

7.5: Turing Machines

Challenge: Design simplest machine that is "as powerful" as conventional computers.



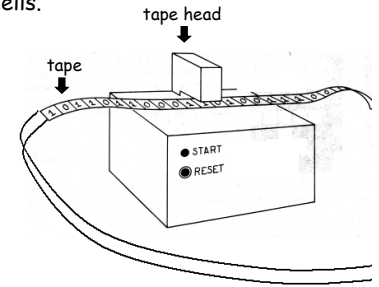
Alan Turing (1912-1954)

Turing Machine: Components

Alan Turing sought the most primitive model of a computing device.

Tape.

- Stores input, output, and intermediate results.
- One arbitrarily long strip, divided into cells.
- Finite alphabet of symbols.



Tape head.

- Points to one cell of tape.
- Reads a symbol from active cell.
- Writes a symbol to active cell.
- Moves left or right one cell at a time.

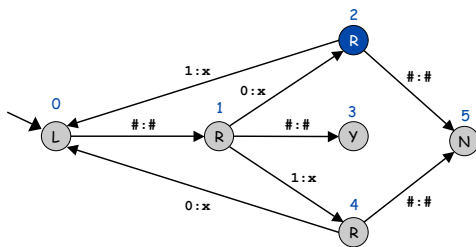
Turing Machine: Fetch, Execute

States.

- Finite number of possible machine configurations.
- Determines what machine does and which way tape head moves.

State transition diagram.

- Ex. if in state 2 and input symbol is 1 then: overwrite the 1 with x, move to state 0, move tape head to left.



Before



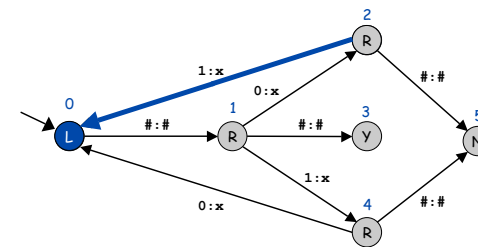
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After



Turing Machine: Initialization and Termination

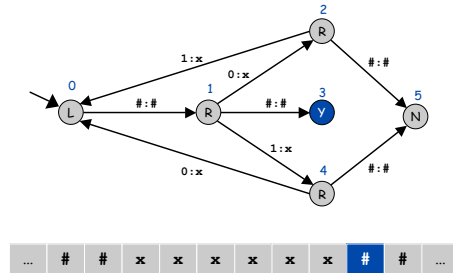
Initialization.

- Set input on some portion of tape.
- Set tape head.
- Set initial state.



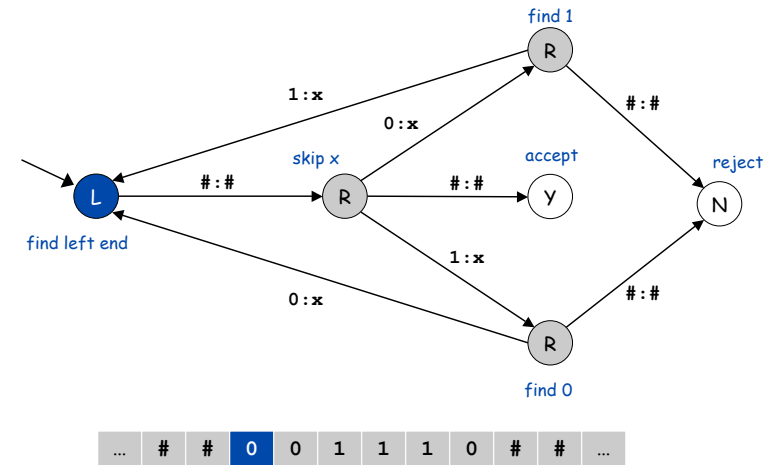
Termination.

- Stop if enter *yes, no, or halt* state.
- Infinite loop possible.



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Example: Equal Number of 0's and 1's



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Turing Machine Summary

Goal: simplest machine that is "as powerful" as conventional computers.

Surprising Fact 1. Such machines are very simple.

Surprising Fact 2. Some problems cannot be solved by ANY computer.

↑
next lecture

Consequences.

- Precursor to general purpose programmable machines.
- Exposes fundamental limitations of all computers.
- Enables us to study the physics and universality of computation.
- No need to seek more powerful machines!

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Alan Turing

Alan Turing (1912-1954).

- Father of computer science.
- Computer Science's "Nobel Prize" is called the Turing Award.

It was not only a matter of abstract mathematics, not only a play of symbols, for it involved thinking about what people did in the physical world... It was a play of imagination like that of Einstein or von Neumann, doubting the axioms rather than measuring effects... What he had done was to combine such a naive mechanistic picture of the mind with the precise logic of pure mathematics. His machines - soon to be called Turing machines - offered a bridge, a connection between abstract symbols, and the physical world. -John Hodges



Alan Turing (left)
Elder brother (right)

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7.5: Extra Slides

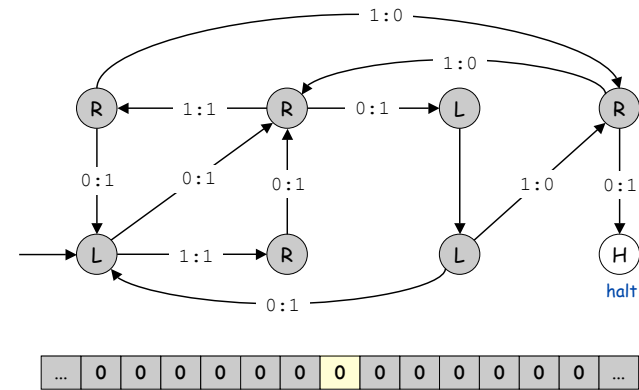


Introduction to Computer Science · Robert Sedgewick and Kevin Wayne · <http://www.cs.Princeton.EDU/IntroCS>

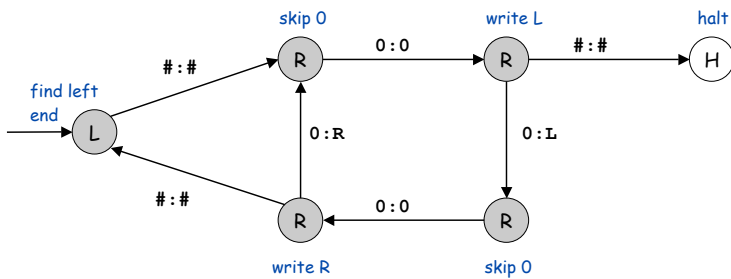
Busy Beaver

A Turing machine with very complex behavior.

- Leaves 4,098 ones on the tape and halts after 47,176,870 steps.



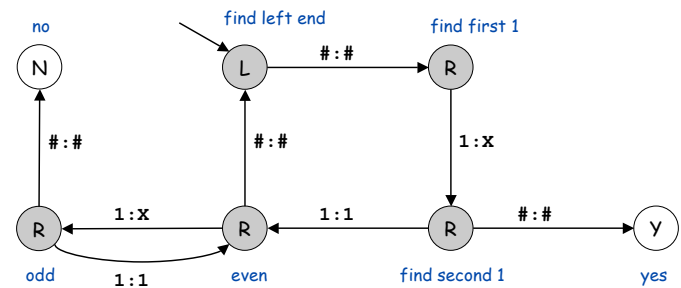
Dragon Curve



... # 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 # ...

... # L L R L L R R L L L R R L R R # ...

Power of Two 1's



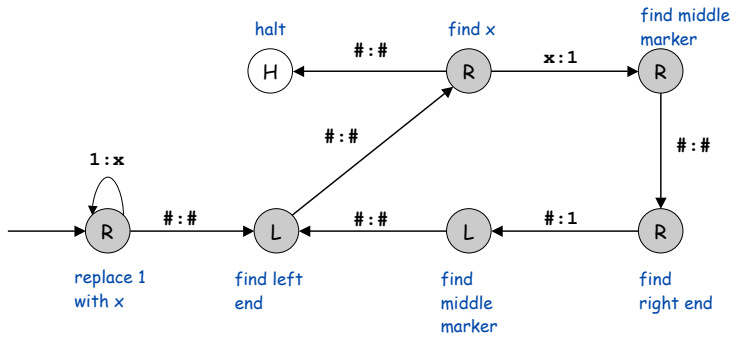
before

... # 1 1 1 1 1 1 1 1 # ...

yes

... # X X X X X X X X # ...

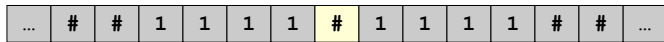
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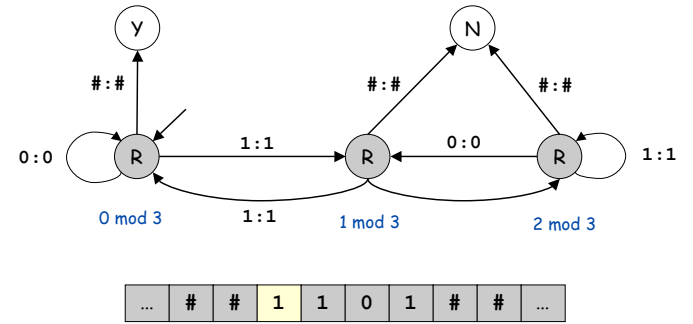
before



after



Divisible-By-Three



Unary to Binary Converter

