Heriot-Watt University Study Guide

BSc Information Technology
Praxis

Interactive University

Edinburgh EH12 9QQ, United Kingdom.

First published 2003 by Heriot-Watt University

British Library Cataloguing in Publication Data

Interactive University

Heriot-Watt University Study Guide: Praxis

1. BScIT I. Praxis

Typeset by: Interactive University, Wallace House, 1 Lochside Avenue, Edinburgh, EH12 9QQ.

Printed and bound in Great Britain by Graphic and Printing Services, Heriot-Watt University, Edinburgh.

Part Number 2006-1448

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Topic 1

Introduction

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Learning Objectives

- *Appreciation of the difference between School and Higher Education*
- *Understanding of what is expected of a student undertaking Higher Education*
- *Awareness of the wealth of information available to today's scholars*
- *Familiarity with the background to the "Case of the Killer Robot" case study*

Only you yourself can be your liberator! (Reich 1945)

1.1 The meaning of *praxis*

You are probably wondering what this thing called *praxis* is all about and why it is regarded as an important part of a degree course in Information Technology of all things. This topic will attempt to sate your curiosity and provide you with satisfactory answers to these very reasonable questions.

One thing you will not be told in these pages is what *praxis* means. You will be asked to answer that question for yourself as your first coursework submission in this topic. The remainder of this topic is concerned with matters which are part of the praxis of Higher Education and being a student. Hopefully you will recognise this once you have discovered what the term *praxis* actually means.

1.2 Schooling versus learning

This course is probably your first experience of Higher Education and the only educational process that you will be familiar with is that which you met at school. Higher, or University, Education is very different from Schooling. The dual aims of this topic are to demonstrate the difference between the two and introduce you to the more demanding expectations of Higher Education.

The quote from Reich at the start of this topic might seem a bit trite but Higher Education is one way in which you really can liberate yourself. No doubt you appreciate this already and it is probably the reason you have enrolled on this course. In studying for an academic degree you will be exposed to new ideas and new ways of thinking about things and this, in itself, will be intellectually liberating. Also, once you graduate, the career opportunities which will be available to you will be greatly enhanced and this can liberate you in all sorts of ways - more control over your daily work, more rewarding and creative work, greater appreciation of your work and remuneration for it.

Consider the following definitions taken from the Oxford English Dictionary

Student		Person	studying in order to qualify himself for some occupation,
		or	devoting himself to some branch of learning or investigation,
		or	under instruction at university or other place of higher education.
Degree	Academic rank conferred as mark of proficiency.		
Graduate		One who	holds an academic degree,
		or	has completed a programme of study.
University	Educational institution designed for instruction or examination or both, of students in all or many of the more important branches of advanced learning.		

Notice how the definitions are couched in Schooling terms - "qualify", "instruction", "examination". Is this really all that University, or Higher, Education is about? What about broadening one's horizons or the latest research findings? Should they not figure in the definitions somewhere?

Consider the following paragraph written by Ivan Illich -

Many students ... intuitively know what the schools do for them. They school them to confuse process and substance. Once these become blurred, a new logic is assumed: the more treatment there is, the better are the results; or, escalation leads to success. The pupil is thereby 'schooled' to confuse teaching with learning, grade advancement with education, a diploma with competence, and fluency with the ability to say something new. (Illich 1971)

Illich wrote this piece quite a few years ago but he would probably not change it much if he were to re-write it today. You might think he is being a bit harsh on schools and schooling. Indeed, your own school experience might have been quite different to that which he describes. Take another look at that last sentence though and ignore the controversial suggestion that schools might be conspiring to deliberately confuse their pupils. Now ask yourself the following questions -

- In how many of the subjects I took at school did I have a strong desire to learn more and in how many did I merely turn up to be taught?
- Was I actively seeking an education at school or did I just attend because that is what young people do?
- In how many of the subjects for which I hold a qualification do I feel at all competent? In how many would it be possible for me to make an original contribution to knowledge?

Hopefully your answers to these questions will at least lead you to concede that Illich's description has some truth in it, even if you think he might be overstating things somewhat. You might be of the opinion that what he describes is the way education has to be when dealing with large classes of young children. There are clearly many issues to be considered in any debate about school education but to consider them here would be to digress from the main purpose of this discussion. That purpose was to arrive at a key point upon which we should all agree -

Whilst we might tolerate, or even advocate, in our schools the educational process which Illich describes, we could not countenance its application in our universities, and this is the single most important thing which distinguishes Higher Education from Schooling.

1.3 Being a student

It is absolutely crucial to your success in Higher Education that you understand what is expected of a student. The following descriptions are provided to help you contrast the expectations of the lecturers you will meet in Higher Education with those of the teachers you probably met in school -

Higher Education

Students discover information for themselves and critically assess it. Understanding the material is crucial. De-schooling, in Illich's sense, might be a necessary part of this process.

Schooling

Teachers organise and deliver up the information. Pupils are assessed on their ability to reproduce it and apply it in very specific ways. Understanding of the material is useful to a pupil but not always essential to examination success.

As a student, you will be expected to use your initiative. You will sometimes be confronted with investigating a subject which is rather ill-defined. Whereas a school pupil might ask "Where do I start?" of their teacher, a student would be expected to work out the answer to that question for themselves or, at the very least, suggest a answer to their lecturer for confirmation, such as "I was planning to start with X and then go on to consider Y and Z. Would this be appropriate in your opinion?"

As a student you will be expected to organise your thoughts and ideas in a manner that makes them intelligible to others. When investigating a subject you are likely to discover many accounts from a variety of sources. Organising this information sensibly is essential to gaining an understanding of it.

As a student you will be expected to critically assess any information you acquire. How up to date it is, how reliable the source appears to be, whether it corroborates, or is itself corroborated by, other information you have obtained or whether it sits in splendid isolation. How professional does it seem? Sloppy use of language and poor presentation are suggestive of an unprofessional, and therefore potentially unreliable, source. You would do well to remember this point when producing your own work.

1.4 Information sources

As a 21st century student you have ready access to considerably more information than students in previous centuries. Libraries remain the most reliable sources of information. It is very rare for incorrect information to enter their portals. Libraries provide access to a lot more materials than you might realise. They collaborate with each other and you can order materials from one library which might be held at another library (but there might be a small fee incurred in this). Libraries use quite a bit of information technology too. If you have not already done so, now would be a good time to obtain instruction from your library on how to search their catalogues and ask about other external materials which they might be able to supply to you.

The World Wide Web (WWW) is an enormous repository of information which is rapidly becoming indispensable to modern scholars. Beware though, there is a lot of dubious information on the WWW. When seeking information, make sure you are accessing reputable organisations such as universities, research institutes and, of course, libraries.

Always cite your sources. References must give sufficient information for others to be able to locate or obtain your source. Referencing information gleaned from the WWW can be problematic. Web sites are transient in nature - here today, gone tomorrow. Whenever possible provide a reference to a more concrete version of material you use, such as a book or journal. When you do have to provide a WWW reference always provide the date on which you accessed the material as well as the date it appears to have been produced. The content of web pages can change and providing an access date offers the possibility of the material being retrieved from an archive after such a change has taken place.

1.5 The "Case of the Killer Robot" case study

This unit employs a case study as a vehicle through which to deliver and integrate a number of themes. "The Case of the Killer Robot" describes a fictional incident in which an operator is killed by an industrial robot. The articles which constitute the case study provide accounts of the development of the software which controlled the robot, the members of the development team and the environments which pertained in the development and client companies. The complete text of "The Case of the Killer Robot" is available in book form (Epstein 1997) but the essential elements of it have also been made available by the author, Richard Epstein, on the World Wide Web (WWW). The author of this unit has reproduced the WWW material (Taylor 2002), with permission, at

http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

It is expected that this will be your primary source for "The Case of the Killer Robot" material. One of your assigned tasks in Topic 2 will be to read some of the articles in "The Case of the Killer Robot" in readiness for its formal introduction in Topic 3. It would be a good idea to make sure that you can access the material now.

1.6 Praxis Schedule

Topic 1	Online	Introduction to praxis
	Tasks	For presentation at first tutorial 1. Look up and write down dictionary definition of "praxis" 2. Write a paragraph on its meaning in context of your course
	Tutorial	Individual reports on meaning of "praxis" Group discussion of reports
Topic 2	Online	Reporting information (written and spoken)
	Tasks	1. Read CKR Background materials and Article 1 before next topic 2. Prepare material on first assigned topic for next tutorial
	Tutorial	Individual reports on first assigned topic Discuss material presented
Topic 3	Online	"The Case of the Killer Robot" [CKR] CKR - Background to the case study & Article 1
	Tasks	1. Read CKR Article 5 before next topic 2. Expand first assigned topic and submit as Coursework Submission A 3. Identify about 3 key points from Coursework Submission A for next tutorial
	Tutorial	Present key points from Coursework Submission A Discuss material presented for Assignment 1
Topic 4	Online	Analysis and Specification CKR - Article 5 (Requirements Specification)
	Tasks	1. Submit Coursework submission A (last chance) 2. Read CKR Articles 2, 3 & 4 before next topic 3. Prepare material on second assigned topic for next tutorial
	Tutorial	Individual reports on second assigned topic Discuss material presented

Topic 5	Online	Design and Development CKR - Articles 2, 3 & 4 (Software Development in Teams)
	Tasks	1. Read CKR Articles 6, 7 & 8 before next topic 2. Expand second assigned topic and submit as Coursework Submission 2 3. Identify about 3 key points from Coursework Submission 2 for next tutorial
	Tutorial	Present key points from Coursework Submission 2 Discuss material presented for Assignment 2
Topic 6	Online	Testing and Usability CKR - Articles 6, 7 & 8 (Software Testing and Usability Evaluation)
	Tasks	1. Submit Coursework Submission 2 (last chance) 2. Read CKR Article 9 before next topic 3. Prepare material on third assigned topic for next tutorial
	Tutorial	Present Assignment 3 (first half of tutorial group)
Topic 7	Online	Ethics and Culpability CKR - Article 9 (Ethics)
	Tasks	1. Think about the issues involved in deciding who was at fault in CKR. 2. Make sure you attend the second set of presentations.
	Tutorial	Present Coursework Submission 3 (second half of tutorial group)
Topic 8	Online	Computer Architectures and Organisation
	Task	1. Think about the future possibilities for computer architectures.
	Tutorial	None

End of unit

1.7 Summary and Assessment

By the end of this topic you should be able to:

- Explain the difference between School and Higher Education
- Describe what is expected of a student undertaking Higher Education
- Be aware of the wealth of information available to today's scholars
- Outline the background to the "Case of the Killer Robot" case study

End of topic 1 test

5 min

Q1: The quote from Wilhelm Reich was taken from a book published in -

a) 1945
b) 1954
c) 1957
d) 1975

Q2: Which of the following was NOT given as an example of the enhanced career opportunities which Higher Education can offer you -

a) Control
b) Creativity
c) Money
d) Power

Q3: Which of the following was suggested as missing from the OED definitions cited -

a) Examinations
b) Instruction
c) Qualifications
d) Research findings

Q4: Which of the following pairs was NOT mentioned by Ivan Illich as something that schools confuse -

a) Education with grade advancement
b) Learning with teaching
c) Process with substance
d) Understanding with knowledge

Q5: Which of the following was NOT suggested as a student characteristic -

a) Critical assessment
b) Initiative
c) Intelligence
d) Intelligibility

Q6: The inventory of items held in a library was called a -

a) Catalogue
b) List

c) Menu
d) Table

Q7: Which of the following were NOT suggested as reputable sources on the WWW -

a) Libraries
b) Newspapers
c) Research institutes
d) Universities

Q8: Web sites were described as being -

a) Abstract
b) Temporary
c) Transient
d) Transitive

Q9: When citing web sources which date should always be provided -

a) Access date
b) Amendment date
c) Expiry date
d) Last modified date

Q10: "The Case of the Killer Robot" was written by -

a) Richard Epstein
b) Nick Taylor
c) John Wiley
d) John Wiley's son

1.8 Coursework Submission 1

Coursework Submission 1

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

Prepare written answers to the following two questions and take them with you to your first tutorial. Typed work is preferable but hand-written work is acceptable on this occasion.

1. What is the dictionary definition of *praxis*?

   Make a written note of this.

2. What do you think *praxis* means in the context of your degree?

   Write a paragraph on this.

1.9 References

Epstein, R.G., 1997, *The Case of the Killer Robot*. John Wiley & Son.

Illich, I., 1971, *Deschooling Society. Pelican Books*, 1976 edition.

Reich, W., 1945, *Listen Little Man!* Pelican Books, 1975 edition.

Taylor, N.K., 2002, *The Killer Robot* [online]. Heriot-Watt University (MACS), 16th December 2002 [cited 7th July 2003]. SHTML. Available from: http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 2

Reporting Information

Contents

Learning Objectives

- *Appreciation of the importance of the receiver of a communication*
- *Awareness of the need to support statements by citing reputable sources*
- *Familiarity with the structure of a written document*
- *Familiarity with the structure and media used in a spoken presentation*

Poets utter great and wise things which they do not themselves understand. (Plato 429-347 BC)

2.1 Communicating ideas

Communication is a funny thing. Even the way the word is used in English is misleading. It suggests something that we do to people rather than for them. "I communicate to you", "Jack communicates with Jill" but when "somebody communicates for another person" the word takes on a completely different meaning. Yet communication, in practice, is all about the people for whom the message is intended.

The receiver of communication is king.

This should be your guiding light when producing any form of communication. If the reader, listener or viewer does not comprehend what the transmitter is trying to convey then the communication is pointless and the transmitter has failed. When you write, speak or demonstrate something for somebody else to digest the responsibility for ensuring that they absorb it successfully lies entirely with you. Blaming your audience for not understanding is not an option, ever.

You might think the previous two paragraphs have been stating the obvious - most people would. However an awful lot of people, whilst accepting the validity of the above, actually do nothing about it. If the receiver of a communication is king then you must show deference to your audience. Your communications must be produced with a particular audience in mind. If your report is too technical it might leave your readers with a headache, if your speech is not sufficiently detailed it is likely to be drowned out by the sound of your audience snoring, and shouting it will not help.

"Too technical"? "Sufficiently detailed"? How do you gauge these intangible qualities? You gauge these largely through experience but also, and always, by knowing your audience. This does not simply mean knowing the technical competencies of your audience; those things which you can expect them to have the background to understand and those things which you cannot. It also means knowing why they have chosen to become your audience; knowing what it is they are hoping to learn from you. This might mean facing up to the unpleasant possibility that it is not what you want to tell them about.

It is for this reason that any communication to a mass audience should commence by explaining what is going to be addressed and why. Few people forget to include the "what" in their communications but the "why" is more frequently overlooked. This, though, is the place where you can persuade that part of your audience who had hoped you would be telling them about something else of the relevance to them of what you are actually going to address.

2.2 Organising your thoughts

What are you trying to say? You must get this clear in your own mind before you even begin to think about putting it across to others. Do you have a single message or are there a number of points you wish to convey?

Even if you have just one "Big Idea" or key conclusion to communicate you will also have a number of building blocks or stepping stones that led you to it. You need to organise these into an intelligible order for your audience so that they can follow your line of argument. Do not overwhelm your audience with more detail than they need but do not frustrate them by leaving gaps in your reasoning which it would be unreasonable to expect them to fill for themselves.

If you have a portfolio of ideas to convey think about the order in which you deliver them. Will some orderings be easier on your audience than others? Perhaps some of the ideas are more related than others and so should be presented together. Perhaps some lead onto others. Maybe there is a chronological order to them. If you can find no logical ordering then at least present your ideas alphabetically - any ordering is better than none at all. Remember also that your audience will probably need to be led into each idea in the portfolio just as with the "Big Idea".

When organising your material it can help to jot down section titles and sub-titles. This hierarchical top-down approach will probably seem very logical and intelligible to you. Beware though, you know what you are trying to say. Your audience does not. The drawback of this approach is that it can leave your audience with a lot of loose ends at the bottom of the branches. You will need to explicitly, and carefully, draw all these loose ends together in a concluding section if you adopt this approach.

Once you have organised your ideas you should be in a good position to decide how to introduce your communication at the start and summarise it at the end. Remember that every communication has three essential parts:

1. Introduction (tell your audience what you are going to say and why)
2. Body (say it)
3. Conclusion (tell them what you have said and remind them why)

2.3 Supporting your statements

Consider the following two statements:

Statement A: *The world is flat.*

Statement B: *The world is round.*

What is the difference between them? You might say "Statement A is false and Statement B is true" and expect that to be sufficient explanation. Suppose you were talking to a young child though. You might (indeed should, if you have any experience of young children!) expect the child to reply "Why?". If you are going to satisfy the child's curiosity you will have to support your statement. Perhaps by citing evidence in favour of Statement B, perhaps by citing evidence that refutes Statement A. Your success in this will depend on how convincing your evidence is - to the child, not to you.

Your evidence might be empirical ("I have flown around the world and I can tell you from personal experience that it is round"). It might be a theoretical proof ("Here are the astrophysical calculations and you can see that the world has to be round in order to orbit the sun in the way it does"). Finally, because you just do not have time to carry out all of the practical experiments or theoretical proofs yourself, you might, and frequently will, want to cite a source which your audience accepts is authoritative. Sadly, young children accept very few sources as authoritative! Why?

Obviously, just as you and your audience can agree on certain sources as being authoritative, so too can you agree on certain statements being common knowledge and not needing justification. You have to form a judgement about what your audience will accept when preparing your communication. Does a statement need to be justified to this audience or will they be content to take it as read? If your assessment of your audience is wrong you will either leave them crying "Why?" like the child or you will bore them with justifications of things they consider obvious.

Sir Isaac Newton once said that he was "standing on the shoulders of giants". We are all standing on the shoulders of giants of course and you should take every opportunity to cite the work of others in support of your own arguments. Supporting your statements, more often than not, means referencing the work of others. It is essential when doing this that you provide sufficient detail for your audience to retrieve the work you have cited and read it for themselves. It is also essential that you respect the intellectual property of others and give them credit when you quote them. Cutting and pasting somebody else's work and passing it off as your own is not just plagiarism, it is theft - Theft of their intellectual property.

The three most common forms of work that you are likely to reference are books, journals and web pages. A usable reference to any of these forms requires at least the following :

- Title of book or article
- Author's name
- Year of publication

For a book the name of the publisher should also be provided. For a journal paper the journal name, volume and page numbers should be included. For electronic media a URL should be given (http://..., etc.) and the date you accessed the material (the citation date) might help your audience to track it down if the URL is no longer valid or the content has been changed. The format of the resource is also recommended.

Here are some examples -

Book

Epstein, R.G., 1997, *The Case of the Killer Robot.* John Wiley & Son.

Journal paper

Turing, A.M., 1950, "Computing Machinery and Intelligence". *Mind*, **59**, pp. 433-460.

Web page

Taylor, N.K., 2002, *The Killer Robot* [online]. Heriot-Watt University (MACS), 16th December 2002 [cited 7th July 2003]. SHTML. Available from:

http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

2.4 Writing reports

If you have organised your thoughts well then the following ten Laws of Good Report Writing (IEE 1999) are all you need:

1. The reader is the most important person;
2. Keep the report as short as possible;
3. Organise for the convenience of the report user;
4. All references should be correct in all details;
5. The writing should be accurate, concise and unobtrusive;
6. The right diagram with the right labels should be in the right place for the reader;
7. Summaries give the whole picture, in miniature;
8. Reports should be checked for technical errors, typing errors and inconsistency;
9. The report should look as good as it is;
10. The reader is the most important person.

Once you have organised your material and deployed your references to support your reasoning the key is to be succinct. Do not waffle or waste space explaining the obvious and use diagrams, images, graphs and tables wherever they sum things up more concisely than words. Keep your sentences short because technical sentences with even only a couple of sub-clauses can be difficult to follow.

Use chapters, sections, sub-sections and paragraphs to break your work up into manageable blocks. Summarise chapters, and possibly sections, at their ends to reinforce the key points for the reader.

Take advantage of computer aids to check the spelling and grammar of your work. Remember the three parts of a communication and make sure that your introduction tells your audience what you are going to cover and why and that your conclusion tells them what you did cover and why. Finally, remember that the receiver of communication is king.

2.5 Making presentations

A spoken presentation is a performance. You might not wish it to be, you might feel that your talk is far too serious or important for you to worry about how you look or sound. However unfortunate you may think it is, these things matter. When you stand in front of an audience and expect them to look at and listen to you then you must consider what they can (or cannot) see and what they can (or cannot) hear. There is something of a contract here. The audience agree to pay attention and not interrupt you unnecessarily for as long as you provide them with sights and sounds that please them, or at least do not annoy them.

Dress presentably, stand up straight (hands out of pockets), look at the audience, make sure your visual aids are clear to those at the back and you will meet the sight requirement of the contract. Speak clearly and enthusiastically at a reasonable speed with sufficient volume for those at the back and an appropriate level of formality/familiarity and you will satisfy the sound requirement too.

Remember that the reason we use presentations is that they permit interaction. If you are not prepared to engage in interaction you might as well write down what you have to say and stay away. Having said that, you should not encourage a lot of interjections. Whilst questions during a talk can help you to decide how much explanation is needed they will disrupt your flow and can result in a poorer experience for the rest of the audience. Always leave time at the end for questions and encourage the audience to save their questions until then.

Nowadays presentations are invariably accompanied by the projection of words and images onto screens. When using words you can use different colours and fonts to introduce variety but do not overdo it. Remember that such devices can make reading more difficult and distract your audience from the message you are trying to get across. Make sure your font sizes are large enough and do not cram too much text onto your slides. These are incredibly common mistakes. Another common mistake is to present diagrams and graphs in which the labels are too small to read. Remember to think of your audience as you prepare your materials.

Think about where you position yourself. Do not obscure your visual aids or muffle your voice through bad positioning. If you cannot avoid obscuring a screen for some of the audience move around during your presentation so they all get a chance to see it. Make eye contact with your audience and speak to them - not the screen, the projector or your feet. Remember the three parts of a communication and tell your audience what you are going to cover at the start and why and what you did cover at the end and why. Do not forget to introduce yourself (and your affiliation if appropriate) at the beginning and remember that the receiver of communication is king.

2.6 Summary and Assessment

By the end of this topic you should be able to:

- Appreciate the importance of the receiver of a communication
- Be aware of the need to support statements by citing reputable sources
- Produce the structure of a written document
- Explain the structure and media used in a spoken presentation

End of topic 2 test

5 min

Q1: Which of the following is NOT an essential part of every communication

a) Abstract
b) Body
c) Conclusion
d) Introduction

Q2: A drawback of the top-down approach to organising a communication is

a) Bottom-up
b) Branches
c) Loose ends
d) Sub-sections

Q3: Who said he was standing on the shoulders of giants

a) Charles Babbage
b) Albert Einstein
c) Isaac Newton
d) Alan Turing

Q4: Which of the following does a journal reference NOT need

a) Author
b) Page numbers
c) Publisher
d) Volume

Q5: Plagiarism was described as

a) Bad mannered
b) Inconsiderate
c) Lazy
d) Theft

Q6: In the ten Laws of Good Report Writing which two were the same

a) 1 and 2
b) 1 and 5
c) 1 and 10
d) 2 and 5

Q7: Sentences in written reports should be

a) Interesting
b) Short
c) Single phrases
d) Technical

Q8: Presentations nowadays invariably use

a) Jokes
b) Microphones
c) Projections
d) Videos

Q9: Which of the following was NOT cited as a common presentation mistake

a) Diagram labels
b) Font colour
c) Font size
d) Font variety

Q10: The receiver of communication is

a) Aerial
b) King
c) Listener
d) Reader

2.7 Coursework Submission 2

Coursework Submission 2

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. Read "The Case of the Killer Robot" Background material and Article 1 (Epstein 1997 or Taylor 2002) before embarking on Topic 3.

2. Each member of your tutorial group is to research a different topic from the list below. They all relate to "The Case of the Killer Robot" and you should read the articles above first. If you are the first tutee on the group list then you are to research the first topic; if the second on the list then the second topic; and so on. You should prepare some preliminary notes on your assigned topic for your next tutorial where each topic will be discussed by the whole tutorial group under the guidance of your tutor. Following the tutorial you will be turning these notes into a 1000 word submission for **Coursework Submission A**. Producing Coursework Submission A is one of the assigned tasks in Topic 3.

Assigned Topics 1- 9

Industrial Robots	- Types - Controllers	1st Tutee 2nd Tutee
Artificial Intelligence	- Sensing - Control	3rd Tutee 4th Tutee
User Interfaces	- Design - Evaluation	5th Tutee 6th Tutee
Safety Critical Systems	- Examples - Interlocks	7th Tutee 8th Tutee
Software Negligence	- Examples	9th Tutee

2.8 References

References

Epstein, R.G., 1997, *The Case of the Killer Robot.* John Wiley & Son.

IEE, 1999, *Technical Report Writing.* Institution of Electrical Engineers, London.

Plato, 429-347 BC, *The Republic*. Penguin Books, 1955 edition. Translated by Henry Desmond Pritchard Lee.

Taylor, N.K., 2002, *The Killer Robot*[online]. Heriot-Watt University (MACS), 16th December 2002 [cited 7th July 2003]. SHTML. Available from:

http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 3

The Case of the Killer Robot

Contents

Learning Objectives

- *Appreciation of the importance of the case study to this unit*
- *Familiarity with the background to the case study*
- *Awareness of the differences between the printed and electronic versions*
- *Appreciation of the need to undertake further reading in support of studies*

A robot may not injure a human being, or through inaction allow a human being to come to harm.

The first of Isaac Asimov's Three Laws of Robotics. See Asimov (1968) for example.

3.1 Background to the case study

You should have read the Background materials and Article 1 of "The Case of the Killer Robot" before starting on this topic. The list of topics which are being investigated for Coursework Submission A all relate to the case study.

"The Case of the Killer Robot" (henceforth to be abbreviated to CKR) was originally conceived by Richard Epstein in 1989 as a teaching aid. He subsequently made the materials freely available on the WWW for use by other academics and there are copies in a number of places. See for instance Gehringer (undated), Melamed (1998) and Taylor (2002). In 1997 an expanded version was published by John Wiley & Son. You are advised to refer to either the book (Epstein 1997) or the website maintained by the author of the Praxis unit (Taylor 2002).

The book differs from the web-based materials not only in being much longer but also in other, important, details. There are more articles in the book and they are not presented in the same order as the web-based materials. If you are working from the book, use the web-based materials to identify the relevant articles.

References to article numbers in this unit refer to the web-based materials.

Some of the characters have been given different names in the book. The name changes (from book to WWW) are as follows:

Book	WWW
CyberWidgets Inc.	Cybernetics Inc.
George Cuzzins	Sam Reynolds
Hiram Milton	Sharon Skinner
Pam Pulitzer	Mabel Muckraker
Silicon Techchronics	Silicon Techtronics

Names in this unit will be taken from the web-based materials.

3.2 Issues raised in the case study

The reason CKR has been chosen as a unifying theme to run through this unit is that it raises many pertinent, but potentially dull, issues in a very entertaining form. Hopefully, by the time you complete this unit, you will agree that Epstein is to be applauded for this achievement.

The issues raised by CKR are many and various so we shall attempt to impose some order onto them by classifying them into four broad categories, as follows:

1. Requirements Analysis and Specification
   Was the solution proposed the correct one for the customer?
   Did the system specified actually produce that solution?
2. System Design and Development
   Was the design method employed appropriate for the specified system?
   Did the development methods and team suit the design?
3. System Testing and Usability
   Was the system thoroughly tested?
   Were the users of the system considered/involved?
4. Ethics and Culpability
   Did everybody concerned act with the best of motives?
   Who should be held responsible for the fatality?

In subsequent topics we shall be looking into these general categories in more detail and you will be researching specific ideas and methodologies in even more detail. Eventually we shall amass sufficient information to attempt an answer to the question of culpability in this case.

For now we shall confine ourselves to a few explanatory remarks relating to the topics which you and your fellow tutees are investigating for Coursework Submission A.

3.3 Robots and artificial intelligence

The Robbie CX30 robot is an industrial manipulator. It is not a human looking android such as one might find in a science fiction film. Industrial robots come in a number of forms ranging from wheeled vehicles to various types of mechanical arms equipped with assorted controllers and end effectors to do the actual work. The CX30 is not mobile; it is a mechanical arm bolted securely to the floor within a cage to reduce the potential hazard to human operators. It has a programmable controller which increases its versatility and thus makes it applicable to a variety of different tasks.

Nor should you expect too much of the robot's artificial intelligence. The Robbie CX30 cannot think. Its "intelligence" manifests itself as an ability to react to a variety of sensor inputs thus providing it with a more adaptive control system than its predecessors. Asimov's Three Laws of Robotics (Asimov 1968) hardly apply to such a primitive device. The field of Artificial Intelligence is vast but those areas most relevant to the Robbie CX30 are sensor processing and decision making based on the information gleaned from that processing.

3.4 Usability and safety critical systems

User interfaces are often the last thing on the minds of system developers who are much more interested in the technical details of their products than the end users of them. However Human Computer Interaction (HCI) or Man Machine Interaction (MMI) should not be considered as an after-thought. Poor interfaces can be unfriendly, inefficient and downright dangerous. The evaluation of what constitutes a good or a bad interface is clearly dependent on who the users are and what they are used to. Involving users in the evaluation is clearly sensible. Involving users earlier on, at the specification, design and development stages, can save time and effort in the long run. Usability engineers have devoted considerable study to understanding how people interact with machinery and computers and there is much guidance available to the designer who is prepared to seek it out.

This is nowhere more true than in the sphere of safety critical systems. Systems which have the potential to cause great damage if they go wrong are designed and developed to minimise the likelihood of a catastrophic failure. The one element of these systems which is always an imponderable is the actual human beings who interact with them. Interfaces to safety critical systems must be designed to eliminate the possibility of inappropriate user actions. This can be achieved in a number of ways ranging from disabling particular user options in certain states of the system to providing hardware interlocks that power the system down in the event of a user physically entering somewhere that would be dangerous to them.

3.5 Software negligence

Injuries and fatalities involving industrial robots have, in fact, been very rare. Unfortunately incidents in which poorly designed or developed software have led to loss of human life are becoming more common. A cursory search on the WWW will turn up all too many such incidents. In many countries nowadays, if the personnel or the company responsible for such software can be shown to have been negligent, criminal sanctions can be applied. Unfortunately the level of proof required by the courts is often unattainable but the law is catching up.

3.6 Summary and assessment

By the end of this topic you should be able to:

- Explain the importance of the case study to this unit
- Describe the background to the case study
- Outline the differences between the printed and electronic versions
- Justify the need to undertake further reading in support of studies

End of topic 3 test

5 min

Q1: Comparing it with the WWW material, Epstein's book is

a) Easier
b) Longer
c) Simpler
d) Shorter

Q2: Sharon Skinner in the WWW materials became who in Epstein's book

a) George Cuzzins
b) Robbie CX30
c) Hiram Milton
d) Sam Reynolds

Q3: Which of the following general categories will NOT be looked at in detail

a) Budgeting and financial control
b) Ethics and culpability
c) Requirements analysis and specification
d) System testing and usability

Q4: Who will be researching specific ideas in the greatest detail in this unit

a) Author of these materials
b) Turina Babbage
c) Robbie CX30 development team
d) You

Q5: The Robbie CX30 robot is

a) An android
b) An industrial manipulator
c) A program which seeks material on the WWW for a search engine
d) A walking machine

Q6: The part of a robot which does the actual work is called

a) An end effector
b) A gripper
c) A tool
d) The tool centre point

Q7: The Three Laws of Robotics are due to

a) Isaac Asimov
b) Arthur C. Clarke
c) Mary Shelly
d) Star Wars

Q8: Which of the following is NOT an alternative name for the field of interface design

a) HCI
b) MMI
c) Usability engineering
d) User friendliness

Q9: Safety critical systems are systems which

a) Are complicated
b) Can cause great damage
c) Are expensive
d) Must not stop

Q10: Software negligence is becoming

a) Less common
b) Less expensive
c) More common
d) More dangerous

3.7 Coursework Submission 3

Coursework Submission 3

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. Read "The Case of the Killer Robot" Article 5 (Epstein 1997 or Taylor 2002) before embarking on Topic 4.
2. You should now turn the notes you made on the topic assigned to you in Topic 2 into a 1000 word submission for Coursework Submission A. This assignment should be submitted at your next tutorial.
3. You should also identify about 3 key points from Coursework Submission A for presentation at your next tutorial.

Reminder of Assigned Topics 1 - 9

Industrial Robots	- Types - Controllers	1st Tutee 2nd Tutee
Artificial Intelligence	- Sensing - Control	3rd Tutee 4th Tutee
User Interfaces	- Design - Evaluation	5th Tutee 6th Tutee
Safety Critical Systems	- Examples - Interlocks	7th Tutee 8th Tutee
Software Negligence	- Examples	9th Tutee

3.8 References

Asimov, I., 1968, *I, Robot*. Granada.

Epstein, R.G., 1997, *The Case of the Killer Robot*. John Wiley & Son.

Gehringer, E., undated, *Risks: Software Safety: Killer Robot* [online]. North Carolina State University [cited 7th July 2003]. HTML. Available from:

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http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 4

Analysis and Specification

Contents

Learning Objectives

- *Appreciation of the importance of the environment in which a system operates*
- *Awareness of the need to support clients in identifying their needs*
- *Familiarity with the ideas of system investigation and modelling*
- *Appreciation of the contents of requirements and functional specifications*
- *Awareness of the role of a requirements specification in a contract to supply*

I'll tell you what I want, what I really really want. (The Spice Girls 1996)

4.1 Determining what needs to be done

You should have read Article 5 of CKR before starting on this topic. The article details elements of the requirements specification which will have formed part of the contract between Silicon Techtronics Inc. and Cybernetics Inc. for the supply of the Robbie CX30 system.

Customers seeking new systems will invariably echo the opening lines of The Spice Girls' song "Wannabe" (quoted at the start of this topic). They know what they want, so sharpen your pencil because here it comes ... They then proceed to become about as meaningful as the "zigazig ah" on which the song ends when describing the details of their requirements. What is going on here? Surely the client has thought through their needs? So why do they seem incapable of spelling them out?

Well they are spelling them out, of course. What they are saying is perfectly intelligible to them. It just does not make sense to you, the supplier. You are going to have to learn a lot more about their business and their current practices in order to understand what they are saying and thus what they say they want. Once you have done that, you (and they) might well come to the conclusion that the system they want is not necessarily the system that they need. The client might be the expert on their business but you have the expertise regarding what is possible and what is not, what the drawbacks are to doing things one way or another way, what the future might bring. etc. and relating all of these to the client's business. Congratulations, you have become a systems analyst.

4.2 Systems analysis

You might think that systems analysis boils down to identifying the problems in a system currently being used and proposing fixes to it. Stair and Reynolds (2003) identify eight reasons for developing a new system and there are probably many more. Only one of their reasons is problems with the existing system. Other reasons include such things as a desire to exploit new opportunities, organisational growth and a need to comply with new regulations or laws. Fixing problems in an existing system is relatively straightforward compared to the other issues the systems analyst might be asked to deal with. Whatever the reasons, the first step is to carry out a thorough, but focused, system investigation.

4.2.1 System investigation

Given an initial site of investigation (identified by the client), it is clearly important to include in the analysis any activities which interact with that site. This could rapidly get out of hand and investigating the workings of a complete enterprise is rarely necessary. However, focusing in on that part of an enterprise which does need thorough analysis is no simple task. The concept of a system boundary (Licker 1987) is useful here. By assessing the dependence of the core components of a system on other activities it is possible to decide whether each of those other activities belongs within the system boundary or to the environment surrounding the system. One of the most useful outcomes of the investigation is a system model.

4.2.2 System modelling

Modelling allows us to build up a picture of the interactions and information flows which exist within a system and between a system and its environment. Different people within an enterprise will see a given system in different ways. Licker (1987) lists seven ways in which an information system might be viewed -

1. The "brains" of the enterprise
2. A decision support system
3. A communication channel
4. A data bank
5. A data transporter
6. A hardware system
7. An appendage to the business

The models which could be produced from these differing perspectives of a system are likely to be quite different. It is important speak to the right people when carrying out the system investigation in order to ensure that the appropriate type of model is built. Note that the managers of systems do not always see things in the same way as staff working with or within systems. Whose view should be used to build the model? It might be that more than one model is necessary to capture the various functions which a system performs.

4.3 Requirements specification

Once a proper understanding of the current system has been obtained, and models of it built, the analyst has sufficient information to discuss the client's requirements. The models created by systems analysts are sometimes real eye-openers to their clients. For instance, it might only be because two people happened to take tea with each other every day that a certain information flow, crucial to the business, was possible. Together, the analyst and the client can identify weak points such as this in current practices, prepare for future changes which are likely to affect a system or completely re-engineer an antiquated system which is past its sell-by date.

If a current system is to be modified the consequences of the modifications need to be clearly understood by both the developer and the client. If a new system is to be introduced it must integrate smoothly with any other systems already in place and its introduction must be planned properly. Development and installation time-scales must be agreed and training of staff to use the new or modified system arranged. Matters such as these should all figure in a requirements specification, in addition to the functional specification of the system.

4.3.1 Functional specification

The functional specification states what the system will do. It specifies all of the functions that the system is required to perform. The level of detail at which this specification takes place is likely to vary for different parts of the system. For some items of functionality it might be crucial that the function be performed in a particular way and this should be stated in great detail. For some items, the interaction with other systems or users might be critical and described in depth. Elsewhere the client may be happy to give the developer a free hand to select the best or most efficient solution.

The one essential is that, whatever is being specified, it is specified clearly and unambiguously so that there can be no confusion surrounding the resulting contract.

4.3.2 The contract

One of the most important documents to emerge from a requirements specification is the contract. This is an unambiguous statement of what is to be delivered. In addition to the price of the system, it will include milestones and deadlines which are to be met by the developer and penalty clauses through which the client will be reimbursed if they are missed. The contract will normally make provision for training of the client's staff by the developer and itemise the documentation to be delivered with the system. It will also state facilities which the client is required to make available to the developer so that integration, evaluation and training can be expedited. Service and maintenance agreements might also form part of the contract although it is becoming common for these to be handled under separate contracts these days.

4.4 Summary and assessment

At this stage you should be able to:

- Appreciate the importance of the environment in which a system operates
- Explain the need to support clients in identifying their needs
- Outline the ideas of system investigation and modelling
- Describe the contents of requirements and functional specifications
- Relate the role of a requirements specification in a contract to supply

End of topic 4 test

5 min

Q1: A client commissioning a development is the best judge of

a) Their business
b) How long the development should take
c) How much the development should cost
d) How to plan the development

Q2: Which of the following statements is true

a) The client is always right
b) The client is always wrong
c) The client knows what they need
d) The client knows what they want

Q3: Systems analysis is all about

a) Analysis
b) Modelling
c) Systems
d) Understanding

Q4: The key to a successful system investigation lies in identifying

a) Boundaries
b) Communication flows
c) Management structures
d) Responsibilities

Q5: The environment of a system is the

a) Atmosphere
b) Hardware
c) Software
d) Systems it interacts with

Q6: How many valid models of a system are there?

a) One
b) Two
c) Seven
d) Probably as many as there are people involved with it

Q7: Which of the following was NOT one of Licker's possible views of a system?

a) Appendage to the business
b) Data bank
c) Data processor
d) Decision support system

Q8: Requirements specifications SHOULD NOT cover

a) Functionality
b) Implementation details
c) Time-scales
d) Training

Q9: Functional specifications include

a) Design decisions
b) Development plans
c) Implementation details
d) Itemised functions

Q10: Contracts SHOULD NOT require the client to assist in

a) Development
b) Evaluation
c) Integration
d) Training

4.5 Coursework Submission 4

Coursework Submission 4

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. **Submit coursework A** if you have not already done so.
2. Read "The Case of the Killer Robot" Articles 2, 3 and 4 (Epstein 1997 or Taylor 2002) before embarking on Topic 5.
3. Each member of your tutorial group is to research a different topic from the list below. They all relate to "The Case of the Killer Robot" and you should read the articles above first. If you are the first tutee on the group list then you are to research the first topic; if the second on the list then the second topic; and so on. You should prepare some preliminary notes on your assigned topic for your next tutorial where each topic will be discussed by the whole tutorial group under the guidance of your tutor. Following the tutorial you will be turning these notes into a 1000 word submission for **Coursework B**. Producing Coursework Submission B is one of the assigned tasks in Topic 6.

Assigned Topics 10 - 18

Structured Systems Analysis & Design Method (SSADM)	1st Tutee
Dynamic Systems Development Method (DSDM)	2nd Tutee
Waterfall Model of Software Development	3rd Tutee
Unified Process Model of Software Development	4th Tutee
Rapid Prototyping	5th Tutee
Extreme Programming (XP)	6th Tutee
Reusable Software	7th Tutee
Open Source	8th Tutee
PRINCE Project Management Method	9th Tutee

4.6 References

Epstein, R.G., 1997, *The Case of the Killer Robot.* John Wiley & Son.

Licker, P.S., 1987, *Fundamentals of Systems Analysis*. Boyd & Fraser.

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http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 5

Design and Development

Contents

Learning Objectives

- *Appreciation of the steps involved in building systems*
- *Awareness of design principles and design types*
- *Familiarity with the System Development Life Cycle*
- *Familiarity with the Software Life Cycle*
- *Familiarity with the Programming Life Cycle*
- *Awareness of the variety of development methodologies*
- *Appreciation of the issues involved in team working*

Rome wasn't built in a day. (Proverb of French origin)

5.1 Getting the system built

You should have read Articles 2, 3 and 4 of "The Case of the Killer Robot" before starting on this topic. The list of topics which are being investigated for Coursework Submission B all relate to this topic. Each topic on the list is a methodology for system analysis and design or development or a means of procuring software or a complete project management system. SSADM is a systems analysis and design tool. The development models are DSDM, Waterfall Model, Unified Process Model, Rapid Prototyping and Extreme Programming. The software sources are Reusable Software and Open Source and PRINCE is a project management system. You will be explaining these to each other in your tutorial group.

Licker (1987) identifies seven stages in the System Development Life Cycle

1. System study, problem definition
2. Preliminary investigation, feasibility study
3. Logical (functional) design
4. Physical design (blueprinting)
5. Implementation (construction)
6. Installation
7. Operation, maintenance

We have looked at the first two stages in the previous topic. In this topic we shall concentrate on the design and development stages (stages 3, 4 and 5).

There are many different sets of design principles and there is no universal agreement on which is best. We shall look at an example set of principles. We shall also look at some different approaches to design. There are also many different development methodologies and, again, much debate about which is best. You will be reporting on these to each other and once you have learnt a little about some of them you will see that they are often applicable to one or other of the design approaches or offer different benefits and carry different drawbacks.

Large tasks require teams of people. Successful teamwork does not just happen as a result of putting all the "best" people together. In fact, a team composed entirely of stars is likely to be plagued with problems. We shall look at why some teams work whilst others fail.

5.2 Design

Design is a creative exercise and so it is not easy, or indeed desirable, to prescribe a fixed set of rules for getting it right. There are however some design principles which can help to guide you towards good designs.

5.2.1 Design principles

Amongst the many sets of design principles, the following six have attracted general support

1. Structure
2. Parsimony
3. Modularity
4. Portability
5. Transparency
6. Conviviality

We shall take each one in turn and briefly look at what they say.

Structure

This is the way the design is organised. An organisational structure which is consistent throughout the design is crucial. Confusion results from disorganisation.

Parsimony

Simplicity and economy are the keys here. Simple things are readily understandable and safe. Minimalist solutions are generally the cheapest.

Modularity

Modularity describes the relationship between the sub-components of a design - the modules. There are two very important measures in assessing the modularity of a design -

1. **Cohesion** is a measure of the strength of the functional association of the elements within a module. Increasing cohesion generally increases *understandability*.

2. **Coupling** is a measure of the degree of interdependence between modules. Decreasing coupling generally increases *adaptability*.

Portability

A system will be applicable to a wider set of problems if it is not unnecessarily tied down to a specific platform or environment. Platform dependence might manifest itself as a reliance on a particular processor, operating system or peripheral. Environmental dependence might result from unwarranted assumptions about the use to which the design or system will be put or through assumptions about the users. Of course, the principles of user-centred design encourage us to design systems with particular user groups in mind. Judgement is called for here.

Transparency

Systems should be designed to be readily understandable and obvious in use. Hidden assumptions should be avoided.

Conviviality

This principle refers to comfort of use. User friendliness and user-centred design are the key concepts here. See the trade-off with portability though.

5.2.2 Design types

In addition to the design principles described above it can also be helpful to try to identify the type of design which you are undertaking. There are three pairs of alternative design types

1. Logical versus Physical Design
2. Functional versus Object-Oriented
3. Top-Down versus Bottom-Up

The options within each pair are not necessarily mutual exclusive. They might both have a role to play in the overall design but they should not be used simultaneously or a messy and confused design will result. Again, we shall take each pair in turn and briefly look at how they differ.

Logical versus physical design

A logical design describes *what* you are trying to deliver. It is concerned with the relationships between the components of the design. It is most appropriate at the earlier, higher level, stages of the design process. Physical design is more detailed and describes *how* the functionality is to be delivered. It details the nuts and bolts of the system and is more appropriate in the later, lower level, stages of the design process.

Functional versus object-oriented

Functional designs identify what is to be done, the data that is required and how the function will be achieved. This type of design works with processes, activities or procedures. Indeed, it is sometimes called procedural design. Object-oriented design takes a different perspective. It first identifies what the parts are. The attributes which the parts possess and what can be done to/with them then become the focus of the design exercise.

Top-down versus Bottom-up

Top-down designs break the whole down into parts whilst bottom-up designs build the whole up from the parts.

5.3 Development

Most of what you will learn about development methodologies will be supplied by your fellow tutees in your tutorial group. It is essential that you play your part in this by delivering the best information that you can to your colleagues.

We shall confine ourselves to discussing some general points here. We have already met the System Development Life Cycle (Licker 1987). There are two further life cycles which are often presented in the Software Engineering literature.

The Software Life Cycle (Sommerville 2000) has five stages

1. Requirements definition
2. System & software design
3. Implementation & unit testing
4. Integration & system testing
5. Operation & maintenance

The Software Life Cycle commences with the, by now familiar, analysis and specification of the system and proceeds through the design stage to the implementation and testing of individual units or modules. Large systems are generally composed of many modules and these need to be integrated and each sub-system tested as the integration proceeds. Finally, the life of a piece of software does not end with its delivery. Operation and maintenance are also key parts of the overall life cycle.

The life cycle describes a highly iterative process with each stage possibly looping back to any previous stage. This iteration reflects a reality which the theorist often overlooks but which the seasoned practitioner is all too well aware of

It is sometimes only in the later stages of a development that a flaw in the logic of an earlier stage becomes evident.

The implementation stage of the Software Life Cycle can be expanded on to produce a Programming Life Cycle (Stair & Reynolds (2003))

1. Systems investigation
2. System analysis
3. System design
4. Language selection
5. Program coding
6. Testing & debugging
7. Documentation
8. Implementation (conversion)

This life-cycle is embellished to produce an eight-stage process which, once again, starts with the systems analyst but now ends at the implementation. Along the way key issues such as language selection, debugging and documentation are explicitly represented. These sub-divisions of the implementation stage in the earlier life-cycles can facilitate the assignment of personnel within a team to the various tasks required.

5.4 Teamwork

Large projects require a team effort. A good team will be composed of individuals with different specialisms and also different character traits. Teams composed of very similar members can generate much friction and be quite unproductive. Try to spot some of the following eight types of team member amongst the Robbie CX30 development team.

1. **The plant**

   A creative and imaginative but unorthodox individual. This type of person can be a bit hard to manage but provides many of the team's ideas.

2. **The enabler**

   A mature and confident individual who can chair meetings. This kind of person can be a bit manipulative but they listen well and can clarify the team's goals.

3. **The fixer**

   An extrovert but amiable individual who is always on the go. This type of person may be a bit undisciplined but often has a lot of useful contacts.

4. **The shaper**

   A dynamic and outgoing individual who likes to take the lead. This kind of person has a tendency to bully others but is good and finding ways around obstacles.

5. **The monitor**

   An introvert and thoughtful individual who rarely gets things wrong. This type of person can be a bit slow but is very discerning and generally the "rock" of the team.

6. **The counsellor**

   A conciliatory and perceptive individual who is sensitive to other people's needs. This kind of person can be a bit indecisive but is essential to the team's harmony.

7. **The workhorse**

   A disciplined and reliable individual who gets on with things in a practical way. This type of person can be a bit unimaginative but is good at making other people's ideas work.

8. **The worrier**

   A stickler for detail who is rather pedantic and never lets go of things. This kind of person can be very annoying but is useful at spotting mistakes and ensuring that deadlines are met.

You can probably recognise elements of yourself in some of the above. More than one of them in fact. Remember that. We all have many different aspects to our characters.

Team dynamics is an important area of study in social psychology. Issues which have been identified as of major importance in teamwork include communication, leadership and conflict resolution. How were these matters handled on the Robbie CX30 project?

5.5 Summary and assessment

At this stage you should be able to

- Explain the steps involved in building systems
- Discuss design principles and design types
- Outline the System Development Life Cycle
- Outline the Software Life Cycle
- Outline the Programming Life Cycle
- Use a variety of development methodologies
- Relate the issues involved in team working

End of topic 5 test

5 min

Q1: Which of the following is NOT a stage in the Systems Development Life Cycle?

a) Installation
b) Physical design
c) Operation and maintenance
d) Winding up

Q2: Design is what kind of process?

a) Algorithmic
b) Creative
c) Provable
d) Random

Q3: Which of the following was NOT suggested as a design principle?

a) Conviviality
b) Modularity
c) Parsimony
d) Sequentiality

Q4: Designing from detailed components through to complete systems is

a) Bottom-up design
b) Logical design
c) Object-orientated design
d) Physical design

Q5: Functional design is concerned with

a) Attributes
b) Components
c) Procedures
d) Relationships

Q6: Who will be telling you most about development methodologies?

a) Fellow tutees
b) This material
c) Tutor
d) You

Q7: The Software Life Cycle differentiates between the following types of testing ?

a) Good & bad
b) Primary & secondary
c) System & unit
d) Thorough & partial

Q8: The Programming Life Cycle explicitly refers to the selection of

a) Algorithms
b) Data structures
c) Programming language
d) Hardware platform

Q9: Teams need to be composed of individuals who

a) Are very similar
b) Get on well
c) Have different skills
d) Work hard

Q10: A thoughtful but introvert person might make a good

a) Counsellor
b) Enabler
c) Monitor
d) Worrier

5.6 Coursework Submission 5

Coursework Submission 5

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. Read "The Case of the Killer Robot" Articles 6, 7 and 8 (Epstein 1997 or Taylor 2002) before embarking on Topic 6.
2. You should now turn the notes you made on the topic assigned to you in Topic 4 into a 1000 word submission for **Coursework Submission B**. This assignment should be submitted at your next tutorial.
3. You should also identify about 3 key points from Coursework Submission B for presentation at your next tutorial

Reminder of Assigned Topics 10 - 18

Structured Systems Analysis & Design Method (SSADM)	1st Tutee
Dynamic Systems Development Method (DSDM)	2nd Tutee
Waterfall Model of Software Development	3rd Tutee
Unified Process Model of Software Development	4th Tutee
Rapid Prototyping	5th Tutee
Extreme Programming (XP)	6th Tutee
Reusable Software	7th Tutee
Open Source	8th Tutee
PRINCE Project Management Method	9th Tutee

5.7 References

Epstein, R.G., 1997, *The Case of the Killer Robot*. John Wiley & Son.

Licker, P.S., 1987, *Fundamentals of Systems Analysis*. Boyd & Fraser.

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Topic 6

Testing and Usability

Contents

Learning Objectives

- *Appreciation of the role of quality assurance departments*
- *Appreciation of the importance of system testing*
- *Awareness of the sorts of things that can and should be tested*
- *Familiarity with the different types and levels of testing possible*
- *Appreciation of the importance of usability issues*
- *Awareness of some key concepts in user interface design*

God doesn't play dice with the universe. (Albert Einstein)

6.1 Making the system usable

You should have read Articles 6, 7 and 8 of "The Case of the Killer Robot" before starting on this topic. They describe some pretty appalling practices at Silicon Techtronics Inc. The resulting Robbie CX30 system was playing dice with its users' safety; it had not been properly tested and very little account had been taken of the users in its design.

Poor testing and lack of regard to usability are the two most serious charges that can be brought against a system. We shall now look into these two aspects of system development. We shall treat the former in a bit more detail than the latter because you should already be acquainted with the basics of usability from assigned topics 5 and 6 which were researched and/or discussed in your tutorial group.

6.2 Testing

We have already met the notions of **unit testing** and **integration testing** in some of the life cycles described in the previous topic. Unit testing, you will recall, involves the testing of individual modules in isolation from each other to ensure that they are correct and integration testing involves testing that the modules communicate with each other correctly and achieve the desired overall goals correctly.

Two other ideas are useful to bear in mind. These are **black box testing** and **white box testing** (Sommerville 2000). Black box testing considers only the inputs and outputs to a system. Its inner details are not scrutinised during such testing, the system is treated as a black box into which one can't see. White box testing, on the other hand, pays considerable attention to the internal details of a system.

The correct functioning of a system can be assured using a number of different techniques:

1. Quality Assurance (QA) procedures and "House" styles
2. Verification and validation
3. Static and dynamic testing

The conscientious developer will often use more than one of these.

Quality assurance procedures and "House" styles

Large companies will generally have Quality Assurance (QA) departments whose functions are to prescribe procedures that should maintain quality levels and to provide a testing regime which is undertaken independently of the development team.

The QA department will lay down "House" styles which are ways of doing things that must be adhered to throughout the company. These styles will cover everything from the way documentation is formatted to the style of the comments required in program code. Metrics will be employed by the QA department wherever possible to quantify those aspects of quality which are amenable to such things, such as the proportion of a piece of code which is devoted to comments.

Most companies will also standardise on one or more of the methodologies for analysis, design and development. International standards, such as ISO 9000 for Total Quality Management, should inform the QA procedures employed.

Verification & Validation

These two concepts are exceedingly useful and it is important to differentiate between them properly.

Verification is the determination of whether a product satisfies the initial conditions. I.e. whether it does the job it *claims* to do. This is an objective test which could make use of formal methods such as proofs of correctness

Validation is the determination of whether a product satisfies the specified requirements. I.e. whether it does the job it was *supposed* to do. This can be a more subjective judgement than verification.

Static and dynamic testing

Static testing involves inspection and analysis of the program code and its supporting documentation. This can be undertaken by computer-based checking in some areas. Syntax checking can be performed by a compiler for instance but identifying semantic errors is less readily achieved automatically. The checking of logic can be assisted by computer-based methods as long as a formal specification is available.

Dynamic testing involves running the program to ensure that the input-output mappings are correct. This can rarely be done in an exhaustive fashion because of the number of possible combinations but equivalence partitioning and boundary points can reduce the work involved.

Equivalence partitioning is the process of identifying classes of input data and classes of output data which have common properties. For example, consider a program which is required to perform an action A if an input lies between 1 and 10 inclusive and an action B otherwise. Three input equivalence classes can be created, one for all inputs less than 1, one for all inputs greater than 10 and one for the inputs between 1 and 10 inclusive. Sample inputs from each class can then be tested rather than testing all of the possibilities

Clearly the values 1 and 10 themselves, along with 0 and 11 are particularly critical. They are the extremes of the three ordered sets used to define the partition classes. They are boundary points and should definitely be tested to make sure that the transitions from action A to action B and vice versa are, indeed, occurring at the correct places.

A further dynamic testing technique is **structural testing**. This requires that each branch of the code is executed at least once during testing.

Finally, **acceptance testing** is essential. This is testing the system in the environment in which it will operate.

How many of these tests appear to have been used in the Robbie CX30 project?

6.3 Usability

Probably the most succinct guidance you can receive on usability is the **Eight Golden Rules** (Shneiderman 1998):

1. Strive for consistency
2. Enable frequent users to use shortcuts
3. Offer informative feedback
4. Design dialogues to yield closure (the user should know when it has ended)
5. Offer simple error handling
6. Permit easy reversal of actions
7. Support internal locus of control (the user should feel in control)
8. Reduce short-term memory load (do not overload user)

These rules ought to be fairly self-explanatory but you should also have received some explanation of them in your tutorial group whilst you were working on Coursework Submission A.

Two further ideas which can be very effective are **metaphors** and **mental models** (Preece et al. 1994).

A metaphor is a figure of speech in which the name of one thing (or some kind of representation of it) is applied to another thing. Probably the most famous metaphor found in user interfaces is the icon of a rubbish bin onto which files can be dragged and dropped in order to delete them. Without even thinking we know, from our everyday experience of real rubbish bins, just what that icon means. Metaphors do need to be obvious though. Straining to create metaphors is pointless. Brilliant flashes of inspiration lie behind good metaphors and rarely hours of hard work.

Mental models are models of the users themselves which are held in the system. They are generally built up over the course of many interactions with a user. Good mental models can help in the prediction of a user's needs and/or goals. Many benefits can result from this ranging from providing an appropriate level of help through to starting tasks up in advance of the user actually requesting them.

6.4 Summary and Assessment

At this stage you should be able to

- Outline the role of quality assurance departments
- Explain the importance of system testing
- Identify the sorts of things that can and should be tested
- Explain the different types and levels of testing possible
- Discuss the importance of usability issues
- Describe some key concepts in user interface design

End of topic test

5 min

Q1: One of the most serious charges that can be brought against a system is

a) Inefficient coding
b) Platform dependence
c) Poor testing
d) Too expensive

Q2: Which of the following was NOT cited as a means of assuring correct functioning ?

a) Carefulness
b) QA procedures
c) Static and dynamic testing
d) Verification and validation

Q3: "House" styles do NOT cover

a) Code comments
b) Documentation formats
c) Dress sense
d) Metrics

Q4: A test of whether a system satisfies its requirements is

a) Black box
b) Validation
c) Verification
d) White box

Q5: Static testing CANNOT be used to check

a) Arithmetic
b) Logic
c) Semantics
d) Syntax

Q6: Equivalence partitioning is used in testing techniques which are

a) Black box
b) Static
c) Structural
d) White box

Q7: Which of the following was NOT one of Shneiderman's 8 golden rules?

a) Enable frequent users to use shortcuts
b) Offer informative feedback
c) Offer customisable desktops
d) Reduce short-term memory load

Q8: A metaphor is

a) A figure of speech
b) An icon
c) A name
d) A rubbish bin

Q9: Metaphors are the result of

a) Artificial intelligence
b) Hard work
c) Inspiration
d) Plagiarism

Q10: Mental models CANNOT assist in

a) Modelling users
b) Providing help
c) Starting tasks
d) Visualisation

6.5 Coursework Submission 6

Coursework Submission 6

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. **Submit Coursework Submission B** if you have not already done so.
2. Read "The Case of the Killer Robot" Article 9 (Epstein 1997 or Taylor 2002) before embarking on Topic 7.
3. Each member of your tutorial group is to research a *different* topic from the list below. They all relate to historical computing devices and this chronology will be brought up to the present day in Topic 8. If you are the first tutee on the group list then you are to research the first topic; if the second on the list then the second topic; and so on. You should prepare a **presentation** on your assigned topic in time for delivery at your next tutorial. The presentations will be spread over the last 2 tutorials in order to give each of you about **7 minutes** for your presentation followed by questions from the rest of your tutorial group. This presentation is **Coursework Submission C**.

Assigned Topics 19 - 27

Napier’s Bones	1st Tutee
Pascaline	2nd Tutee
Multiplier Wheel	3rd Tutee
Difference & Analytical Engines	4th Tutee
Tabulating Machine	5th Tutee
Z1-Z4	6th Tutee
Colossus	7th Tutee
ENIAC/EDVAC	8th Tutee
EDSAC	9th Tutee

6.6 References

Epstein, R.G., 1997, *The Case of the Killer Robot*. John Wiley & Son.

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Taylor, N.K., 2002, The Killer Robot [online]. Heriot-Watt University (MACS), 16th December 2002 [cited 7th July 2003]. SHTML. Available from:

http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 7

Ethics and Culpability

Contents

Learning Objectives

- *Appreciation of the distinction between incompetence and impropriety*
- *Awareness of the existence of different moral systems and principles*
- *Familiarity with the stakeholder approach to ethical decision making*
- *Familiarity with some popular tests of ethicality*
- *Awareness of the distinction between moral and legal responsibility*
- *Experience in thinking through a complicated legal case*

For such actions as are prejudicial to the interests of others, the individual is accountable... (Mill 1859)

7.1 Right and wrong

You should have read Article 9 of "The Case of the Killer Robot" before starting on this topic. In that article Harry Yoder draws attention to the blurred boundaries between legal, technical and ethical issues. Well, the law is the law and ignorance of it is not normally accepted as a defence

The boundary between technical and ethical issues is nothing like as clear cut however. If something goes wrong with a piece of technology, due to a design flaw say, it might simply be a result of incompetence or it might be due to some form of impropriety. The former, although possibly very unfortunate, would not lead us to doubt the morals of the people involved in the way that the latter would. Of course, the incompetence itself might be the result of some morally dubious choice on somebody's part. For instance an employee taking a cavalier attitude to their work or an employer employing an underqualified friend in a skilled position.

We tend to ascribe great importance to the motives for an action when trying to decide whether it was morally right or wrong. You should note, however, that not all moral systems take this attitude. Objectivists hold that actions are good or bad in and of themselves and the intentions behind them therefore become irrelevant. Egoists argue that everybody should put their own self-interest before all else and have little interest in any other motives.

7.2 Ethical decision making

Kallman and Grillo (1993) suggested a very useful approach to making ethical decisions - whether this be to determine the morality of somebody else's actions or to help determine an ethical course of action to follow yourself. Their approach is to list all of the stakeholders in the decision.

Anybody who might be affected, either positively or negatively, by the choice being made should be given proper consideration. Stakeholders are not always easy to identify - some are only affected very indirectly. It can be helpful to tabulate the options and the stakeholders, noting the effect of each option upon each stakeholder.

Kallman and Grillo also produced a collection of useful tests which we extend slightly for presentation here:

The Golden Rule
Treat others as you would have them treat you.

Other Person's Shoes Test
Does what you are proposing treat others as you would have them treat you if you were in their position rather than yours (cf The Golden Rule).

Legality Test
Is what you are proposing legal?

Smell Test
Does what you are proposing smell right?

Parent Test
Would you tell your parents what you are proposing?

Media Test
Would you be happy for the media to find out what you are proposing?

Market Test
Is your proposed course of action such a good thing that you could actually sell it?

Always identify the important stakeholders and the key facts of a situation. It can help to write them down. Clarify the options open to you. Apply as many tests to each option as you feel are appropriate and consider the impact on the various stakeholders. Do this and you are unlikely to be accused of not giving due consideration to the consequences of your decisions.

An ethical analysis might help us to decide who was morally responsible for the fatal accident in the case study but it might not tell us whose actions actually caused it. We shall now look at who might be considered culpable, or legally to blame.

7.3 Culpability in the case study

"The Case of the Killer Robot" presents us with a smoking gun in the form of the death of Bart Matthews but who or what pulled the trigger?

We are told very little about the client company, Cybernetics Inc., in the case study but the fatal accident occurred on their premises during the course of Bart Matthews' employment with them. We might have more to go on at Silicon Techtronics but we must not overlook the part played by Cybernetics Inc. in our haste to rifle through all that Robbie CX30 project team material.

Cybernetics Inc. and Silicon Techtronics and their employees can both be assessed in terms of the people and methods employed and the culture of their organisations. We can tabulate this:

	Cybernetics Inc.	**Silicon Techtronics**
People	Management Staff trainers Installation engineers Machine operators Maintenance personnel	Management Development team Individual developers Quality assurers
Methods	Training regimes Safety practices Installation procedures Live testing Maintenance procedures	Management methods Development methods Programming methods Programming language Quality assurance
Culture	Technological familiarity "Safety first" Pressure	Leadership Team spirit Pride in job "Safety first" "Ivory snow theory" Pressure

In ascertaining where the blame is to be placed we should investigate each item in the table and not just stop at the first one that reveals a cause. There are likely to be many causes.

We know there was a bug in the control software written by Randy Samuels. Why was it not picked up during testing? Was Cindy Yardley to blame? Would the bug even have occurred if a different programming language or development methodology had been used? Was Sam Reynolds to blame? Was the "Ivory snow theory", and hence Ray Johnson, to blame? Should the system have failed to safety anyway, as a "safety first" policy would require? Should the user interface have permitted a more rapid emergency stop procedure? Was Bart Matthews up to the job? Was he himself to blame? Should he have been given better training?

The physical realisation of the system was a shared responsibility of both companies and included things like the installation environment, the hardware configuration and the safety mechanisms. Were these adequate? What about the pressure that both companies were under, did this lead to short-cuts being taken?

You probably see where we are heading now. You are not going to get a clear-cut answer from me. Take some time to think about these matters and see if you can form an opinion for yourself.

7.4 Summary and Assessment

At this stage you should be able to:

- Outline the distinction between incompetence and impropriety
- Identify different moral systems and principles
- Explain the stakeholder approach to ethical decision making
- Describe some popular tests of ethicality
- Explain the distinction between moral and legal responsibility
- Identify pertinent facts in a complicated legal case

End of topic test

5 min

Q1: We generally ascribe importance to what when making moral judgements?

a) Actions
b) Costs
c) Motives
d) Risks

Q2: People or organisations who should be considered in an ethical analysis are?

a) Clients
b) Stakeholders
c) Troublesome
d) Victims

Q3: The Golden Rule is

a) Do not put off until tomorrow what you can do today
b) One man's meat is another man's poison
c) Too many cooks spoil the broth
d) Treat others as you would have them treat you

Q4: Which of the following was NOT suggested as a test of ethicality?

a) Legality
b) Parent
c) Smell
d) Taste

Q5: Culpable means to be at fault in what sense?

a) Commercial
b) Ethical
c) Legal
d) Religious

Q6: How many causes can be identified for Bart Matthews' death?

a) Many
b) None
c) One
d) Two

Q7: How pure is ivory snow ?

a) 99.33%
b) 99.44%
c) 99.55%
d) 99.66%

Q8: Cindy Yardley worked as a?

a) Interface designer
b) Professor of Ethics
c) Programmer
d) Software tester

Q9: Ray Johnson was?

a) CEO of Silicon Techtronics
b) Chief of the Robotics Division
c) Professor of Computer Science
d) Project Manager of Robbie CX30 team

Q10: The physical realisation of the Robbie CX30 installation did NOT include

a) Bart Matthews
b) Hardware configuration
c) Installation environment
d) Safety mechanisms

7.5 Coursework Submission 7

Coursework Submission 7

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework.

1. Think about the issues involved in determining who was at fault in "The Case of the Killer Robot". Were the actions of all concerned understandable? Could they be defended? Should the blame be shared or does it fall on one particular individual or organisation in your opinion?

2. Make sure you attend the second set of presentations on historical computing devices even if you have already made your own presentation. These talks provide the background to Topic 8.

Assigned Topics 19 - 27

Napier’s Bones	1st Tutee
Pascaline	2nd Tutee
Multiplier Wheel	3rd Tutee
Difference & Analytical Engines	4th Tutee
Tabulating Machine	5th Tutee
Z1-Z4	6th Tutee
Colossus	7th Tutee
ENIAC/EDVAC	8th Tutee
EDSAC	9th Tutee

7.6 References

Epstein, R.G., 1997, *The Case of the Killer Robot*. John Wiley & Son.

Kallman, E.A. & Grillo, J.P., 1993, *Ethical Decision Making and Information Technology*. McGraw-Hill.

Mill, J.S., 1859, *On Liberty*. Penguin Books, 1985 edition.

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http://www.macs.hw.ac.uk/~nkt/praxis/epstein/index.sht

Topic 8

Architectures and Organisation

Contents

Learning Objectives

- *Appreciation that computers do not have to be digital, sequential and electronic*
- *Awareness of the existence of a theoretical discipline of computer science*
- *Familiarity with computer architectures of the past*
- *Appreciation of computer architectures of the present*
- *Experience in thinking about the development of computer technology*

Consider the past and you shall know the future. (Proverb of Chinese origin)

8.1 The essence of computing

So far in this unit we have been concerned with the software that runs on computers and how it is produced. We shall now take a look at the hardware but before doing so we should heed the fact that we have been able to ignore the hardware thus far.

It is all too easy to make the mistake of thinking of computers only in terms of the digital, sequential, electronic machines we use today. Whilst the early machines which you have been looking into were much less powerful than modern computers, they do show that the science of computing has a separate existence to the hardware that is used to implement it. Certainly, the hardware of the day imposes practical restrictions on what is possible and which cannot be ignored, but might there be some idealised theoretical device, set free from these hardware limitations, about which issues of computation could be discussed and analysed unfettered by the physical mechanisms available at a given time?

Indeed there is and there is also a growing corpus of theoretical results in computer science which are totally independent of hardware issues. Nor is this a new field, for it has its origins back in 1936 when Alan Turing developed a theoretical device which has since become known as the Universal Turing Machine (Turing 1936). Using this abstract artefact it is possible to investigate the really big questions in computer science such as what can be computed and what cannot - ever.

Information Technology might be a child of digital, sequential, electronic computers but it will outlive them and there are new hardware avenues opening up which we must be ready to embrace.

8.2 Yesterday's computers

You have already investigated or attended presentations on a number of historical computing devices. We shall briefly fill in some of the gaps here.

8.2.1 The mechanical age

Probably the most successful of the mechanical calculators was De Colmar's *Arithmometer* which was built to perform insurance calculations in about 1820. Versions of this device continued to be produced well into the 20th century.

The idea of a difference engine was first presented by Johann Muller in 1784, a German master builder. It is not clear whether Charles Babbage was aware of Muller's design but he was aware of the work of Alfred Deacon, another British designer of difference engines working in the early 19th century, and this may have informed Babbage's work.

Charles Babbage actually designed three difference engines in addition to the Analytical

Engine. Most people are unaware of the earliest one, which this author has elsewhere dubbed *Difference Engine No. 0* (Taylor 1992), but it is significant in being the only machine that Babbage actually built. It was completed in 1822 and demonstrated to the Astronomical Society in London.

At the same time as Babbage was working on his designs, a father and son team from Sweden, Georg and Edvard Scheutz, were building machines based on simplified designs of Babbage's Difference Engine No. 1. The Scheutzes produced three difference engines in total - one prototype (1843) and two others which were sold to the Dudley Observatory in Albany, USA (1853) and the General Register Office in London (1859).

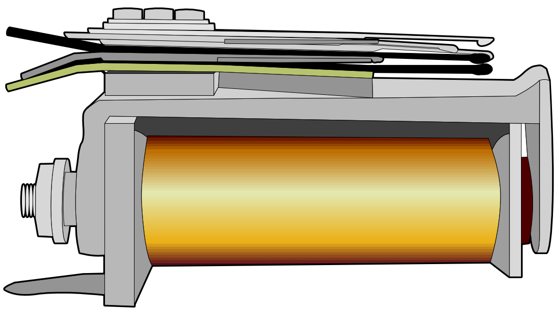
Other developers of difference engines include another Swede Martin Wiberg in 1860 and the American Barnard Grant in 1876 (Swade 1991).

8.2.2 The electro-mechanical age

The 20th century saw the advent of general purpose computing devices. The key ingredient in a truly general purpose computer is the ability to change the course of a series of calculations depending on the data being processed. Babbage's Analytical Engine would have been able to do this but only to a very limited degree.

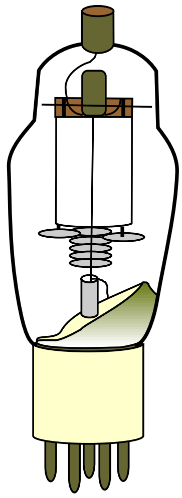
The importance of switching devices in the development of computing machinery has meant that the history of computers has sometimes been called the history of "switchology".

8.2.2.1 Relays



Konrad Zuse's Z1-Z4 machines (1934-45) and the Harvard Mark I (due to Howard Aiken in 1944) used electro-magnetic relays as their switches. This continued dependence on mechanical components meant that the machines remained large and unreliable (as well as rather noisy!).

8.2.2.2 Valves

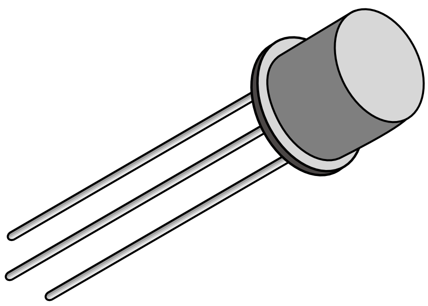


At Bletchley Park in 1943, Colossus (due to Flowers, Broadhurst and Chandler) became the first computer to use thermionic valves. In 1946 ENIAC (due to Mauchly and Eckert) became the first totally electronic computer. It inspired the design of EDVAC which incorporated the idea of storing the program as data within the computer and organising the central processing unit in a particular way (von Neumann 1945). The stored program computer, or **von Neumann architecture**, was born and led to the development of the Manchester Mark I (due to Kilburn and Williams), EDSAC (due to Wilkes), the UNIVAC 1 (Mauchly and Eckert) and nearly all modern-day computers. For this reason, these machines are called **first generation** computers.

8.2.3 The electronic age

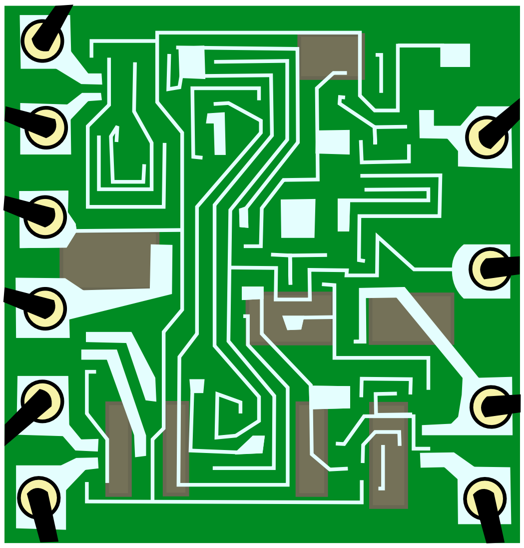
Valves too were unreliable devices and would bring computers crashing to a halt every few minutes but the next development in switchology was just around the corner.

8.2.3.1 Transistors



In 1947 Bardeen, Brattain and Shockley of Bell Labs invented the transistor. This device which was smaller, cheaper, faster and more reliable than the valve ushered in the second generation of computers.

8.2.3.2 Integrated circuits

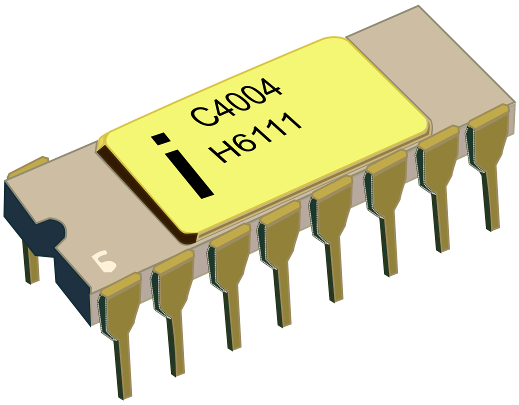


In 1958 Robert Noyce of Fairchild Semiconductor and Jack Kilby of Texas Instruments independently developed the integrated circuit, a semiconductor chip with a number of transistors packed onto it. The switch had just become even smaller, faster and cheaper. The integrated circuit, or silicon chip, became the **third generation** of computers. Noyce went on to become a co-founder of Intel Corporation.

8.3 Today's computers

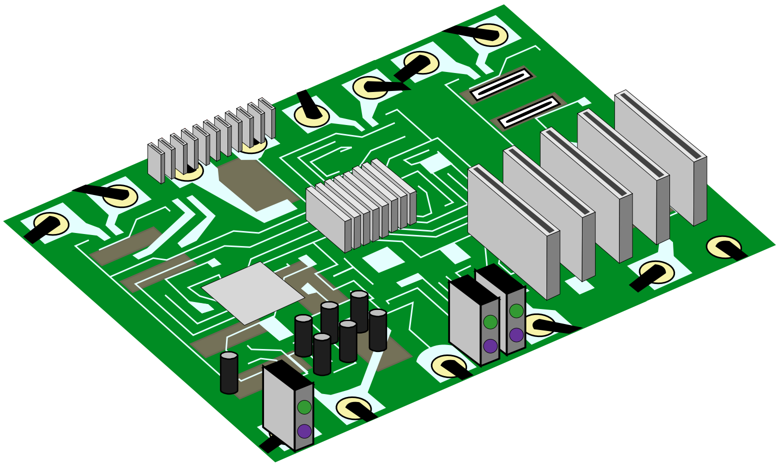
One further development was necessary to bring us to the familiar computer architecture of today. This was the microprocessor.

8.3.1 Microprocessors



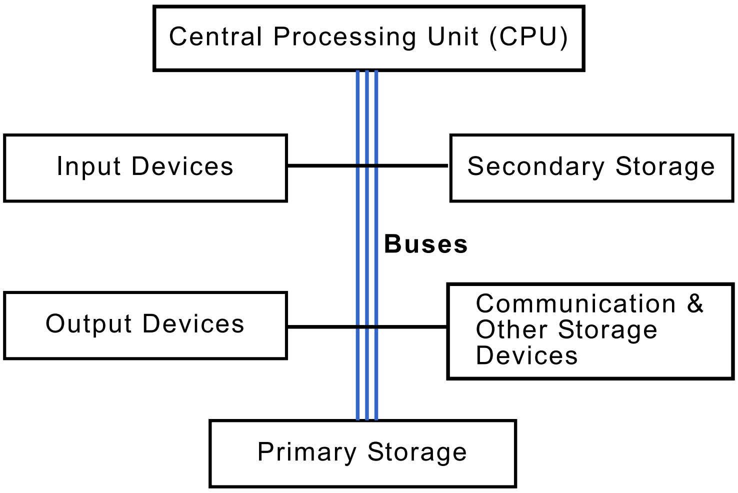
In 1971 the Intel 4004 was announced. It was a complete computer on a single silicon chip. The microprocessor is often referred to as the **fourth generation** of computers but it should be noted that it is considerably more than just another piece of "switchology".

8.3.1.1 Personal computers



In 1975 the Altair 8800, the first microcomputer, was launched. This was the first of the machines which we now call personal computers or PCs.

A typical PC consists of a Central Processing Unit (CPU) and assorted input, output and storage devices.



The CPU has a von Neumann architecture and consists of a Control Unit, an Arithmetic and Logic Unit (ALU) and various Registers. The Control Unit can load values into the Registers for processing by the ALU and also use the values stored in the Registers to address memory locations.

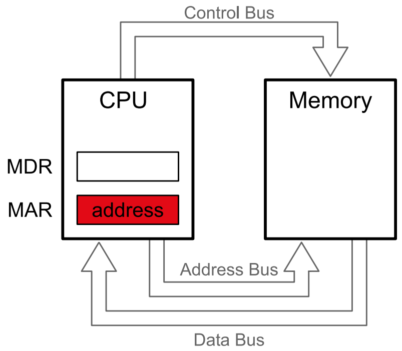
Input devices are used to enter information and include such things as keyboards, mice, joysticks, tablets and touch-sensitive screens. Output devices are monitors, printers, speakers and removable storage media.

Primary storage is Random Access Memory (RAM) which is volatile and requires a power source to maintain what is held. Secondary storage is non-volatile and does not need power to retain information. Hard disks are the most common form of secondary storage. Other storage devices include external disk drives, DVDs, etc.

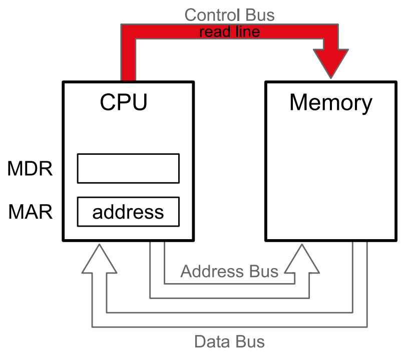
Communication devices cover things like network communication ports and modems. All of these components are linked within the PC by means of buses which can transmit data at very fast rates.

The following animation demonstrates a CPU using two registers (the Memory Address Register and the Memory Data Register) to fetch a data item from a particular address in primary memory for processing.

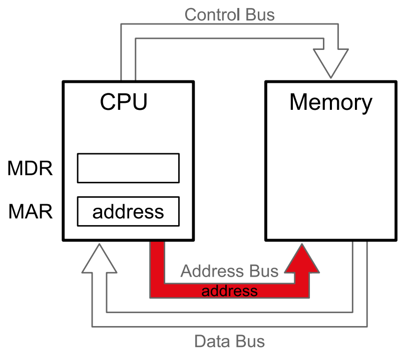
The Memory address to be read is placed in the Memory Address Register.



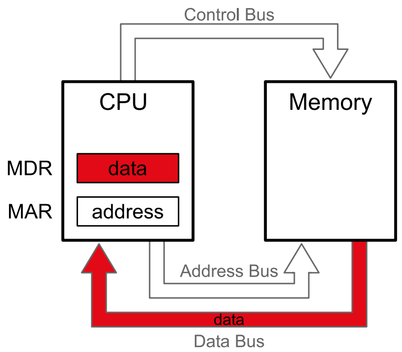
The read line of the control bus is activated.



The address is sent along the Address Bus to the memory.



Then the data is returned along the Data Bus to the CPU and is placed in the MDR.



8.3.2 Parallel processors

The computers we have been looking at up to now have been sequential. They perform one instruction after another. Parallel processors perform many instructions simultaneously using computer architectures which contain multiple processors. Credit for the first computer which used parallelism should probably go to the Gamma 60 developed by the Compagnie des Machines Bull in 1958. The first machine with a highly parallel architecture was the Illiac IV conceived by Daniel Slotnick in 1965 and built by Burroughs in 1974. Parallel processing can take two main forms; SIMD and MIMD.

8.3.2.1 SIMD

Single Instruction Multiple Data (SIMD) machines apply the same instruction to many items of data simultaneously. Also known as array processors, they are particularly useful when the same operation is required to be applied to many values. For example, multiplying a collection of fractions by 100 to turn them into percentages.

8.3.2.2 MIMD

Multiple Instruction Multiple Data (MIMD) machines also work on multiple data items but permit each one to have a different instruction applied to it. They are much more versatile than SIMD machines and allow computational tasks to be broken down into sub-tasks which, as long as they are independent of each other, can be carried out simultaneously by different processors.

8.3.2.3 Pipelining

Pipelining maximises the speed at which the same sequence of instructions can be applied to many items of data. This sort of processing is quite common. Each processor is allocated one of the instructions to perform and the data is pipelined from one processor to another in a stream. In a MIMD computer with, say, 5 processors, the first data item is presented to the first processor and processed, no gain over a sequential machine so far. The result of this processing is then passed to the second processor which then performs its operation. Meanwhile, back at the first processor, and at the same time, the second data item is being processed in accordance with the first instruction. By the time the fifth data item has been presented to the first processor all of the processors are busy performing their own operation on a different data item in parallel.

8.4 Tomorrow's computers

It is likely that the electronic computer will serve us well for some time to come. In 1965 Gordon Moore of Intel predicted that the number of transistors per integrated circuit would double every 18 months. He expected his prediction to hold for no more than a decade. Nearly 40 years on *Moore's Law*, as it has come to be called, remains valid and chips running at Terahertz speeds have been produced.

However, other possible architectures for computer design are now appearing on the horizon. It is possible that switchology will move on from the electronic age into an opto-electronic, chemical or even biological age. Some of these developments will take us beyond the traditional von Neumann architecture into a world of analogue and parallel computers and some will even leave switchology itself in their wake.

8.4.1 Optical computers

One of the limitations of integrated circuits is that electrical connections cannot cross each other without short-circuiting, even in semiconductors. If the circuits were carrying coherent rays of light instead of electrical impulses this would not be a problem. This is one reason why there has been much research into the development of optical computers.

8.4.2 Nanocomputers

The development of a scanning tunnelling microscope by researchers at IBM has made it possible to see and also manipulate individual atoms. This has opened up the possibility of creating nanocomputers whose switches are on an atomic scale rather than the molecular scale of current semiconductor devices. See Drexler (1992) for coverage of the whole field of nanotechnology.

8.4.3 Biocomputers

Developments in biology and genetics are also providing many new ideas for biocomputing machinery in the future. Biological phenomena such as ligand bonding, enzymes and DNA have the potential to offer much more than just another form of switch. See Kaminuma and Matsumoto (1991) for a more detailed coverage of biocomputers.

8.4.4 Quantum computers

Finally, we should mention quantum computers. Quantum theory suggests that it might be possible to produce computers that work with *qubits*, or quantum bits, as opposed to normal bits (Deutsch 1985). These are bits which are, at one and the same time, both *0 and 1*, not *0 or 1*. They are in a superposition of the two states *0* and *1* and only when they are examined does the superposition collapse and the qubit become either a *0* or a *1*. This offers the possibility of carrying out many computations simultaneously (on all of the combinations of a number of superpositioned qubits for instance) and algorithms have already been developed for factorisation and searching.

8.5 Summary and assessment

At this stage you should be able to:

- Explain that computers do not have to be digital, sequential and electronic
- Outline the existence of a theoretical discipline of computer science
- Describe computer architectures of the past
- Detail computer architectures of the present
- Outline the development of computer technology

End of topic 8 test

Q1: Modern day computers are NOT

a) Digital
b) Electronic
c) Mechanical
d) Sequential

Q2: The Universal Turing Machine is

a) Analogue
b) Electronic
c) Optical
d) Theoretical

Q3: The most successful mechanical calculator was probably

a) Arithmometer
b) Multiplier Wheel
c) Napier's Bones
d) Pascaline

Q4: The transistor was NOT invented by

a) Bardeen
b) Brattain
c) Kilby
d) Shockley

Q5: In comparing valves to transistors, valves were

a) Cheaper
b) Faster
c) Less reliable
d) Smaller

Q6: The microprocessor is often regarded as which generation of computer

a) First
b) Fourth
c) Second
d) Third

Q7: A CPU uses what to store values

a) ALU
b) Buses
c) Diskettes
d) Registers

Q8: MIMD machines process

a) Atomic data
b) Multiple data
c) Quantum data
d) Single data

Q9: Biocomputers would NOT use

a) DNA
b) Enzymes
c) Ligand bonds
d) Schrodinger's cat

Q10: A superposition would be found in a

a) Nanocomputer
b) Quantum computer
c) SIMD machine
d) Transistor

8.6 Assigned task

Assigned task

Think about the future possibilities for computer architectures.

8.7 References

Deutsch, D., 1985, ’Quantum Theory, the Church-Turing Principle and the Universal Quantum Computer’, *Proceedings of the Royal Society of London A*, 400, pp. 97-117.

Drexler, K.E., 1992, *Nanosystems: Molecular Machinery, Manufacturing and Computation*. John Wiley & Son.

Kaminuma, T. & Matsumoto, G. (eds), 1991, *Biocomputers*, Chapman and Hall.

Swade, D., 1991, *Charles Babbage and his Calculating Engines*. Science Musem: London.

Taylor, N.K., 1992, ’Charles Babbage’s Mini-Computer - Difference Engine No. 0’, *IMA Bulletin*, **28** (6), pp. 112-114.

Turing, A.M., 1936, ’On Computable Numbers, with an application to the Entscheidungsproblem’, *Proceedings of the London Mathematical Society*, Series 2, **42**, pp. 230-265.

von Neumann, J., 1945, ’First Draft of a Report on the EDVAC’, Moore School of Engineering, University of Pennsylvania.

Topic 9

Coursework Submission

Contents

Please refer to the Student Guide to Plagiarism before you complete and submit your coursework

There are three formal assessments, each carrying on-third of the marks for the unit.

The first two assignments are 1000 work essays and should be submitted at the tutorials associated with Topics 3 and 5 (but at the very latest, before the tutorials associated with Topics 4 and 6).

Prompt feedback will be provided on the first assignment to inform the students' production of the second one.

The third assignment is a formal presentation which each tutee makes to the rest of their group in one of the last two tutorials (those associated with Topic 6 and 7). About half of the group should present on each occasion. These presentations will be assessed by the tutor.

Your tutor will provide you with further details of the coursework. Guidance on the submissions is given at sections 1.8, 2.7, 3.7, 4.5, 5.6, 6.5 and 7.5 in the materials.

Answers to questions and activities

1 Introduction

End of topic 1 test (page 8)

Q1: d) 1975

Q2: d) Power

Q3: d) Research findings

Q4: d) Understanding with knowledge

Q5: c) Intelligence

Q6: a) Catalogue

Q7: b) Newspapers

Q8: c) Transient

Q9: a) Access date

Q10: a) Richard Epstein

2 Reporting Information

End of topic 2 test (page 17)

Q1: a) Abstract

Q2: c) Loose ends

Q3: c) Isaac Newton

Q4: c) Publisher

Q5: d) Theft

Q6: c) 1 and 10

Q7: b) Short

Q8: c) Projections

Q9: d) Font variety

Q10: b) King

3 The Case of the Killer Robot

End of topic 3 test (page 25)

Q1: b) Longer

Q2: c) Hiram Milton

Q3: a) Budgeting and financial control

Q4: d) You

Q5: b) An industrial manipulator

Q6: a) An end effector

Q7: a) Isaac Asimov

Q8: d) User friendliness

Q9: b) Can cause great damage

Q10: c) More common

4 Analysis and Specification

End of topic 4 test (page 33)

Q1: a) Their business

Q2: d) The client knows what they want

Q3: d) Understanding

Q4: a) Boundaries

Q5: d) Systems it interacts with

Q6: d) Probably as many as there are people involved with it

Q7: c) Data processor

Q8: b) Implementation details

Q9: d) Itemised functions

Q10: a) Development

5 Design and Development

End of topic 5 test (page 43)

Q1: d) Winding up

Q2: b) Creative

Q3: d) Sequentiality

Q4: a) Bottom-up design

Q5: c) Procedures

Q6: a) Fellow tutees

Q7: c) System & unit

Q8: c) Programming language

Q9: c) Have different skills

Q10: c) Monitor

6 Testing and Usability

End of topic test (page 51)

Q1: c) Poor testing

Q2: a) Carefulness

Q3: c) Dress sense

Q4: b) Validation

Q5: a) Arithmetic

Q6: a) Black box

Q7: c) Offer customisable desktops

Q8: a) A figure of speech

Q9: c) Inspiration

Q10: d) Visualisation

7 Ethics and Culpability

End of topic test (page 59)

Q1: c) Motives

Q2: b) Stakeholders

Q3: d) Treat others as you would have them treat you

Q4: d) Taste

Q5: c) Legal

Q6: a) Many

Q7: b) 99.44%

Q8: d) Software tester

Q9: b) Chief of the Robotics Division

Q10: a) Bart Matthews

8 Architectures and Organisation

End of topic 8 test (page 72)

Q1: c) Mechanical

Q2: d) Theoretical

Q3: a) Arithmometer

Q4: c) Kilby

Q5: c) Less reliable

Q6: b) Fourth

Q7: d) Registers

Q8: b) Multiple data

Q9: d) Schrodinger's cat

Q10: b) Quantum computer