MCAST MASTER OF SCIENCE IN MECHATRONICS

CODE: UC7-E12-18
Launching November/December 2020

Online Application and Cost Details Available at :
https://shortcourses.mcast.edu.mt/courses/MASTERS

Entry Requisite: First degree in engineering; ICT; technology.

Delivery Mode - Blended Learning over 5 Semesters (2 ½ Years): 7 Modules taught in a total of around 30 weekend campus sessions (a weekend session consists of a Friday evening lecture from 17:30 to 20:30 and a Saturday morning lecture from 9:00 to 13:00) and 3 modules carried out online through eLearning using the MCAST Moodle Platform.

The Master of Science in Mechatronics programme provides students with a broad range of knowledge and skills in the field of automation and control of production processes and equipment, as well as in the field of mechatronic devices and systems control. It focuses on the study of network technologies (e.g. Ethernet, Industrial Protocol, Profinet, Modbus, Profibus, Devicenet, Control Net), and development of SCADA system (Supervisory Control and Data Acquisition) construction. Practical use of real-time systems is also an important part of the programme. Students shall apply the theoretical principles of industrial robotics and mechatronics, mechatronic and robotic actuators, and modern technologies of microcontroller applications.

Learning Outcomes

Upon successful completion of this Masters Programme the participants will be able to:

1. *Appraise the purpose, functioning and need for mechatronic systems in modern industry and everyday life as true interdisciplinary systems;*
2. *Assess various mechanisms, sensors, actuators and controllers as components of a mechatronic system;*
3. *Model and design mechatronic systems based on customer requirements, specifications, and best practice examples;*
4. *Develop a stand-alone mechatronic system based on user-case specifications;*
5. *Integrate a mechatronic system as an intelligent upgrade of an already functioning system in industry;*
6. *Plan development projects independently and in teams;*

First Year (Semesters 1 & 2: 30 ECTS) – Exit Option: Post Graduate Certificate

1. Mechanisms and Machine Design
2. Mechatronic System Design
3. Control Systems Technology
4. Signals and Systems
5. Industrial Robot Design and Control

Second Year (Semesters 3 & 4: 30 ECTS) – Exit Option: Post Graduate Diploma

6. Practical Control and Applications in Mechatronic Systems
7. Software Design and Analysis
8. Computational Modelling and Simulation of Dynamic Systems
9. Industrial Robot Programming and Applications
10. 3D Technologies in Mechatronic System Design

Third Year (Semester 5: 30 ECTS) – Final Exit: Masters

Dissertation

STUDY UNIT 1

Mechanisms and Machine Design

MQF Level 7

6 ECTS

E-learning: No

Rationale

Analysis and design of mechanisms is of vital importance to any machine design, particularly in mechatronics and robotics. Basic principles of linear and rotary displacement, accompanied with velocity and acceleration analysis of rigid bodies, set the rules of the physical description of complex rigid bodies. These principles are used in the synthesis of cams, spurs, bevel, helical and worm gears, as well as gear trains. Furthermore, these principles are used in the analysis and synthesis of linkages, planar and spatial. Static stress analysis of linkages is followed by dynamical analysis and design rules, down to the simplest mechanical components. Typical nonlinearities, backlash and manufacturing tolerances, which are vital for the quality of design of complex mechanisms with joints and linkages, are presented in a systematic way to pave the way for the calibration procedures of mechanisms. Finally, industrial robots are given as the best examples to bridge theory and implementation in various mechatronic design examples.

Learning Outcomes

Upon completion of this unit learners will be able to:

1. Explain the concepts in mechanism analysis and synthesis;
2. Interpret the practical considerations relating to mechanism design and manufacturing;
3. Devise the mechanism calibration process;
4. Interpret the various elements and the processes of robot design and analysis;
5. Assess robot manufacturing issues such as backlash and tolerances with respect to resolution;

STUDY UNIT 2

Mechatronic System Design

MQF Level 7

6 ECTS

E-learning: No

Rationale

This unit will introduce students to mechatronic systems, explain their purpose and application cases, keeping a balance between mechanical and software subsystems, with the aim of presenting design principles based on VDI2206 instructions. Toward this end mechatronic system requirements are provided, illustrated with use cases and specifications, as well as hardware design of the system starting from use-cases analysis. Students will also learn about object oriented software design based on use-cases, selection of components, proof of concept importance in the design process and the integration of R&D into product design. Finally, this unit deals with the testing and integration of subsystems during the development process, project documentation guidelines and software bundles for design and documentation.

Learning Outcomes

Upon completion of this unit learners will be able to:

1. Describe the fundamentals of a mechatronic system;
2. Comply with the mechatronic system design principles of the vdi2206;
3. Justify the optimal materials for specific mechatronic systems;
4. Choose adequate standard mechanical components for support and housing of mechatronic systems used in specific conditions;
5. Describe the basics of linkages and power transmission and choose the basic mechanical components used for power transmission;
6. Select optimal wiring, cabling and routing processes for given mechatronic system specifications;

7. Appraise field-programmable gate arrays, field-programmable interconnect components, and field-programmable analog arrays;
8. Explain and compare between the most important steps in the testing process;

STUDY UNIT 3

Control Systems Technology

MQF Level 7

6 ECTS

E-learning: No

Rationale

Students will gain basic knowledge on control system technology, starting with an introduction to systems, design and modelling, followed by measurement and data acquisition. More specifically, students will learn the basics of filtering and signal conditioning, local sensor networks, actuation for small size automation production processes, solenoids latches, pneumatics, PWM control, small DC motors and driving principles, integrated solutions for actuation. A focus will also be placed on state flow control of automation systems, modelling and practical issues, mechanical transmission in mechatronic systems and small gearboxes. Students will also learn about typical control signals and control with feedback and/or feedforward, including linear control algorithms, the design of feedforward control signals for gravity, inertia and friction compensation, practical decomposition of complex control system and the control of decomposed system.

Other specific topics will include advanced model-based control of mechatronic systems, technology for intelligent control and fuzzy logic control. Students will also be introduced to Network Protocol Stacks including: the general requirements, resource sharing, multiplexing, layered network architecture, program interfacing, as well to the ISO/OSI reference model and 5-layer model. This unit will provide basic knowledge about direct link networks, reliable transmissions and use of automatic repeat request protocols and sliding window algorithm. Finally, students will be enabled to use Local Area Networks: Ethernet (IEEE 802.3), Wireless LAN (IEEE 802.11, IEEE 802.15) - physical structures, access protocol and operational properties. End-to-end Protocols: Unreliable (UDP) and reliable (TCP) protocols, segment formats, connection establishment and termination, sliding window and adaptive retransmission. This unit also covers domain naming and hierarchies, and embedded systems networks: specific requirements and design issues of embedded systems networks: topologies, protocols, robustness, error handling, as well as synchronous and asynchronous protocols, with examples of embedded systems networks: I2C, SPI, CAN, LIN and the coding of digital data. The work on the basics of network security will include cryptographic algorithms: secret key, public key, message digest; and for security services will include privacy, authentication, integrity control and non-repudiation.

Learning Outcomes

Upon completion of this unit, learners will be able to:

1. Evaluate the principles and concepts of automated control within the context of mechatronics systems.
2. Summarise the principle elements of mechatronic systems;
3. Develop the control of automated systems through the application/use of control logic tools;
4. Assess the concepts of feedback and feedforward within the context of mechatronic systems;
5. Create and evaluate model-based control of mechatronic systems based on fuzzy logic;
6. Describe the concepts of networked control systems;

STUDY UNIT 4

Signals and Systems

MQF Level 7

6 ECTS

E-learning: Yes

Rationale

Signals and systems is an introduction to analogue signal processing - a topic that forms an integral part of engineering systems in many diverse areas, including seismic data processing, communications, speech processing, image processing, defence electronics, consumer electronics and consumer products. This unit presents and integrates the basic concepts for both continuous-time and discrete-time signals and systems. Signal and system representations are developed for both time and frequency domains. These representations are related through the Fourier transform and its generalisations, which are explored in detail. Filtering and filter design, modulation, and sampling for both analog and digital systems, as well as exposition and demonstration of the basic concepts of feedback systems for both analog and digital systems, are discussed and illustrated.

Learning Outcomes

Upon completion of this unit learners will be able to:

1. Describe the concepts of continuous-time and discrete-time signals and systems;
2. Create a signal and system representation in the time and frequency domains related through the fourier transform;
3. Assess the concept and representation of the periodic sampling of a ct signal;
4. Assess the concepts of modulation techniques;
5. Devise laplace transformation tasks within the context of signals and systems;
6. Interpret and design feedback systems;
7. Interpret the concepts and properties of the z-transform and carry out z-transform tasks;

STUDY UNIT 5

Industrial Robot Design and Control

MQF Level 7

6 ECTS

E-learning: No

Rationale

Students will first learn about the kinematics of rigid bodies, orthogonal coordinate transformations, finite rotations, rotation matrix, open kinematic chain, kinematics and direct and inverse kinematic problems in order to understand the more advanced topics about redundant robotic systems and resolving redundancy robot, dynamics and differential equations of motion for robotic, systems modelling, robotic systems with closed and branched kinematic chains, connection via prismatic or revolute joints. They will also learn about robot actuation and power transmission, modularity and scalability in robot design, including robot control tasks, positioning versus manoeuvring, trajectory planning, task and mission control. Students will gain basic knowledge and skills in singularity avoidance in trajectory planning, forward control, gravity compensation, friction compensation, direct and inverse dynamic control. This will be completed with the practical realisation of robot control with PLC and AC drives, including robot control via the vectoring principle. Finally, students will learn about the specific practical issues such as robot tools and grippers, the integration of robots with painting and welding tools, force-torque sensors for safety and assembly tasks, safety equipment in robotics and robot networking for integration, maintenance and service.

Learning Outcomes

Upon completion of this unit learners will be able to:

1. Formulate the DH notion for an industrial robot and set the inertial parameters for dynamic simulation;
2. Develop a model of an industrial robot for dynamical analysis and choose the motor drives by specified tasks in the operational space;
3. Examine trajectories according to a given velocity profile;
4. Assess a robot workspace with the aim of proposing reductions in energy use;

STUDY UNIT 6

Practical Control and Applications in Mechatronic Systems

MQF Level 7

6 ECTS

E-learning: No

Rationale

The importance of mechatronic system control is emphasised via a holistic approach. We have based this unit on the concept that a good mechatronic system is one that has a good balance between mechanical complexity and the required processing power. This unit studies the two main parts of mechatronic system: mechanics and drives on one side and sensors, controller and algorithms on the other. Specific cases of linear and rotary movement against different linear or nonlinear loads are presented in every detail to find out where the challenge to controller is. For given examples, further analysis of control architecture is analysed in a complete bundle of DIO, AIO, PWM, Communication, UI. Sample code is analysed and implemented on testbeds. In particular, focus is placed on trajectory generation, PID algorithm, increasing stability margin and improving positioning accuracy.

Programmable logic controllers and AC drives are given as an alternative solution for a larger-scale of mechatronic system. A case of distributed control will be analysed in detail. Interface of different user interfaces and HMI to microcontrollers and PLCs will be presented along with development tools. Further into the unit an overview of the key issues for the construction and verification of programmable logic and real-time/embedded systems will be given. Real-time operations and real-time operating systems, concurrent processes, process-to-process communication and synchronisation, interrupt handling, resource allocation, software, instrumentation, processor technology, design and development of programmable logic, simulation and verification will also be covered.

Learning Outcomes

Upon completion of this unit learners will be able to:

1. Design and engage analogue electronics circuitry complementary to a given microcontroller;
2. Develop typical communication protocols for identified embedded systems;
3. Write code to control the positioning of a one-axis mechatronic system;
4. Analyze software complexity in order to meet the constraints of low complexity embedded systems;

STUDY UNIT 7

Software Design and Analysis

MQF Level 7

6 ECTS

E-learning: No

Rationale

This unit will enable students to understand data structures (array, list, stack, queue, tree), the definition and significance of algorithms, algorithm design and classification, and analysis of algorithms (worst-case, estimation rules, growth rate). It will also introduce students to software engineering processes, best practices of software engineering, generic models of software development (Waterfall, Iterative, Agile), software development life cycles, Bubble Sort, elaborating modelling patterns, requirements engineering, incremental model, and evolutionary models. Students will then learn about Unified Process, Extreme Programming (XP), software requirements specification (SRS), Unified Modelling Language (UML), case diagram, sequence diagram, UML interaction diagram, state machine diagram, activity diagram, communication diagram.

As part of this unit students will also gain knowledge and skills in software architecture, overall structure design, architecture design activities, architecture styles, documenting software architecture, client-server architectural patterns, broker architectural pattern, software design issues, object-oriented design principles; objects, classes, messages and methods. Finally this unit will enable students to apply object-oriented design using UML, as well as to become skilled in testing, fault-error-failure, program failure sources, testability, exhaustive testing, selective testing, white-box testing, combination testing, selective testing, control structure testing, condition testing, basis path testing, loop testing, black box testing, equivalence partitioning, boundary value analysis, data flow testing, inter-class testing, behaviour testing and regression testing.

Learning Outcomes

Upon successful completion of this unit, learners will be able to:

1. Develop different forms of data structures and algorithms;
2. Explain the concept of software engineering and use its various tools and methods in the context of mechatronic systems;
3. Explain the software development life cycle, software development models, and best practices of software engineering;
4. Interpret the different concepts, patterns and documentation of software architecture;
5. Interpret unified modeling language (uml);
6. Prepare unified modeling language (uml) diagrams or object oriented design;
7. Compile software testing tasks;

STUDY UNIT 8

Computational Modelling and Simulation of Dynamic Systems

MQF Level 7

6 ECTS

E-learning: Yes

Rationale

This unit will enable students to deal with multi-domain engineering systems at a level of detail suitable for design and control system implementation. They will be able to understand network representation, state-space models, multi-port energy storage and dissipation, Legendre transforms, nonlinear mechanics, transformation theory, Lagrange and Hamiltonian forms and control-relevant properties. Application examples will provide students with practical knowledge, focused on electro-mechanical transducers, mechanisms, electronics, fluid and thermal systems, compressible flow, chemical processes, diffusion, and wave transmission.

Learning Outcomes

Upon successful completion of this unit, learners will be able to:

1. Describe the basic concepts of system modelling;
2. Develop different techniques for the modelling of a dynamic system;
3. Develop state-space models and simulation within the context of dynamic systems;
4. Prepare modelling procedures, forms and components for the creation of non-linear mechanical systems;
5. Interpret and solve hybrid system simulation at mission level;

STUDY UNIT 9

Industrial Robot Programming and Applications

MQF Level 7

4 ECTS

E-learning: No

Rationale

This unit covers basically the use of industrial robots, taking into account the automotive industry as the cradle of robotics. Therefore, students will learn first about robot applications in the automotive industry, i.e. in painting, welding, cutting, assembly and inspection, but also about human-robot applications and interactions, and about the new applications of robotics in the automated production environment. This unit will also provide students with the skills for assembly tasks with a human in the loop, the placement of robot tables, adapters, and holders for increasing efficiency, remote control and programming. Students will also be able to understand the design of robot equipment for integration in a robotic environment, the networking of robots for cooperative operations, as well as some specific issues such as image processing for robot guidance and safety, sense of touch for precise assembly and safety. Finally, students will learn robot programming in CAD-CAM environment, the analysis of trajectories, torque, singularity conditions, robot tables programming and integration in robot controller, how to use sensors on holders and adapters for assembly and welding, and how to apply typical HMI for manual handling of a robot.

Learning Outcomes

Upon successful completion of this unit, learners will be able to:

1. Develop the torque vectoring mode of a 2 DOF robot system;
2. Evaluate robotic motion, ranges and actuator loads for unknown gravity loads;
3. Compile a program for a robot in a virtual environment;
4. Analyse robot motion parameters in a virtual environment and deploy the code to the robot;

STUDY UNIT 10

3D Technologies in Mechatronic System Design

MQF Level 7

6 ECTS

E-learning: Yes

Rationale

3D Additive Manufacturing is an innovation in manufacturing parts of complex shape. With 3D technologies, the shape complexity does not increase additional costs and the use of material is relatively reduced. The key to unlock the user benefits of multifunctional and multi-technologies inspired to 3D lies in the design freedoms that the 3D approach stimulates. This huge degree of design flexibility gives the potential of design and manufacturing of hybrid and multifunctional components and structures. Such structures combine sensorics, actuators, slots for controllers and power supply, conveniently fitted and enclosed. Lots of industries are benefiting from an acceleration of innovation by exploiting the freedom of design where the personalisation principle is widely adopted, also in industries far from consumer goods manufacturing such as mechatronics in automotive sectors. The next generation of machines and systems for 3D manufacturing will be easily transferrable to different applications. In particular, they will be required to integrate multiple subtractive and additive technologies in hybrid solutions and operating by persistently monitoring and adapting the deposition or subtraction processes.

Learning Outcomes

Upon successful completion of this unit, learners will be able to:

- Explain the basic terms and definitions of additive manufacturing;
- Evaluate and employ the various steps forming the additive manufacturing process chain;
- Evaluate the different additive manufacturing processes, their technologies, classification and applications;

- Explain the role, use and application of materials in additive manufacturing;
- Describe multiprocess additive manufacturing within the context of 3d technologies;
- Explain the principles of 3d printer operations based on different manufacturing materials and technology;
- Describe model design and the additive manufacturing process;