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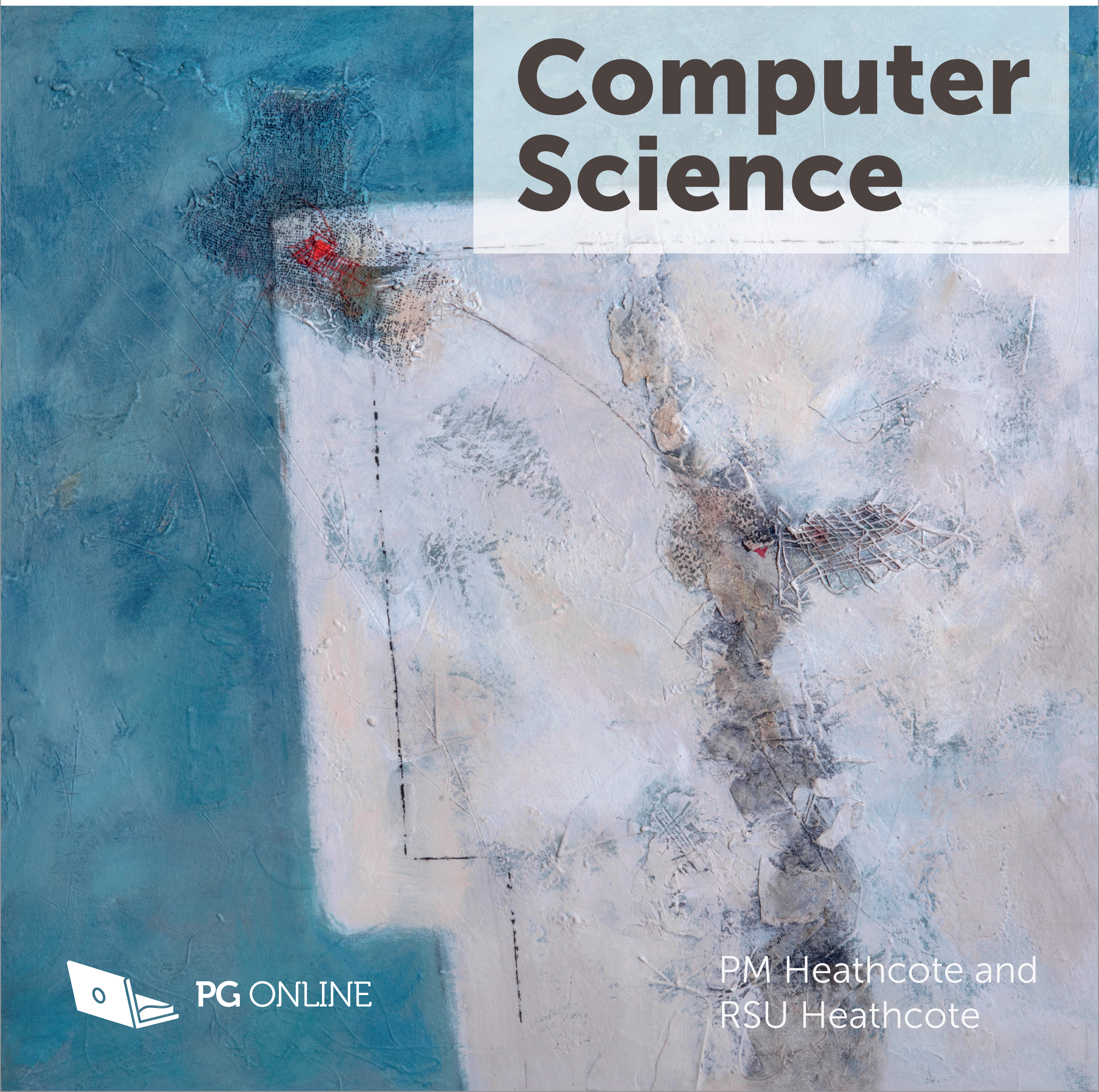
OCR AS and A Level

Computer Science



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Chapter 4 – Input devices

Objectives

- Describe different input devices
- Explain how different input devices can be applied as a solution to different problems

Barcodes

Barcodes first started appearing on grocery items in the 1970s, and today they are used for identification in thousands of applications from tracking parcels, shipping cartons, passenger luggage, blood, tissue and organ products around the world to the sale of items in shops and the recording of the details of people attending events. Keeping track of anything accurately is now almost unimaginable without barcodes.

A handheld barcode scanner used for scanning medical samples

There are two different types of barcode: Linear barcodes such as the one shown above and 2D barcodes such as the Quick Response (QR) code, which can hold more information than the 1D barcode.

A 2D barcode

2D barcodes are used for example in ticketless entry to concerts, or access through gates to board a Eurostar train or passenger airline. They are also used in mobile phone apps that enable the user to take a photo of the code which may then provide them with further information such as a map of their location, product details or a website URL.

Barcode readers

There are four different barcode readers available, each using a slightly different technology for reading and decoding a barcode. The four types are pen-type readers, laser scanners, CCD readers and camera-based readers.

A-Level only

The statements `input(radius)`

`area = pi * radius * radius`

could be 'tokenised' and stored as the lexical string 1 3

5 4 2 7 3 7 3

Q2: What further entries to the symbol table will the lexical analyser make on encountering the statement

```
circumference = 2 * pi * radius
```

Add the entries to the symbol table and then tokenise the statement.

Note that the lexical analyser puts the identifier and its run-time address in the symbol table, so that it can replace them in the source code by 'tokens'. It will not fill in the 'kind of item' and 'type of item'; this is done later by the **syntax analyser**.

Accessing the symbol table

Since the lexical analyser spends a great proportion of its time looking up the symbol table, this activity has a crucial effect on the overall speed of the compiler. The symbol table must therefore be organised in such a way that entries can be found as quickly as possible. The most common way of organising the symbol table is a **hash table**, where the keyword or identifier is 'hashed' to produce an array subscript. As with any hash table, synonyms (collisions) are inevitable, and a common way of handling them is to store the synonym in the next available free space in the table.

Syntax analysis and semantic analysis

Syntax analysis is the process of determining whether the sequence of input characters, symbols, items or tokens form a valid sentence in the language. In order to do this, the language has to be expressed as a set of rules, using for example **syntax diagrams** or **Backus-Naur** form.

Parsing is the task of systematically applying the set of rules to each statement to determine whether it is valid. **Stacks** will be used to check, for example, that brackets are correctly paired. The priorities of arithmetic operators will be determined, and expressions converted into a form (such as **reverse Polish notation**) from which machine code can more easily be generated.

The **semantics** of the program will also be checked in this phase. **Semantics** define the meaning rather than the grammar of the language; it is possible to write a series of syntactically correct statements which nevertheless do not obey the rules for writing a correct program. An example of a semantic error is the use of an undeclared variable in Pascal, or trying to assign a **real** value to an **integer** variable, or using a real number instead of an integer as the counter in a **for … next** loop.

Q3: Give other examples of a semantic error.

Code generation and optimisation

This is the final phase of compilation, when the machine code is generated. Most high-level language statements will be translated into a number of machine code statements.

Code optimisation techniques attempt to reduce the execution time of the object program by, for example, spotting redundant instructions and producing object code which achieves the same net

The compression of sound and video works in a similar way. **MP3** files use lossy compression to remove frequencies too high for most of us to hear and to remove quieter sounds that are played at the same time as louder sounds. The resulting file is about 10% of original size, meaning that 1 minute of MP3 audio equates to roughly 1MB in size.

Voice is transmitted over the Internet or mobile telephone networks using lossy compression and although we have no problem in understanding what the other person is saying, we can recognise the difference in quality of a voice over a phone rather than in person. The apparent difference is lost data.

Lossless compression

Lossless compression works by recording patterns in data rather than the actual data. Using these patterns and a set of instructions on how to use them, the computer can reverse the procedure and reassemble an image, sound or text file with exact accuracy and no data is lost. This is most important with the compression of program files, for example, where a single lost character would result in an error in the program code. A pixel with a slightly different colour would not be of huge consequence in most cases. Lossless compression usually results in a much larger file than a lossy file, but one that is still significantly smaller than the original.

Q1: What type of compression is likely to be used for the following: a website image, a zipped file of long text documents and images, a PDF instruction manual?

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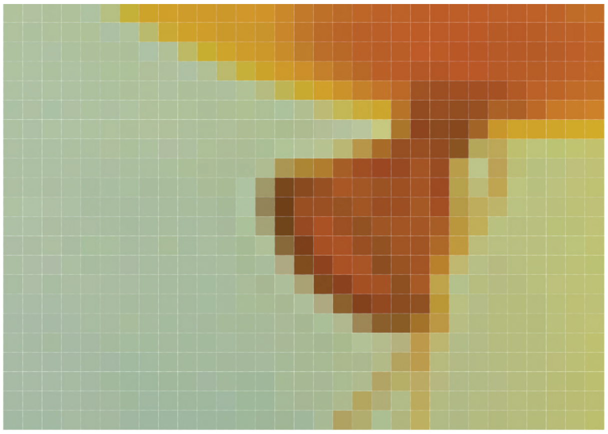
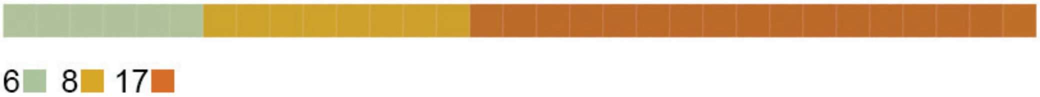
A-Level only

Run Length Encoding (RLE)

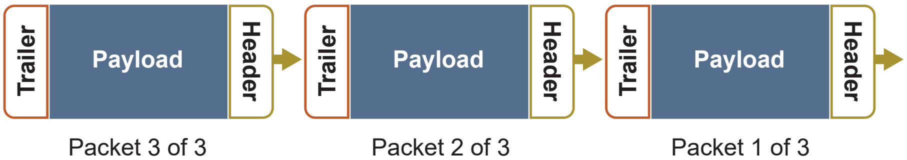
If you were ordering food from a takeaway restaurant for a group of five friends, it is likely that you might ask for "5 pizzas" rather than "one pizza, and another pizza, and another pizza etc." **Run Length Encoding** exploits the same principle. Rather than recording every pixel in a sequence, it records its value and the number of times it repeats.



For this section of the balloon image, the encoding for the first row might crudely translate to:
6 green, 8 yellow and 17 orange, using one binary value for the colour value and another for the number of contiguous matching pixels in the run. This would reduce the data necessary to store this row to 6 bytes (00000110 00000001 00001000 00000010 00010001 00000011) rather than 31 bytes assuming a bit depth of 8 and values for each colour of 00000001, 00000010 and 00000011.



The header (much like the box(es) of a consignment you might send or receive through the post) includes the sender's and the recipient's IP addresses, the protocol being used with this type of packet and the number of the packet in the sequence being sent, e.g. packet 1 of 8. They also include the **Time To Live** (TTL) or **hop limit**, after which point the data packet expires and is discarded.



Data packets queueing to be sent

Q1: Why is the sender's IP address included in the packet header?

The payload of the packet contains the actual data being sent. Upon receipt, the packets are reassembled in the correct order and the data is extracted.

Routing packets across the Internet

The success of packet switching relies on the ability of packets to be sent from sender to recipient along entirely separate routes from each other. At the moment that a packet leaves the sender's computer, the fastest or least congested route is taken to the recipient's computer. They can be easily reassembled in the correct order at the receiving end and any packets that don't make it can be requested again.

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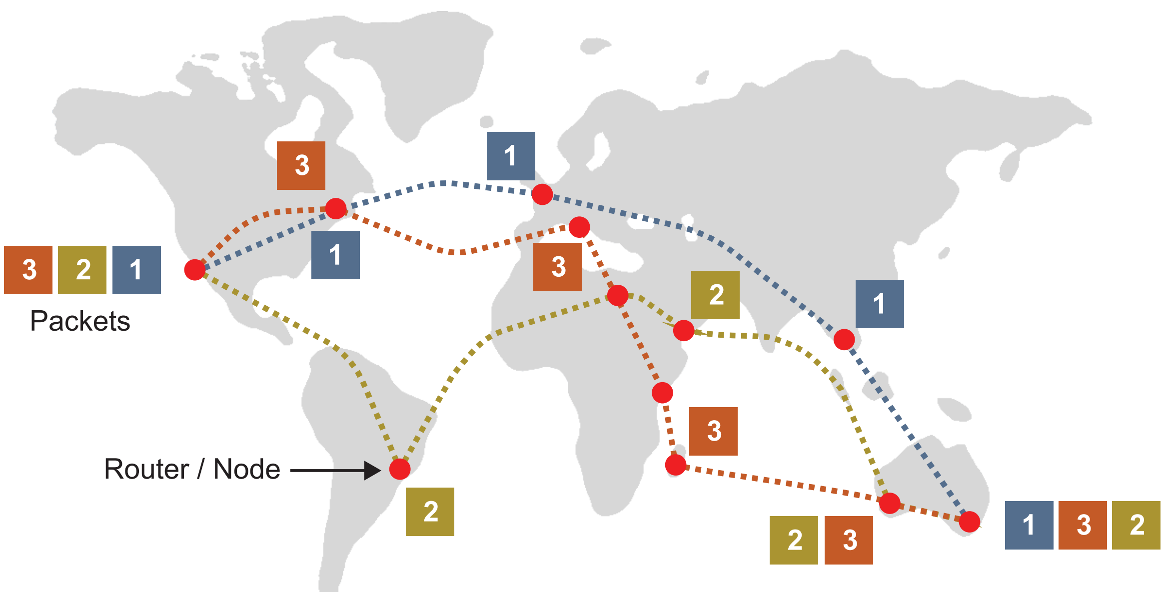


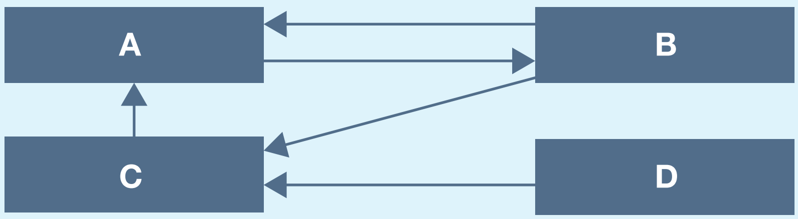
Q2: What information is included in the packet header to enable the receiving computer to reassemble packets in the correct order?

A-Level only

Example 2 shows the iterative process used to calculate and recalculate the PageRank (PR) of a group of webpages where the starting point is unknown.

Example 2

As the number of web pages grows, more complex link structures are created. After the addition of one extra web page, the PageRank is recalculated and adjusted to reflect the new pages and links.



First iteration: (Assumes a PR of 1 for each page where not known.)

d	$= 0.85$		
$PR(A)$	$= (1 - d) + d(PR(B)/2 + PR(C)/1)$	$PR(A)$	$= 0.15 + 0.85 * (0.5 + 1) =$ **1.425**
$PR(B)$	$= (1 - d) + d(PR(A)/1)$	$PR(B)$	$= 0.15 + 0.85 * 1.425 =$ **1.361**
$PR(C)$	$= (1 - d) + d(PR(B)/2 + PR(D)/1)$	$PR(C)$	$= 0.15 + 0.85 * (0.681 + 1) =$ **1.578**
$PR(D)$	$= (1 - d) + d(0)$	$PR(D)$	$=$ **0.15**

Second iteration: (Uses new PR figures from first iteration.)

d	$= 0.85$		
$PR(A)$	$= (1 - d) + d(PR(B)/2 + PR(C)/1)$	$PR(A)$	$= 0.15 + 0.85 * (0.681 + 1.578) =$ **2.07**
$PR(B)$	$= (1 - d) + d(PR(A)/1)$	$PR(B)$	$= 0.15 + 0.85 * 2.07 =$ **1.909**
$PR(C)$	$= (1 - d) + d(PR(B)/2 + PR(D)/1)$	$PR(C)$	$= 0.15 + 0.85 * (0.955 + 0.15) =$ **1.089**
$PR(D)$	$= (1 - d) + d(0)$	$PR(D)$	$=$ **0.15**

Third iteration:

d	$= 0.85$		
$PR(A)$	$= (1 - d) + d(PR(B)/2 + PR(C)/1)$	$PR(A)$	$= 0.15 + 0.85 * (0.955 + 1.089) =$ **1.887**
$PR(B)$	$= (1 - d) + d(PR(A)/1)$	$PR(B)$	$= 0.15 + 0.85 * 1.887 =$ **1.754**
$PR(C)$	$= (1 - d) + d(PR(B)/2 + PR(D)/1)$	$PR(C)$	$= 0.15 + 0.85 * (0.877 + 0.15) =$ **1.023**
$PR(D)$	$= (1 - d) + d(0)$	$PR(D)$	$=$ **0.15**

After three iterations, the PageRank of each page begins to settle. In reality many more iterations would be necessary before the figures stop moving, but three iterations get us close enough to understand the process and begin to see some results.

Page A now has a slightly higher ranking than B since it has another vote from page C. Page B has a higher rank than pages C and D because it has 100% of the votes from A, a high ranking page in itself. Page C has a comparatively moderate ranking since it has two inbound links from other pages that also have inbound links. C's vote from page D however is not given significant importance since page D has no inbound links and therefore has a low PageRank.

Q5: What factors may result in a web page A's rank rising or falling over time as it is revised?

A

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A-Level only

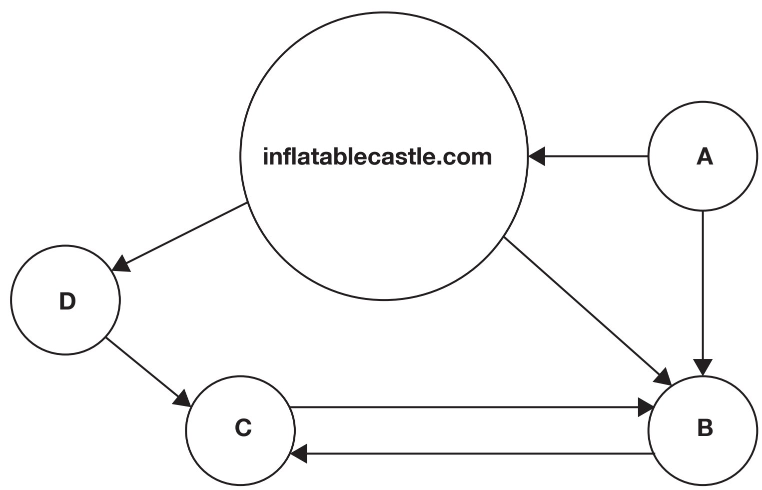
Exercises

1. The owner of website www.inflatablecastle.com is trying to improve the positioning of his homepage inflatablecastle.com/index.html in search engine listings.

   (a) Other than PageRank, give **three** design factors that may affect the company homepage's positioning in search results. [3]

   Google's PageRank algorithm *PR(A) = (1-d) + d (PR(T1)/C(T1) + ... + PR(Tn)/C(Tn))* calculates a ranking for each web page that has a significant bearing on search results.

   (b) With reference to the diagram below, explain which page is likely to have the highest PageRank. You are not expected to perform any calculations. [2]



   (c) Looking at the algorithm, what factors directly influence the PageRank of the homepage index.html at inflatablecastles.com? [2]

   (d) PageRank uses a damping factor d in its algorithm. Explain the purpose of *d*. [2]

2. Search engines provide a listing of all web pages with content relevant to a set of search terms.

   (a) Explain how search engines produce this list. [2]

   (b) With reference to the screenshot below, state which line of code contains metatags. [1]

   (c) Briefly explain the purpose of the meta description. [2]

```
1  <html>
2  <head>
3  <meta http-equiv="Content-Type" content="text/html; charset=utf-8">
4  <TITLE>Fossils</TITLE>
5  <META NAME="Keywords" CONTENT="dinosaur, lyme, regis, limestone,
   ammonite, bone, jurassic, strata, rock, geology, paleontology">
6  <META NAME="Description" CONTENT="Fossils are the preserved remains
   of animals or plants, commonly found embedded in sedimentary
   layers of rock.">
7  <head>
8  <body>
9  </body>
10 </html>
```

5-26

A

Q5: Why not simply leave the array element names[2] blank after deleting Ken?

First, items are moved up to fill the empty space by copying them to the previous spot in the array:

Holly	**James**	**Nathan**	**Paul**	**Sophie**	**Sophie**	

Finally the last element, which is now duplicated, is replaced with a blank.

Holly	**James**	**Nathan**	**Paul**	**Sophie**		

A-Level only

Linked lists

Definition

A linked list is a dynamic data structure used to hold an ordered sequence, as described below:

- The items which form the sequence are not necessarily held in contiguous data locations, or in the order in which they occur in the sequence
- Each item in the list is called a **node** and contains a **data field** and a next address field called a **link** or **pointer field** (the data field may consist of several subfields.)
- The data field holds the actual data associated with the list item, and the pointer field contains the address of the next item in the sequence
- The link field in the last item indicates that there are no further items by the use of a **null** pointer
- Associated with the list is a pointer variable which points to (i.e. contains the address of) the first node in the list

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Operations on linked lists

In the examples which follow we will assume that the linked list is held in memory in an array of records, and that each node consists of a person's name (the data field) and a pointer to the next item in the list.

We will explore how to set up or initialise an empty list, insert new data in the correct place in the list, delete an unwanted item and print out all items in the list. We will also look at the problem of managing the free space in the list.

A node record may be defined like this:

```
type nodeType
   string name
   integer pointer
endType

dim Names[0..5] of nodeType
```

Initialising a linked list

We need to keep two linked lists; one for the actual data, and one for the free space. When a new item is added, it is put in the node pointed to by `nextfree`. When a node is deleted, it is linked into the free space list.

Chapter 41 – Simplifying Boolean expressions

Objectives

A
- Use the following rules to derive or simplify statements in Boolean algebra:
  - o de Morgan's Laws
  - o commutation
  - o association
  - o distribution
  - o absorption
  - o double negation
- Write a Boolean expression for a given logic gate circuit, and vice versa

A-Level only

de Morgan's laws

Augustus de Morgan (1806-1871) was a Cambridge Mathematics professor who formulated two theorems or laws relating to logic. These laws can be used to manipulate and simplify Boolean expressions. Although his theoretical work had little practical application in his lifetime, it became of major significance in the next century in the field of digital electronics, in which TRUE and FALSE can be replaced by ON and OFF or the binary numbers 0 and 1.

8-41

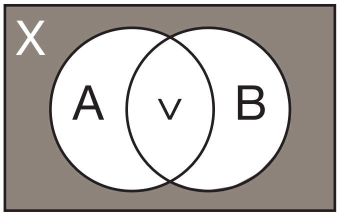
Using de Morgan's laws, any Boolean function can be converted to one which uses only NAND functions or only NOR functions, and these can be further converted to an expression using all NAND functions or all NOR functions.

Thus, any integrated circuit can be built from just one type of logic gate. This is an advantage in manufacturing where costs can be kept down by using only one type of gate.

de Morgan's first law

$$\neg(A \vee B) = \neg A \wedge \neg B$$

The truth of this is clear from the Venn diagram on the right. Suppose we have a variable X defined by



$$X = \neg(A \vee B)$$

Looking at the Venn diagram, A ∨ B is represented by the white area. Since X is not in A ∨ B, it consists of all the grey area. This can be defined as everything not in A and not in B, i.e.

$$X = \neg A \wedge \neg B$$

Q1: Complete the following truth table to show that $\neg(A \vee B) = \neg A \wedge \neg B$

A	B	¬A	¬B	A ∨ B	¬(A ∨ B)	¬A ∧ ¬B
0	0					
0	1					
1	0					
1	1					

A \ BC	00	01	11	10
0			1	1
1	1		1	1

Here, the group outlined in green "wraps around" but is still a single group. The expression simplifies to

B ∨ (A ∧ ¬C)

Q3: Simplify the same expression as above, (¬ A ∧ B) ∨ (B ∧ ¬ C) ∨ (B ∧ C) ∨ (A ∧ ¬ B ∧ ¬ C), but this time use a Karnaugh map with the following headings:

C \ AB	00	01	11	10
0				
1				

The four-variable problem

With four variables, each row or column represents a combination of two variables.

Example 4

Represent the expression A ∨ (A ∧ ¬ B ∧ C ∧ D) in a Karnaugh map, and hence simplify the expression.

AB \ CD	00	01	11	10
00				
01				
11	1	1	1	1
10	1	1	1	1

AB \ CD	00	01	11	10
00				
01				
11	1	1	1	1
10	1	1	1	1

This simplifies to A.

Summary of the Karnaugh map method

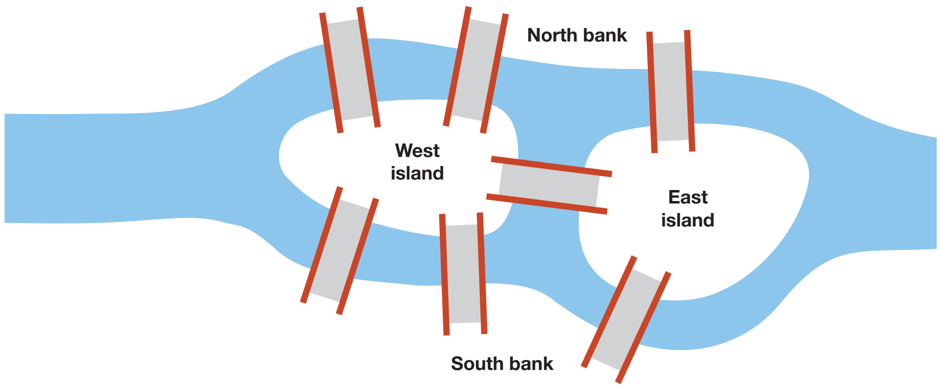
1. Construct the Karnaugh map step by step, placing 1s in the squares for each sub-expression separated by an OR symbol (∨)
2. Group any octet (8 squares)
3. Group any quad (4 squares that have not already been grouped, making sure to use the minimum number of groups
4. Group any pair which contains a 1 adjacent to only one other 1 which is not already in a group
5. Group any isolated 1s which are not adjacent to any other 1s.
6. Form the OR sum of all the terms generated by each group.

Abstraction by generalisation

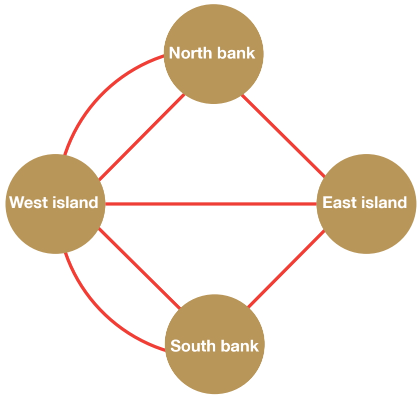
There is a famous problem dating back more than 200 years to the old Prussian city of Königsberg. This beautiful city had seven bridges, and the inhabitants liked to stroll around the city on a Sunday afternoon, making sure to cross every bridge at least once. Nobody could figure out how to cross each bridge once and once only, or alternatively prove that this was impossible, and eventually the Mayor turned to the local mathematical genius Leonhard Euler.

The map of 18th century Königsberg

Euler's first step was to remove all irrelevant details from the map, and come up with an abstraction:

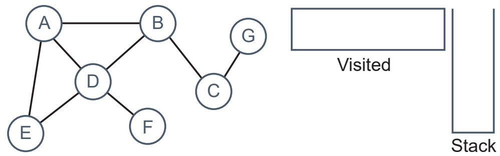


To really simplify it, Euler represented each piece of land as a circle and each bridge as a line between them.

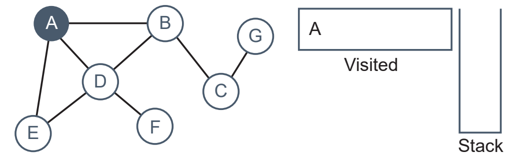


A-Level only

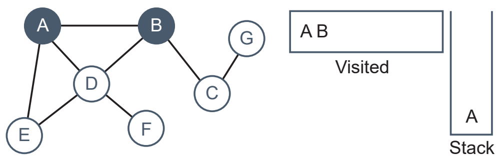
It is easiest to understand how this works by looking at the graphs below. This shows the state of the **stack** (here it just shows the current node when a recursive call is made), and the contents of the **visited** list. Each visited node is coloured dark blue.



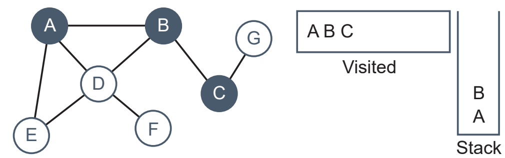
1. Start the routine with an empty stack and an empty list of visited nodes.



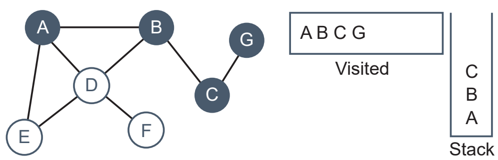
2. Visit A, add it to the visited list. Colour it to show it has been visited.



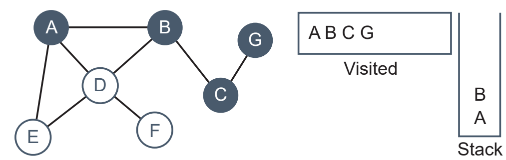
3. Push A onto the stack to keep track of where we have come from and visit A's first neighbour, B. Add it to the visited list. Colour it to show it has been visited.



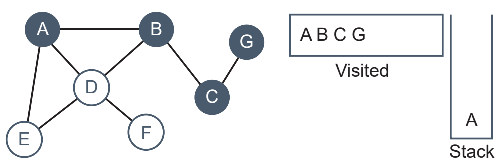
4. Push B onto the stack and from B, visit the next unvisited node, C. Add it to the visited list. Colour it to show it has been visited.



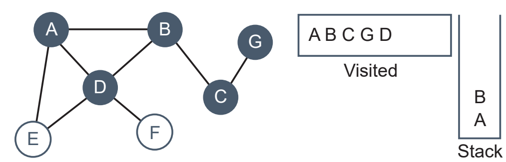
5. Push C onto the stack and from C, visit the next unvisited node, G. Add it to the visited list. Colour it to show it has been visited.



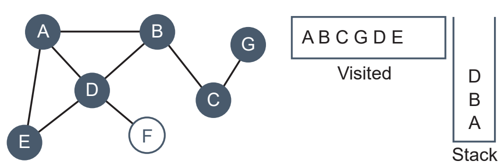
6. At G, there are no unvisited nodes so we backtrack. Pop the previous node C off the stack and return to C



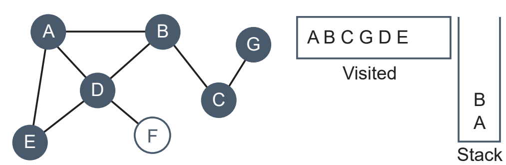
7. At C, all adjacent nodes have been visited, so backtrack again. Pop B off the stack and return to B.



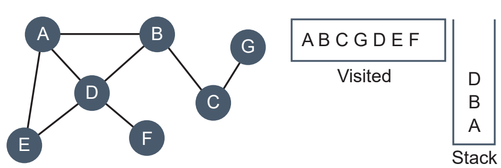
8. Push B back onto the stack to keep track of where we have come from and visit D. Add it to the visited list. Colour it to show it has been visited.



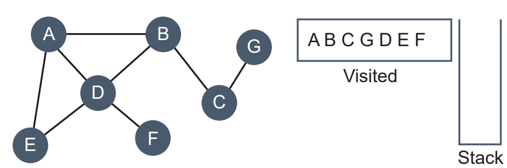
9. Push D onto the stack and visit E. Add it to the visited list. Colour it to show it has been visited.



10. From E, A and D have already been visited so pop D off the stack and return to D.



11. Push D back onto the stack and visit F. Add it to the visited list. Colour it to show it has been visited.



12. At F, there are no unvisited nodes so we pop D, then B, then A, whose neighbours have all been visited. The stack is now empty which means every node has been visited and the algorithm has completed.

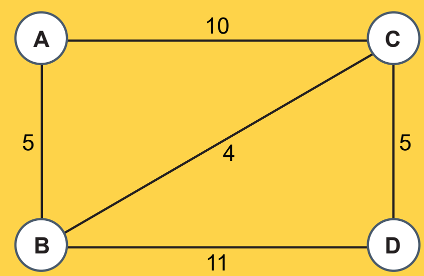
12-63

A-Level only

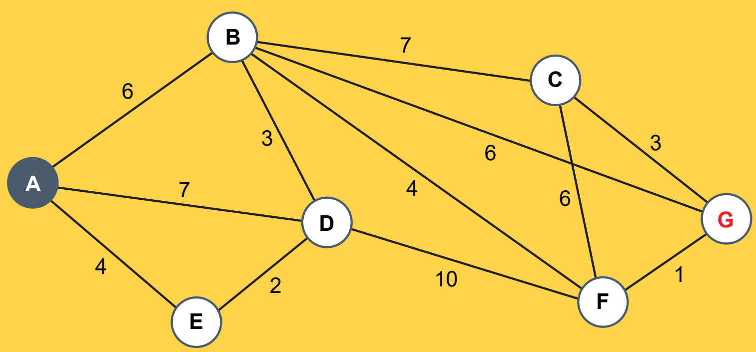
The queue is empty, all the nodes have now been visited so the algorithm ends.

We have found the shortest distance from A to every other node, and the shortest distance from A is marked in blue at each node.

Q1: Copy the graph below and use the method above to trace the shortest path from A to all other nodes. Write the shortest distance at each node.



Q2: Use a similar method to trace the shortest path from A to all other nodes. Write the shortest distance at each node. What is the shortest distance from A to G?



12-64

The A* algorithm

Dijkstra's algorithm is a special case of a more general **path-finding algorithm** called the **A* algorithm**. Dijkstra's algorithm has one **cost function**, which is the real cost value (e.g. distance) from the source node to every other node.

The A* algorithm has two cost functions:

1. g(x) – as with Dijkstra's algorithm, this is the real cost from the source to a given node.
2. h(x) – this is the approximate cost from node x to the goal node. It is a **heuristic function**, meaning that it is a good or adequate solution, but not necessarily the optimum one. This algorithm stipulates that the heuristic function should never overestimate the cost, therefore the real cost should be greater than or equal h(x).

The total cost of each node is calculated as f(x) = g(x) + h(x).

The A* algorithm focusses only on reaching the goal node, unlike Dijkstra's algorithm which finds the lowest cost or shortest path to every node. It is used, for example, in video games to enable characters to navigate the world.

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Cover picture:

'Away Day'
Mixed media on canvas, 61x61cm
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PG ONLINE

ISBN: 978-1-910523-05-6

9 781910 523056