CASE STUDY 3: INTEGRATED AND CONTROL TECHNOLOGY

This Case Study was written by Kevin Taylor from Robotic Education Products (Aust), www.robotics.com.au. Kevin specifically explains modern robot technology using a ‘systems approach’ similar to that used in this book. The article explores different and specific types of robots, their configurations, functions, applications and effects on people and their work environments.

Technological developments have always played a major part in shaping society, just as society influences the development of new technologies. Advances and developments in technology have meant less physical work, more choices, fewer manual skills and greater complexity in our lives. However, the need for physical interaction with most technological systems remains. We may own programmable washing machines, microwave ovens and remote control televisions, but we still need to ‘work them’ to some extent.

We have witnessed an increased adoption of integrated and controlled technologies, and a marked increase in the development and use of robots. We integrate technologies (mechatronics) such as electronics, mechanics, microelectronics, pneumatics and hydraulics to create operating systems. These are programmed or controlled remotely to perform specific functions. Some, including robots, are trained to work alone and solve unexpected problems.

These technologies continue to influence change in society and in particular, the workplace. Production and manufacturing industries have become more automated with fewer people doing the actual work. Automated and controlled production lines, computer-controlled machining and assembly robots are key features of many modern industries.

Robots

In Karel Capek’s Rossum’s *Universal Robots* (RUR) play in 1920, the Czechoslovakian dramatist used the word ‘robot’ to describe the character that produced a number of artificial organic men. In the Czech language ‘robota’ meant forced labour. In the Greek language the word ‘robot’ was ‘auto man’, which means moving automatically.

Our human world has the task of becoming familiar with technology as it enters our physical environment where we, the inhabitants, spend our time. This is inside our homes, at schools, the workplace, hospitals, operating theatres and cinemas. We need to consider the effects that robots have on humans and their physical, working and social environments.
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**Where they are used ...**

**A robot's appearance ...**

What is a robot?
Everyone has a different opinion.
‘A robot is any machine or mechanical device that operates automatically with human-like skill.’
– Random House Dictionary
‘A machine that in appearance or behaviour imitates either a person or a specific action of that person, such as limb movement.’ – Robots by Peter Marsh
‘A robot is a machine that does something automatically in response to its environment.’ – Steve Mendelsohn in Robot Review
‘A robot is a bunch of motors controlled by a programmable computer.’ – BERT by Karl Brown.
‘A robot is a computer with muscles.’ – Dr John Billingsley

Robot characteristics
Use
- Industrial – painting, welding, materials handling
- Non-Industrial – personnel, dangerous situations, social help, educational, hobby

Mobility
- Fixed robots work within a limited space or area.
- Mobile robots permit work in various areas.
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Motion control
The type of motion control determines the level of complexity of robot movement. There are two main types of motion control systems used in robots: non-servo controlled and servo controlled.

**Non-servo robots** have their movements set and limited by mechanical end stops. Movement continues until it literally ‘bangs’ into the end point. It is not possible for the robot to accurately stop between these two points.

**Servo-controlled robots** are much more flexible than non-servo robots as they can be made to stop at any number of points within their working space. This extra control is made possible by the use of a feedback system. There is a built-in sensing ability that constantly feeds back the actual position and compares it to the intended position. Constant corrections are made automatically to reduce the tracking error. Precise movements accurate to less than 2 mm are made possible. Servo-controlled robots permit the complex tracking of perfect straight lines, curves and circles.

Evolution of robots

**First-generation robots**
First-generation robots include both playback and numerically controlled (NC) robots. Playback robots memorise a route which has been ‘taught’ by a human operator who physically guides the robot along the desired route. An excellent example of a playback robot is a spray-painting robot that has memorised the movements of a human spray painting an object. The robot repeats exactly what it was taught.

Numerically controlled (NC) machines are more advanced in that no physical teaching is necessary. The robot programmer programs the movements directly into the computer memory. The main disadvantage of first-generation robots is that they have little or no sensory feedback. If a piece of material to be drilled was incorrectly positioned it would drill it anyway. Or, if a human wandered in front of the robot while it was welding, it would be happy to weld him, or her, to the job!
Second-generation robots
Second-generation robots incorporate basic sensory systems to feed back information to the computer controller so that they can respond to their environment. For example, infrared sensors might detect that a human has entered the danger zone. This information is fed back to the computer; a decision is made based on memorised ‘choices’ and the robot is stopped. Second-generation robots are sometimes called adaptive robots.

Third-generation robots
Third-generation robots will be those robots that use artificial intelligence (Al) computers. These intelligent robots will be able to recognise, learn and think. They will be able to program themselves and adapt to situations not previously encountered.
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Robot arm configurations

**Rectangular coordinate robot**
This robot has a cube-shaped work envelope. The side view shows that its horizontal arm can rise and fall on the vertical column and also move in and out. The top view shows that it slides back and forth on its base instead of pivoting. These robots are easily programmed, relatively inexpensive and very precise in operation.

**Cylindrical coordinate robot**
This work envelope is a portion of a cylinder. In the side view it can be seen that the arm has the same movements as the rectangular coordinate robot. However in the top view it can be seen that the entire arm can pivot or rotate around the base, although it cannot rotate a full 360 degrees.

**Spherical coordinate robot**
The work envelope shape for this robot is a portion of a sphere. In the top view the action is the same as that of the cylindrical robot. However, in the side view it can be seen that it does not rise and fall on the vertical column but instead pivots up and down to form an arc. These robots are useful for lifting and moving objects.
### Jointed-arm robot

The work envelope shape is complex because of the action of the joints. This robot resembles the human arm. Its joints are called the waist, shoulder, elbow and wrist. The side view clearly shows that the robot arm can reach very low and high and behind itself. Because of its increased flexibility and strength, this robot is used often in industry; however, they are the most expensive to produce and require a complex control system.

### Spine robot

This snake-like robot has extraordinary flexibility and the most complex work envelope of all robots. Spine robots are best suited for work in hard to reach places such as spray-painting the inside of a car. However, they do not have the same lifting ability as other robots.

### End effectors

End effectors are the types of tool attached to the end of the robot arm. The ability of most end effectors to be automatically changed to a different tool is a major factor that makes robots flexible machines. The tools could be screwdrivers, wrenches, arc welders, drills, cutters, deburrers or ladles for moving molten metal. Also, special end effectors are available such as fingers and vacuum and magnetic grippers.

### Robot system analysis

All robots are systems; that is, robots are comprised of a set of parts forming a whole. The robot system can be analysed from general to specific using system analysis. The first stage of system analysis is to consider the system as a ‘black box’. We do not know what is inside the ‘box’, but we can identify the input and output of the system. The original input to a robot is human direction; the output is many types of work done automatically.
**Functional units**

The second stage of analysis is to look inside the black box where we find the subsystems or functional units of the robot. Each functional unit performs a specific task and has its own input and output. Robots have four main functional units: controller, actuators and drives, power supply and sensors.

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**Four subsystems**

The function of the controller is to govern the operation of the actuators (devices that make motion) and drives (which modify motion). The power supply provides the energy needed for the entire system. In addition to the three main subsystems, second-generation robots have sensors that receive output feedback from the actuators and pass the information to the controller to provide error correction. External environmental information can also be received by the sensors and sent back to the controller to make necessary adjustments in operations.

**Controller**

The purpose of the controller is to direct the operation of the robot actuators. The input is information received from people and sensors. The output consists of electrical commands sent to the actuators. Today, virtually all robots are controlled by computers. Computers have two very important sections: the hardware (the actual parts) and the software (the coded instructions). Good hardware and good software are required in effective robot controllers.

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**Actuators and drives**

Actuators receive the command signals from the controller as their input. As their output they give physical movement. The drive mechanically modifies the motion into a convenient form such as slower speed. There are three basic types of actuators – hydraulic, pneumatic and electric.

**Hydraulic actuators**

Hydraulic actuators provide movement by pumping fluid (usually oil) through pipes and hoses to hydraulic cylinders or motors. The flow of the fluid is controlled by electric valves. As fluid is pumped into the cylinder the rod of the cylinder extends. Similarly, as fluid is pumped into a hydraulic motor the output shaft rotates.
The major advantage of hydraulic actuators is their ability to lift loads of up to approximately 14,000 kilograms. Another advantage is that they do not generate sparks like electric motors and can therefore be used in explosive environments, such as industrial spray painting.

**Pneumatic actuators**

Pneumatic actuators work in the same principle as hydraulic actuators but use compressed air instead of fluid. Pneumatic actuators are especially useful when quick movements are required. Pneumatic grippers are good at holding objects because of the ‘springiness’ caused by the gas under pressure. However, pneumatic manipulator arms are inaccurate because the springiness causes the arm to drop under load.

**Electric actuators**

Electric actuators cause motion when electrical current flows through them. They are electric motors that fall into two basic categories: continuous rotation motors and stepper motors. Continuous rotation motors keep turning until the power is turned off and can be only crudely controlled. Stepper motors will give highly accurate movements because they move in precise steps of a few degrees rotation at a time. They are commonly used in smaller and in medium-sized robots.

**Drives**

Drives are usually used to slow down the high-speed rotation of actuators. Drives include such speed-reducing mechanisms as screw drives and gears. The gear is a basic mechanism that is connected by the centre hole to the rotary shaft of the actuator. Each gear is a wheel having precise teeth that fit into a similar wheel of the same type. Used in pairs, gears can reduce actuator speed.

**Power supply**

Power supplies provide the energy for the entire robots system to work. They receive as their input some form of energy which is usually electrical power. Their output is a usable power in the form of electricity (fixed power supplies or mobile batteries), pressurised hydraulic fluid or compressed air.

**Sensors**

Sensors are critical components of all modern robots and provide the output and environmental feedback needed for the robot to correct itself. Sensors fall into two general categories, direct-contact and non-contact. Direct-contact sensors include all types of touch sensors that use mechanical switches, strain gauges or pressure sensors. Non-contact sensors detect at a distance, and include infrared beam, sound, light, ultrasonic, radar, sonar, laser beam and visual sensors.

The development of improved sensors is needed for the advancement of robotics. Without sophisticated sensors, third-generation robots will not be able to obtain the information that is required to make good decisions. Visual sensors are being developed that can recognise object shapes, and this will enable the robot controller to make a ‘model’ of the environment. For this reason, vision is perhaps the most important of all sensory capabilities that must be perfected.
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A summary of what the technology offers

Robots perform an increasing number of functions and tasks in society and particularly in the modern workplace. They offer advantages and no doubt some disadvantages. Robots and other control technologies (such as automated production lines, motor vehicle control systems and programmable domestic-use machines) can do so much for us.

Some examples of integrated and control technology use include:
1. product assembly lines, where products are moved along and assembled automatically
2. computerised machining and assembly of product parts
3. robot arms for spraying and welding motor vehicle bodies
4. assembly of car parts, machines and circuit boards
5. remote-controlled vehicles and water craft, mining, marine use, mowing lawns and vacuum cleaning floors
6. building space stations
7. entertainment such as toys, games, cars, boats and planes
8. motor vehicle computer systems, GPS, etc.

Robots can:
1. work non-stop
2. produce multiple products faster
3. work to fine tolerances
4. operate in dangerous environments, for example, underwater, in hot and cold conditions, and with chemical use and handling
5. perform different roles when reprogrammed
6. do the dangerous jobs, for example, in nuclear plants, deep sea operations, bomb disposal
7. do many of the jobs that humans once did
8. create new jobs
9. transform working environments from human labour to hi-tech dominated areas.