4 Modelling Issues

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- Implementing and testing on representative inputs
  - How do you choose your inputs?
  - May be very time-consuming.
  - Very reliable results if done correctly.
  - Results only hold for a specific machine and for a specific set of inputs.

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  - How do you choose your inputs?
  - May be very time-consuming.
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- Theoretical analysis in a specific model of computation.
  - Gives asymptotic bounds like "this algorithm always runs in time $\mathcal{O}(n^2)$".
  - Typically focuses on the worst case.
  - Can give lower bounds like "any comparison-based sorting algorithm needs at least $\Omega(n \log n)$ comparisons in the worst case".

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Example 1

Suppose n numbers from the interval $\{1, \ldots, N\}$ have to be sorted. In this case we usually say that the input length is n instead of e.g. $n \log N$, which would be the number of bits required to encode the input.

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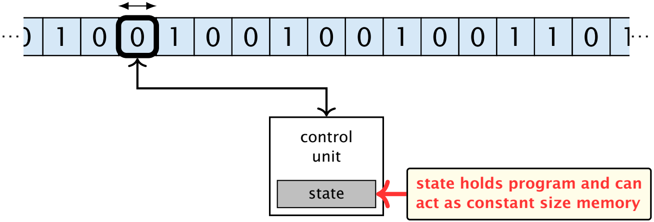
Version 2. is often easier, but focusing on one type of operation makes it more difficult to obtain meaningful results.

Turing Machine

- Very simple model of computation.



Turing Machine

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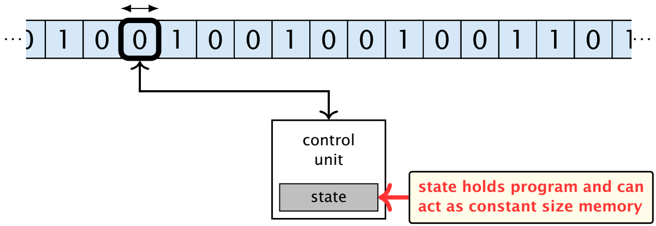

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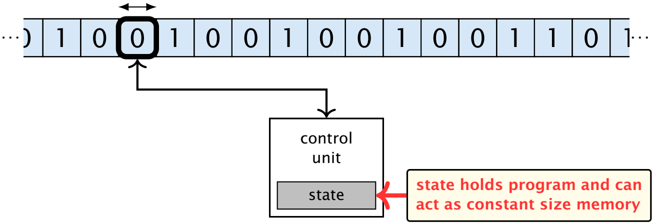

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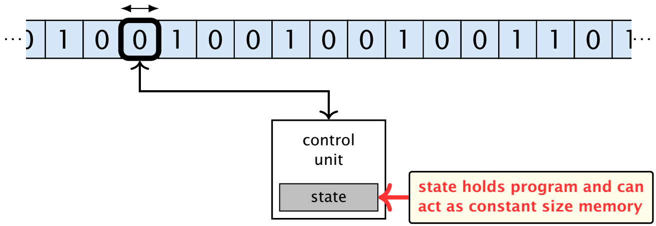

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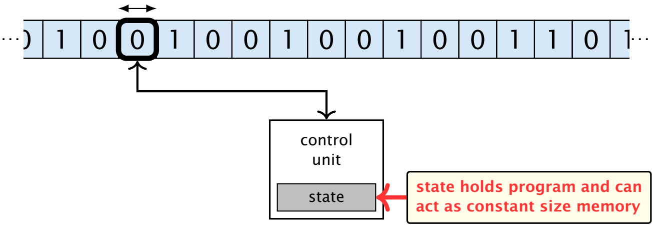
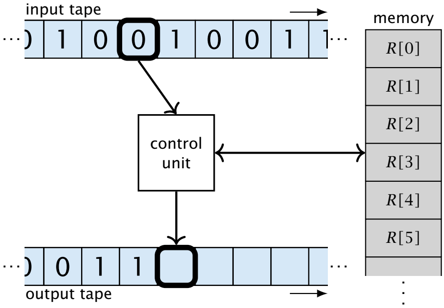
$\Rightarrow$ **Not a good model for developing efficient algorithms.**



Random Access Machine (RAM)

- Input tape and output tape (sequences of zeros and ones; unbounded length).



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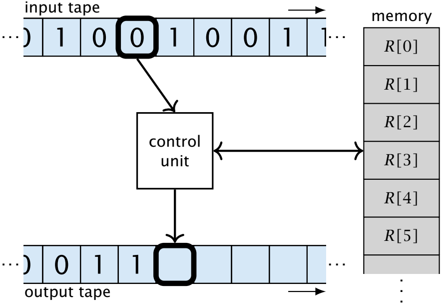

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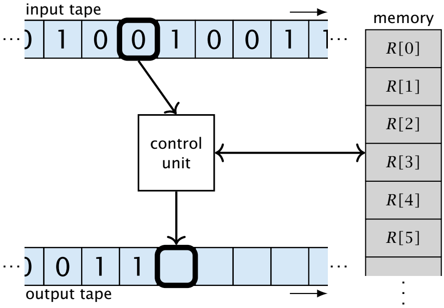

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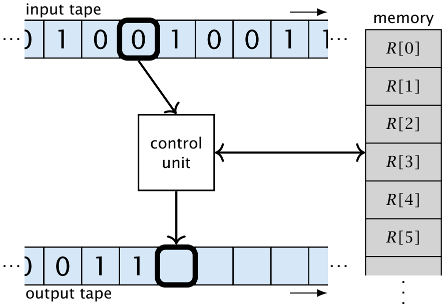

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  - $R[i]$ `:=` $R[j]$ `+` $R[k]$`;`
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Bounded word RAM model: cost is uniform but the largest value stored in a register may not exceed 2^w, where usually $w = \log_2 n$.

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Algorithm 1 RepeatedSquaring(n)

$r \leftarrow 2$;
for $i = 1 \rightarrow n$ **do**
  $r \leftarrow r^2$
return r

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  more general: probability measure μ

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  The average cost of data structure operations over a worst case sequence of operations.
- randomized complexity:
  The algorithm may use random bits. Expected running time (over all possible choices of random bits) for a fixed input x. Then take the worst-case over all x with $|x| = n$.