

What are robots?

In popular media robots are often presented as *humanoid* machines that are able to perform complex tasks in a seemingly intelligent manner. The reality is usually quite different.

Robots are machines that can be *programmed* to perform repetitive tasks with a high degree of precision *autonomously*, i.e. with little or no human intervention. They may also be capable of changing their behaviour in response to changing conditions. This is often facilitated by 'machine vision'.

Industrial robots

In industry robots are often used to:

- pick up items and move them to another place
- inspect items and reject those that do not meet specifications
- analyse products automatically
- pack items into boxes for sale or transport
- store and retrieve items as required.

In the motor industry robots are commonly used to carry out much of the assembly, *welding* and painting of vehicles.

Types of robotic manipulation

Basic *articulated* robot arms can swivel or turn in two dimensions (XY) and move up and down in the Z-direction. More advanced articulated robots have many rotating joints and can perform more complex movements, e.g. *SCARA robots*.

They are generally faster than XYZ robots. Examples include car-assembly robots (as shown above) and product handling robots in factories.

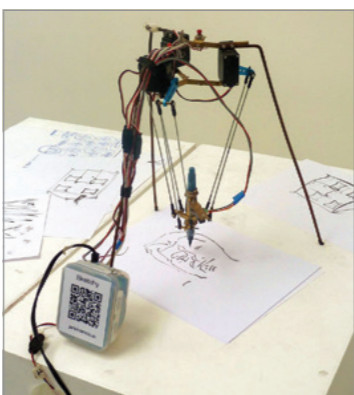
XYZ robots (or *Cartesian* robots) can move only along three axes that are at right angles to one another.



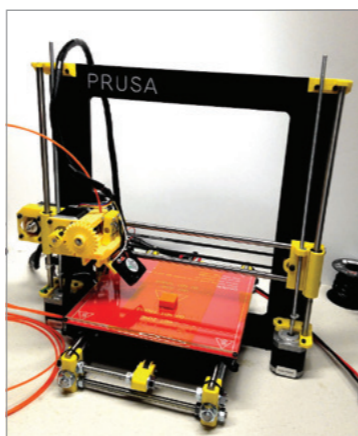
Automation of container movement (Wikipedia image)

Examples include 3-D printers and robotic stacking of shipping containers.

Delta robots (or parallel arm robots) can handle small items very quickly and accurately, such as packing chocolates in a sweet factory.



Delta robot



X-Y-Z 3-D printer. Image from Wikipedia by J. Abella

Because every movement involves all three arms, calculation of their positions is complex. The image (left) shows a home-made portrait-drawing delta robot.

Reasons for using robots

Common reasons for using robots include the following:

- to free people from repetitive, dangerous or boring tasks so that they can use their time for more creative work
- to increase speed, accuracy and consistency of operations and so reduce costs.

Multiple technologies involved in robotics

Robotics is regarded as an *interdisciplinary* branch of engineering and science because it involves knowledge and skills from many different areas including mechanics, engineering, *electronics*, *hydraulics* and *pneumatics*, computer programming, machine vision and *sensory feedback*.

Flexibility and autonomy

Many of the robot types mentioned above carry out a sequence of operations, such as *welding* at a specific number of points in the assembly of a motor car. The operations are programmed in advance and require little or no human intervention.

In situations that are less predictable robotic devices must be able to detect changes in their environment and respond appropriately.

Autonomous motor cars need information, not only about the route and speed limits, but they must also be able to detect and react to other vehicles and to



Robotic lawn mower

unexpected or abnormal situations. Actions that experienced drivers can easily perform may be difficult to programme into robotic cars. For example, to move from one busy lane into another one, the vehicle must measure the speed and spacing of the other vehicles, indicate at an appropriate time and change speed and direction, all in a few seconds.

Less complex tasks can be carried out by automatic lawn mowers. They can be programmed to move randomly around an area defined by a buried boundary wire.

Environmental sensing and machine vision

Autonomous vehicles use a number of technologies for environmental sensing including multiple cameras, *radar*, *lidar*, *sonar* and *GPS*. How does a robotic control system make 'sense' of all the inputs? Attaching a video camera to a computer is not enough. Video images must be analysed and interpreted in real time by the computer and then merged with the information from all the other sensors so that it can respond appropriately. This is by far the most challenging aspect of autonomous robotics.

Robots in the workplace

Robots are usually designed to perform a limited set of operations. They generally cannot match human flexibility or creativity. However, because they do not get tired or bored, they can outperform human operators in many repetitive tasks.

Robotic systems are already in use:

- filling medical prescriptions in hospitals
- for semi-autonomous chemical testing; some can test hypotheses and interpret the results of experiments
- stacking and retrieving, e.g. in *warehouses*
- autonomous package delivery, by drone
- street cleaning or sweeping
- extraterrestrial exploration, e.g. the Mars Rover.

Can robots learn for themselves?

Over the last twenty years or so great advances have been made in the area of what is called 'machine learning'. One area in which this has been successfully applied is in interpretation of medical *diagnostic scans*. Rather than attempting to 'teach' the system to identify abnormalities in scanned images, hundreds of scans were fed into the computer along with the records of the patients who were followed over a period of months or years. By analysing all the data the computer systems identified elements in the scans that were associated with disease more accurately than the experts who had originally examined the scans.

This kind of function is generally classified as 'artificial intelligence' because it mimics what an intelligent human operator might be able to do. Today we take for granted that virtual assistants such as Siri or Alexa can respond 'intelligently' to our spoken requests. But is this 'intelligence' or the product of a complex *electronic neural network* that is somewhat comparable to a biological neural network?

Boston Scientific in Clonmel

The Clonmel operation is responsible for the production of over 250,000 implantable medical devices per annum. Boston Scientific Clonmel manufactures lifesaving pacemakers and defibrillators for patients suffering from cardiac arrhythmias and heart failure.

Boston Scientific Clonmel also produces life enhancing neuromodulation devices for patients who suffer from chronic pain and motor movement disorders. It actively promotes and participates in the local community through initiatives such as its Schools Programme where Boston Scientific facilitates Transition Year students on work experience and sponsors a Student of the Year award in local schools, culminating in an opportunity for summer work. Boston Scientific is actively involved in Junior Achievement activities, with over 19 employees delivering programmes in the region.

Find out more about the work of Boston Scientific at www.bostonscientific.com

Syllabus References

The main syllabus references for the lesson are:

Leaving Certificate Technology (2007 Syllabus)

Introduction to robotic control:

- use of computers or other programmable devices to control various devices
- understand the principles of combinational and sequential logic
- programme a robotic device to carry out specified operations and to sense functions (pp. 32-33).

Leaving Certificate Computer Science (2018 specification)

- Students will learn: the process of designing computational artefacts such as web pages, digital animations, simulations, games, apps and robotic systems (p. 2)
- Computer science students will: ... Create an interdisciplinary artefact using some form of analytics; Develop a computer system that simulates or models a problem that is difficult to solve analytically; Implement an embedded system that uses sensors and controls digital inputs and outputs. (p. 15)

Science and Technology in Action is also widely used by **Transition Year** classes.

Learning Outcomes

On completion of this lesson, students should be able to:

- Describe what is meant by the term 'robot'.
- Describe the type of actions robots can perform and outline possible uses of robots in industry.
- Explain what is meant by the term 'sensors' and how they are important in robotics.
- Distinguish between XYZ, SCARA and Delta robots.
- Outline the main reasons for using robots in industry.
- Explain why robotics is regarded as an interdisciplinary branch of engineering and science.
- Outline some practical problems associated with the introduction of autonomous vehicles.
- Outline what is meant by "machine vision" and how it may be implemented.
- Discuss the rationale for using robots in the workplace as well as the potential positive and negative consequences of their use for employees.
- Discuss the benefits and risks associated with the use of smart technology in the home that can listen to what we say and can learn what our shopping preferences might be. How secure is our data and is it being used ethically?

Student Activities

1. Answer the questions below after you have viewed the video at: <https://www.youtube.com/watch?v=uoC2ZGRI8a8>
 - (a) What is a robot and what are the main parts of a robot. Give some examples of 'end effectors'.
 - (b) What were the first robots used for?
 - (c) What is a programmable robot. When were the first programmable robots made and what did they do?
 - (d) What is meant by artificial intelligence and why is it essential for 'machine vision'?
 - (e) What is the main problem in making 'humanoid robots'?

See also: <https://www.youtube.com/watch?v=HX6M4QunVmA>
2. View the video about programming industrial robots at the web location below and then answer the questions: <https://www.youtube.com/watch?v=OzJ9V3UMnh4>
 - (a) In what areas are robots used?
 - (b) How were the first robots programmed?
 - (c) Draw a diagram to show the function of a 'feedback loop'.
 - (d) Outline three ways in which industrial robots might be programmed to perform a task: 'teach mode', 'lead through programming', 'learning from demonstration'.
3. Explore some ways of making a gripper for a robotic arm using a stepper motor or other suitable means.
4. Explore designs for a simple programmable robotic arm for use with an Arduino or other microcontroller.

True/False Questions

- | | |
|---|-----|
| a) Robots are machines that can be programmed to perform specific tasks. | T F |
| b) Humanoid robots are autonomous machines. | T F |
| c) Adding a camera to a robot gives it machine vision. | T F |
| d) Some industrial robots can pack items into boxes. | T F |
| e) Cartesian robots are the same as articulated robots. | T F |
| f) Delta robots are used for stacking shipping containers. | T F |
| g) Robots are particularly good at performing repetitive tasks. | T F |
| h) Robotics involves electronics, engineering and many other disciplines. | T F |
| i) Autonomous vehicles use several technologies for environmental sensing. | T F |
| j) Artificial intelligence enables some robotic systems to gradually learn and improve with practice. | T F |

Check your answers to these questions on www.sta.ie.

Examination Questions

Leaving Certificate Technology (HL) 2011, part C, Q. 1c

The 'hands' of a robot are often referred to as *end effectors*. Mechanical grippers and vacuum grippers are examples of such end effectors.

- (i) Distinguish between the use of mechanical grippers and vacuum grippers as methods of robotic manipulation of objects.
- (ii) Describe the main features of a SCARA robot such as the one shown. (SCARA - Selective Compliant Assembly Robot Arm)



Leaving Certificate Technology (OL) 2016 C, Q. 1

The image shows a robotic arm. The arm has six degrees of freedom.

- (i) Describe, using notes and annotated sketches, what is meant by 'degrees of freedom'.

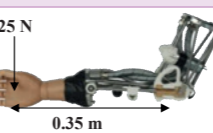
Give two applications of robots in mass production systems.

In time, robots will outsmart human beings and rule the world! Indicate whether you agree or disagree with this statement and briefly justify your answer.

- (c) With reference to the robotic arm shown, describe what is meant by the term 'end effector'.

Calculate the moment acting about the elbow of the robotic arm if a load of 25 N is acting on the hand.

- (d) Name and describe the main features of the robotic arm shown. Describe, using annotated sketches, the work envelope of the robotic arm shown.



Leaving Certificate Technology (HL) 2015 part C, Q. 1c

The da Vinci SI robot has four robotic arms and seven degrees of freedom. It gives surgeons the ability to perform the most complex and delicate procedures. Each arm is controlled using servo motors with encoders.

- (i) Suggest two benefits of robotic surgery.
- (ii) Explain the terms 'degree of freedom' and 'encoder'.



Did You Know?

Some relevant third level courses in Ireland

- Athlone IT:** Automation & Robotics (B.E. Level 7, 3 years)
- CIT:** Robotics (5 ECTS Credits at Level 7, 12 weeks)
- DCU:** Mechatronic Engineering (B.E. Hons, Level 8, 4 years)
- NUI Maynooth:** Robotics & Intelligent Devices (B.Sc. Hons, Level 8, 4 years)
- TCD:** Electronic and Computer Engineering (joint programme) (B.A. Hons, Level 8, 4 years)
- TU Dublin:** Mechatronic Engineering (B.E. Level 7, 3 years; B.E. Hons, Level 8, 4 years)
- UCD:** Electrical Engineering (B.E. Hons, Level 8, 4 years)
- University of Limerick:** Engineering in Industrial Automation & Robotic Systems (B.E. Level 7, 3 years)

Notes

Autonomous robots

Routine tasks such as mowing grass or cleaning streets and parks are now being carried out, at least experimentally, by robotic machines. They typically use cameras and bumper sensors to detect and avoid collisions with people or with other obstacles. However, the level of autonomy is not great.

The Curiosity Mars rover has a somewhat higher level of autonomy. It is assigned a 'destination' each morning and must make its own way there. It uses stereo cameras to map the local area and, using that data, it chooses the best route. Its software was upgraded in 2016 to enable it to better identify potential targets for sampling or chemical analysis and to modify its route accordingly. However, its level of autonomy cannot be compared to that of a human explorer. (Wikimedia image by NASA/JPL)

Revise The Terms

Check the meaning of the following key terms:

articulated, Cartesian, delta robots, diagnostic scans, electronic neural network, electronics, GPS, humanoid, hydraulics, lidar, pneumatics, programmed, radar, SCARA robots, sensory feedback, sonar, warehouses, welding, XYZ robots

Check the Glossary of terms for this lesson on www.sta.ie