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Variants of Turing Machines & Nondeterminism

Chapter 4: Turing machines

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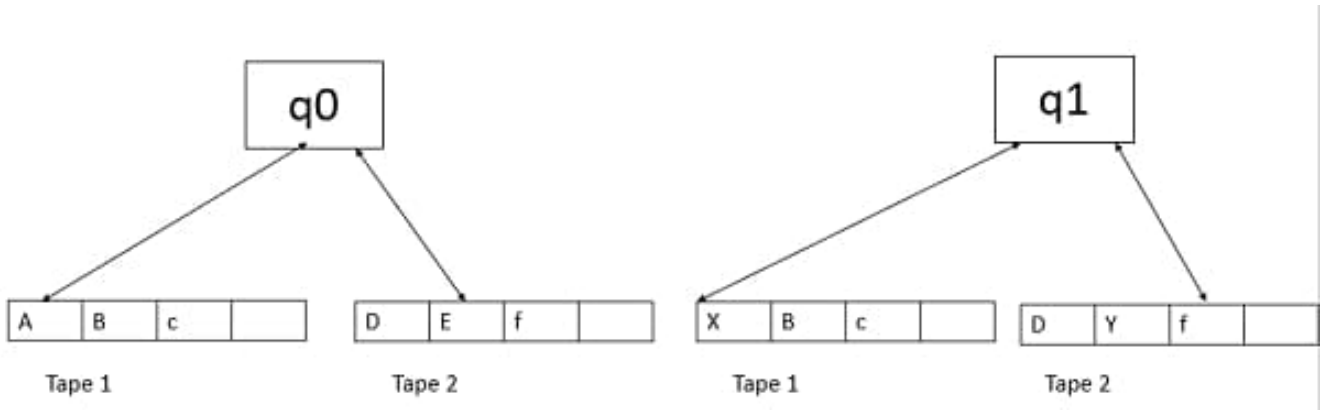
Variations of Turing Machine

- Turing machines are powerful computational models that can simulate any algorithmic process.
- A standard Turing machine consists of a single tape and a single read-write head. However, there are variations of Turing machine that have been developed to address different computational challenges.
- These variations differ mainly in structure and operation, but they all have the same computational power as the standard Turing machine.

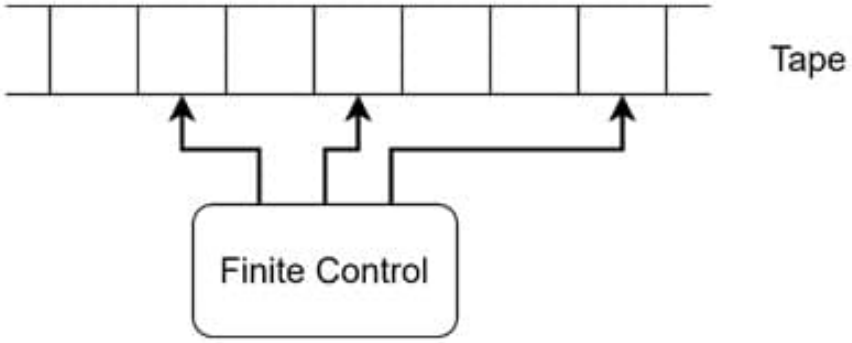
Multi-tape Turing Machine

- As the name suggests, a multi-tape Turing machine is an extension of the standard Turing machine where multiple tapes are available for input, output, and computation.
- Each tape has its own read-write head, and the machine's transition function is based on the current state and the symbols read by each head.



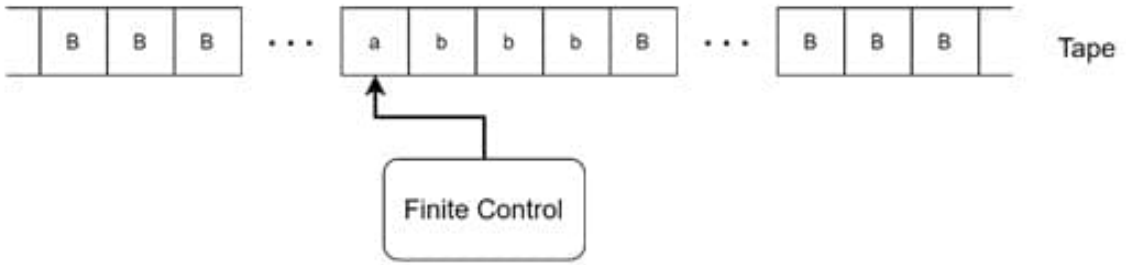
Multi-head Turing Machine

- In a multi-head Turing machine, a single tape is used, but it has multiple read-write heads.
- These heads can independently read and write symbols, enabling the machine to perform complex tasks more efficiently.



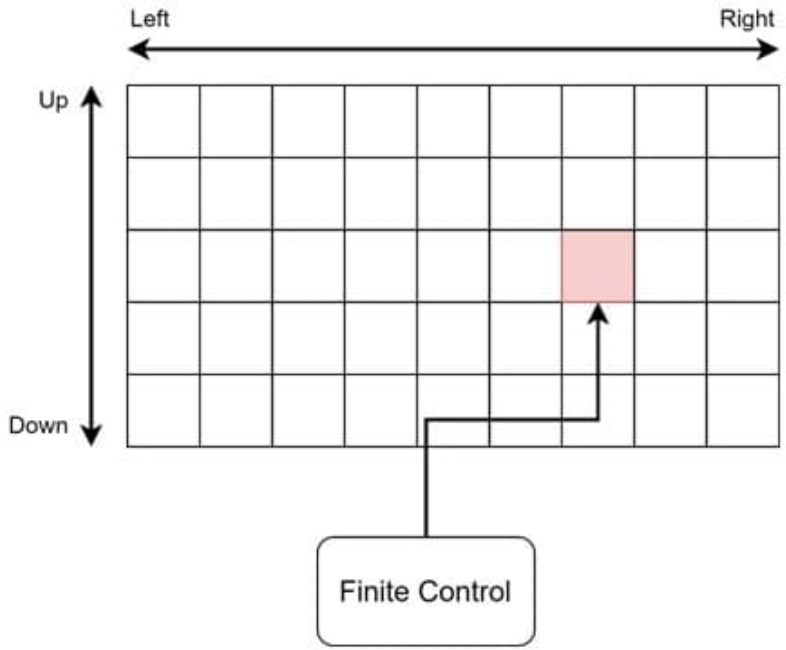
Two-way Infinite Tape Turing Machine

- A two-way infinite tape Turing machine allows the tape to extend infinitely in both directions, unlike the standard machine where the tape extends infinitely in only one direction.
- This removes the boundary on the left side of the tape.



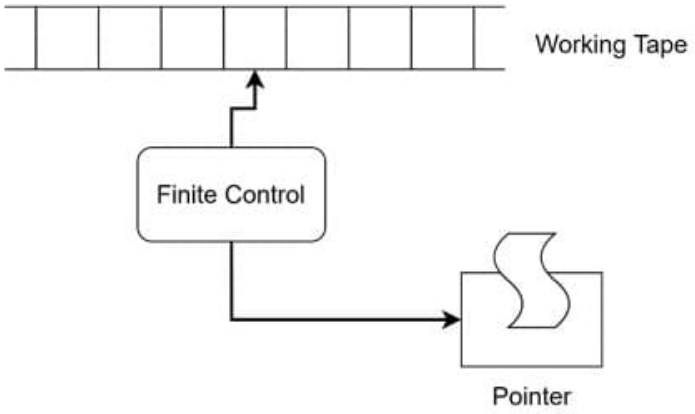
K-dimensional Turing Machine

- A K-dimensional Turing machine extends the concept of the tape to multiple dimensions.
- For example, a two-dimensional Turing machine as given in the following diagram, has a tape that extends infinitely in both the X and Y directions.



Enumerator Turing Machine

- An enumerator Turing machine is designed to generate strings of a language. It is equipped with a work tape and an output tape.
- The machine writes symbols to the output tape, which is then printed.



Enumerator Turing Machine

- The enumerator repeatedly writes symbols on the output tape based on its transition functions.
- Once a string is completed, it is printed, and the machine resets to generate the next string.
- This type of Turing machine is useful for tasks where the goal is to list all valid strings of a language, such as generating all possible solutions to a problem.

Non-deterministic Turing Machine

- In a Non-Deterministic Turing Machine, for every state and symbol, there are a group of actions the TM can have.
- So, here the transitions are not deterministic. The computation of a non-deterministic Turing Machine is a tree of configurations that can be reached from the start configuration.
- An input is accepted if there is at least one node of the tree which is an accept configuration, otherwise it is not accepted.
- If all branches of the computational tree halt on all inputs, the non-deterministic Turing Machine is called a Decider and if for some input, all branches are rejected, the input is also rejected.

Non-deterministic Turing Machine

A non-deterministic Turing machine can be formally defined as a 6-tuple (Q, X, ∑, δ, q_0, B, F) where –

- Q is a finite set of states
- X is the tape alphabet
- **∑** is the input alphabet
- **δ** is a transition function;
- δ : Q × X → P(Q × X × {Left_shift, Right_shift}).
- q_0 is the initial state
- B is the blank symbol
- F is the set of final states

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