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WP5. Improving existing MSc programs in Jordan & Lebanon by implementing or including AI and Robotics courses

DEVELOPING SYLLABI AND CONTENT FOR ADDED/ MODIFIED COURSES IN EXISTING MASTER PROGRAMS

November, 2021

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Contents

1 Preface

The goal of work package five is to implement or include AI and robotics courses into existing master programs in Jordan and Lebanon in order to improve these programs. Based on the results of the surveys in WP1, Task 5.1 aims at modifying the curriculum of existing master programs in universities in Jordan and Lebanon by developing syllabi and content for added and/or modified courses. Therefore, it stands to reasons to also consider the simultaneous outcomes of WP2 (Development of New M.Sc. and B.Sc. Programs in AI and robotics) in this work package. It is worth noting that the present document will later be part of the report about work package WP5.

In order to avoid ambiguity and double work, the consideration and syllabi creation of courses which are part of WP2 and WP5 is done in WP2. For the sake of completeness, these courses are listed in this document but are not further considered here.

The present document comprises all information about the master programs considered in WP5. For each program, the courses to be modified are listed and a compact description is given. After that, an overview of the general procedure to improve the syllabi of the considered courses is given. Moreover, for these courses, the developed and improved syllabi are given in Section 6. For the sake of completeness, in addition to the modified courses, an overview of newly implemented courses which are considered in WP 2 is provided and the appendix of this document comprises a list of already existing courses which are not modified but part of the considered programs.

1.1 Considered Programs and Courses

In total, four different master programs at four universities in Jordan and Lebanon are considered. These are:

- Mechanical Engineering – Mechatronics (Jordan University of Science and Technology)
- Computer Engineering and Networks (University of Jordan)
- Robotics and Intelligent Systems (Lebanese University)
- Computer Engineering (Beirut Arab University)

The courses which are considered within Task 5.1 are summarized in Table *1*. Courses which both appear in WP2 and WP5 are considered in WP2 in order to avoid ambiguity. For the sake of clarity, these courses are shown in Table *2*.

Table 1: Courses to be improved in Task 5.1.

JUST	UJ	LU	BAU
Artificial Intelligent Systems	-	Optimization	Fuzzy Sets, Logic, and Applications
Mobile Robots		Introduction to Data mining and Machine learning	Neuronal Networks
		Modeling, Identification, Observation and Control of Dynamic Systems	Data Mining
		Advanced Statistical Learning	Pattern Recognition
		Nonlinear Control Applied to Robotics Systems	

Table 2: Courses with syllabi creation in WP2.

JUST	UJ	LU	BAU
-	Advanced AI and ML	Advanced Robotics	Cognitive Robotics
	Advanced Big Data Analysis		Computational Aspects of Robotics
	Computer Vision		Reinforcement Learning
			Autonomous Systems

1.2 Procedure for Improvement of the Syllabi

In this paragraph, a short description of the general procedure in order to improve the courses of WP5 is given. In a first step, the former syllabi are incorporated into the general DeCAIR Course Syllabus Form by the corresponding course lecturers. Simultaneously, based on the expertise of the DeCAIR group, two experts are assigned two each course. One expert is from a European partner university and one expert from a partner university in Jordan or Lebanon, resulting in a group of three which is led by the course leader, usually the course lecturer. Then, this group self-reliantly organizes personal discussions in order to revise the original syllabi. Based on these discussions, the course leader improves the corresponding DeCAIR Course Syllabus Form and sends it back to the work package leader.

The course leader, the assigned experts, and some further details on the corresponding courses are shown in Table *3*.

Table 3: Experts assigned to the courses considered within WP5.

	Program	Course		Author/ Course-leader	Responsible European Expert	Responsible Expert from JO/LB
JUST	Mechanical Engineering - Mechatronics	Artificial Intelligent Systems	ME 781	Wafa Batayneh, Ahmad Bataineh	UGR (Jorge Casillas)	UJ (Ramzi Saifan)
		Mobile Robots	ME 795	Ahmad Al-Shorman	UST (Mario Rosenfelder)	UJ (Musa Alyaman)
LU	Robotics and Intelligent Systems	Optimization	RSI01	Rafic Younes, Clovis Francis	UST (Mario Rosenfelder)	JUST (Khaled Hatamleh)
		Introduction to Data mining and Machine learning	RSI02	Fahed Abdallah, Clovis Francis	UGR (Jorge Casillas)	BAU (Rola Kassem)
		Modeling, Identification, Observation, and Control of Dynamic Systems	RSI03	Clovis Francis, Billal Komati	UNIPI (Lucia Pallottino)	UJ (Adham Al Sharkawi)
		Advances in Statistical Learning	RSI05	Fahed Abdallah, Clovis Francis	UGR (Jorge Casillas)	BAU (Rola Kassem)
		Nonlinear Control Applied to Robotics Systems	RSI08	Clovis Francis	UST (Mario Rosenfelder)	TTU (Mohammad Obeidat)
BAU	Computer Engineering	Fuzzy Sets, Logic, and Applications	COMP 605	Issam Damaj	UNIGE (Francesco Masulli)	TTU (Ayman Mansour, Murad M. Alaqtash)
		Neuronal Networks	COMP 609	Issam Damaj	UNIGE (Francesco Masulli)	JUST (Ahmad Bataineh)
		Data Mining	COMP 612	Issam Damaj	UNIGE (Giovanna Guerrini)	LU (Fahed Abdallah)
		Pattern Recognition	COMP 618	Issam Damaj	UNIGE (Francesco Masulli)	LU (Joumana Farah)

2 Existing Master Program at JUST: Mechanical Engineering - Mechatronics

University	**Jordan University of Science and Technology**
Master Program	**Master in Mechanical Engineering - Mechatronics**

2.1 Existing Courses to be modified/ improved

Course	ECTS/ Hours	Prerequisite
Obligatory Courses		
ARTIFICIAL INTELLIGENT SYSTEMS (ME781) • This course will introduce students to the basic concepts regarding soft computing approaches used to enhance the artificial intelligence systems and incorporate the human knowledge in computing processes. Special emphasis will be placed on fuzzy logic, neural networks, hybrid systems and their application in designing intelligent systems. • lecture outline: a. Introduction to Artificial Intelligent Systems (existing 3 Hours X 1 Lecture) b. Fuzzy Logic with Application (existing 3 Hours X 3 Lectures) (Note: Reduced theory) c. Artificial Neural Networks with Application (Feed-forward (existing) and Recurrent neural networks (to be added)) (3 Hours X 3 Lectures) d. Deep Learning and Data Science with Application ((to be added) 3 Hours X 3 Lectures) e. Hybrid Neuro-Fuzzy Systems (ANFIS) with Application (3 Hours X 1 Lecture (existing)) f. Introduction to Genetics Algorithms with Application (3 Hours X 1 Lecture (existing))	3 hours	
Elective Courses		
Mobile Robots (ME795) This course aims to introduce basic knowledge about Mobile Robot types and categories. In addition, the course provides the	3 hours	

basic concepts and algorithms required to develop mobile robots that act autonomously in complex environments. The main emphasis is placed on mobile robot locomotion and kinematics, environment perception, map-based localization and mapping, and motion planning. The lectures and exercises of this course introduce several types of Mobile Robots such as wheeled robots, legged robots, and drones. • lecture outline: a. Introduction to Mobile Robots. (Existing 3 Hours X 2 Lectures). (Note: Reduced theory) b. Mobile Robot Kinematics, Dynamics, and Control. (Existing 3 Hours X 5 Lectures) (Note: increased emphasis on kinematics and Control). c. Perception (Existing 3 Hours X 1 Lectures). (Note: increased emphasis on practical side). d. Localization. (Existing 3 Hours X 1 Lectures) e. Path Planning. (Existing 3 Hours X 2 Lectures). f. Locomotion. (Existing 3 Hours X 1 Lectures) (Note: Reduced theory). g. Case study. (To be added 3 Hours X 2 Lectures).		

2.2 Courses considered in WP2

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3 Existing Master Program at UJ: Computer Engineering and Networks

University	**University of Jordan-Computer Engineering Department**
Master Program	**Computer Engineering and Networks (Thesis Track)**

Remarks

- The student should finish 33 credit hours successfully and they are distributed as follows:
    - Five Obligatory courses
    - Three elective courses selected from the list of elective courses
    - The Thesis course equals 9 credit hours
- Based on the national accreditation policy and regulations
    - The Research methodology course is added to the obligatory courses

The number of obligatory courses cannot be less than 5.

3.1 Existing Courses to be modified/ improved

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3.2 Courses considered in WP2

- Advanced Artificial Intelligence and Machine Learning (to be modified/ improved)
- Advanced Big Data Analysis (to be modified/ improved)
- Computer Vision (to be added), comments on the program-courses

4 Existing Master Program at LU: Robotics and Intelligent Systems (RSI)

University	**Lebanese University (P4)**
Master Program	**Robotics and Intelligent Systems (RSI)**

4.1 Existing Courses to be modified/ improved

Course	ECTS/ Hours	Prerequisite
Obligatory Courses		
RSI01: Optimization - Deterministic optimization - Stochastic optimization - Constrained optimization - Robust optimization Needs: Meta-heuristics and Natural Inspired Optimization. Case studies.	3/18	Operations Research
RSI02: Advanced Data Analysis Introduction to RDF and learning, discrimination in the Gaussian case, performance evaluation and model selection, non-parametric methods, Parzen kernel method, k-nearest neighbour rule, feature extraction, principal component analysis (PCA), kernel-based methods: SVM, KFD, KACP, decision trees. Needs: advanced topics in Big Data, Data Science, Python for AI and Data Science - Case studies.	4/24	Statistics
RSI03: Modeling, Identification, observation and control of dynamics systems Examples of modelling Analysis of system properties (controllability, observability, passivity, stability...) Control techniques (in state space, feedback, feedforward, state feedback linearisation, input-output linearisation, optimal control, robust control...) Linear observers. Identification of dynamics systems. Non parametric estimation. Least Square estimate. Autoregressive techniques: ARX, ARMAX, BJ, OE, …	4/24	Linear, Digital and Non Linear Control

Needs: advanced topics in identification, identification of a closed loop systems- Case studies with real signals measurements.		
RSI-05 : Advanced Statistical Learning Discriminant analysis (quadratic, linear, and derived models); EM algorithm, application to unsupervised classification by mixture models and semi-supervised learning; logistic regression; decision trees and ensemble methods (bagging and random forests, boosting). Needs: advanced techniques in Machine Learning and Deep Learning- Case studies.	4/24	Statistics, RSI02
RSI08: Non Linear Control for Robotics Systems Control of conventional rigid robots by linearization and decoupling. Singularity problem - Control of conventional rigid robots by a Lyapunov type approach - Control of underactuated rigid robots by linearizing dynamic looping. Application to overhead cranes and balancing robots - Control of underactuated rigid robots by a Lyapunov type approach. Application to overhead cranes - Modelling and control of wheeled mobile robots by linearising dynamic looping. Problem of singularities and stabilization of equilibrium points. Passivity-based control. Needs: advanced control techniques with applications: inversed pendulum, railway system, Balanced Ball on Rim Control of a UAV, …	4/24	Linear, Digital and Non Linear Control, RSI03
Elective Courses		
None		

4.2 Courses considered in WP2

- Advanced Robotics (to be added)

5 Existing Master Program at BAU: Computer Engineering

University	**Beirut Arab University**
Master Program	**ME in Computer Engineering**

5.1 Existing Courses to be modified/ improved

Course	ECTS/ Hours	Prerequisite
COMP 605 Fuzzy Sets, Logic, and Applications • Fuzzy set and related concepts. • Logical connectives. • Mapping of fuzzy sets. • ~~Extension principle.~~ • Fuzzy relations & fuzzy set ordering. Fuzzy logic inference. • Applications: fuzzy control, signal processing, pattern recognition, decision making, expert systems, fuzzy Logic in Databases, Information Retrieval with Fuzzy Logic, Fuzzy Intelligent Agents, Automotive Applications. • Knowledge Engineering and Data Mining.	3 Credits	None
COMP 609 Neural Networks • Perception, back propagation, and adaptive neural networks. • Transformation by layered networks, statistical neurodynamics, associative memory and neural learning. • Supervised, unsupervised, reinforcement and deep learning. • Applications to functional approximations, signal filtering, pattern recognition, data mining, etc.	3 Credits	None
COMP 612 Data Mining • Data mining and knowledge discovery, motivation of using data mining, data mining models, data mining techniques: association rules, classification in data-mining clustering, tree learning, neural network and Bayesian methods, support vector machines, ensemble learning, and deviation detection. • Sequential patterns mining, applications, and case studies.	3 Credits	None

COMP 618 Pattern Recognition • ~~Review of Probability Theory, Conditional Probability and Bayes Rule, Random Vectors, Correlation, Covariance.~~ • ~~Review of Linear Algebra, Linear Transformations.~~ • Decision Theory, ROC Curves, Likelihood Ratio Test, Linear and Quadratic Discriminants. • Template-based Recognition, Feature Extraction, Eigenvector and Multilinear Analysis. • Training Methods, Maximum Likelihood and Bayesian Parameter Estimation. • ~~Linear Discriminant/ Perceptron Learning, Optimization by Gradient Descent.~~ • ~~Support Vector Machines.~~ • ~~K-Nearest-Neighbor Classification.~~ • ~~Non-parametric Classification, Density Estimation, Parzen Estimation.~~ • ~~Unsupervised Learning, Clustering, Vector Quantization, K-means.~~ • ~~Hidden Markov Models.~~ • ~~Linear Dynamical Systems, Kalman Filtering.~~ • ~~Bayesian Networks.~~ • ~~Decision Trees.~~ • Classification techniques: k-nn, LVQ, SVM, decision tree, ANN, CNN, GAN. • Clustering techniques: k-means, VQ, dendrogram, gap statistics. • Applications: image analysis, computer vision, speech analysis, man and machine diagnostics, person identification, spam filtering, industrial inspection, financial data analysis and forecast, and genetics.	3 Credits	None

5.2 Courses considered in WP2

- Cognitive Robotics (to be added)
- Computational Aspects of Robotics (to be added)
- Reinforcement Learning (to be added)
- Autonomous Systems (to be added)

Remarks

- Some of the needed equipment and training for staff are identified as part of DeCAIR project.

6 Syllabi

The developed syllabi for the courses considered in Task 5.1 are given in the following

DeCAIR Course Syllabus Form

Author(s)	Wafa Batayneh, Ahmad Bataineh, Laith Sawaqid		
Author Organization Name(s)	Jordan University of Science and Technology		
Work Package Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
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2				U	
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Project Website: http://DeCAIR.ju.edu.jo/

Course title	**ARTIFICIAL INTELLIGENT SYSTEMS**
Course number	**ME 781**
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	6 (3 + 3)
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	Students are assumed to have good background in mathematics, particularly, calculus and linear algebra, and linear control systems. Additionally, the students should have good programming skills, preferably, using MATLAB.
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Any Semester
Catalogue description	This course will introduce students to the basic concepts regarding soft computing approaches used to enhance the artificial intelligence systems and incorporate the human knowledge in computing processes. Special emphasis will be placed on fuzzy logic, neural networks, hybrid systems and their application in designing intelligent systems, Deep Learning and Data Science with Application.
Objectives	1) Introduce the students to the different Artificial Intelligence systems. 2) Introduce the students to the Fuzzy Logic and its applications in Engineering Sciences. 3) Introduce the students to the different types of neural networks and its applications in Engineering Sciences. 4) Introduce the students to hybrid Artificial Intelligent techniques with a focus on Adaptive Neuro-Fuzzy Inference system (ANFIS) and its applications in Engineering Sciences. 5) Introduce the students to different searching algorithms with a focus on Genetic Algorithms and its applications.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	**Intended learning Outcome (ILO)**	**Program learning outcome (PLO)***

	1	Demonstrate a sound understanding of the main techniques and algorithms in AI and its applications in Engineering Sciences.	1, 3
	2	Solve linear and nonlinear problems by using different AI methods.	1, 3
	3	Use MATLAB and its specialized Toolboxes to solve AI problems.	3
	(*) The PLOs are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered in class or through Microsoft Teams /Zoom and will be recorded for later access in case of online learning. • The student attends the class presentations and participates in the discussions. • The student studies the reference material, including books and videos. • The student carries out a term project for solving a problem using AI methods. • The student presents the term project in class.		
Learning material type	Class handouts, some instructor keynotes, selected YouTube videos,		
Resources and references	A- Required book(s), assigned reading and audio-visuals: 1. Jyh-Shing Roger Jang, Chuen-Tsai Sun, Eiji Mizutani," Neuro-fuzzy and soft computing: a computational approach to learning and machine intelligence", Prentice Hall, 1997 François Chollet, Deep Learning with Python, Manning Pub. 2018. B- Recommended book(s), material and media: 2. Zilouchian A. & Jamshidi M., "Intelligent Control Systems Using Soft Computing Methodologies", CRC press, 2001. 3. Yen J. & Langari R., "Fuzzy Logic Intelligence Control & Information", Prentice Hall, 2000. 4. Hagan M. & Demuth H., "Neural Network Design", PWS Publishing, 1996. 5. Lee K., "First course on fuzzy theory and applications", Springer, 2005.		

Topic outline and schedule

Week	Topic	ILO	Resources
1	Introduction to AI and soft computing methods	1	
2	Introduction to Fuzzy Set Theory	1	
3	Generalized Modus Ponens (GMP), Mamdani vs. Sugeno Reasoning	1	
4	Control using Fuzzy Logic	2	
5	Apply using Matlab	3	
6	Introduction to Neural networks	1	
7	Supervised, Unsupervised, and Reinforcement Learning	1	
8	Feedforward Neural Networks	1	
9	Mid-Term Exam		
10	Recurrent neural networks	1	
11	Deep neural networks	1	
12	Apply Neural Networks using Matlab	2, 3	
13	ANFIS	2, 3	
14	Genetic Algorithms	2, 3	
15-16	Term Project Presentations		

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	15%	Programming aspects	W2-W14

	Midterm exam	20%	Introduction through classical techniques	W9
	Term project report and presentation	15%	Practical and presentation aspects	W15
	Final exam	50%	All material	W16
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university policies will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and E-Learning course page • Program announcements Facebook group
Additional information	None

Appendix

Learning Outcomes for the MSc in in Mechatronics Engineering

Students who successfully complete the MSc in Mechatronics Engineering will be able to:

1- Integrated systems: Work with, and develop, integrated systems through all stages. This includes design, operation, fault diagnosis and troubleshooting.
2- Leadership: Lead industry modernization and automation effort; make decisions when selecting, procure and commission advanced engineering systems; lead and manage their multidisciplinary technical teams.
3- Innovation: Develop competitive and innovative technical solutions to complex engineering problems while driving innovations into the resulting product.
4- Broad-based: Adapt research and development to achieve optimal technical solutions, and take into account socioeconomic, environmental, and innovative technology.

DeCAIR Course Syllabus Form

Author(s)	Mohammad Jaradat, Ahmad Al-Shorman, Khaled Hatamleh		
Author Organization Name(s)	Jordan University of Science & Technology		
Work Package Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
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2	05/9/2021	Ahmad Alshorman	Topic outline and schedule, Original document	U	1-5
3	12/9/2021	Ahmad Alshorman	Appendix	I,U	2,5
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Course title	Mobile Robots
Course number	ME 795
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	**6** (3 + 3) * includes HWs and LAB work
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	Students are assumed to have good background in mathematics, and basic knowledge in linear feedback control systems. Additionally, the students are preferred to have good programming skills.
Level and type (compulsory, elective)	Masters' elective course
Year of study and semester	second year, first semester
Catalogue description	An introduction to mobile robot essentials covering the following topics: mobile robot types, categories, platforms, locomotion mechanisms, kinematics, modeling, autonomous systems sensing / perception, motion and feedback control, path planning and navigation.
Objectives	1. Introduce basic knowledge about Mobile Robot types and categories. 2. Provide the basic concepts and algorithms required to develop mobile robots that act autonomously in complex environments. 3. Introduce mobile robot locomotion and kinematics. 4. Introduce mobile robot environment perception and map-based localization and mapping. 5. Introduce mobile robot motion planning and control.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	**Intended learning Outcome (ILO)**	**Program learning outcome (PLO)***
1	Describe the characteristics of different mobile robot configurations or geometry.	1

	2	Deriving mobile robot kinematics	2
	3	Develop solution for mobile robot sensing, perception, and vision	3
	4	Solve mobile robot localization and mapping problems	4
	5	Solve path planning problem for mobile robots	3,4
	6	Design controller for mobile robot	1,4
	(*) The PLOs are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: Methods include lectures, labs, case studies, assignments, and a team project. Different software tools are used throughout the course, labs, and implementation of the mechatronics project. The project is suggested to be done by a student, (or group of two students). Deliverables for the project are a written report and presentation/demo of the project due at the end of the semester. • Lectures and LABs are delivered in campus. Related material is provided online over student's course link. • Students can study the reference material, including textbooks and provided videos. • The Robotics and Artificial Intelligence lab is available for students to practice the practical aspects and solve the practical homework assignments. • Student will carry out a term project in groups. Deliverables includes a professional report and a presentation for the project in class towards end of the semester.		
Learning material type	Textbook, class handouts, some instructor keynotes, selected videos, and access to a personal computer and the internet.		
Resources and references	A- Required book(s), assigned reading and audio-visuals: 1. Siegwart, Nourbakhsh and Scaramuzza, Introduction to Autonomous Mobile Robots,2nd edition, MIT press, 2011. 2. Alonzo, Mobile Robotics: Mathematics Models and Methods, Cambridge press, 2014.		

B- Recommended book(s), material, and media:

1. Corke P., Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.
2. Guowei Cai, Ben M. Chen, Tong Heng Lee, Unmanned Rotorcraft Systems, Springer Tracts in Advanced Robotics, 2011.
3. Sebastian T., Wolfram B., Dieter F., Probabilistic Robotics, MIT press, 2005.
4. Bruno Siciliano, Robotics: modelling, planning and control, springer, 2009.
5. S. G. Tzafestas, Introduction to mobile robot control, Elsevier, 2013.

Topic outline and schedule

Week	Topic	ILO	Resources
1	Introduction to mobile robotic systems.	1	A1, B4
2, 3	Mobile robot locomotion mechanisms.	1, 2	A1, B2,B5
4, 5	Kinematics and dynamics of mobile robots.	2	A1, A2
6, 7, 8	Autonomous systems perception and vision	3	A1, B1
9, 10	Mobile robot path planning and navigation.	5	A1, B4
11, 12	Mobile robot localization.	4	A1, B3
13, 14	Mobile Robot Control	6	A1, B1
15, 16	Review and Evaluation (Final Exam)		A1

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	10%	All topics	W2-W12
Midterm exam	20%	Introduction through Autonomous systems	W8

			perception and vision	
	Term project report and presentation	20%	Mobile robot control	W15
	Final exam	50%	All material	W16
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with legal excuse. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% off penalty for each day late. • Term project report and presentation must be submitted on time (no delays). C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be student's authentic work. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and Moodle course page • Robotics and Artificial Intelligence Lab to demonstrate and implement the practical aspects of the course.
Additional information	None

Appendix

Learning Outcomes for the MSc in Mechatronics Engineering

Graduates of the MS in Mechatronics Engineering program will have the following abilities:

1. Integrated systems : Work with, and develop, integrated systems through all stages. This includes design, operation, fault diagnosis and troubleshooting.

2. Leadership : Lead industry modernization and automation effort; make decisions when selecting, procure and commission advanced engineering systems; lead and manage their multidisciplinary technical teams.

3. Innovation : Develop competitive and innovative technical solutions to complex engineering problems while driving innovations into the resulting product.

4. Broad-based : Adapt research and development to achieve optimal technical solutions, and take into account socioeconomic, environmental, and innovative technology.

DeCAIR Course Syllabus Form

Author(s)	Rafic Younes		
Organization Name(s)	Lebanese University		
WP Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
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Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Optimization
Course number	RSI01
Credit hours (lecture and lab)	24 contact hours
ECTS (weekly contact and self-study load)	4
Prerequisites/co-requisites	Operations research
Prerequisites by topic	Students are assumed to have good background in mathematics and operations research, particularly, calculus, linear algebra, statistics, and probability. Additionally, the students should have good programming skills, preferably, using Matlab Simulink, Python and Javascript.
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Year 2, first semester
Description	After having presented the fundamental notions and tools for solving the optimization problem, this course presents the concepts of the deterministic, stochastic and robust optimization techniques as well as optimization under constraints formalism.
Objectives	1. Introduce students to the techniques and tools used in optimization. 2. Introduce students to the different optimization approaches and formalisms: deterministic, stochastic and robust optimization techniques as well as constraint optimization.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	Program learning outcome (PLO)*
1	Demonstrate a sound understanding of the main areas of AIR.	1
2	Solve an AIR problem by developing an appropriate optimization approach.	3
3	Communicate the development of an optimization	4,5

		problem through a detailed technical report and a short presentation.	
	4	Use Matlab, Python and Javascript libraries to develop programs for solving optimization problems.	3
	(*) The PLOs are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams/ZOOM and will be recorded for later access. Lectures could be delivered in class if the situation allows it. • The AI Lab is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments • The student carries out a term project for solving a problem using optimization techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material	Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.		
Resources and references	Recommended book(s), material and media: 6. Lecture notes prepared by the Instructor 7. Numerical Optimization, Jorge Nocedal, Stephen J. Wright, Springer 8. Numerical Optimization, Theoretical and Practical Aspects. Bonnans, J.-F., Gilbert, J.C., Lemarechal, C., Sagastizábal, Springer 9. Metaheuristic Optimization: Nature-Inspired Algorithms Swarm and Computational Intelligence, Theory and Applications. Okwu Modestus, Tartibu Lagouge.		

Topic outline and schedule

Lecture	Topic	Hours	ILO	Resources
1	Introduction and Motivation: Engineering applications of Optimization	2	1	1,2,3, 4
2	Non Linear optimization: Optimization Models	2	2,3, 4	1,2,3
3	Non-linear analytical optimization: Optimality conditions Convex Optimization, Unconstrained problems	2	2,3, 4	1,2,3
4	Non-linear analytical optimization: Numerical search, Equality, Inequality	2	2,3, 4	1,2,3
5	Non Linear Optimization: Duality	2	2,3, 4	1,2,3
6	Unconstrained Optimization methods: Direct, random search methods	2	2,3, 4	1,2,3
7	Unconstrained Optimization methods: 1 Descent method, Line search, Gradient descent method, Steepest descent method, Newton's method, Conjugate gradient method, Quasi-Newton's methods	2	2,3, 4	1,2,3
8	Meta-heuristic methods: Simulated Annealing, Particle Swarm Optimization	2	2,3, 4	1,4
9	Meta-heuristic methods: Artificial Bee Colony Algorithm, Ant Colony		2,3, 4	1,4
10	Genetic Algorithms	2	2,3, 4	1,4

	11	Software for optimization: MatLab Optimization toolbox	2	5	1
	12	Various applications: Vehicles and drones path planning optimization.	2	5	1

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Term project report, programs and presentation	100%	Programming and use of optimization toolboxes for engineering problem solving	W14
Total	**100%**		

Student requirements

The student should have a computer and internet connection.

Course policies

A- Attendance policies:

- Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard.

B- Absences from exams and submitting assignments on time:

- A makeup exam can be arranged for students with acceptable absence causes.
- Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty.
- The project report must be handed in in time.

C- Health and safety procedures:

- All health and safety procedures of the university and the school should be followed.

D- Honesty policy regarding cheating, plagiarism, misbehavior:

- Open-book exams
- All submitted work must be of the submitting student.
- Other text or code must be properly quoted with clear source

	specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team • Control Lab for practicing the practical aspects and solving the programming assignments.
Additional information	None

Appendix

Learning Outcomes for the MSc in Artificial Intelligence and Robotics

Students who successfully complete the MSc in Artificial Intelligence and Robotics (AIR) will be able to:

1. Demonstrate a sound understanding of the main areas of AIR including artificial neural networks, machine learning, data science, industrial and service robots, and intelligent and autonomous robots.
2. Apply a critical understanding of essential concepts, principles and practices of AIR, and critically evaluate tools, techniques and results using structured arguments based on subject knowledge.
3. Apply the methods and techniques of the AIR fields in the design, analysis and deployment of AIR solutions and solving practical problems.
4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation and presentation.
5. Demonstrate life-long learning, independent self-learning and continuous professional development skills in the AIR fields.
6. Demonstrate a sound understanding of the ethical, safety and social impact issues of AIR solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Fahed abdallah		
Organization Name(s)	Lebanese University		
WP Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
WP Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
Submission Date	14/9/2021	**Project Month**	M9

Revision History

Version	Date	Author	Description	Action *	Page(s)
1	1/8/2021	Clovis Francis	Master RSI Updated Courses Syllabus	C	1-6
2	22/10/2021	Clovis Francis	Version 2	U	
3	11/11/2021	Clovis Francis	Version 3	U	
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

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manner, but not in any way that suggests the partnership, or the European Commission endorses you or your use. You may not apply legal terms or technological measures that legally restrict others from using the material in the same manner that you did.

Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Introduction to Data mining and Machine learning
Course number	RSI02
Credit hours (lecture and lab)	
ECTS (weekly contact and self-study load)	4 (24 hours of total contact hours)
Prerequisites/co-requisites	Statistics (MATH 211)
Prerequisites by topic	Students are assumed to have good background in mathematics, particularly, calculus, linear algebra, statistics, and probability. Additionally, the students should have good programming skills, preferably using Python.
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Year 2, first semester
Description	This course provides an introduction of basic concepts of decision theory and data mining and to present machine learning methods and implementation techniques. It gives an overview over various types of data (for example sensor data, images, tables, text, graphs) and its properties. The covered topics include data preprocessing and preparation (for example normalization, PCA), introduction to classification and regression methods and model selection, Kernel based methods for classification and regression (SVM, KFD…), basics of unsupervised learning and introduction to clustering (representative based clustering and hierarchical clustering), Introduction to neural network for regression and classification, association rules and Recommendation systems.
Objectives	3. Introduce students to the basic concepts of decision theory and data mining. 4. Introduce students to the different classification and regression methods and model selection, Kernel based methods for classification and regression (SVM, KFD…) 5. Introduce students to basics of unsupervised learning and to clustering 6. Introduce students to basic in itemset mining 7. Apply data mining techniques in real-world applications
Intended learning outcomes	Upon successful completion of this course, students will be able to:

	<table><tr><th>No</th><th>Intended learning Outcome (ILO)</th><th>Program learning outcome (PLO)*</th></tr><tr><td>1</td><td>Demonstrate a sound understanding of the main areas of AIR.</td><td>1</td></tr><tr><td>2</td><td>Solve an AIR problem by developing an appropriate optimization approach.</td><td>2,3</td></tr><tr><td>3</td><td>Use Matlab, R or Python libraries to develop programs for solving AIR problems.</td><td>2,3,4</td></tr><tr><td>4</td><td>Apply machine learning techniques in selected applications</td><td>2,3,4,5,6</td></tr></table> (*) The PLOs are listed in the appendix
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams/ZOOM and will be recorded for later access. Lectures could be delivered in class if the situation allows it. • The AI Lab is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments • The student carries out a term project for solving a problem using Machine Learning techniques. • The student develops a professional report for the term report. • The student presents the term project in class.
Learning material	Textbook, class handouts, some instructor keynotes, selected videos, and access to a personal computer and the internet.
Resources and references	Recommended book(s), material and media: 1) Lecture notes prepared by the Instructor 2) Wes McKinney, Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, O'Reilly Media, 2nd Edition, 2018.

3) Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification, 2nd ed. Wiley, New York, 2001.
4) Mohammed J. Zaki and Wagner Meira, Jr, Data Mining and Machine Learning: Fundamental Concepts and Algorithms, Second Edition Cambridge University Press, March 2020. (ISBN: 978-1108473989)
5) https://dataminingbook.info/ : You can find here resources like slides, videos and other materials for the new edition of the DMA book.

Topic outline and schedule

Lecture	Topic	Hours	ILO	Resources
1	Introduction to Data Mining and Machine Learning	1	1	1, 4
2	Data Analysis Foundations: types of data and data preprocessing and preparation + mathematical background	3	1,2 ,3	1,4
3	Decision Theory and probabilistic classification: Focuses on Gaussian Case	3	2,3 ,4	1,3,
4	Kernel based methods for classification and regression	5	2,3 ,4	1,2,4
5	Introduction to neural network for regression and classification	6	2,3 ,4	1,4,5
6	Introduction to clustering	3	2,3 ,4	1,4,5
7	Frequent Pattern Mining and Association Rules	3	2,3 ,4	1,4,5

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time

	Term project report, programs and presentation	50%	Programming and use of optimization toolboxes for engineering problem solving	W12
	Final Exam	50%	Decision, classification and data mining	W12
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team • Control Lab for practicing the practical aspects and solving the programming assignments.
Additional information	None

Appendix

Learning Outcomes for the MSc in Artificial Intelligence and Robotics

Students who successfully complete the MSc in Artificial Intelligence and Robotics (AIR) will be able to:

1. Demonstrate a sound understanding of the main areas of AIR including artificial neural networks, machine learning, data science, industrial and service robots, and intelligent and autonomous robots.

2. Apply a critical understanding of essential concepts, principles and practices of AIR, and critically evaluate tools, techniques and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the AIR fields in the design, analysis and deployment of AIR solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation and presentation.

5. Demonstrate life-long learning, independent self-learning and continuous professional development skills in the AIR fields.

6. Demonstrate a sound understanding of the ethical, safety and social impact issues of AIR solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Clovis Francis		
Organization Name(s)	Lebanese University		
WP Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
WP Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
Submission Date	1/11/2021	**Project Month**	M11

Revision History

Version	Date	Author	Description	Action *	Page(s)
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2	22/10/2021	Clovis Francis	Version 2	U	
3	1/11/2021	Clovis Francis	Version 3		
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

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Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Modeling, Identification, observation and control of dynamics systems
Course number	RSI03
Credit hours (lecture and lab)	
ECTS (weekly contact and self-study load)	5 (total of 30 contact hours)
Prerequisites/co-requisites	Continuous and discrete automatic Control, continuous and discrete signal processing.
Prerequisites by topic	Students are assumed to have good background in mathematics and signal processing, particularly in calculus, linear algebra, statistics, and probability. Students are expected to have good knowledge in systems state space and transfer function representations in both continuous and discrete spaces. Additionally, the students should have good programming skills, preferably, using Matlab Simulink and Python.
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Year 2, first semester
Description	After having presented the fundamental notions of the modelling of dynamic systems, this course presents the concepts of identification of the systems parameters in time and frequency domains. Parametric (ARX family) and nonparametric Identification of dynamics systems are also addressed in this course. The Least square estimate is presented to achieve the best fitting of measured data. The control part of this course introduces some state-of-the-art advanced control topics including Feedforward control, Lyapunov control design, Sliding Mode Control and Backstepping control.
Objectives	1. Introduce students to the techniques used in identification of dynamical systems including parametric and non-parametric methods. 2. Introduce students to the techniques used in advanced control of dynamic systems and especially nonlinear systems. 3. Introduce students to the synthesis techniques of linear am nonlinear

<table>
<tr><td></td><td>observers
4. Introduce students to the programming techniques and libraries used in Identification.</td></tr>
<tr><td>Intended learning outcomes</td><td>Upon successful completion of this course, students will be able to:
<table>
<tr><th>No</th><th>Intended learning Outcome (ILO)</th><th>Program learning outcome (PLO)*</th></tr>
<tr><td>1</td><td>Demonstrate a sound understanding of the main areas of Artificial Intelligence and Robotics (AIR) including dynamics systems modelling, identification and control</td><td>1</td></tr>
<tr><td>2</td><td>Solve an identification and control problem by developing an appropriate experimental system.</td><td>3</td></tr>
<tr><td>3</td><td>Communicate the development of a Control and identification of dynamics systems through a detailed technical report and a short presentation.</td><td>4</td></tr>
<tr><td>4</td><td>Use Matlab and its specialized libraries to develop programs for solving identification and control problems.</td><td>3</td></tr>
</table>
(*) The PLOs are listed in the appendix</td></tr>
<tr><td>Teaching and learning methods</td><td>Development of ILOs is promoted through the following teaching and learning methods:
• Lectures will be delivered through Microsoft Teams/ZOOM and will be recorded for later access. Lectures could be offered in class if the situation allows it.
• The Control lab is open for the students to practice the practical aspects and solve the programming homework assignments.
• The student attends the class presentations and participates in the discussions.
• The student joins the related online team/group and participates in its discussions.
• The student studies the reference material, including books and videos.
• The student solves the programming assignments in identification, observation and control.
• The student carries out a term project for solving a problem using</td></tr>
</table>

<table>
<tr><td></td><td>identification and control techniques.
• The student develops a professional report for the term report.
• The student presents the term project in class.</td></tr>
<tr><td>Learning material</td><td>Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.</td></tr>
<tr><td>Resources and references</td><td>Recommended book(s), material and media:
1. Lecture notes prepared by the Instructor
2. Hassan Khalil, Nonlinear Systems, 3rd Edition, Prentice Hall, 2001.
3. J.J. Slotine and W. Li, Applied Nonlinear Control, Prentice Hall, 1991.
4. Identification of Physical Systems by Rajamani Doraiswami · Chris Diduch · Maryhelen Stevenson, WILEY, 2014
5. MatLab System Identification toolbox user guide: https://au.mathworks.com/help/ident/getting-started-1.html
6. Control of Robot Manipulators in Joint Space, R. Kelly, V. Santibanez, A. Loria, Springer 2005</td></tr>
<tr><td>Topic outline and schedule</td><td>
<table>
<tr><th>Lecture</th><th>Topic</th><th>Hours</th><th>ILO</th><th>Resources</th></tr>
<tr><td>1</td><td>Signal processing tools for identification</td><td>2</td><td>1</td><td>1,4</td></tr>
<tr><td>2</td><td>Identification toolbox of Matlab</td><td>2</td><td>4</td><td>1,4,5</td></tr>
<tr><td>3</td><td>Non parametric identification in the frequency and the time domains</td><td>3</td><td>1, 2, 4</td><td>1,4</td></tr>
<tr><td>4</td><td>Linear regression and least square estimate</td><td>3</td><td>1, 2, 4</td><td>1,4</td></tr>
<tr><td>5</td><td>Model parameters estimation</td><td>3</td><td>1, 2</td><td>1,4</td></tr>
<tr><td>6</td><td>Case study</td><td>2</td><td>5</td><td>1,4</td></tr>
<tr><td>7</td><td>Introduction to Feedforward Control</td><td>3</td><td>1</td><td>1,2,3</td></tr>
<tr><td>8</td><td>Lyapunov Control Design</td><td>3</td><td>1, 2</td><td>1,2,3</td></tr>
</table>
</td></tr>
</table>

	9	Sliding Mode Control	3	1, 2	1,2,3
	10	Backstepping Control	3	1, 2	1,2,3
	11	Applications and case studies	3	5	1,2,3,6

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Term project report and presentation in identification	50%	Programming of identification techniques	W10
Term project report and presentation in control	50%	Programming of control and observation techniques	W15
Total	**100%**		

Student requirements

The student should have a computer and internet connection.

Course policies

A- Attendance policies:

- Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard.

B- Absences from exams and submitting assignments on time:

- A makeup exam can be arranged for students with acceptable absence causes.
- Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty.
- The project report must be handed in in time.

C- Health and safety procedures:

- All health and safety procedures of the university and the school should be followed.

D- Honesty policy regarding cheating, plagiarism, misbehavior:

	• Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team • Control Lab for practicing the practical aspects and solving the programming assignments.
Additional information	None

Appendix

Learning Outcomes for the MSc in Artificial Intelligence and Robotics

Students who successfully complete the MSc in Artificial Intelligence and Robotics (AIR) will be able to:

1. Demonstrate a sound understanding of the main areas of AIR including artificial neural networks, machine learning, data science, industrial and service robots, and intelligent and autonomous robots.

2. Apply a critical understanding of essential concepts, principles and practices of AIR, and critically evaluate tools, techniques and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the AIR fields in the design, analysis and deployment of AIR solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation and presentation.

5. Demonstrate life-long learning, independent self-learning and continuous professional development skills in the AIR fields.

6. Demonstrate a sound understanding of the ethical, safety and social impact issues of AIR solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Fahed abdallah, Benjamin Quost		
Organization Name(s)	Lebanese University		
WP Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
WP Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
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3	11/11/2021	Clovis Francis	Version 3	U	
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Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Advances in statistical learning
Course number	RSI05
Credit hours (lecture and lab)	
ECTS (weekly contact and self-study load)	3 (18 contact hours)
Prerequisites/co-requisites	RSI 02 (Introduction to Data mining and Machine learning)
Prerequisites by topic	Students are assumed to have good background in mathematics, particularly, calculus, linear algebra, statistics, and probability. Additionally, the students should have good programming skills, preferably using Python.
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Year 2, first semester
Description	The objective of this course, which follows RSI02, is to present advanced methods of machine learning, in order to build efficient pattern recognition systems. After a few reminders of the principles of machine learning (supervised, unsupervised, semi-supervised), we will study some advanced pattern recognition techniques. The studied methods will be applied to classic datasets, so as to illustrate their properties and compare them in concrete situations.
Objectives	1. Introduce students to advanced methods of machine learning. 2. Introduce students to advanced pattern recognition techniques 3. Apply the studied methods to real-world datasets
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	Program learning outcome (PLO)*
1	Demonstrate a sound understanding of the main areas of AIR.	1
2	Solve an AIR problem by developing an appropriate	2,3

		optimization approach.	
	3	Use Matlab, R or Python libraries to develop programs for solving AIR problems.	2,3,4
	4	Apply machine learning techniques in selected applications	2,3,4,5,6
	(*) The PLOs are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams/ZOOM and will be recorded for later access. Lectures could be delivered in class if the situation allows it. • The AI Lab is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments • The student carries out a term project for solving a problem using optimization techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material	Textbook, class handouts, some instructor keynotes, selected videos, and access to a personal computer and the internet.		
Resources and references	Recommended book(s), material and media: 1) Lecture notes prepared by the Instructor 2) Wes McKinney, Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, O'Reilly Media, 2nd Edition, 2018. 3) Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification, 2nd ed. Wiley, New York, 2001. 4) Mohammed J. Zaki and Wagner Meira, Jr, Data Mining and Machine Learning: Fundamental Concepts and Algorithms, Second Edition Cambridge University Press, March 2020. (ISBN: 978-1108473989) 5) https://dataminingbook.info/ : You can find here resources like slides, videos and other materials for the new edition of the DMA		

<table>
<tr><td></td><td>book.</td></tr>
<tr><td>Topic outline and schedule</td><td>
<table>
<tr><th>Lecture</th><th>Topic</th><th>Hours</th><th>ILO</th><th>Resources</th></tr>
<tr><td>1</td><td>Introduction and reminders: supervised, unsupervised, semi-supervised learning</td><td>2</td><td>1</td><td>1, 4,5</td></tr>
<tr><td>2</td><td>Discriminant analysis (quadratic, linear, and derived models)</td><td>3</td><td>2,3</td><td>1, 3,4,5</td></tr>
<tr><td>3</td><td>Logistic regression</td><td>3</td><td>2,3</td><td>1, 3,4,5</td></tr>
<tr><td>4</td><td>Decision trees and ensemble methods (bagging and random forests, boosting)</td><td>4</td><td>2,3</td><td>1,4,5</td></tr>
<tr><td>5</td><td>EM algorithm, application to unsupervised classification and mixture models and to semi-supervised learning</td><td>6</td><td>2,3</td><td>1,4,5</td></tr>
<tr><td>6</td><td>Term Project Presentations</td><td>3</td><td>1,2 .3</td><td>1,2,4,5</td></tr>
</table>
</td></tr>
<tr><td>Evaluation tools</td><td>Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:
<table>
<tr><th>Assessment tool</th><th>Mark</th><th>Topic(s)</th><th>Time</th></tr>
<tr><td>Term project report, programs and presentation</td><td>50%</td><td>Programming and use of optimization and ML toolboxes for engineering problem solving</td><td>W12</td></tr>
<tr><td>Final Exam</td><td>50%</td><td>Decision, classification and data mining</td><td>W12</td></tr>
<tr><td>Total</td><td>100%</td><td></td><td></td></tr>
</table>
</td></tr>
</table>

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team • Control Lab for practicing the practical aspects and solving the programming assignments.
Additional information	None

Appendix

Learning Outcomes for the MSc in Artificial Intelligence and Robotics

Students who successfully complete the MSc in Artificial Intelligence and Robotics (AIR) will be able to:

1. Demonstrate a sound understanding of the main areas of AIR including artificial neural networks, machine learning, data science, industrial and service robots, and intelligent and autonomous robots.

2. Apply a critical understanding of essential concepts, principles and practices of AIR, and critically evaluate tools, techniques and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the AIR fields in the design, analysis and deployment of AIR solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation and presentation.

5. Demonstrate life-long learning, independent self-learning and continuous professional development skills in the AIR fields.

6. Demonstrate a sound understanding of the ethical, safety and social impact issues of AIR solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Clovis Francis		
Organization Name(s)	Lebanese University		
WP Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
WP Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
Submission Date	24/10/2021	**Project Month**	M10

Revision History

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1	1/8/2021	Clovis Francis	Master RSI Updated Courses Syllabus	C	1-6
2	22/10/2021	Clovis Francis	Version 2		
3					
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

Disclaimer

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manner, but not in any way that suggests the partnership, or the European Commission endorses you or your use. You may not apply legal terms or technological measures that legally restrict others from using the material in the same manner that you did.

Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Non Linear Control Applied to Robotics Systems
Course number	RSI08
Credit hours (lecture and lab)	
ECTS (weekly contact and self-study load)	3 (Total 18 contact hours)
Prerequisites/co-requisites	Linear Control (Continuous and discrete), Analysis of Non Linear Systems
Prerequisites by topic	Students are assumed to have good background in mathematics and Linear Control Systems, particularly, calculus, linear algebra, time and frequency responses of dynamics systems, regulator synthesis techniques for continuous and time discrete systems). The students are also assumed to be familiar with nonlinear systems analysis: first harmonic method, phase plane method, linearization by Jacobian method. Additionally, the students should have good programming skills, preferably, using Matlab Simulink, Python..
Level and type (compulsory, elective)	Masters' compulsory course
Year of study and semester	Year 2, first semester
Description	The students will be introduced to: control of conventional rigid robots by linearization and decoupling, Singularity problem, Control of conventional rigid robots by a Lyapunov type approach, Control of under actuated rigid robots by linearizing dynamic looping.
Objectives	Introduce students to the techniques used in Non Linear control: Lyapunov, Feedback Linearization, Input-output Linearization, input-state Linearization Introduce students to the different Mathematical tools for nonlinear Control: Diffeomorphism, Frobenius theorem.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	Program learning outcome (PLO)*

	1	Demonstrate a sound understanding of the main areas of nonlinear control.	1
	2	Solve a nonlinear control problem by developing an appropriate control approach.	2
	3	Communicate the development of a nonlinear control problem through a detailed technical report and a short presentation.	3,4
	4	Use Matlab, Python libraries to develop programs for solving non linear control problems.	3
	(*) The PLOs are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams/ZOOM and will be recorded for later access. Lectures could be delivered in class if the situation allows it. • The Control Lab is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments • The student carries out a term project for solving a problem using nonlinear control techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material	Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.		
Resources and references	Recommended book(s), material and media: 1. Lecture notes prepared by the Instructor 2. Non Linear Systems by Hassan Khalil, Prentice Hall 3. Nonlinear Systems, Analysis, Stability and Control by Shankar Sastry, Springer		

Topic outline and schedule

Lecture	Topic	Hours	ILO	Resources
1	Introduction and motivation: Linear vs Nonlinear systems. Jacobian Linearization techniques limitations. Examples of nonlinear phenomena (chaos, limit cycles, bifurcation).	2	1	1, 2,3
2	Analysis of systems properties : stability, controllability, observability	2	1	1, 2,3
3	Diffeomorphism		3	1, 2,3
4	Linearization techniques: Feedback Linearization	2	2, 3, 4	1, 2,3
5	Linearization techniques: Input-output Linearization	2	2, 3, 4	1, 2,3
6	Linearization techniques: Input-state Linearization	2	2, 3, 4	1, 2,3
7	Frobenius theorem	2	2, 3, 4	1, 2,3
8	Advanced NL control techniques: SMC control	2	2, 3, 4	1, 2,3
9	Various applications: control of robotic manipulators, control of under actuated systems (drones)	2	2, 3, 4	1

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Report	60%	Programming and use of nonlinear control techniques for engineering problem solving	W12
Presentation	60%	Work presentation and public discussion	W12
Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team • Control Lab for practicing the practical aspects and solving the programming assignments.
Additional information	None

Appendix

Learning Outcomes for the MSc in Artificial Intelligence and Robotics

Students who successfully complete the MSc in Artificial Intelligence and Robotics (AIR) will be able to:

1. Demonstrate a sound understanding of the main areas of AIR including artificial neural networks, machine learning, data science, industrial and service robots, and intelligent and autonomous robots.

2. Apply a critical understanding of essential concepts, principles and practices of AIR, and critically evaluate tools, techniques and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the AIR fields in the design, analysis and deployment of AIR solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation and presentation.

5. Demonstrate life-long learning, independent self-learning and continuous professional development skills in the AIR fields.

6. Demonstrate a sound understanding of the ethical, safety and social impact issues of AIR solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Issam Damaj		
Author Organization Name(s)	Beirut Arab University		
Work Package Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
Submission Date	14/11/2021	**Project Month**	M11

Revision History

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1	15/8/2021	Issam Damaj	Original (base) document	C	1-5
2	14/11/2021	Issam Damaj	After the review by partners	C	3, 5
3					
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

Disclaimer

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the project and the partnership, and indicate if any changes were made. You may do so in any reasonable manner, but not in any way that suggests the partnership, or the European Commission endorses you or your use. You may not apply legal terms or technological measures that legally restrict others from using the material in the same manner that you did.

Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Fuzzy Sets, Logic, and Applications
Course number	COMP 605
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	6 (3 + 3)
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	None
Level and type (compulsory, elective)	Masters' elective course
Year of study and semester	Any
Catalogue description	Fuzzy set and related concepts. Logical connectives. Mapping of fuzzy sets. Fuzzy relations and fuzzy set ordering. Fuzzy logic inference. Applications: fuzzy control, signal processing, pattern recognition, decision making, expert systems, fuzzy Logic in Databases, Information Retrieval with Fuzzy Logic, Fuzzy Intelligent Agents, Automotive Applications. Knowledge Engineering and Data Mining.
Objectives	This course introduces students to the basic concepts of modeling in systems using fuzzy sets. The concepts of fuzzy logic are introduced and their role in applications such as fuzzy control, signal processing, pattern recognition, etc. The students are introduced to the of fuzzy logic toolboxes and libraries in tools such as MATLAB and Python.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	Program learning outcome (PLO)*
1	Demonstrate understanding of basic knowledge of fuzzy sets, operations, and their properties.	1, 3
2	Demonstrate understanding of the fundamental	1, 3

		concepts of Fuzzy logic.	
	3	Apply the concepts of Fuzzy sets and logic various applications.	3, 4
	4	Use Fuzzy logic toolboxes and libraries in under MATLAB and Python.	2, 4

(*) The PLOs are listed in the appendix

Teaching and learning methods

Development of ILOs is promoted through the following teaching and learning methods:

- Lectures will be delivered through Microsoft Teams and will be recorded for later access.
- The Digital Systems Lab. is open for the students to practice the practical aspects and solve the programming homework assignments.
- The student attends the class presentations and participates in the discussions.
- The student joins the related online team/group and participates in its discussions.
- The student studies the reference material, including books and videos.
- The student solves the programming assignments in fuzzy logic.
- The student carries out a term project for solving a problem using fuzzy logic techniques.
- The student develops a professional report for the term report.
- The student presents the term project in class.

Learning material type

Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.

Resources and references

A- Required book(s), assigned reading and audio-visuals:

1. Ross, Timothy J. "Fuzzy logic with engineering applications. Southern Gate." ed: Chichester, West Sussex, United Kingdom: Wiley (2017).

B- Recommended book(s), material and media:

2. Klir, George J., Ute St. Clair, and Bo Yuan. Fuzzy set theory: foundations and applications. Prentice-Hall, Inc., 1997.

Topic outline and schedule

Week	Topic	ILO	Resources

	1	Introduction to Fuzzy Logic	2	1, 2
	2	Fuzzy Set Theory	1	1, 2
	3	Fuzzy Arithmetic	2, 4	1, 2
	4	Fuzzy Relations	1, 2	1, 2
	5	Possibility Theory	2	1, 2
	6	Fuzzy Inference	1	1, 2
	7	Approximate Reasoning	1	1, 2
	8	Fuzzy Hierarchical Control	3, 4	1
	9	Pattern Recognition	3, 4	1
	10	Fuzzy Logic in Databases	3, 4	1
	11	Information Retrieval with Fuzzy Logic	3, 4	1
	12	Fuzzy Intelligent Agents	3, 4	1
	13	Engineering Applications	3, 4	1
	14	Computer Network Applications	3, 4	1
	15	Term Project Presentations	1-4	1, 2

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	10%	Theoretical aspects	W1-W7
Midterm exam	30%	Applications	W8-W14
Term project report and presentation	20%	Practical and presentation aspects	W8-W15

	Final exam	40%	All material	W16
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and Moodle course page • AI Lab for practicing the practical aspects and solving the programming assignments. • Program announcements Facebook group
Additional information	None

Appendix

PLOs for the ME in Electrical and Computer Engineering

Students who complete the ME in Electrical and Computer Engineering (ECE) will be able to:

1. Demonstrate a sound understanding of the main areas of ECE including hardware and embedded systems, software systems, networks and cybersecurity, and artificial intelligence and machine learning.

2. Apply a critical understanding of essential concepts, principles, and practices of ECE, and critically evaluate tools, techniques, and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the ECE fields in the design, analysis, and deployment of ECE solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation, and presentation.

5. Demonstrate life-long learning, independent self-learning, and continuous professional development skills in the ECE fields.

6. Demonstrate a sound understanding of the ethical, safety, and social impact issues of ECE solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Issam Damaj		
Author Organization Name(s)	Beirut Arab University		
Work Package Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
Submission Date	14/11/2021	**Project Month**	M11

Revision History

Version	Date	Author	Description	Action *	Page(s)
1	15/8/2021	Issam Damaj	Original (base) document	C	1-5
2	24/10/2021	Issam Damaj	After the review by partners	C	5
3					
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

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the project and the partnership, and indicate if any changes were made. You may do so in any reasonable manner, but not in any way that suggests the partnership, or the European Commission endorses you or your use. You may not apply legal terms or technological measures that legally restrict others from using the material in the same manner that you did.

Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Neural Networks
Course number	COMP 609
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	6 (3 + 3)
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	None
Level and type (compulsory, elective)	Masters' elective course
Year of study and semester	Any
Catalogue description	Perception, back propagation, and adaptive neural networks. Transformation by layered networks, statistical neurodynamics, associative memory and neural learning. Supervised, unsupervised, reinforcement and deep learning. Applications to functional approximations, signal filtering, pattern recognition, data mining, etc.
Objectives	This course introduces students to the concepts of neural networks. The concepts of neural networks and the knowledge of supervised learning, computation and dynamical systems, reinforcement learning, and unsupervised learning using neural networks are introduced and their role in applications. The students are introduced to the of toolboxes and libraries in tools such as MATLAB and Python.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	PLO*
1	Demonstrate understanding of the role of neural networks in engineering, artificial intelligence, and cognitive modeling.	1, 3
2	Solve problems using supervised learning in neural networks	3, 4

	3	Demonstrate understanding of computations and dynamical systems using neural networks.	1, 3
	4	Solve problems using reinforcement learning in neural networks.	3, 4
	5	Solve problems using unsupervised learning in neural networks.	3, 4
	6	Demonstrate understanding of basic deep learning principles.	1, 3
	7	Apply neural network techniques in selected applications	2, 5, 6
	8	Use neural networks toolboxes and libraries in under MATLAB and/or Python.	2, 4
	(*) The Program learning outcome (PLOs) are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams and will be recorded for later access. • The Digital Systems Lab. is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments in Neural Networks. • The student carries out a term project for solving a problem using Neural Networks techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material type	Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.		
Resources and references	A- Required book(s), assigned reading and audio-visuals: 1. Simon, O. "Haykin, Neural Networks and Learning Machines." (2009).		

B- Recommended book(s), material and media:

2. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep learning. MIT press, 2016.

Topic outline and schedule

Week	Topic	ILO	Resources
1	Introduction, McCulloch-Pitts networks	1	1
2	Perceptrons	1	1
3	Regression and least mean square algorithm	1, 2	1
4-5	Multilayer perceptrons	1	1
6-7	Radial-basis function networks	6	1
8-9	Support vector machines	2	1
10	Unsupervised learning and self-organization	4, 5	1
11-12	Boltzmann machines and deep networks	6	1
13	Convolutional networks	7	1
14	Recurrent networks	7	2
15	Term Project Presentations	3, 7, 8	2

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	10%	Theoretical aspects	W1-W7
Midterm exam	30%	Applications	W8-W14
Term project report and presentation	20%	Practical and presentation aspects	W8-W15

	Final exam	40%	All material	W16
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and Moodle course page • AI Lab for practicing the practical aspects and solving the programming assignments. • Program announcements Facebook group
Additional information	None

Appendix

PLOs for the ME in Electrical and Computer Engineering

Students who complete the ME in Electrical and Computer Engineering (ECE) will be able to:

1. Demonstrate a sound understanding of the main areas of ECE including hardware and embedded systems, software systems, networks and cybersecurity, and artificial intelligence and machine learning.

2. Apply a critical understanding of essential concepts, principles, and practices of ECE, and critically evaluate tools, techniques, and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the ECE fields in the design, analysis, and deployment of ECE solutions and solving practical problems.
   d
4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation, and presentation.

5. Demonstrate life-long learning, independent self-learning, and continuous professional development skills in the ECE fields.

6. Demonstrate a sound understanding of the ethical, safety, and social impact issues of ECE solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Issam Damaj		
Author Organization Name(s)	Beirut Arab University		
Work Package Number & Title	Work Package 5: Improving Existing M.Sc. Programs in Jordan and Lebanon by Implementing or Including AI and Robotics Courses		
Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
Due Date of Delivery	30/11/2021	**Project Month**	M11
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Revision History

Version	Date	Author	Description	Action *	Page(s)
1	15/8/2021	Issam Damaj	Original (base) document	C	1-5
2	14/11/2021	Issam Damaj	After the review by partners	C	2, 3, 5
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Email: DeCAIR@ju.edu.jo

Project Website: http://DeCAIR.ju.edu.jo/

Course title	Data Mining
Course number	COMP 612
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	6 (3 + 3)
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	None
Level and type (compulsory, elective)	Masters' elective course
Year of study and semester	Any
Catalogue description	Data mining and knowledge discovery, motivation of using data mining, data mining models, data mining techniques: association rules, and classification in data-mining clustering, ~~tree learning, neural network and Bayesian methods, support vector machines, ensemble learning, and deviation detection~~. Introduction to recommender systems. Sequential patterns mining, applications, and case studies.
Objectives	This course introduces the concepts, principles, methods, and implementation techniques~~, and applications of data mining~~. The course put emphasis on data mining functions, pattern discovery, techniques, clustering, and sequential pattern mining. The students are introduced to the use of modern data mining tools.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	PLO*
1	Demonstrate understanding of pattern discovery concepts, methods, and applications.	1, 3
2	Identify efficient pattern mining methods and evaluation	3, 4

		issues.	
	3	Apply well-known sequential pattern mining methods.	3, 4
	4	Apply graph pattern mining.	3, 4
	5	Apply pattern-based classification	3, 4
	6	Demonstrate understanding of basic concepts, methods, and applications of cluster analysis.	1, 3
	7	Apply pattern-based ~~mining~~ techniques in selected applications.	2, 5, 6
	8	Use modern data mining toolboxes and libraries.	2, 4
	(*) The Program learning outcome (PLOs) are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams and will be recorded for later access. • The Digital Systems Lab. is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments in data mining. • The student carries out a term project for solving a problem using data mining techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material type	Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.		
Resources and references	A- Required book(s), assigned reading and audio-visuals: 1. Han, J., Kamber, M., & Pei, J. (2011). Data mining: Concepts and techniques (3rd ed.). Waltham: Morgan Kaufmann.		

B- Recommended book(s), material and media:

2. Introduction to Data Mining (Second version 2018), P.-N. Tan, M. Steinbach, and V. Kumar, Addison Wesley, 2018.

Topic outline and schedule

Week	Topic	ILO	Resources
1	Pattern Discovery Overview	1	1
2	Data Mining Process	1	2
3-4	Association Rules	1, 2	2
5	Pattern Evaluation	2	1
6	Sequential Pattern Mining	3	1
7	Graph Pattern Mining	4	1
8-10	Pattern-Based Classification	5	1
11	Pattern Mining Applications	7	1
12	Pattern Discovery Programming	7, 8	1
13	Recommender Systems	1, 2	1, 2
14	Cluster Analysis	6	1
15	Term Project Presentations	7, 8	1, 2

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	10%	Theoretical aspects	W1-W7
Midterm exam	30%	Applications	W8-W14
Term project report and	20%	Practical and presentation	W8-W15

	presentation		aspects	
	Final exam	40%	All material	W16
	Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and Moodle course page • AI Lab for practicing the practical aspects and solving the programming assignments. • Program announcements Facebook group
Additional information	None

Appendix

PLOs for the ME in Electrical and Computer Engineering

Students who complete the ME in Electrical and Computer Engineering (ECE) will be able to:

1. Demonstrate a sound understanding of the main areas of ECE including hardware and embedded systems, software systems, networks and cybersecurity, and artificial intelligence and machine learning.

2. Apply a critical understanding of essential concepts, principles, and practices of ECE, and critically evaluate tools, techniques, and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the ECE fields in the design, analysis, and deployment of ECE solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation, and presentation.

5. Demonstrate life-long learning, independent self-learning, and continuous professional development skills in the ECE fields.

6. Demonstrate a sound understanding of the ethical, safety, and social impact issues of ECE solutions and products.

DeCAIR Course Syllabus Form

Author(s)	Issam Damaj		
Author Organization Name(s)	Beirut Arab University		
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Activity Number & Title	Task 5.1: Developing syllabi and content for added/modified courses in existing master programs in universities of partner countries		
Work Package Leader	Peter Eberhard, University of Stuttgart		
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3					
4					

(*) Action: C = Creation, I = Insert, U = Update, R = Replace, D = Delete

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Course title	Pattern Recognition
Course number	COMP 618
Credit hours (lecture and lab)	3 (3 + 0)
ECTS (weekly contact and self-study load)	6 (3 + 3)
Prerequisites/co-requisites by course number and name	None
Prerequisites by topic (other than the formal prerequisites above)	None
Level and type (compulsory, elective)	Masters' elective course
Year of study and semester	Any
Catalogue description	Decision Theory, ROC Curves, Likelihood Ratio Test, Linear and Quadratic Discriminants. Template-based Recognition, Feature Extraction, Eigenvector and Multilinear Analysis. Training Methods, Maximum Likelihood and Bayesian Parameter Estimation. Classification techniques: k-nn, LVQ, SVM, decision tree, ANN, CNN, GAN. Clustering techniques: k-means, VQ, dendrogram, gap statistics. Applications: image analysis, computer vision, speech analysis, man and machine diagnostics, person identification, spam filtering, industrial inspection, financial data analysis and forecast, and genetics.
Objectives	This course introduces the concepts, principles, methods, implementation techniques, and applications of pattern recognition. The course put emphasis on Bayesian decision theory, evaluation, clustering, feature selection, classification methods, recognizing structures, and applications. The students are introduced to the use of modern pattern recognition tools.
Intended learning outcomes	Upon successful completion of this course, students will be able to:

No	Intended learning Outcome (ILO)	PLO*
1	Demonstrate understanding of Bayesian Decision Theory and classification methods.	1, 3

	2	Apply methods for pattern recognition.	3, 4
	3	Select appropriate techniques for addressing recognition problems.	3, 4
	4	Implement pattern recognition algorithms.	3, 4
	5	Apply pattern recognition techniques in selected applications.	2, 5, 6
	6	Use modern data mining toolboxes and libraries.	2, 4
	(*) The Program learning outcome (PLOs) are listed in the appendix		
Teaching and learning methods	Development of ILOs is promoted through the following teaching and learning methods: • Lectures will be delivered through Microsoft Teams and will be recorded for later access. • The Digital Systems Lab. is open for the students to practice the practical aspects and solve the programming homework assignments. • The student attends the class presentations and participates in the discussions. • The student joins the related online team/group and participates in its discussions. • The student studies the reference material, including books and videos. • The student solves the programming assignments in pattern recognition. • The student carries out a term project for solving a problem using pattern recognition techniques. • The student develops a professional report for the term report. • The student presents the term project in class.		
Learning material type	Textbook, class handouts, some instructor keynotes, selected YouTube videos, and access to a personal computer and the internet.		
Resources and references	A- Required book(s), assigned reading and audio-visuals: 1. Svensén, Markus, and Christopher M. Bishop. "Pattern recognition and machine learning." (2007). 2. Duda, Richard O., Peter E. Hart, and David G. Stork. "Pattern classification, ed." W. Interscience (2001). B- Recommended book(s), material and media: 3. Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.		

Topic outline and schedule

Week	Topic	ILO	Resources
1	Introduction to Pattern Recognition	2, 3	1, 2
2-3	Bayesian Decision Theory	1	1, 2
4	Linear Discriminants	2	2
5	Tree Classifiers	2,4, 6	2
6	Parametric Techniques	2	2
7	Non-Parametric Techniques	2	2
8-9	Unsupervised Methods	2, 4, 6	1
10-12	Other Classification Techniques	2, 4, 6	1
13-14	Graphical Models: SSM, HMM, and Bayesian Networks.	1	1
15	Term Project Presentations	5, 6	1, 2, 3

Evaluation tools

Opportunities to demonstrate achievement of the ILOs are provided through the following assessment tools:

Assessment tool	Mark	Topic(s)	Time
Homework assignments	10%	Theoretical aspects	W1-W7
Midterm exam	30%	Applications	W8-W14
Term project report and presentation	20%	Practical and presentation aspects	W8-W15
Final exam	40%	All material	W16
Total	**100%**		

Student requirements	The student should have a computer and internet connection.
Course policies	A- Attendance policies: • Attendance is required. Class attendance will be taken every class and the university polices will be enforced in this regard. B- Absences from exams and not submitting assignments on time: • A makeup exam can be arranged for students with acceptable absence causes. • Assignments submitted late, but before announcing or discussing the solution can be accepted with 25% penalty. • The project report must be handed in in time. C- Health and safety procedures: • All health and safety procedures of the university and the school should be followed. D- Honesty policy regarding cheating, plagiarism, misbehavior: • Open-book exams • All submitted work must be of the submitting student. • Other text or code must be properly quoted with clear source specification. • Cheating will not be tolerated. E- Available university services that support achievement in the course: • Microsoft Teams team and Moodle course page • AI Lab for practicing the practical aspects and solving the programming assignments. • Program announcements Facebook group
Additional information	None

Appendix

PLOs for the ME in Electrical and Computer Engineering

Students who complete the ME in Electrical and Computer Engineering (ECE) will be able to:

1. Demonstrate a sound understanding of the main areas of ECE including hardware and embedded systems, software systems, networks and cybersecurity, and artificial intelligence and machine learning.

2. Apply a critical understanding of essential concepts, principles, and practices of ECE, and critically evaluate tools, techniques, and results using structured arguments based on subject knowledge.

3. Apply the methods and techniques of the ECE fields in the design, analysis, and deployment of ECE solutions and solving practical problems.

4. Demonstrate the ability to produce a substantial piece of research work from problem inception to implementation, documentation, and presentation.

5. Demonstrate life-long learning, independent self-learning, and continuous professional development skills in the ECE fields.

6. Demonstrate a sound understanding of the ethical, safety, and social impact issues of ECE solutions and products.

7 Outcome of Task 5.1

Using the previous description and comments, this document describes the improved existing master programs and their individually revised syllabi. Each syllabus has been revised by means of a group of particular experts, see also Table *3*, and the resulting improved syllabi have been given. Hence, this consideration forms the basis for remaining Tasks 5.2 (Approval for the modified or added courses to existing master programs from the governing university boards) and 5.3 (Implementing improved/new courses in universities of Partner Countries by scheduling and offering courses for enrolment) of WP5. Furthermore, it can be seen as a guideline for the subsequent work package WP6 in which existing bachelor programs are to be improved by implementing AIR related courses.

Appendix: Existing Courses which are not added or modified

Existing Courses at JUST (not added/modified)

Course	ECTS/ Hours	Prerequisite
Obligatory Courses		
• (ME 701) Advanced Applied Mathematics Integral Transforms, Fourier Transforms, Legendre Transforms, two-sided Laplace transforms, special functions (Gamma, Beta, and Bessel functions), Legendre polynomials, and error function. Partial differential equations (different methods of solution). Linear algebra. Applications in Mechanical Engineering.	3 hours	
• (ME 770) Embedded Systems for Mechatronics Microprocessor hardware and software modules. Microcontrollers hardware and software architectures, microcontrollers programming and interface with real-time mechatronics systems. Designing stand-alone embedded systems for mechatronics products. Case studies and course projects.	3 hours	
• (ME 771) Advanced Control Systems Analog controller design methods: lead and lag compensators, pole placement, model matching, two-parameter configuration, introduction to state-space control system, state estimator and state feedback, canonical realizations, stability, controllability and observability, minimal realizations, introduction to optimal control, linear quadratic regulator, introduction to robustness, introduction to digital control system, and intelligent control.	3 hours	
• (ME 773) Modeling and Simulation of Dynamics Systems Introduction to multi-domain systems. Mechanical, thermal, fluid, electrical, electronic, electromechanical system dynamics, emphasis on modeling and simulation of hybrid systems using modern computer-aided tools.		
• (ME 790) Seminar Seminar on project planning development and realization, case studies of engineering systems design and realization,		

current research topics in mechatronics engineering including areas such signal processing, image processing, control, robotics, intelligent systems, computer vision, MEMS, Etc.	3 hours 1 hour	
Elective Courses		
• (ME 715) Advanced Vibration • (ME 774) Programming Tools and Methods for Mechatronics Engineers • (ME 775) Power Electronics and Electrical Drives • (ME 776) Electro-Pneumatic and Hydraulic Systems • (ME 777) Advanced Industrial Instrumentation and Control • (ME 778) Sensors and Actuators • (ME 779) Real-Time Systems • (ME 780) Automated Manufacturing Systems • (ME 783) Distributed Control Systems • (ME 784) Introduction to Robotics • (ME 785) Micromechantronic Systems and Applications • (ME 786A) Special Topics in Mechatronics System Applications A • (ME 786B) Special Topics in Mechatronics System Applications B • (ME 787) Introduction to Computer Networking • (ME 789) Advanced Robotics Control • (ME 762) Project Management • (ME 792) Intelligent Control Systems • (ME 793) Mechatronics System Design-I • (ME 794) Mechatronics System Design-II • (ME 796) Machine vision	3 hours each	

Existing Courses at UJ (not added/modified)

Course	ECTS/ Hours	Prerequisite
Obligatory Courses		
Research Methodology • Issues in Research Mythologies, Performance Evaluation and Benchmarking. Measurement Tools and techniques, Trace Driven and Execution Driven Simulation. Choice of metrics. Benchmarks. Statistical techniques for Performance Evaluation. Trace Generation and Validation, Synthetic Traces, Verification of Simulators. Design of Experiments. Analytical Modeling of Processors, Statistical modeling, Hybrid Techniques. Workload Characterization. Literature Surveys and Writing Research Papers and Reports	3 credit hours	
Probability and Queuing Theory • Probability and random variables, distributions and density functions, stochastic processes, Markov chains, modeling and analysis of queuing systems with applications in computers and networking where topics include birth-death processes and simple Markovian queues, networks of queues and product form networks, single and multi-server queues, multi-class queuing networks, fluid models, adversarial queuing networks, as well as heavy-traffic theory and diffusion approximations	3 credit hours	
Network Systems Design • This course gives a broad view of the current state of computer networking research. Topics include: Internet architecture; Internet routing: the Border Gateway Protocol (BGP), routing characterization, routing security, Internet AS relationships, traffic engineering, end host congestion control; quality-of-service, network security: intrusion detection systems, worms, and honey pots; mobile and wireless networking; peer to peer and overlay networking; content distribution networks; sensor networks; critical network infrastructure services: Domain Name Server (DNS), mail servers, etc.; network measurement: distance estimation, bandwidth	3 credit hours	

measurement, trouble shooting tools; network management		
Advanced Networks and Systems Security(Move to the elective course) • Review of Computer Networks. Number Theory and Field Arithmetic. Sources of Network Threats. Data Encryption: Cryptography and Ciphering. Risk Management. Key Management. Protocols and Algorithms of Security Systems. Email and Web Security and Firewalls. Performance Evaluation of Security Systems.	3 credit hours	
Advanced Computer Architecture • Review of computer design principles, processor design, RISC processors, pipelining, and memory hierarchy. Instruction level parallelism (ILP), dynamic scheduling, multiple issue, speculative execution, and branch prediction. Limits on ILP and software approaches to exploit more ILP. VLIW and EPIC approaches. Thread level parallelism, multiprocessors, chip multiprocessors, and multithreading. Cache coherence and memory consistency. Advanced memory hierarchy design, cache and memory optimizations, and memory technologies. Advanced topics in storage systems. Designing and evaluating I/O systems	3 credit hours	
Elective Courses		
Advanced Wireless Networks • Introduction to wireless networks: physical layer, MAC and IEEE 802.11, HIPERLAN, Bluetooth, channel assignment and channel hopping, power control and rate control, multi-radio, network layer, mobile IP, and naming, routing in mobile networks, transport protocol in wireless networks; types of wireless networks: wireless mesh networks, sensor networks, cellular networks, delay tolerant networks, RFID and WiMax; wireless network management and security: localization, network usage studies, network diagnosis, network security.	3 credit hours	Network Systems Design

Multimedia Engineering • Signal processing concepts exploited in the field of multimedia applications, issues in multimedia applications design, multimedia data processing and representations, multimedia compression standards (text, image, video and audio), multimedia content representation, content-based multimedia retrieval, watermarking techniques and security, multimedia network communications	3 credit hours	
Advanced Parallel Processing • Architectures for explicit parallelism. Multithreaded processors, small- and large-scale multiprocessor systems. Shared-memory coherence and consistency. Graphics processing units. Effect of architecture on communication latency, bandwidth, and overhead. Latency tolerance techniques. Interconnection networks. The development of programs for parallel computers. Basic concepts such as speedup, load balancing, latency, system taxonomies. Design of algorithms for idealized models. Programming on parallel systems such as shared or distributed memory machines, networks. Grid Computing. Performance analysis. Case studies.	3 credit hours	Advanced Computer Architecture
Advanced Digital System Design • Multi-Level Combinational Design, Programmable Logic Synthesis, Arithmetic Circuits, Sequential System Design, Finite State Machine Optimization, Analysis of Asynchronous Sequential Systems, Asynchronous Sequential System Design, Multi-Valued Logic Synthesis, Multi-Valued System Optimization, Regular Digital System Design, Static and Dynamic Hazards, Testing Techniques for Modern Digital Systems, Design-For-Testability	3 credit hours	
Advanced Distributed Systems • Introduction to Distributed Systems, Distributed Operating Systems, Processes and Inter-process Communication (IPC), Distributed File Systems, Remote Procedure Calls (RPC), Security Models, Distributed Architectures and Technologies, Middleware, Object Based Distributed Systems, Messaging and Message Oriented Systems, Agent-Based Systems, Distributed Application Project.	3 credit hours	
Advanced Algorithms	3 credit	

• Emphasis will be placed on fundamental algorithms and advanced methods of algorithmic design, analysis, and implementation. Techniques to be covered include network flows, linear programming, Integer linear programming, NP-completeness, solving NP-complete problems using approximate and heuristic approaches, and dynamic programming.	hours	
Advanced Cloud Computing • Cloud computing models, techniques, and architectures, distributed computing models and technologies, Infrastructure-as a-Service (IaaS), Platform-as-a-Service (PaaS), Software-as-a Service (SaaS), virtualization, security and privacy issues, performance and systems issues, capacity planning, disaster recovery, Cloud OS, federated clouds, challenges in implementing clouds, data centers, cloud hosted applications, and other advanced and research topics in cloud computing	3 credit hours	Network Systems Design
Advanced Digital Image Processing • Introduction to digital image processing techniques for enhancement, compression, restoration, reconstruction, and analysis, 2-D signals and systems, image analysis, image segmentation, achromatic vision, color image processing, color imaging systems, medical imaging, image sharpening, interpolation, decimation, linear and nonlinear filtering, camera modeling, stereo vision, pose calculation, object recognition, optical flows, visual tracking, color vision, and beginning concepts of computational geometry.	3 credit hours	
Advanced Topics in Computer Engineering and Networks • Topics of special interest in current computer engineering and networks issues. The course description is specified by the department at every course offering.	3 credit hours	

Existing Courses at LU (not added/modified)

Course	ECTS/ Hours	Prerequisite
Obligatory Courses		
RSI06- Modelling and Optimisation of Logistics Systems: The objective of this course is to introduce different methods and tools to model and solve linear optimization problems with a particular focus on transport and logistics problems. In this course we also give a brief introduction to complexity theory. Complexity theory, NP-class, polynomial reduction, Turing reduction, NP-complete class in the strong and weak sense. Linear programming, modelling of transport and logistics problems, flows in networks, scheduling etc. Solution methods for combinatorial problems, dynamic programming, tree methods.	3/18	RSI01
RSI07- Diagnosis and Fault Tolerance of Dynamic Systems: This course covers various techniques for the design of fault-tolerant dynamic systems. Topics includes model-based techniques for fault diagnosis, graph-theory analysis techniques for linear systems, and the application of traditional fault tolerance techniques to the synthesis of reliable control mechanisms. The course will also cover recent areas of research on the subject such as tolerating packet dropouts in networked control systems, information exchange in multi-agent systems despite the presence of malicious agents, and the analysis of the vulnerability of large-scale complex systems (such as the power grid and the internet) to attacks and faults. Course content: Fault and attack models in dynamic systems, graphical models of dynamic systems, structured systems theory, model-based diagnosis and analytical redundancy, observers and residue generators, fault-tolerant combinatorial systems. Applications: error control coding for reliable	4/24	RSI03, Linear, Digital and Non Linear Control

controller design, stability during packet dropping in network control systems, identification of malicious attackers in multi-agent networks, attack and fault tolerance in large complex networks.		
Elective Courses		
None		

Existing Courses at BAU (not added/modified)

Course	**ECTS/ Hours**	**Prerequisite**
Elective Courses		
COMP 601 Distributed Operating Systems	3 Credits	None
COMP 602 Advanced Computer Architecture	3 Credits	None
COMP 603 Advanced Algorithms	3 Credits	None
COMP 604 Advanced Computer Networks	3 Credits	None
COMP 606 Coding Theory	3 Credits	None
COMP 607 Advanced Microprocessor-Based Systems	3 Credits	None
COMP 608 Advanced Topics in Computer Graphics	3 Credits	None
COMP 610 Online Algorithms	3 Credits	None
COMP 611 Non-Traditional Database Systems	3 Credits	None
COMP 613 Data Warehousing	3 Credits	None
COMP 614 Security Protocols	3 Credits	None
COMP 615 Advanced Computer Control and Robotics	3 Credits	None
COMP 616 Modern Trends in Computer Engineering I	3 Credits	None
COMP 617 Modern Trends in Computer Engineering II	3 Credits	None
COMP 619 Advanced Compiler Design	3 Credits	None
COMP 620 Introduction to Embedded Computing	3 Credits	None
COMP 621 Software for Embedded Systems	3 Credits	None
COMP 622 Real-Time Systems	3 Credits	None