UNIT 21
DATA LOGGING, COMPUTER CONTROL AND ROBOTICS (ADVANCED)

AVCE Information and Communication Technology

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Contents

SECTION 1 INTRODUCTION

When faced with the word ‘computer’ most people think of a desktop PC running programs under the complete control of the user sat in front of it. As far as the user is concerned, the computer does not take action on its own – it does what we tell it to do from the keyboard (usually). In fact the microprocessor at the heart of the PC is making many thousands of simple decisions per second as it runs its machine code program. Most of these decisions are based on what action you take as the operator – clicking the mouse and typing in text at the keyboard. However a microprocessor can control hardware other than a monitor screen and can respond to inputs from other types of devices. For example it can input temperature data, compare it with a set value, and switch on a room heater if necessary. This is Computer Control.

A computer can also take a reading of say, temperature at regular intervals and save these readings in memory for analysis later. This is Data Logging.

Finally, if a computer can make itself mobile by driving electric motors, sense its environment with for example, touch sensors, then we have a Robot. We are assuming of course that the computer program can interpret the sensor input correctly so that it moves with some degree of recognisable ‘intelligence’.

SUMMARY OF LEARNING OUTCOMES

The student will:

- Understand the concepts of logging data using a dedicated microprocessor system, be able to construct such a system and demonstrate its use.
- Understand the concepts of computer control and demonstrate this understanding with practical project work.
- Be able to develop a simple robotic system and program it to perform a task using sensory feedback.

LINKS WITH OTHER UNITS

Unit 1: Presenting Information (Advanced) provides foundation skills necessary for presenting a review.

Unit 11:Computer-Aided Design & Manufacture (Advanced) links well with the detailed practical aspects covered in this unit.

Unit 23: Operating Systems & Systems Architecture (Advanced) provides a more in-depth treatment of the internal working of a microprocessor system.

SECTION 2 OVERVIEW OF LEARNING AND ASSESSMENT STRATEGIES

TEACHING AND LEARNING STRATEGIES

The Internet has a great deal of information on data logging, control and robotics. Students can research suppliers and items for sale, and they can also look at accounts of research and student projects in this subject from around the world. Such information supplements that available from books and journals.

Compared to many other units, this unit is very hardware oriented and could present special difficulties with the supply of suitable materials and equipment. There is also the problem of variability in practical skills within the class. To cater for this, we have supplied suggestions for activities that can be tackled using two very different types of hardware resource:

- using the LEGO® Mindstorms™ Robotic Invention System as a basis for all data logging, control and robotics activities. Your school may already have most of the necessary components as part of the Dacta™ system used for teaching basic mechanics to an earlier age group. The activities presented here will make more advanced use of the facilities provided by the Programmable Brick.

- using commercial microcontroller boards based on the 8051, PIC or Basic Stamp devices. Robot mechanics can be constructed by a technician or by the students themselves from kits of parts (see **Additional Resources**).

Projects can be carried out using one of two possible approaches:

- students research the available equipment and potential applications, produce a design specification, then work to meet this design or:

- students work by trial and error (‘research and experimentation’) to develop a system.

Either is acceptable if it is properly documented. In some cases the project may involve a combination of both of these techniques.

There is no objection to the use of ready-made commercial products, but clearly any project must have sufficient complexity and level of difficulty to justify the title ‘advanced’.

ASSESSMENT STRATEGIES

Learning should be supported by the assessment programme. Opportunities should be available for peer and self-assessment in order to develop students' skills in being responsible for their own learning and development.

As this unit is assessed by portfolio, students must be encouraged to document all their work in a clear and concise manner. Each student should maintain a log book of all their practical work. It should be emphasised to the student that such log books are kept by the professionals and are a valuable resource when a particular sequence of steps needs to be repeated, sometimes months later.

Students should receive clear briefings on the methods of assessment and clear feedback concerning the outcomes of all assessed work. Guidance on the requirements for the higher grades should also be provided.

KEY SKILLS DEVELOPMENT

There may be opportunities to create evidence for their **Communications** portfolio: when they are working as part of a team producing the presentations, discussing ideas and producing design notes.

There may be opportunities to create evidence for their **Information Technology** portfolio:
when they are accessing information via the internet or from CD based information systems. They will be writing reports which will involve the use a word-processor, and perhaps using a drawing package to produce technical drawings and schematics.

There may be opportunities to create evidence for their **Working with Others** portfolio:
when they are planning, designing and reviewing their work as part of a design team.

SECTION 3 SUGGESTED DELIVERY & ACTIVITY SCHEDULE

TOPIC	TEACHING SCHEDULE	ACTIVITIES	RESOURCES
1	Sensors Determine what a sensor is and what it does. Identify sensors in everyday life.	Activity 1 Class discussion Individual research	Web sites Students own experience Examples for study
2	Sensor working Active & Passive sensors How sensors work Analogue & Digital outputs	Activity 2 Class discussion Individual research	Tutor input Bolton, *Mech*, Chap 2 Elgar, *Sen*, Chaps 2–7
3	Sensor interfacing Analogue to Digital conversion The microcontroller chip	Activity 3 Individual research & design Construct simple system from parts	Manufacturers' data sheets. Web sites LEGO and/or other microcontroller kits
4	Microcontroller programming When to use Assembler When to use a High-Level language	Activity 4 Assess different programming languages	LEGO and/or other microcontroller kits Programming software. Web sites
5	Reading sensor data Programming in Assembler Programming in a High-Level language, e.g. Visual Basic	Activity 5 Program the microcontroller to read a sensor input	Penfold, *Adv*, Chaps 1 & 2. LEGO and/or other microcontroller kits Programming software
6	Data logging Automatic data gathering Identify data logging applications	Activity 6 Individual research Produce report	Web sites
7	Programming a data logger Sample rate considerations Accuracy of measurements Size of log Data transfer to a PC	Activity 7 Program the microcontroller to log sensor readings	Penfold, *Adv*, pp235-8 LEGO and/or other microcontroller kits Programming software
8	Interpretation of logged data Data processing Data display	Activity 8 Process and display data	Spreadsheet software, e.g. Microsoft *Excel* Programming language software

9	Control systems The concept of Feedback Open and Closed Loop control Human processing intelligence Machine 'intelligence'	Activity 9 Identify and categorize control situations in everyday life. Class discussion	Elgar, *Sen*, Chap 12 Tutor input
10	Feedback using sensors Simple limit (on/off) sensing Feedback of variable values Responding to feedback	Activity 10 Design a simple system to demonstrate feedback in action.	Tutor input
11	Closed loop control Actuators Computer control of actuators Control stability	Activity 11 Add actuator(s) to activity 10, controlled by sensor input	Bolton, *Mech*, Chap 7 LEGO and/or other microcontroller kits Programming software
12	Robots What makes a machine a robot? Why replace humans with robots? Why *not* replace humans with robots? Drive technologies Safety issues	Activity 12 Individual research Class discussion	Tutor input Web sites Guest speakers
13	Mechanical design of robots Robot arms & mobile robots Actuator selection Transmission design Chassis design	Activity 13 Individual research, Class discussion. Design & build robot mechanism	Tutor input Web sites LEGO and/or other microcontroller kits. Workshop tools.
14	Design of robot electronics Sensor interfaces Motor drive circuits Microcontroller selection Programming	Activity 14 Individual research, Class discussion. Put together robot electronic control system.	Tutor input Web sites LEGO and/or other microcontroller kits. Programming software Workshop tools.
15	Standard Ways of Working Maintaining files on computer Logging ICT problems Backing-up data Mechanical construction Electronic construction	Activity 15 This activity will be spread over the entire time needed to complete the unit.	Access to a computer network with personal directory space. Workshop tools.

SECTION 4 SUGGESTED LEARNING ACTIVITIES

ACTIVITY 1: Sensors

Key Skills: C3.1a, C3.1b, C3.2, C3.3, IT3.1

A human being cannot function without sensory input, and makes full use of the five (known) senses: sight, sound, touch, taste and smell. The brain takes in information from the body's 'sensors', processes it and then drives the actuators (muscles) in response. This is a bit simplistic, but it is in essence what we are trying to replicate when designing an 'intelligent' machine. The first activity then is to identify machine sensors, and locate examples in everyday use

Tasks

1. Identify the natural 'sensors' available to the human brain. Study each in turn and perform experiments to understand the extent and limitations of your own senses. For example, what are the minimum and maximum focussing distances for your eyes? How much of what you see is actually in focus, and how much are you just 'aware' of: in other words, how large is your peripheral vision?

2. Conduct some research and find out about artificial (man-made) equivalents to your own body's sensors that might be used to allow a computer to 'sense' things. Look for the latest ideas and products on the Internet and if they are available to buy, find out roughly how much they cost. Note that the human sense of touch is normally considered to include temperature sensing.

3. Study the man-made sensors you have found and compare their abilities with the results of your investigation of your own senses. How well do the latest developments compare with their human equivalents?

4. Investigate sensors in ordinary appliances and machines around you, <u>without</u> dismantling anything without permission! How sophisticated are these sensors? For example, how sophisticated is the temperature sensor in an automatic kettle? Would it be useful as a temperature measuring device? If not, why not?

5. Investigate sensors for which there is no direct human equivalent. For example, magnetic field detectors.

6. Assemble the results of your investigations into a brief report or presentation for your portfolio.

ACTIVITY 2: Sensor Working
Key Skills: C3.1a, C3.1b, C3.2, IT3.1

Having assembled a mass of information on the different types of artificial sensors available, the students need to categorize these in the way they connect or interface with the artificial ‘brain’ or computer. They also need to have some idea of how they work in order to understand their limitations. How deep this understanding goes will depend on the level of experience/interest in electronics of individual students. At this point it might be a good idea to form the groups which will be needed later, splitting the class into those taking the ‘**LEGO**’ route and those going for more challenging design and construction methods (the ‘**MICRO**’ groups).

Tasks

1. Create a list of electronic sensors and investigate how each performs its task. Remember that in all cases these artificial sensors convert whatever they are measuring, temperature, sound level, etc, into an electrical signal suitable for processing by an electronic circuit.

2. Construct a table of sensors that might be useful for measurement of everyday parameters such as temperature and light level. We don’t need to include things like nuclear radiation in this list: just stick to the basics. Classify them in four categories: passive or active, analogue or digital. Passive sensors require no separate power supply from the interface, active ones do. For example, a simple light sensor is passive, an active one will need a powered light source so that it can measure the light reflected from an object. Most sensors are analogue, in that they continuously vary some electrical signal in response to a varying input. A simple switch is a digital sensor: it only has two output states, on or off, logic one or logic zero.

LEGO groups can find out about their particular sensors from the recommended books or web sites (see **Additional Resources**).

ACTIVITY 3: Sensor Interfacing
Key Skills: C3.1a, C3.2, WO3.1, WO3.2

Now that the students have categorized sensors, they need to know how to connect them to the computer so that measurements can be taken. They will need to understand the process of Analogue to Digital conversion, because many of their sensors will have *analogue* outputs, but the computer requires a *digital* input. There is no need for a lot of detail about the workings of the converters here, just a general understanding of their purpose.

Tasks

1. Investigate the electronic process required to translate the varying output from your analogue sensors to the language of ones and zeros, bits and bytes that the computer understands. For example, you may need a device which converts a voltage *level* to an 8-bit binary *number*.

2. You will be constructing a simple robot later that will require a brain and sensory input. How complex this task is depends on whether you have chosen to use LEGO or other more basic electronic hardware. Either way, investigate how sensors are interfaced to the 'brain' that you will be using.

LEGO groups have no design decisions to make: the sensors simply plug into the Programmable Brick. Students should however, endeavour to understand how the microcontroller chip inside is interfaced to the sensor, using books and Internet resources (see **Additional Resources**).

MICRO groups will need to investigate the capabilities of commercially available microcontroller systems. Some microcontroller devices have analogue inputs built in; for example the big PIC chips. Others will require separate conversion devices.

ACTIVITY 4: Microcontroller Programming

Key Skills: C3.1a, C3.1b, C3.2, IT3.1, IT3.2, WO3.1, WO3.2

Whatever microcontroller system is chosen, it will need programming to perform its task. Students should investigate the programming systems available with a view to selecting the best for their practical work.

Tasks

1. Use the Internet and other resources available to find out about different computer programming languages suitable for microcomputer-based systems. Create a table and sort them into different categories (high and low level, structured and object oriented).

2. Come to some conclusions about the merits and disadvantages of using each of the languages you have discussed and add these to your table. Include factors such a purchase cost as well as suitability and ease of use.

LEGO groups have a large range to choose from, including Visual BASIC, C, FORTH and even Java, as well as the simple graphical RCX language supplied with the Mindstorms kits. Many of these languages are available as freeware downloadable from the Internet.

MICRO groups will probably be looking at assembler level programming, using tools supplied with a development board. Some chip manufacturers supply complete toolsets including assembler and simulator. For example, the makers of the PIC microcontroller have made all their development software available for free download on their web site. Other options should be considered, such as FORTH, used extensively for robot work, with versions also available as freeware for many types of microcontroller device.

ACTIVITY 5: Reading Sensor Data

Key Skills: C3.1a, C3.2, IT3.1, IT3.2, WO3.1, WO3.2

The students should now gain some experience in programming using their chosen software and hardware. They should become familiar with the processes of program compilation/assembly/debugging on the PC, followed by downloading, usually via a serial port, to the microcomputer system. Their initial work with simple programs will also allow them to understand how to transfer sensor information into the computer and make use of it.

Tasks

1. Investigate how your microcomputer 'brain' will communicate with any sensors you might connect to it. You will need to look at your list of useful sensor hardware and work out how your controlling computer program will take readings from each device. Do you need to know precise port or memory addresses? Does analogue to digital conversion require the computer to wait for data? If so, how long and how does the computer know when the data is ready?

2. Connect up a simple 'touch' sensor (a switch) to your microcomputer and write a program to 'read' it and indicate its status.

3. Connect up a more complex sensor providing 'level' information (e.g. a light sensor) and write a program to display the values read in.

LEGO groups will have little difficulty here as all the interfacing is taken care of, and the firmware within the Programmable Brick handles all the low-level communication with the supplied sensors.

MICRO groups will need a detailed understanding of the sensors and their interfacing requirements as they will have to create their own low-level device handlers. This is not as horrific a task as it sounds and those students who succeed will have gained a very valuable insight into computer working.

ACTIVITY 6: Data Logging
Key Skills: C3.1a, C3.1b, C3.2, IT3.1, IT3.2, WO3.1, WO3.2

As a break from purely practical work, students should investigate what is meant by the term: data logging.

Tasks

1. Identify situations where you might want to take many measurements over a period of time and store them for processing later.

2. Using your list of situations, identify those where some sort of automated system would be preferable to 'eyes, notebook and pen'. Say why the automation would be useful in each case.

3. Think of situations where the 'human' gathering of data is not possible. For example in hostile environments, or where things are happening too fast for human observation.

4. Using some of the applications you have found, try and work out the likely requirements for an automated system in each case. For example, type and number of sensors, data storage capacity, etc.

ACTIVITY 7: Programming a Data Logger
Key Skills: C3.1a, C3.2, IT3.1, IT3.2, WO3.1, WO3.2

The students should now look at some of the practical aspects of setting up a data logging system using their computer systems and sensors. Assuming they have successfully interfaced some sensors and have programmed the system to read them, then this activity becomes largely software only.

Tasks

1. Decide on a parameter you would like to measure and of which you would like to obtain a set of readings. Your choice will be limited by the sensors you have available.

2. Identify the requirements of the logging application: How often is a measurement to be made? How accurate does the measurement need to be? The latter refers to the resolution of the analogue to digital conversion. Find out what that means. How much storage space is needed for the log? In other words, the number of readings to be accumulated before they are read out and processed. Will the data need to be transferred to the PC for processing and display? If so, how?

3. Having identified all the requirements, set about creating and testing a data-logging program to perform the task.

LEGO groups will find that the Programmable Brick has some limited data-logging functions built-in. They should investigate its capabilities and limitations in this area. They should attempt to program the device to get around these limitations.

MICRO groups will have far fewer limitations than the LEGO groups, and they have the option to program in assembler language for reading and logging data at a fast rate (high sampling speed) and keeping as much as possible of the microcontroller's memory free for data storage. It all depends on what they are attempting to do. Working at this 'low-level' means that a lot more can be achieved because the restrictions imposed by the user-friendly nature of the LEGO brick software and firmware do not apply.

ACTIVITY 8: Interpretation of Logged Data

Key Skills: C3.1a, C3.2, IT3.1, WO3.1, WO3.2

Generally, the information gathered by a data logging system requires some further processing before being presented in some graphical format. A table of results is usually difficult to interpret so conversion to a line or block graph is usually required.

Tasks

1. When the data logger has done its work, you will have a set of data values stored (usually) in consecutive locations within its memory. Work out how you are going to transfer them to the PC for further processing and display. Ideally the data should be transferred to a disk file: whatever software you are using to communicate with your logger may have the facility to do this.

2. How is data presented to the user in a manner that allows for a quick understanding of its significance? You should already be familiar with graph plotting principles: investigate the facilities offered by a spreadsheet package such as Microsoft *Excel* or similar.

3. Create a spreadsheet to convert a table of 'raw' sensor values to more recognisable units, For example, the 'raw' data might consist of 8-bit numbers from a temperature sensor that need to be converted to degrees centigrade. The conversion factor will depend entirely on the hardware you are using.

4. Use the spreadsheet graphing feature to plot the results in a manner that makes them easy to understand. The graph will have the measured parameter on the Y-axis, with time on the X-axis.

LEGO groups will find that all the data transfer, processing and graph plotting programs can be written in a high-level language such as Visual BASIC. LEGO ROBOLAB, part of the Dacta education range, has special data-logging software.

MICRO groups will have to work with whatever communication system is provided by the microcontroller board they are using, and some ingenuity may be required to get the data onto the PC hard disk for processing by spreadsheet software.

ACTIVITY 9: Control Systems

Key Skills: C3.1a, C3.2, IT3.1, WO3.1, WO3.2

So far we have only considered automating the process of taking measurements. This is only half the story. The computer system used for reading the sensors can also drive actuators such as motors and solenoids. These are *output* devices, where the sensors are *input* devices. We have 'Open-Loop' control if these actuators are commanded to operate with no 'Feedback' to check what actually happened. An example is a simple sequence controller which switches things on and off at set times. If there is feedback from sensors to indicate the actual effect of actuator operation, then we have the potential for 'Closed-Loop' control. For example, an electronic thermostat that sensors the temperature, checks the value against a reference value, and then activates heating or cooling systems as necessary. This activity should be used to ensure student understanding of these concepts.

Tasks

1. Investigate as many examples of control systems as you can find. Don't confine your search to electronic control: consider other types such as hydraulic and mechanical.

2. Find out what the terms: Open-Loop and Closed-Loop control mean. Categorize the examples of control systems you have found using these terms.

3. What is 'Feedback'? Find out what it means in the context of control.

4. Look again at your list of control systems. Most will use simple or complex 'machine' intelligence to make decisions based on the feedback. Now think of situations where there is a human 'in the loop'.

ACTIVITY 10: Feedback using Sensors

Key Skills: C3.1a, C3.2, IT3.1, IT3.2, WO3.1, WO3.2

Students should now design a simple feedback control system. A starting point could be one of the assessment activities described in Section 5. They will need to consider what parameter(s) they are trying to control, what sort of sensors will be needed to produce the required feedback signal(s) and finally the nature of the computer control program.

Tasks

1. Decide upon the subject for a project to design and build a closed-loop control system. Your tutor will have some suggestions. The results of this project will form a major part of your assessment. As this will be a group activity, start planning how you will carry it out and allocate tasks to each member of the team.

2. Having decided upon your project subject, draw up a specification for the performance of the final design.

3. Establish what kind of sensors will be needed to provide the control feedback. Do you need simple on/off indications or does a level measurement need to be made? What performance characteristics will the sensors need?

4. Think about the processing requirements. The processor will have two sorts of inputs: the feedback from the output, and a ‘command’ input. An example of the latter is the temperature set by the dial on an electronic thermostat. How will the processor respond to the feedback signal?

LEGO groups will be limited in their choice of sensors, unless they feel confident enough to build their own: the LEGO books referenced in the Additional Resources section provide details of ‘home-made’ sensors.

MICRO groups will only be limited by resources, their own abilities and imagination. As a result they will have a difficult decision-making process.

ACTIVITY 11: Closed Loop Control

Key Skills: C3.1a, C3.3, IT3.3, WO3.1, WO3.2

Students should now study the various ‘actuators’ or output devices, likely to be used in any control system and those to be used in their project work specifically. They will need to understand performance data in order to make the right choice and have some understanding of the necessary drive electronics.

Tasks

1. Once your control system has sensed a condition, and the processor decided what action (if any) needs to be taken to correct for a difference between it and the Command input, a signal will need to be sent to actuators to correct the ‘error’. Investigate possible actuators that could be used in control systems. Match each actuator you have discovered with a suitable sensor to provide feedback on what the device actually did.

2. Look at the human body: does it have any actuators? If so, what are they and what provides feedback on their actions?

3. You will have already decided which parameters you wish to control; you must now work out what actuators will be needed. Remember that an actuator in this case does not necessarily imply mechanical movement: a heating element is an actuator for control purposes.

4. Investigate what interface electronics will be required to link the outputs of the microcontroller device to the electrical inputs of the actuator. For example, an electric motor, even a small one, will require much more current than the microcontroller outputs can supply.

5. Although the theory is beyond the scope of this unit, use the Internet and other resources to discover some of the problems facing the control system designer: particularly that of Control Loop Stability.

LEGO groups have a limited choice of actuators and all electronic interfacing is taken care of, but they should still do some research into the subject.

MICRO groups once again are only limited by resources and imagination and will need to consider carefully the electronic interfacing issue.

ACTIVITY 12: Robots

Key Skills: C3.1a, C3.2, WO3.1, WO3.2

Time should be taken to stand back from the nuts and bolts of automatic control and consider the impact on society of automation and intelligent robots. Students should study social, ethical and safety issues.

Tasks

1. Investigate what the word ‘robot’ actually means. Discuss with your colleagues what turns a mere machine into robot.
2. Investigate the use of robots in industry. In many cases they have replaced human workers. Using a specific case study, for example robots on the assembly line of a car plant, identify the reasons for their use. Why are they better than humans in these jobs?

3. Identify environments where robots can operate, but which are too hazardous for humans.

4. Identify the consequences of automation on society. Should social and moral issues be taken into account when proposals for automation are made?

5. Investigate the safety issues of robot automation – especially mobile robots!

6. Investigate the different drive technologies used in industrial robots: they don’t all use electric motors. Do these technologies create special safety problems?

ACTIVITY 13: Mechanical Design of Robots
Key Skills: C3.1a, C3.2, IT3.1, WO3.1, WO3.2

Most robots are made up using two broad areas of technology: mechanical and electrical (electronics). The combined discipline is now given the name 'Mechatronics'. Although this is an ICT study unit, there is an overlap with engineering, and any student developing an interest in robotics will need to understand some aspects of these other areas.

Tasks

1. Investigate the mechanisms used in robot designs to perform physical tasks. For example how do robots grip objects securely without breaking them? Start by finding as much material as you can on commercial/industrial robots and then move on to the mechanics necessary for a 'home-made' arm or mobile machine.

2. Assume you have been given the task of designing a small robotic arm or a mobile robot. Carry out research into the types of actuator you might use. You may be doing this as part of an assessment exercise anyway, and in that case careful and well-documented research is needed because you will be building your design!

3. Actuators often needed some form of 'transmission' system to link them to 'tools' such as grippers or road wheels. It might take the form of a gearbox the usual purpose of which is to reduce the high rotation speed of a motor to a much lower level, and at the same time increase the turning force or 'torque' that can be exerted. The theoretical relationships linking speed and torque in gearbox design are quite easy to understand. Investigate them and see their relevance in robot design.

4. The moving and electronic parts of a robot must be assembled together to produce a product 'fit for purpose'. Crudely, this means designing a chassis that will allow the tasks to be carried out <u>and</u> not fall to pieces after five minutes! Investigate materials and construction techniques for your home-made robot design.

LEGO groups are once again limited in the components available to them. However, the LEGO component inventory is very large so the restrictions are not that great. They will still need to research into transmission design and understand the capabilities of the LEGO motors. Chassis design is not easy if a reasonably robust product is required.

MICRO groups are still only limited by their imagination and available resources.

ACTIVITY 14: Design of Robot Electronics

Key Skills: C3.1a, C3.2, IT3.1, WO3.1, WO3.2

The detail design of the robot control electronics should now be given consideration. This includes the sensor and drive interfaces, the precise choice of microcontroller chip and the control program that makes it all happen.

Tasks

1. Examine the wide choice of microcontroller devices available to the robot designer. Get data sheets and specifications from manufacturers' and suppliers' web sites. Give careful thought to the factors influencing your choice: going for the fastest and most powerful is not always best. Other factors to consider are cost, and availability of programming tools such as simulators and program debuggers.

2. Investigate and design interfaces that fit between the sensors and output devices, and the microcontroller chip.

3. Finally, consider the control program itself. Decide upon the tasks you want your robot to perform and create a 'flowchart' to indicate how the processor program will work. Translate this flowchart into an actual program using the computer language of your choice: assembler language for fast, compact code or a high-level language such as Visual BASIC for ease of writing and debugging.

LEGO groups have little design work, concentrating instead on programming.

ACTIVITY 15: Standard Ways Of Working

Key Skills: C3.1a, C3.2, C3.3, IT3.1, IT3.2

This is a kind of distributed activity, performed by each individual student alongside and part of other work. Without these basics, the student will probably end up losing their precious work at some stage. There are also issues relating to this type of creative work in particular.

Tasks

1. Learn how to save and maintain computer files in appropriate directories. Make sure that data filenames reflect the contents clearly, ideally containing version numbers. With software such as Microsoft *Word* and *PowerPoint*, fill in the Properties box for each data file you create. If Tool Tips are enabled (Windows option) then all a file's properties will be displayed when the cursor rests on the filename entry in Windows Explorer. This is a small detail, but can save a lot of time when hunting for a particular file.

2. Maintain back-up copies of data files on floppy disks (or ZIP disks if available).

3. Remember to keep a log of all apparent ICT faults, software glitches or system crashes. A network manager can use this information to establish fault patterns and stop further problems.

4. You should develop some skills in mechanical construction. This does not have to be ‘heavy’ engineering, but an ability to bend thin aluminium and steel to make chassises would be useful as would cutting and drilling using basic tools.

5. Basic electronic construction skills should be developed; the main one being reliable soldering of electronic components into circuit boards without damage to them or yourself!

SECTION 5 SUGGESTED ASSESSMENT ACTIVITIES

NOTES FOR TEACHERS

Assessment Activity 1: Schools MicroMouse Competition

The National Schools' MicroMouse competition has been running for a number of years now and provides an excellent incentive for students to get to grips with the practical aspects of technical subjects. MicroMouse is divided into two main classes: white-line followers and maze solvers. Normally schools race white-line followers. Students then 'graduate' to full maze-solving mobile robots and can take part in international competitions. The hardware involved in a white-line follower can be very simple: a couple of opto-sensors, one or two small chips, two motors and some bits and pieces, or you can go for a full microprocessor-controlled monster. The LEGO Mindstorms kit also has all the parts necessary to make a very competitive mouse. See the web site at: **http://micromouse.cs.rhul.ac.uk** for more details.

Assessment Activity 2: Designing a Mars Explorer

There has been a surge of interest in the planet Mars recently, and the success of the *Sojourner* mobile explorer robot has shown what can be done at (relatively) low cost. Students could attempt to design and possibly build their own explorer robot. A large proportion of the work would be research into the problems of a hostile environment, and in the case of Mars, controlling a robot when all forms of communication are subject to a time delay of at least 20 minutes! Obviously a 'real' vehicle is beyond the scope of this unit, but design problems can be considered and some solutions demonstrated by a working prototype. Once again, LEGO has sufficient versatility to work here. See the NASA site: **http://mars.jpl.nasa.gov/**. It has masses of material aimed at children in schools.

Assessment Activity 3: A Controlled Environment

This project does not involve many (if any) moving parts. The 'environment' in question could be an aquarium, a house, a greenhouse or even a museum display case for a priceless but delicate object. The students have a range of parameters that could be controlled: heat, light, humidity, ventilation. These climatic factors tend to vary slowly, so any computing element will not need to be particularly fast in operation, and control problems such as instability are unlikely to arise. There is plenty of scope for students to develop data-logging and trend-display programs.

ASSESSMENT ACTIVITY 1: Schools MicroMouse Competition
Key Skills: C3.1a, C3.1b, C3.2, C3.3, IT3.1, IT3.2, IT3.3, WO3.1, WO3.2

Situation

Your aim is to design, construct and program a small mobile robot called a MicroMouse to compete in a national competition. The robot will race around a fixed course, following a white line, as fast as possible and under control. It will be self-contained, carrying its own power supply (batteries) and all 'intelligence' will be on-board (no umbilical cables). For more details of the rules see the web site: **http://micromouse.cs.rhul.ac.uk.**

Tasks

1. Thoroughly research the rules for the MicroMouse competition (available from the above web site). These rules are very detailed and cover the racecourse design itself, and all the things you can (and can't) use in your mouse design.

2. Decide on a 'technology' for your mouse: LEGO or 'home-made'. If the latter, you will need to decide upon a suitable microcontroller. It is possible to make a white-line follower without any computing elements, but that would not be appropriate for this ICT unit.

3. Design, construct, program and test your mouse. Try and optimize your design to get around corners as fast as possible without spinning-off. The problems of cornering are exactly the same as those affecting a car.

4. If you feel you have a competitive mouse, enter it in the national competition.

Assessment

All aspects of design and construction will form part of the assessment. Your project log-book will be critically examined to make sure you have carried out the project in a planned, methodical manner. You can still get an excellent grade even if the mouse isn't exactly a world beater!

ASSESSMENT ACTIVITY 2: Designing a Mars Explorer
Key Skills: C3.1a, C3.1b, C3.2, C3.3, IT3.1, IT3.2, IT3.3, WO3.1, WO3.2

Situation

A compact and rugged autonomous vehicle needs to be designed for a mission to the planet Mars. It will be a platform for various experiments, but your job is to develop a mobile robot that will have to think for itself: commands sent from Earth will take 20 minutes to reach it.

Tasks

1. Study the environment in which the robot will have to work on Mars. A good starting point for research is the NASA site at: **http://mars.jpl.nasa.gov/.**

2. Start considering the implications of the terrain on your mechanical design. Don't worry about the ruggedness of the prototype. Instead, concentrate on specific design features like suspension and steering.

3. Construct a prototype vehicle to demonstrate your ideas. LEGO Mindstorms components would be perfectly satisfactory for this purpose.

4. Think about the implications of a 20 minute communications lag. The robot will be sent short commands like: 'turn 45 degrees left and move forward 2 metres at 0.1 metres/second'. The software program will have to translate these into low-level instructions driving motors, while monitoring sensors to confirm that the movement is being carried out correctly.

5. Develop and test the control program.

Assessment

All aspects of design and construction will form part of the assessment. Your project log-book will be critically examined to make sure you have carried out the project in a planned, methodical manner. You will only get the higher grades if you provide adequate justification for your design steps. You will not be penalised just because your robot fails to function in some way; the important thing is to be able to explain *why*.

ASSESSMENT ACTIVITY 3: A Controlled Environment

Key Skills: C3.1a, C3.2, C3.3, IT3.1, IT3.2, IT3.3, WO3.1, WO3.2

Situation

While it is impossible (at the moment) to control the world climate, it is perfectly possible to create and control a small environment for a specific purpose. You have a number of alternatives to choose from, including an aquarium, a dwelling house, a greenhouse or museum display case. You may be able to think of other examples. Select one, and design the electronic control system necessary to maintain the selected conditions.

Tasks

1. Establish all the parameters that need to be controlled in your selected environment. Determine the values of these parameters (the 'set points') and how far they may vary from the set points (tolerances).

2. Decide how big the controlled environment will be, and what the 'actual' environment outside is (room temperature will not vary too much, but the weather outside a greenhouse may involve large temperature fluctuations).

3. Investigate the sensors and actuators you will need to use. The most obvious actuator will be a heating element, but ventilator opening motors and fans may be used too.

4. Using all the data you have gathered so far, assess the performance requirements for the actuators.

5. Select a suitable microcontroller system to provide the necessary ‘intelligence’ and put together a design.

6. Construct, program and test your design to make sure that it performs to specification.

Assessment

All aspects of design and construction will form part of the assessment. Your project log-book will be critically examined to make sure you have carried out the project in a planned, methodical manner. You will only get the higher grades if you provide adequate justification for your design steps. You will not be penalised just because your design fails to perform to specification in some areas; the important thing is to be able to explain *why*.

SECTION 6 ADDITIONAL RESOURCES

Textbooks

Mechatronics
W.Bolton
Longman
ISBN 0582357055

Introducing Robotics with LEGO® Mindstorms™
Robert Penfold
Babani publishing
ISBN 0859349012

More Advanced Robotics with LEGO® Mindstorms™
Robert Penfold
Babani publishing
ISBN 0859349020

Extreme Mindstorms™
D.Baum, M.Gasperi, R.Hempel & L.Villa
Apress
ISBN 1893115844

Sensors for Measurement & Control
P.Elgar
Longman
ISBN 0582357004

Microprocessor Systems
W.Bolton
Longman
ISBN 058241881X

Internet Web Sites

The Swallow Systems site at **http://swallow.co.uk** contains a lot of useful reference material for builders of small mobile robots. They also supply robot kits and parts.

A lot of reference material for various microcontroller devices can be found at **http://www.rentron.com** who also supply kits and parts.

The site **http://www.stampsinclass.com** is provided by a supplier of Basic Stamp kits and projects. Much educational material is available for free download.

The site **http://www.plazaearth.com/usr/gasperi/lego.htm** provides a lot of detail about the inner workings of the LEGO sensors together with details of how to make your own.

The main MicroMouse UK site is **http://micromouse.cs.rhul.ac.uk** with the Schools' competition at **http://micromouse.cs.rhul.ac.uk/schools.** More information at: **http://www.uel.ac.uk/mrru.**

The author's web site at: **http://www.wgmarshall.freeserve.co.uk** contains mobile robot resources and links.

Index sites for robotics resources: **http://www.robotics.com/robots.html**, **http://www.eg3.com/ee/robotics.htm** and **http://www.robohoo.com**.