Computer Science Unplugged

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- CS Unplugged is a book of activities that illustrate computer science principles without using a computer.
- Activities are short and are designed to be easily integrated into classes and include exercises and lesson plans for teachers.
The basic edition of Computer Science Unplugged has 20 classroom exercises for you to use with your students.

Each exercise has a number of extensions, activities and background information.

All activities can be done without the use of computers, but they all demonstrate fundamental principles used in computers today.

FORMATS

- Activities
- Books
- Show
- Web site
- Videos
- Garden
Data in computers is stored and transmitted as a series of zeros and ones.

- How can we represent words and numbers using just these two symbols?

Letters are represented in computers in binary also:

<table>
<thead>
<tr>
<th>Letter</th>
<th>Decimal</th>
<th>Binary</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>00001</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>00010</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>00011</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>00100</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>26</td>
<td>11010</td>
</tr>
</tbody>
</table>
COUNT THE DOTS

A 1  N  14  01010  J
B 2  01001
C 3  S
D 4  T
E 5  I
F 6  N
G 7  B
H 8  I
I 9  E
J 10
K 11
L 12  Y  25  00101
M 13  Z  26  10010

COUNT THE DOTS

HAPPY BIRTHDAY, GERI HALLIWELL!

Born August 6, 1972
• Computer screens are divided up into a grid of small dots called **pixels** (**picture elements**). In a black and white picture, each pixel is either black or white.

• Computers store drawings, photographs and other pictures using only numbers.

• The following activity demonstrates how a computer image can be stored efficiently.

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• The letter *a* has been magnified to show the pixels. When a computer stores a picture, all that it needs to store is which dots are black and which are white.
This technique is called run-length encoding.

- Fax transmission
- Compression of images

Color encoding

- Use two numbers per run
  - First number is how many pixels as before
  - Second number is what color (1=red, 2=green, ...)

COLOR BY NUMBERS

6,5,2,3
4,2,5,2,3,1
3,1,9,1,2,1
3,1,9,1,1,1
2,1,11,1
2,1,10,2
2,1,9,1,1,1
2,1,8,1,2,1
2,1,7,1,3,1
1,1,1,1,4,2,3,1
0,1,2,1,2,2,5,1
0,1,3,2,5,2
1,3,2,5
• Since computers only have a limited amount of space to hold information, they need to represent information as efficiently as possible. This is called compression.
• By coding data before it is stored, and decoding it when it is retrieved, the computer can store more data, or send it faster through the Internet.
• This exercise illustrates how a children's rhyme can be compressed.

YOU CAN SAY THAT AGAIN!

PITTER PATTER
PITTER PATTER
LISTEN TO THE RAIN
PITTER PATTER
PITTER PATTER
ON THE WINDOW PANE
YOU CAN SAY THAT AGAIN!

The arrows and boxes are presented with 2 numbers.

- **PITTER PA(7,4)**
  - 7: count back 7 positions
  - 4: copy 4 letters/spaces

- Sometimes boxes point back to a box with a blank inside.
YOU CAN SAY THAT AGAIN!

- The storage capacity of computers is growing at an unbelievable rate.
  - In the last 25 years, the amount of storage provided on a typical computer has grown about a million fold.
- We can *compress* the data so that it takes up less space.
  - This exercise uses Ziv-Lempel coding, or LZ coding, invented by two Israeli professors in the 1970s.
  - ZIP files, GIF images

CARD FLIP MAGIC

- When data is stored on a disk or transmitted from one computer to another, we usually assume that it doesn't get changed in the process. But sometimes things go wrong and the data is changed accidentally.
- This activity uses a magic trick to show how to detect when data has been corrupted, and to correct it.
This exercise illustrates even parity.

When computer data is transmitted to another computer, extra bits are added so that the number of 1s is even.

The receiving computer can detect if something gets messed up during the transmission and can correct it if there is one error.

What happens if there are two errors?
CARD FLIP MAGIC

- Another example of “parity” (checksum digits):
  - Algorithm:
    - Add the digits (up to but not including the check digit) in the odd-numbered positions (first, third, fifth, etc.) together and multiply by three.
    - Add the digits (up to but not including the check digit) in the even-numbered positions (second, fourth, sixth, etc.) to the result.
    - Take the remainder of the result divided by 10 (modulo operation) and subtract this from 10 to derive the check digit.

TWENTY GUESSES

- Can you read the following sentence?

  Ths sntnc hs th vwls mssng.

- You probably can, because there is not much "information" in the vowels.
- This activity introduces a way of measuring information content.
TWENTY GUESSES

• I am thinking of a number between 0 and 127.
• Start off with 20 pieces of candy.
• You may only ask questions that have a "yes" or "no" answer.
• For each question, you will lose one piece of candy.
• Once you guess correctly, you can keep whatever candy remains.

To pick a number between 0 and 127, you only need 7 guesses.
  ▪ Always shoot for the middle number of the range and eliminate half the possibilities!
  ▪ This concept is called binary search.
• If the number was between 0 and 1,023, you would only need 3 additional guesses.
• You can guess a number between 0 and 1,048,575 in only 20 guesses!
This activity illustrates structures used in parallel sorting networks.

- Kids sort data by walking through a sorting network laid out on the floor.
- The network simulates how a parallel network would sort data.
  - Kids find out that data can be sorted a lot faster in parallel!
Computers are often used to put lists into some sort of order (e.g. names into alphabetical order, appointments or e-mail by date, etc.)

- If you use the wrong method, it can take a long time to sort a large list into order, even on a fast computer.

- In this activity children will discover different methods for sorting, and see how a clever method can perform the task much more quickly than a simple one.

Start with 8 containers with different amounts of sand or water inside. Seal tightly.

- Children are only allowed to use the scales to compare the relative weights of two containers.
- Only two containers can be compared at a time.
LIGHTEST & HEAVIEST

- METHOD 1 is called Selection Sort.
- METHOD 2 is called Quick Sort.
- Generally, quick sort is a lot faster than selection sort is.

Order of Complexity

<table>
<thead>
<tr>
<th>Number of Operations</th>
<th>(O(2^n))</th>
<th>(O(n^2))</th>
<th>(O(n \log n))</th>
<th>(O(n))</th>
<th>(O(\log n))</th>
<th>(O(1))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n) (amount of data)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Computers are often required to find information in large collections of data.
Computer scientists study quick and efficient ways of doing this.
This activity demonstrates three different search methods so children can compare them.

Battleships are lined up at sea.
Each battleship has a number that is hidden.
How many guesses does it take for you to find a specific battleship?
- The number of guesses is the child's score.
- The lowest score wins.
BATTLESHEIPS

GAME 1: Ships are randomly ordered.

FIND SHIP # 717

GAME 2: Ships are in increasing order.

FIND SHIP # 5905
GAME 3: Ships are ordered into 10 groups based on the sum of the digits of the ship modulo 10.

**Your Ships**

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>E</td>
<td>H</td>
<td>I</td>
<td>J</td>
<td>L</td>
<td>M</td>
<td>N</td>
<td>P</td>
<td>T</td>
</tr>
<tr>
<td>B</td>
<td>F</td>
<td>I</td>
<td>J</td>
<td>K</td>
<td>O</td>
<td>P</td>
<td>Q</td>
<td>R</td>
<td>U</td>
</tr>
<tr>
<td>C</td>
<td>G</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>S</td>
<td>T</td>
<td>U</td>
<td>V</td>
<td>W</td>
</tr>
<tr>
<td>D</td>
<td>G</td>
<td>J</td>
<td>K</td>
<td>L</td>
<td>S</td>
<td>T</td>
<td>U</td>
<td>V</td>
<td>W</td>
</tr>
</tbody>
</table>

**Number of Shots Used:**

FIND SHIP # 9503 3A

• These three games illustrate
  - linear search
  - binary search
  - hashing

• What is the maximum number of guesses required for each of these search techniques
  - for 26 battleships?
  - for n battleships?
• Our society is linked by many networks: telephone, utilities, roads
• For a particular network, there is usually some choice about where the links can be placed.
• This exercise examines a complete network to determine the links necessary to connect all the components of the network at minimal cost.
THE MUDDY CITY

a graph
THE MUDDY CITY
THE MUDDY CITY

• This exercise illustrates how to build what we call the “minimal spanning tree”.
  ▪ A tree does not have any cycles where you can get back to where you were before.
• This exercise does not give us the shortest path from one location to another.
  ▪ But there is another algorithm for that!

POOR CARTOGRAPHER

• Many optimization problems involve situations where certain events cannot occur at the same time (e.g. scheduling meetings and classes).
• Coloring regions of a map with different colors is effectively the same problem as we will show in this exercise.
POOR CARTOGRAPHER

• Given a map, color each region with a color so that no two adjacent regions use the same color.
• If two region touch only at one point, they are not considered adjacent.
  - Example: Arizona and Colorado
• How many colors are sufficient to color a map?
• How many colors are necessary to color a map?
"undirected graph"
The conjecture that any map can be colored using only four colors was formulated in 1852 but was not proven until 1976 with the help of a computer!
POOR CARTOGRAPHER

- Can we color a map with 3 colors?
- This problem is intractable.
- The only way we know to solve this problem in general is to derive all possible colorings and see if we come across a valid coloring.
- How many colorings are there for a map with 25 regions?
- How long would it take to analyze all of these colorings if it takes 1 second to analyze one coloring?

TREASURE HUNT

- Computer programs often need to process a sequence of symbols such as words in a document or even the text of another program.
- Computer scientists use a Finite State Machine (FSM), a set of instructions to see if the sequence is acceptable or not.
- This exercise uses the FSM idea using treasure maps!
TREASURE HUNT

• Goal: Find Treasure Island, starting from Pirates’ Island.
• Friendly pirate ships sail along fixed routes between islands offering rides to travelers.
• Each island has two departing ships, A and B.
• Determine all possible sequences of ships that a traveler can take to arrive at Treasure Island.
• Use your map to record all the ship routes.

What is the quickest route?

"directed graph"
Traffic Light State Machine

$C_M C_S$ $C_M =$ Light Color for Main Street
$C_S =$ Light Color for Side Street

$T_M =$ Boolean Timer for Min. Green Light on Main St.
$T_S =$ Boolean Timer for Max. Green Light on Side St.
$T_Y =$ Boolean Timer for Yellow Light

Cell Phone State Machine

in Unified Modeling Language (UML)

Entry: LCD0n ()
Exit: LCD0E ()
When you have a lot of people using one resource (such as cars using roads, or messages getting through the Internet), there is the possibility of "deadlock".

- A way of working cooperatively is needed to avoid this happening.

- This exercise illustrates cooperative problem solving and (potentially) deadlock.
THE ORANGE GAME

• A shared resource in New York:

THE ORANGE GAME

• Set up:
  ▪ Each child is assigned a label or color.
  ▪ Give two labeled oranges (or colored balls) to each child except one child, who gets only one.
    ▪ Each child should not hold his or her own label or color initially.
  ▪ The children form a circle.

• Goal:
  ▪ Each child must end up with the orange(s)/ball(s) of his or her own label/color.
THE ORANGE GAME

• Passing Rules:

1. Only one orange/ball may be held in each hand.

2. An orange/ball can only be passed to an empty hand of an immediate neighbor in the circle. (A child can pass either of their two oranges/balls to their neighbor.)

3. (optional) No talking.

THE ORANGE GAME

• Routing and deadlock are problems in many networks, such as road systems, telephone and computer systems.

• Engineers spend a lot of time figuring out how to solve these problems - and how to design networks that make the problems easier to solve.
Computers are usually programmed using a "language", which is a limited vocabulary of instructions that can be obeyed.

One of the most frustrating things about programming is that computers always obey the instructions to the letter, even if they produce a crazy result.

This activity gives kids some experience with this aspect of programming.
Is this a good algorithm for making a PB&J sandwich?

1. Pick up some bread and put it on the table.
2. Put peanut butter on the bread.
3. Pick up some more bread and put it on the table.
4. Get jelly out of the jar.
5. Spread the jelly on second piece of bread.
6. Put the bread together to make your sandwich!
The teacher's version of Computer Science Unplugged is available online at
http://www.csunplugged.org
- The book is FREE to download and use!
- Additional material will be published soon to add even more activities, including video to demonstrate how to use these activities effectively in your classroom.

10100 01000 00001 01110 01011

11001 01111 10101

(THANK YOU)