Human Communication 1
Lecture 17

Computation and cognitive science -Turing's machine

- Turing’s ‘machine’ is a mathematical abstraction
- Turing also pioneered the idea that computation was *the Royal Road* to the mind

Turing's machine consists of

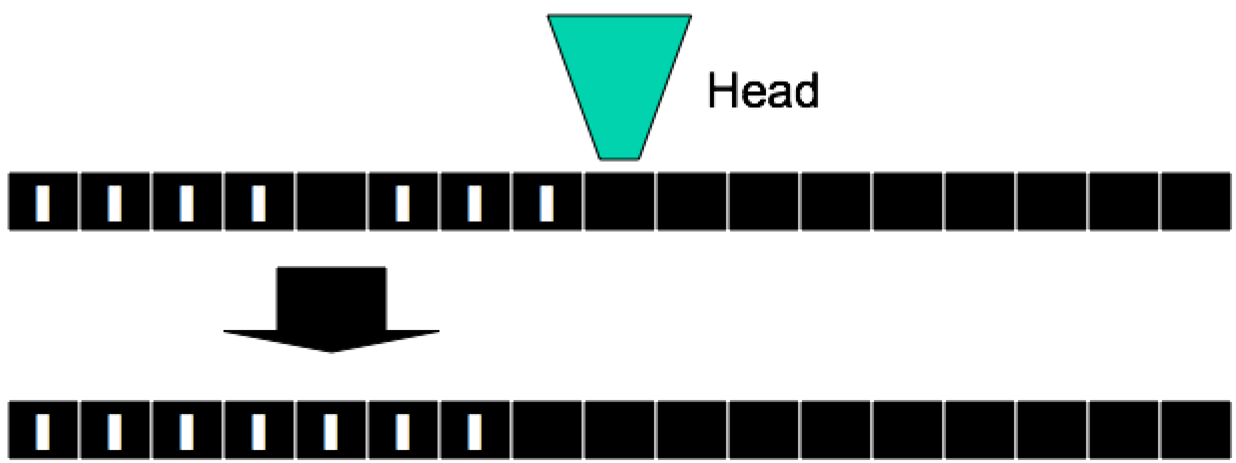
- Tape: divided into cells containing symbols from a finite table
- Head: that can read and write on the tape
- Finite table: containing instructions as symbols
- State register: storing the state of the Turing table, one of finitely many

Turing's machine

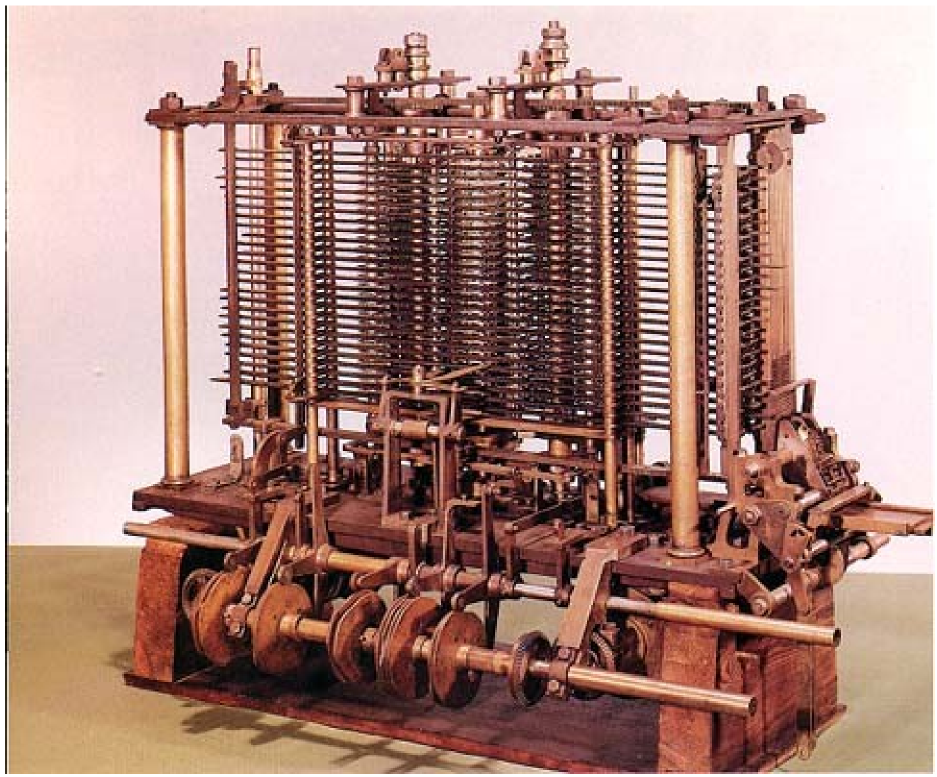
- Head can read, erase, write symbols, and move tape one square left or right
- Head is defined by a few rules e.g. *if the symbol below head is '1', erase it, write a '0', and move one square left*
- Input for problem is posed by writing it on the tape at start time
- Output from the problem is on the tape at 'halt' time

A simple example: adding

- An adding machine — two numbers in ‘tally notation’ separated by blank
- Machine finds blank, ‘moves 1s across blank’ until finished
- *Infinite* (or extendable) machines — can always add more tape



A Turing machine?



What is so important about Turing's machine?

- *Active* head vs. *passive* memory
- Universal machine treats *program* as *data*
- *Hardware* vs. *software*, distinguish abstract computation from physical implementation
- Considers any range of alternative implementations
- Establishes an abstract 'informational' level for describing behaviour

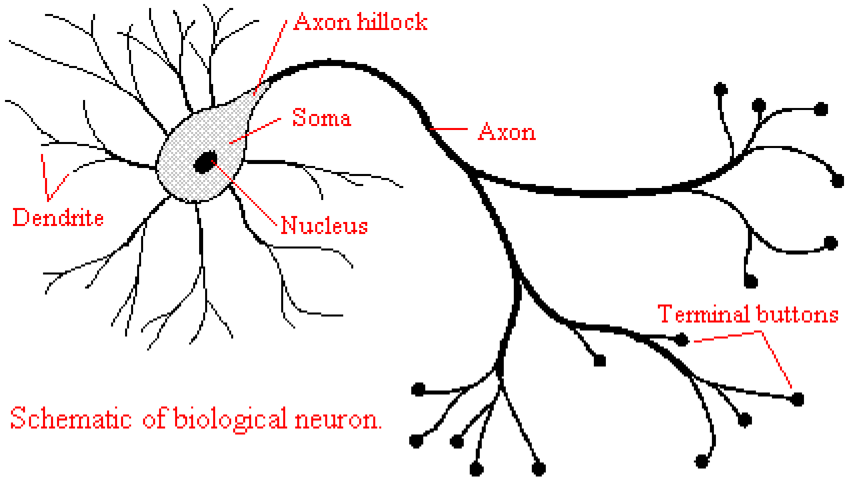
An example of levels

- How do people compute answers to syllogisms? *All B are A. C is B. What relation must there be between A and C?*
- Example: All men are mortal. Socrates is a man. Socrates is mortal.
- Alternative answers by using:
  - sentential rules
  - images of the things they are about
- But the brain is all neurons, how to capture differences?

Biological computation 1

- Brains have a very different *computational architecture* from engineered computers
- A *neuron* is a cell with many *dendrites* and one *axon*
- Axons connect with dendrites at *synapses*
- The neuron collects information (as electro-chemical impulses) through its dendrites' synapses

A neuron



(From http://vv.carleton.ca/~neil/neural/neuron-a.html)

Biological computation 2

- As a function of collected information, it transmits a pulse down its axon
- Synapse may be *excitatory* or *inhibitory*
- Neurons learn by changing the resistance of their synapses (*connection weights*)
- This architecture referred to as *neural network* or *'connectionist'*
- Easy to implement some computations, hard to do others

So who needs abstractions?

- Turing's framework separates *what* is computed from *how* it is computed
- Different architectures make different things easy/hard
- But need a level above the detail
- E.g., in describing the structures of language
- E.g., clause embedding

Abstraction

Computer science provides concepts for describing how hard things are to compute, or to learn, *regardless of the architecture*

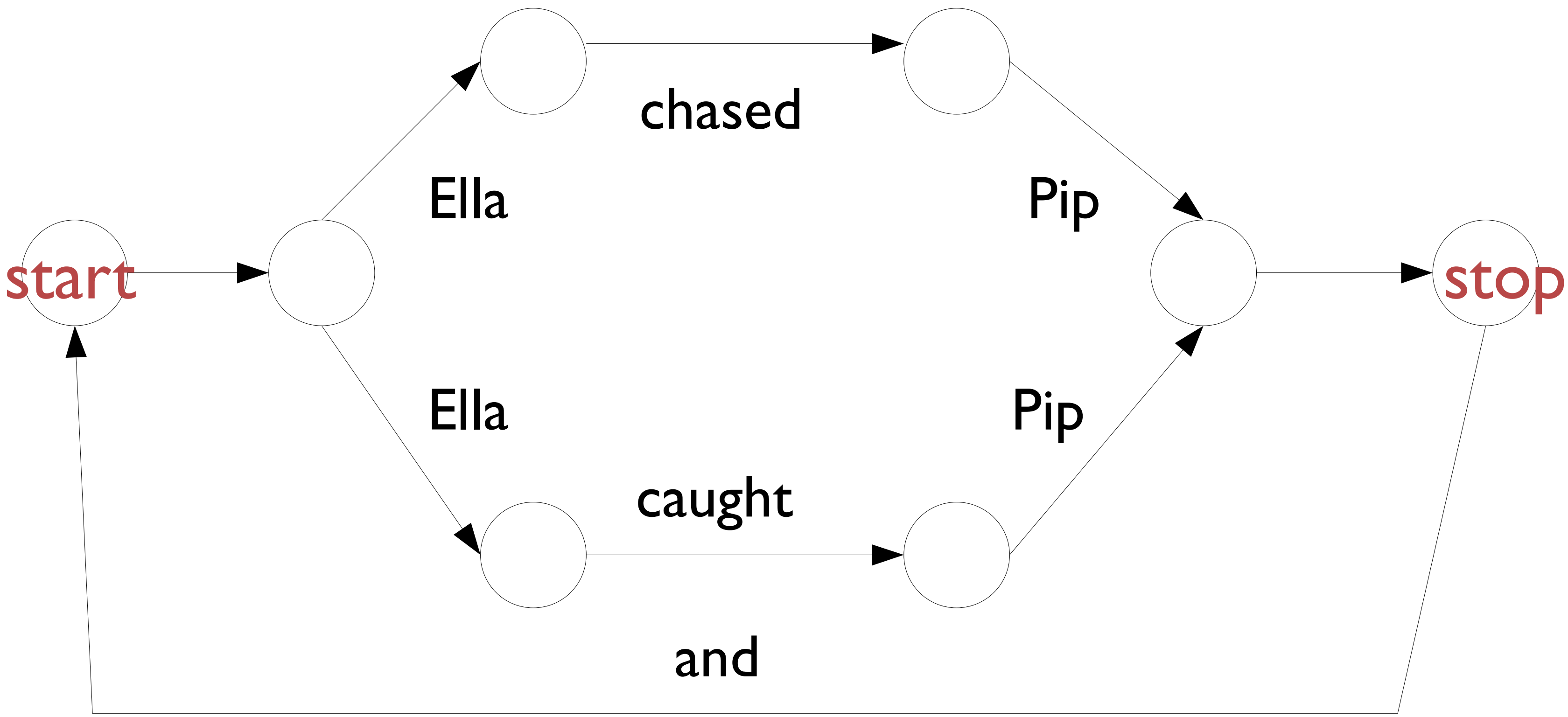
Abstract grammars:

Finite state machine/grammar has no memory of previous computations, except last rule + current symbol

Finite state machine/grammar

- Mimics behavioristic models
- Represented as nodes (states) and links (transitions)
- Current state is single activated state

Example for finite state.



Higher power automata/grammars

- Context free vs. Context sensitive
- e.g. the dog runs

  the dogs run
- Gives all options for singular and plural vs. have variable parsed/passed to match each case

Representation can get theories of mind into trouble 1

- An infinite regress argument:
  - How do we judge that two triangles are the same shape?
- *Theory*: we have an image of the triangles in our mind and we compare them
- *Problem*: How do we compare them?
- Well, we have a little *homunculus* who scans them and compares . . .

Representation can get theories of mind into trouble 2

- And how does the homunculus compare them?
- Well, she has a mental image . . .
- The regress is infinite if the homunculi aren't *discharging* any functions from level to level

(David Hume of the 18th century Edinburgh Enlightenment first noticed this problem)

Computation

- The operations on representations are defined and 'mechanical'
  - they offer the possibility of *discharging* mental functions.
- Turing machine head contains only mechanically applicable rules
- Turing machine can compute anything that can be computed

Representation 1

- Computation works on representations, by transforming them
- Turing machines represent say numbers as 0s and 1s on its tape
- Head's operations are defined as transformations on representations
- E.g. erase Y and write Z
- *Representations are things which stand for other things*

Representation 2

- Some features of representations are significant, others not
- E.g., *C*, C and c are different renderings of the same character, 3rd letter of alphabet
- These differences are *generally* not significant but C and G are significantly different
- Syntax!

Engineering representations

Much of AI is about engineering representations.

- Representations have huge effects on ease of computation
- Long-division in roman numerals is hard
- Maps are efficient if you don't know where you will go
- Route descriptions are efficient if you only need one route
- Mathematics is all about getting the right representation

Discovering representations

- Psychologist's problem is *analysing* representations
- E*xternal* and *internal* representations
- Deduce *internal* representations in the black box
- Control environment and observing behaviour, *functional* level
  - E.g. working memory for letter-strings is auditory
  - E.g. representations which underlie understanding of discourse

A piece of discourse:

Napoleon entered as the door opened. The commander strode across the room to the fireplace. He stood in front of the ginger haired woman seated on the sofa. The mud-spattered man addressed his immaculately dressed cousin. . . .

Some questions (2 slides)

Now judge which of the following sentences ocurred in the paragraph:

1. Napoleon was mud-spattered from his travels
2. The mud-spattered man addressed his immaculately dressed cousin
3. The commander walked across the room to the fireplace
4. Napoleon addressed his immaculately dressed cousin

More questions

5. He stood in front of the woman with ginger hair seated on the sofa
6. As the door opened, Napoleon entered
7. The woman crossed the room from the fireplace
8. He stood in front of the ginger haired woman seated on the sofa
9. He stood in front of the ginger haired woman seated on the sofa to the right of the fireplace

Easy and hard questions

- 7 is generally easy to reject, in direct conflict with the paragraph
- 3 has a *walked* for *strode*, people are quite good at detecting
- Problems with alternative *referring expressions*, *Napoleon*, *the commander*, *mud-spattered man*, *cousin*, *woman with red hair*, . . . which are in which sentences?
- Spatial description in 9 which is not in 8
- Distinction between the *gist* and the *wording*
- People remember the *gist*

Inferring representations

If you can't remember whether it was X or Y

- Then the representation does not discriminate between X and Y
- The *basis* of the discrimination may be almost anything
- Difference between *walked* and *strode*
- May be remembered on the basis of some nebulous tone to incident
- D*oesn't* mean that representation consists of the words

Identity crises

- Identities *must* be resolved
- Try rewriting the paragraph so that it is not determined whether Napoleon is the cousin
- But nothing explicitly says Napoleon commander, or Napoleon = commander
- *Reference resolution* is most obviously a problem with pronouns
- Knowledge intensive process, based partly on the likelihoods
- Going beyond the information given

Going beyond the information given

- A father and his son were driving down the motorway late one night when they were involved in a serious accident with another car. An ambulance rushed them to hospital. The son was badly hurt though the father was only slightly injured. The father was admitted to a ward. They took the son immediately to the operating theatre, where the surgeon was waiting. The surgeon took one look at the boy and said ‘I can’t operate. That’s my son.’