  - Logical sequence, good flow. Supporting body of literature mentioned.
  - Development of topics described clearly. Smooth progression from topic to topic.
  - Key points & challenges sufficiently highlighted.
- ***Layout of Visual Aids***
  - Clear power point slides, uncluttered. Concise & precise slides.
  - Use of good English. Good use of charts, tables, diagrams, etc.
- ***Questions & Answers***
  - Clear understanding of the the questions.
  - Concise answer responding to the point of the question.

TECHNICAL CONTENT:

- ***Introduction***
  - Problem statement & project objectives. Coverage of all main points of the project.
  - Literature review and conclusions. Relevance to the need of industry, society etc.
- ***Technical Competency***
  - Viability of the design concept. Justification of the approach
  - Design methodology. Practical Implications.
  - Quality of the concept presentation. Interpretation of the achieved results.
  - Use of relevant tools/equipment/software.
- ***Conclusions, Future Work & Professional ethics***
  - Conclusions: advantages and disadvantages.
  - Level of the project objectives achievement.
  - Future work and possible improvements.
  - Consideration in design and solution. Applicability to real-life situations.
  - Compliance with good practices and standards.