Unit T17: Robotic Systems in Engineering

Unit code:	H/503/7416
QCF level:	6
Credit value:	15

Aim

This unit aims to give learners a comprehensive understanding of robotic technologies, their capabilities and limitations, and the theoretical frameworks of robot control. The unit will also enable learners to develop the skills needed to provide robotic solutions to engineering problems.

Unit abstract

Robotic systems are traditionally used in engineering to produce systems with behaviours that are highly repeatable and accurate, such as production line robots for painting, welding or assembly in the manufacturing industry. More recently, robotic technologies have also been used by engineers to produce systems that can operate in environments that are inaccessible to humans, for example collapsed buildings, deep sea oil wells, mine fields, nuclear reactors or even distant planets.

This unit covers current robotic technologies in terms of their capabilities and limitations, including sensor and actuator technologies for industrial, mobile and service robots and technologies for data integration and control.

The unit also explores the theoretical frameworks related to robotic systems, including kinematics, dynamics, localisation, navigation and mapping.

Learning outcomes

On successful completion of this unit a learner will:

1 understand the capabilities and limitations of robot technologies

2 understand the theoretical frameworks for robot control

3 be able to develop and evaluate robotic solutions to engineering applications.

Unit content

1 Understand the capabilities and limitations of robot technologies

Capabilities and limitations: eg motion, degrees of freedom, speed, torque, controllability, energy consumption, accuracy, drift, sensory modality, digitalization, data formats, range, accuracy, active/passive sensing

Technologies: sensors (proprioceptive, position, proximity, vision); actuators (joints, motors)

Sensor fusion mechanisms: spatial representation, eg Cartesian, Polar, linear, logarithmic; standardisation; integration

Control architectures: eg reactive, deliberative, behaviour-based, hybrid

2 Understand the theoretical frameworks for robot control

Robot motion: forward kinematics, inverse kinematics, dynamics

Localisation: eg dead reckoning, triangulation, filter-based

Mapping: eg metric, probabilistic, topological

3 Be able to develop and evaluate robotic solutions to engineering applications

Environment: eg land, marine, air

Manipulation: eg reaching, grasping

Integrated solutions: sensors; actuators, eg wheels, legs, arms, hands; sensor fusion mechanisms; control architectures; structural integration

Testing: test case development (range, randomisation); performance metrics; evaluation (repeatability, significance)

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 understand the capabilities and limitations of robot technologies	1.1 Analyse the critical capabilities and limitations of given robot technologies 1.2 Justify the use of robot technologies for a specific engineering application 1.3 Critically evaluate data representations and standardisations for the integration of sensor data in robotic systems 1.4 Critically evaluate the appropriateness of different control architectures for given environments
LO2 understand the theoretical frameworks for robot control	2.1 Solve given problems of robot motion within relevant theoretical frameworks 2.2 Solve given problems of robot localisation within relevant theoretical frameworks 2.3 Solve given problems of robot mapping within relevant theoretical frameworks
LO3 be able to develop and evaluate robotic solutions to engineering applications	3.1 Critically evaluate the requirements for robot motion in different environments 3.2 Critically evaluate the requirements for effective operation in different manipulation scenarios 3.3 Develop effective robotic solutions integrating appropriate robot technologies, data fusion methods, control architectures and structural elements 3.4 Critically evaluate developed robotic solutions.

Guidance

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

The content of this unit has been designed and mapped against the Engineering Council's current Learning Outcomes for IEng Accreditation. The completion of the learning outcomes for this unit will contribute knowledge, understanding and skills towards the evidence requirements for IEng Registration.

See *Annexe B* for summary of mapping information for IEng Accreditation.

Essential requirements

Learners will require an opportunity to gain experience with development of complete robotic systems. A high-fidelity simulator such as the Webots simulator from the Cyberbotics company, Microsoft Robotics Developer Studio or the open source Player/Stage/Gazebo applications could be used if real robotic hardware is not available. Ideally, learners will gain experience from control of real robotic hardware, eg the Mindstorms robot development kit from Lego, to give them an appreciation of the difficulties related to the development and control such systems.

Delivery

The presence of both practical and theoretical content provides an opportunity to engage the students in a practical project relatively early on in the delivery and to use the practical activity as a supporting context for the theoretical content. Learner engagement in a project may be increased by framing the project in terms of a student competition.

The architecture and integration aspects of robotics can also successfully be taught through the use of case studies of well-published robotic systems such as the Mars rovers or the Roomba robotic vacuum cleaner.

Assessment

The assessment strategy should include both a practical assessment element, such as a project where learners develop a robotic solution to a given problem, and a theoretical assessment element such as a written examination.

Resources

A project-based assessment would typically require a set of related workshops to support learners in the early stages. These workshops would require extra resources in terms of tutors to run them.

At a minimal cost, the unit's practical element could be focused on an open source simulator. However, the learner would gain a deeper insight into the relevant problems if real robotic hardware resources were made available.

Books

Arkin R – *Behavior-Based Robotics* (MIT Press, 1998) ISBN 978-0262011655

Bekey G A – *Autonomous Robots: From Biological Inspiration to Implementation and Control* (MIT Press, 2005) ISBN 978-0262025782

Craig J J – *Introduction to Robotics: Mechanics and Control: International Edition*, 3rd edition (Prentice Hall, 2004) ISBN 978-0201543612

Thrun S, Burgard W and Fox D – *Probabilistic Robotics* (MIT Press, 2005) ISBN 978-0262201629

Journals

IEEE Transactions on Robotics (IEEE Robotics and Automation Society) ISSN 1552-3098

International Journal on Robotics Research (Sage) ISSN 0278-364

Robotica (Cambridge University Press) ISSN 0263-5747

Robotics and Autonomous Systems (Elsevier) ISSN 0921-8890

Websites

kn.theiet.org/communities/robotics/mechatronics	IET knowledge network on robotics and mechatronics
marsrovers.nasa.gov/home	The NASA JPL Mars Exploration Rover Mission
mindstorms.lego.com/	Lego's website for the Mindstorms robot development kit
www.ieee-ras.org/	IEEE Robotics and Automation Society
www.iroboteurope.co.uk/	iRobot company, makers of the Roomba vacuum cleaning robot

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