Explorers need maps: Abstraction, representations and graphs

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Aims

- Give you deeper understanding of core topics
  - Abstraction and data representation in problem solving
  - Graph data structures and finite state machines
  - Computational thinking
- Give you practical ways to teach computing in a fun, thought provoking way
  - away from computers, focus on concepts

- Linked activity sheets and booklets can be downloaded from our website:

www.teachinglondoncomputing.org

The Knight’s Tour Puzzle

Adapted from an idea
by Maciej Syslo & Anna Beata Kwiatkowska, Nicolaus Copernicus University

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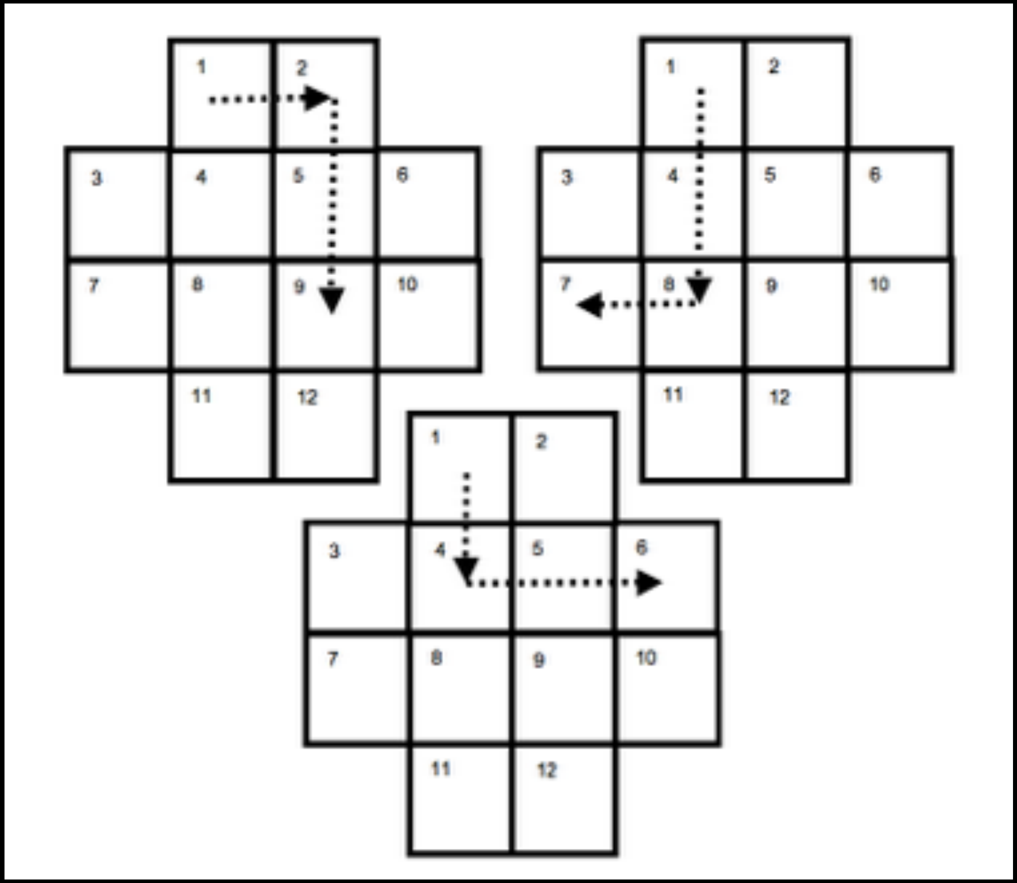
A Puzzle to solve

- To get you thinking about problem solving let’s start with a puzzle to solve…
- What strategies do you use to try to solve it?
- Is it a hard or easy puzzle?
    - What age group is it suitable for?

The Knight's Tour Puzzle



- Work out an algorithm for a chess Knight to visit all squares on the board returning to the start
- Record the steps (the algorithm)

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How difficult is it?

- What strategies do you use to solve it…
- Is it a simple puzzle?
  - What age group could tackle it?

- Let's look at a simpler puzzle and return to the Knight's Tour later

The Tour Guide Puzzle

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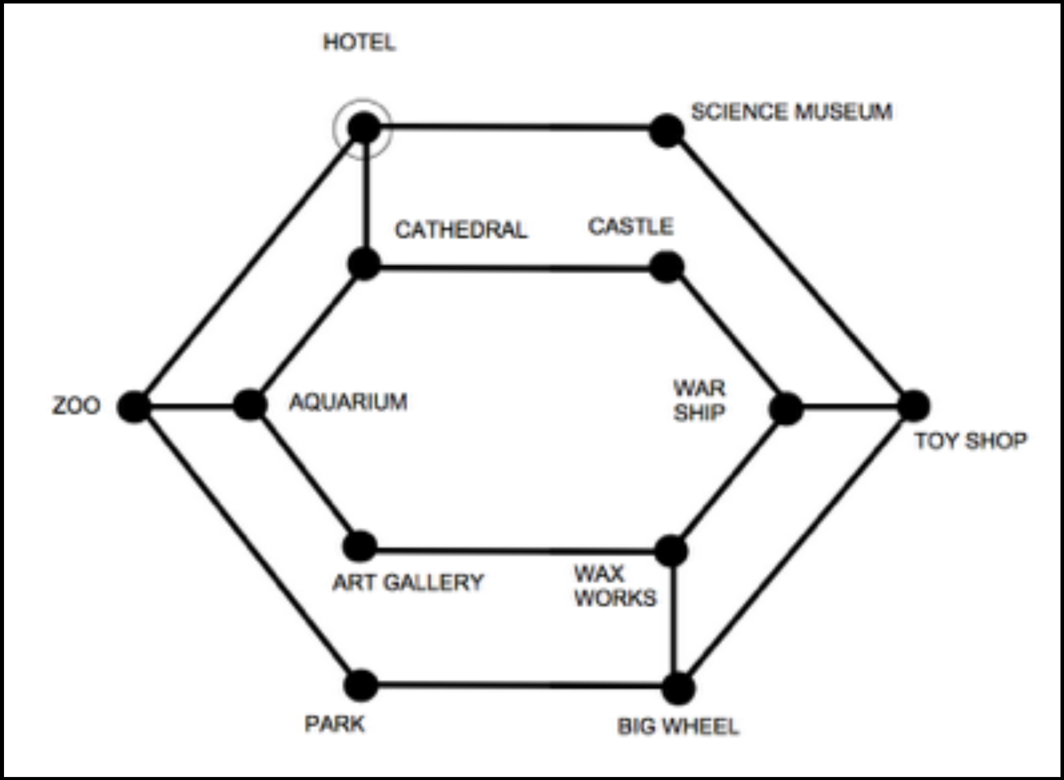
The Tour Guide Puzzle



The Tube Map

- Starting at the hotel, plan a route so that tourists can visit every tourist attraction just once ending up back at the hotel.
- Record the steps (the algorithm)

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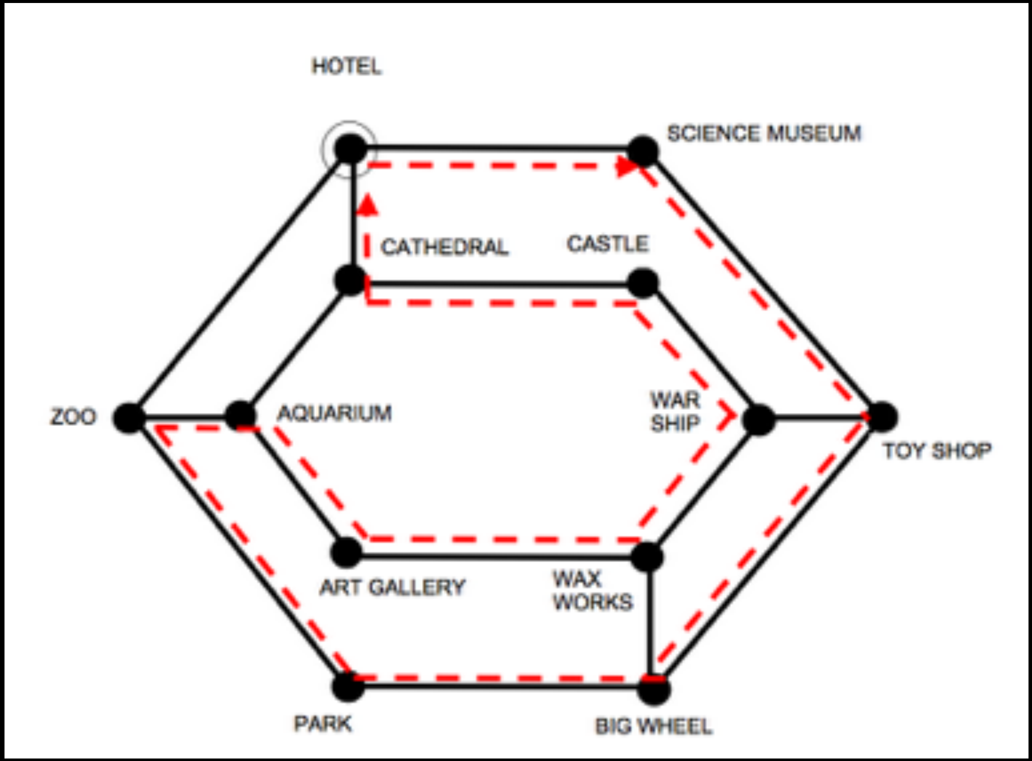
How difficult is it?

- What strategies do you use to solve it…
- Is it a simple puzzle?
    - What age group could tackle it?

- Is it simpler than the Knight’s Tour?
    - Why / Why not?

The Tour Guide Solution



- Starting at the hotel, this route visits every tourist attraction just once ending up back at the hotel.
- There are many others possible!

The Tube Map

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What is a graph?

- The tube map is in computing terms a ‘graph’ data structure
- A graph is just a way of representing information about links between things.
- It consists of
  - nodes (circles) showing ‘places’.
  - Edges (lines) showing which places are linked.
  - A directed graph uses arrows to show one-way links (eg one-way streets)

The Knights Tour Puzzle (again)

The Knight’s Tour as a graph

- Draw the Knights Tour puzzle as a graph.
  - Use nodes for squares
  - Edges show which squares you can jump to from each square

- The graph is the map you draw as you explore the ‘state space’ of the puzzle.
- Once you have a map, answering questions about it is easier

Draw a graph of the Knight's Tour puzzle

- You need an algorithm to exhaustively explore the state space
    - ie explore possible puzzle positions

An algorithm for drawing graphs

- Start at the start position, draw a node (a circle) and label it with the square number.
- Draw edges (arrows) to each place you can jump to from it, adding new nodes for those places.
- Repeat for each new node added until there are no new nodes added.

- The same algorithm is used to create graphs of gadget interaction design

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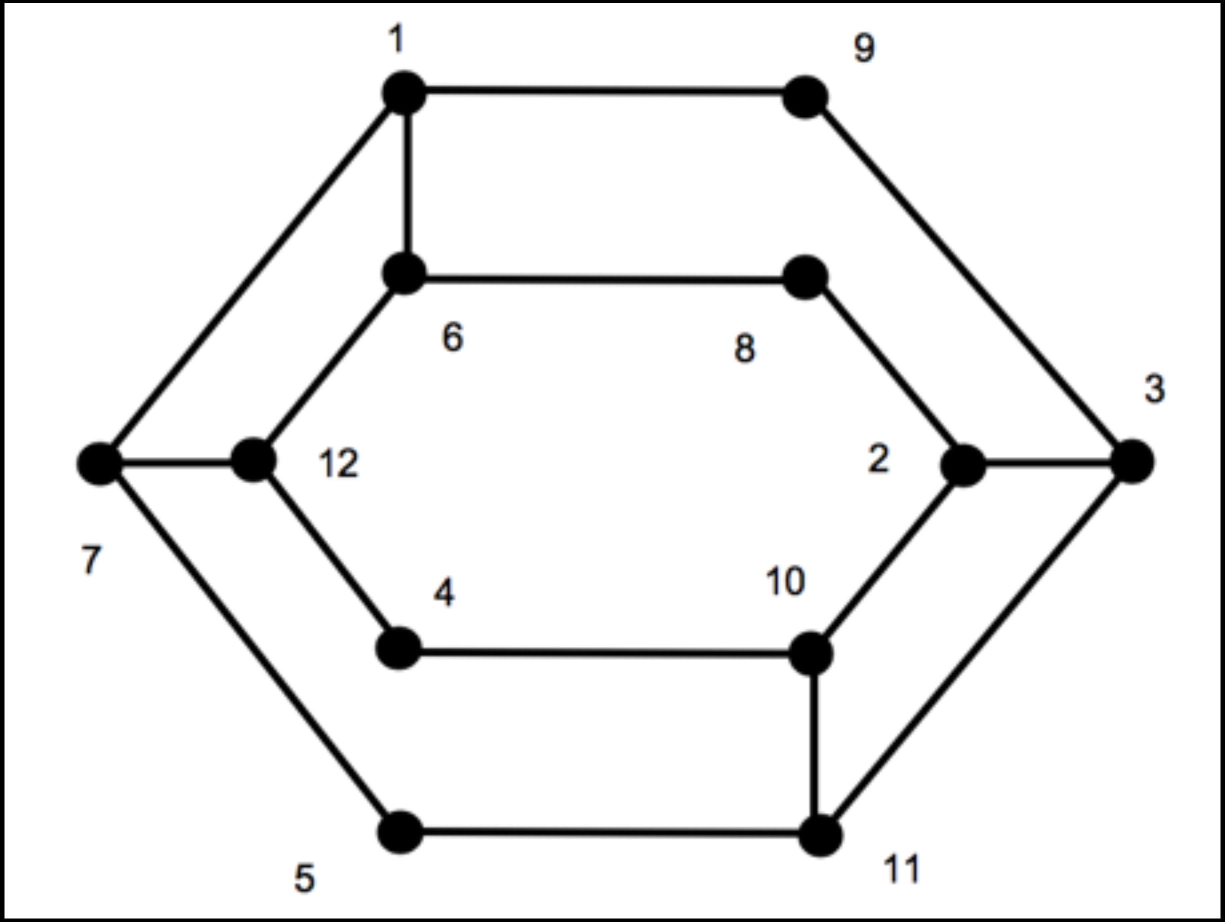
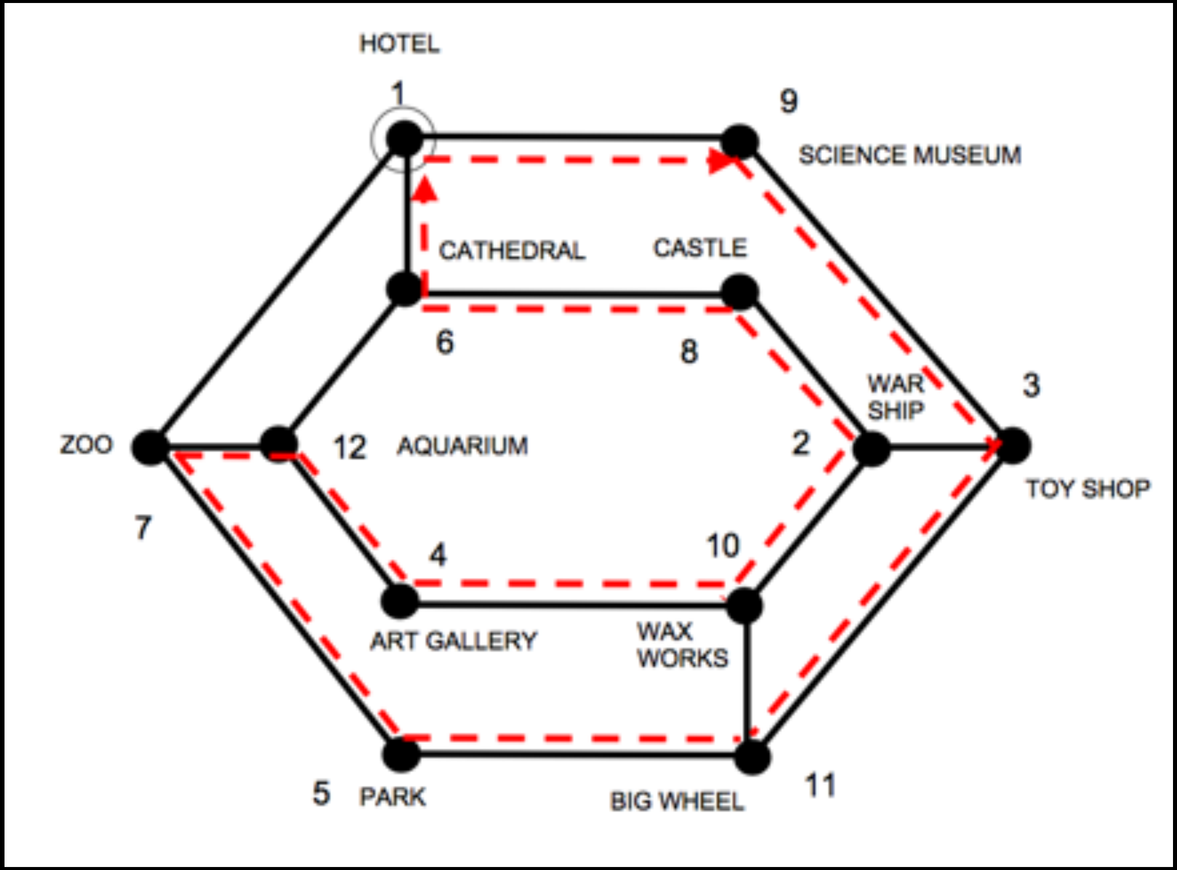
Here's a graph of the Knight's Tour
Now solve the puzzle …



Here’s a solution of the Knight’s Tour puzzle



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Is it simpler than the Knight’s Tour?

- In fact they are two versions of exactly the same puzzle
  - Identical if viewed through an abstraction
- Solve one and you’ve solved the other
- The graph abstraction gives a clear map of the problem.
- It throws away spurious information, highlighting the information that matters.

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Generalisation

- Solve one and you have solved both
  - once they are generalised to the same graph problem
- We also came up with a general algorithm for creating a graph of a puzzle.
- Finding a circuit round a graph is called a Hamiltonian Circuit problem
  - We could now develop an algorithm for finding a Hamiltonian Circuit of any graph.

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Computational Thinking Lessons

- Algorithmic thinking
- Logical Thinking
- Abstraction
- Generalisation

HexaHexaFlexagon Automata

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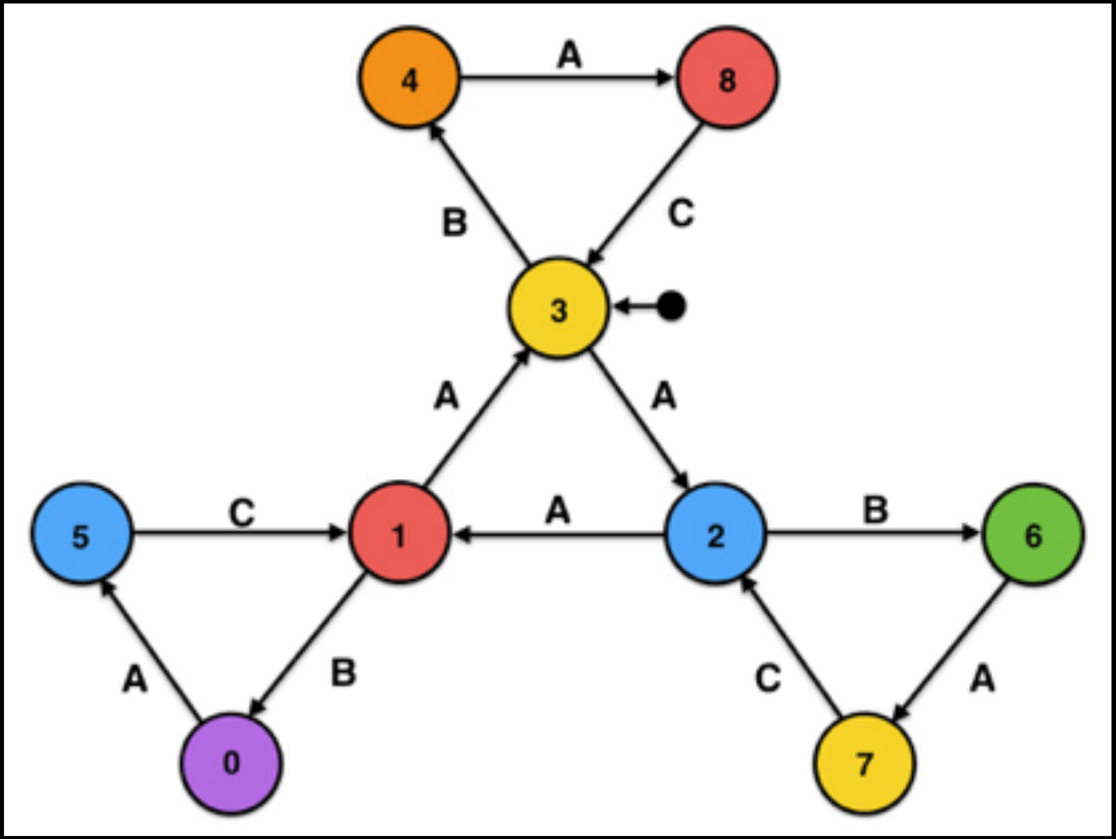
Hexahexaflexagons

- Hexahexaflexagons are simple folded paper puzzles.
  - Fold it up and unfold it from the middle to reveal new sides.
- There are 9 ‘sides’ to the flexagon. Find them all.
- Make a map (a graph) to allow you to move at will around the flexagon.
- Use your new found knowledge of graphs to explore the hexahexaflexagon.
- Find a Hamiltonian circuit!

Here’s a graph of the Hexahexaflexagon



Finite State Machines

- A directed graph can actually be thought of as a ‘program’: a finite state machine.
  - It describes computation

Finite State Machines

- A finite state machine has
    - Nodes that represent 'states' of the machine
    - A start state (one specific node to start from)
    - Edges that represent 'transitions' between states
        - They have labels giving the action that will lead to the transition being taken.
    - Outputs: what happens when you are in a state

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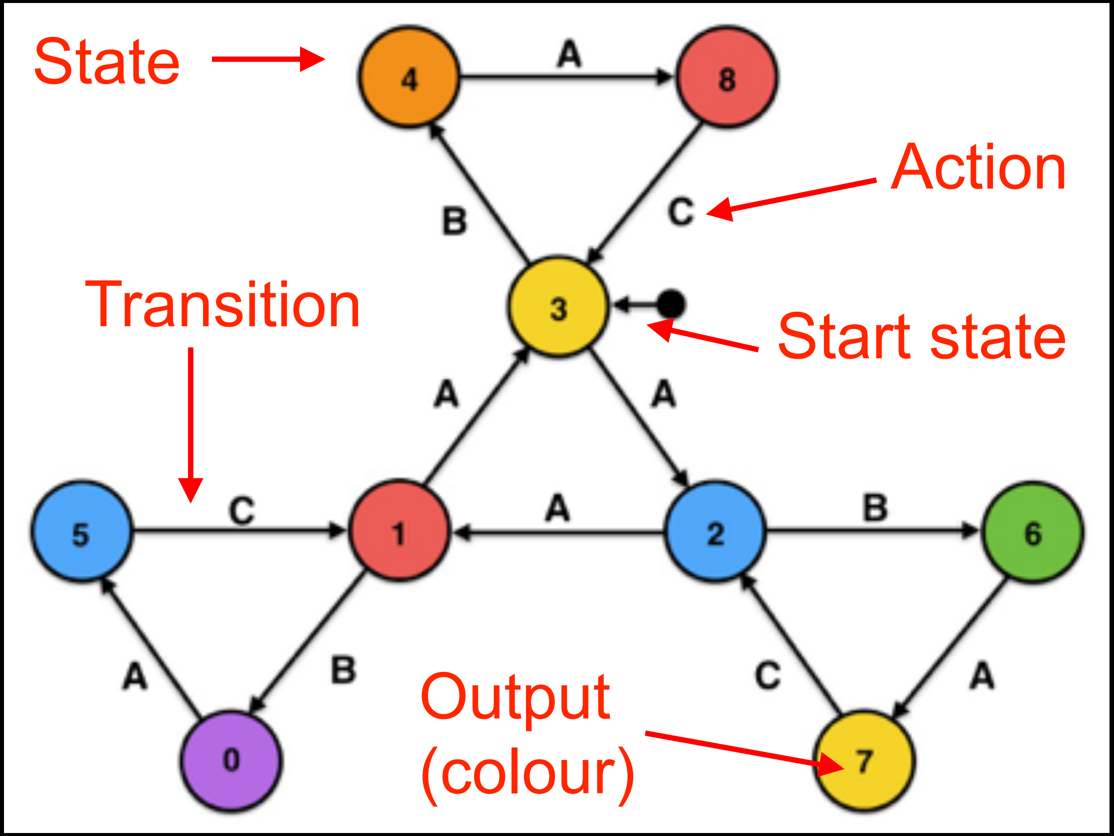
The Hexahexaflexagon finite state machine



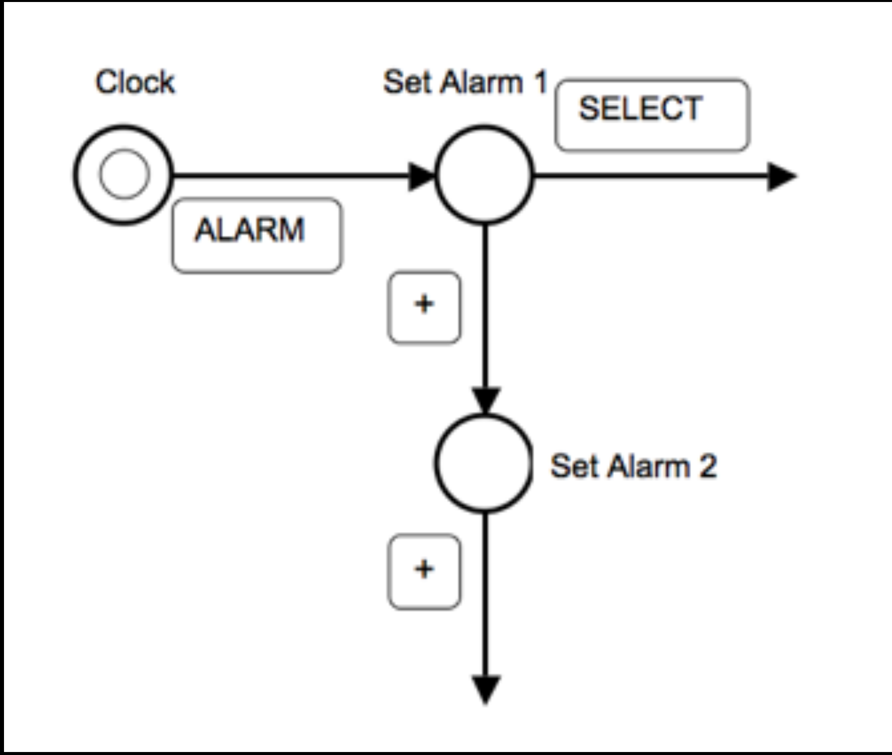
$$\begin{tikzcd}
 & 4 \arrow[rr, "A"] & & 8 \arrow[dl, "C"] & \\
 & & 3 \arrow[ul, "B"] \arrow[dr, "A"] & & \\
5 \arrow[r, "C"] & 1 \arrow[ur, "A"] \arrow[dl, "B"] & & 2 \arrow[ll, "A"] \arrow[r, "B"] & 6 \arrow[dl, "A"] \\
0 \arrow[u, "A"] & & & 7 \arrow[u, "C"] &
\end{tikzcd}$$

Finite State Machines as computational models

- Use finite state machines to do computational modelling of whatever it describes.
- Actions are inputs that move us from state to state and outputs get printed.
- Used to rapidly prototype devices
- Used to help plan the design of interfaces, websites, the modes of a device, etc
- Eg Now write a Scratch simulation of a flexagon based on the finite state machine

Modelling gadgets, websites, etc

- All this applies to gadgets (and software generally)
- Take your digital watch, central heating controller, digital radio, …
- Create finite state machines of them
- Then use it as the basis to write your own program
- Also make graphs as a model of a website



Working out the finite state machine of an alarm clock chi+med

Checking properties

- Use to check properties of the design
  - is it easy to get back to the home state from any state…
  - Does an action have the same effect everywhere,
  - Can important tasks be done in few steps
  - etc
- We are using this to check the safety of medical devices with regulators

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Summary

The way you represent information has a powerful effect on the ease of problem solving

- Graphs are a good representation for any problem that involves links between 'places'
- Finite state machines turn them in to computational models
- Check designs work

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More support

On our website to support this session:

- Activity sheets
- Story sheets
- Slides

Details of more worskshops/courses

- free unplugged sessions
- subsidised courses (e.g. on A'level computing)

www.teachinglondoncomputing.org

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- See also www.csunplugged.org for more unplugged finite state machine activities

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