Turing Machines

• Finite Automata
  – finite control
  – no run-time memory

• Pushdown Automata
  – finite control
  – a single pushdown stack with unlimited size

• Turing Machine
  – finite control
  – a tape of memory with unlimited size
  – read and write a symbol at any place of the tape
Turing Machine

- A Turing machine is similar to a computer. It consists of the following components.
  - a finite control
  - a tape with unlimited number of cells, each for one symbol
  - a tape head
  - tape symbols
  - input symbols
Pushdown Automata

| $a_1$ | $a_2$ | ..., | $a_i$ | .... | $a_n$ |

Tape

Finite Control
Turing Machine: Definition

- A single tape deterministic TM is a system \((Q, \Sigma, \Gamma, \delta, q_0, \Delta, F)\)
  - \(Q\) is a finite set of states
  - \(\Gamma\) is a finite set of table symbols
  - \(\Sigma\) is a finite set of input symbols, which is a subset of \(\Gamma\)
  - \(\Delta\) is the blank symbol in \(\Gamma\)
  - \(\delta\) is a transition function mapping from \(Q \times \Gamma\) to \(Q \times \Gamma \times \{L, R\}\)
    (it may be undefined for some arguments).
  - \(q_0\) is the initial state.
  - \(F\) is the set of final states.
Language Accepted by Turing Machine

• Initial configuration
  – the first $|x|$ tape cells contain the input string $x$ and the rest of the cells are $\Delta$’s
  – the state is the initial state
  – the tape head is in the leftmost cell of the tape

• An input string $x$ is accepted if
  – it halts at a final state

• An input string is not accepted if
  – it halts at a non-final state, or
  – it never halts
Language Defined by TM

• Every regular language is Turing-acceptable.

• Every context-free language is Turing-acceptable.
Used As A Function

- When a TM halts at a state, there may be some nonblank symbols left in the tape. These symbols are called as the output of the TM.

- Therefore, a TM is a function that accepts an input string and outputs another string. Particularly, input strings could be digit strings.

- A TM may not halt on some input strings, so the output of some input strings may not be defined.