Chap. 10
Other Models of Turing Machines

10.1 소개 - STM의 power 증명?

M 이용 STM에서 simulate 하는 과정

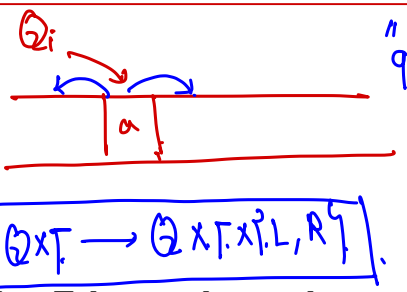
Agenda of Chapter 10

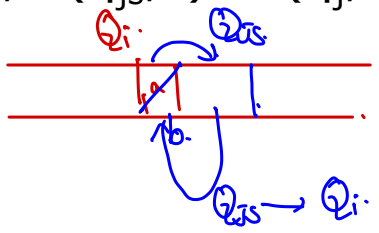
- Minor variations on the Turing machine theme
  - Turing machines with a Stay-option
  - Turing machines with multiple tracks
  - Turing machines with semi-infinite tape
  - The off-line Turing machine
- Turing machines with more complex storage
  - Multitape Turing machines
  - Multidimensional Turing machines
- Nondeterministic Turing machines
- A Universal Turing machine

Turing Machine with minor variations (1/3)

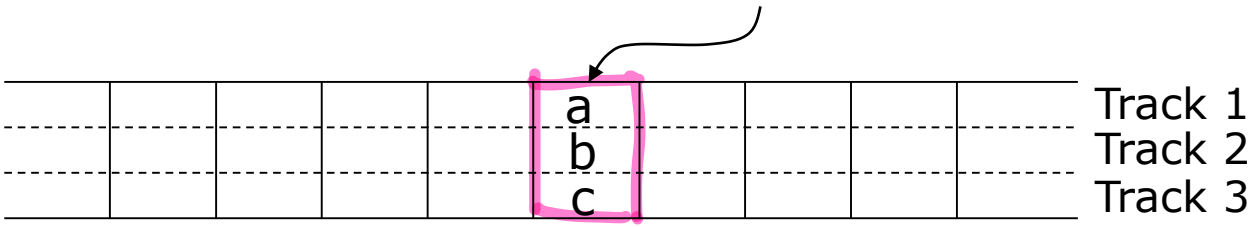
- Turing Machine with a stay-option
  - $\delta : Q \times \Gamma \rightarrow Q \times \Gamma \times \{L, R, S\}$
  - simulation with standard TM

    $\delta(q_i,a) = (q_j, b, S) \Leftrightarrow \delta(q_i,a) = (q_{js}, b, R), \delta(q_{js},c) = (q_j, c, L)$ for all c





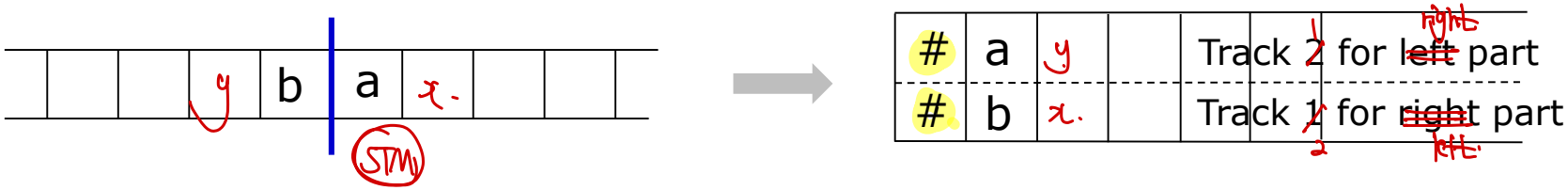
- Turing Machine with multiple tracks



  - String on three tracks can be considered as a symbol

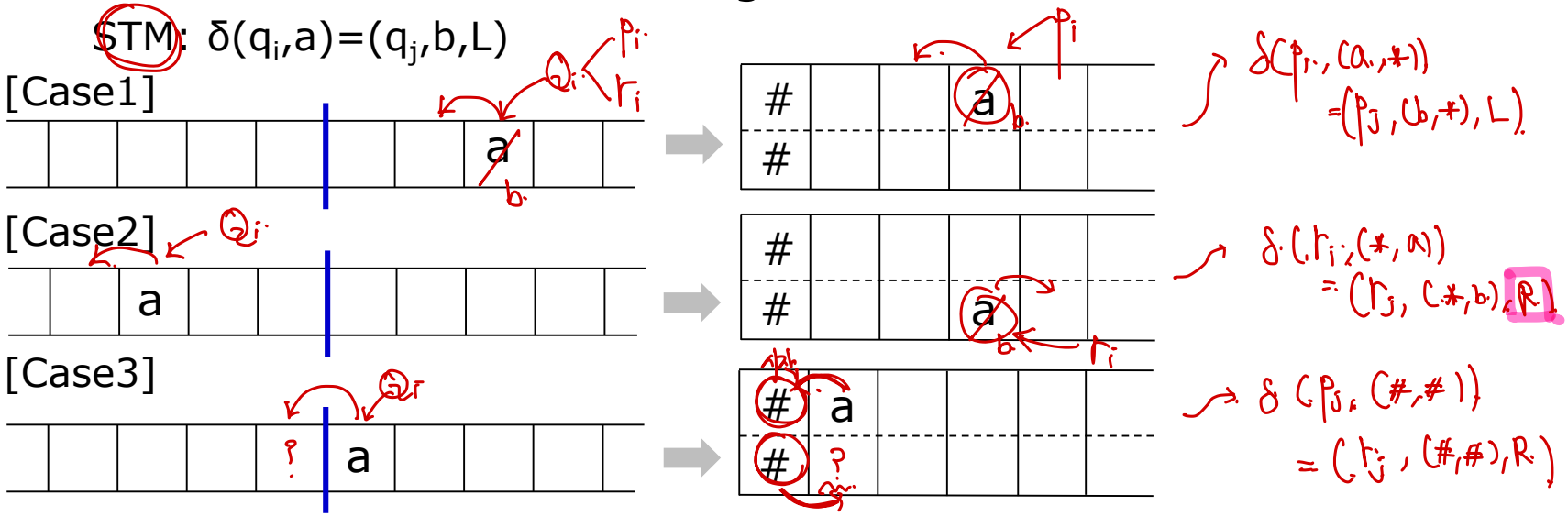
Turing Machine with minor variations (2/3)

- Turing machine with semi-infinite tape
  - Tape is unbounded only in one direction
  - Semi-infinite tape with 2-tracks can simulate Standard TM.



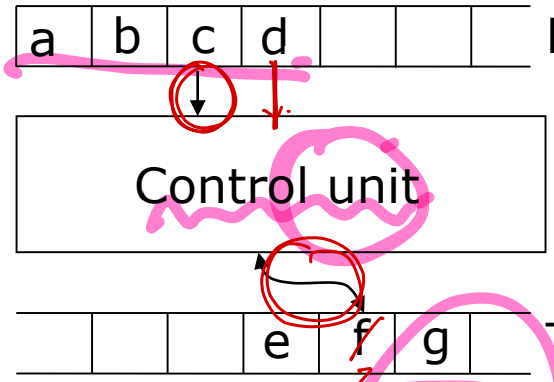
  - Simulation of STM using semi-STM

STM: $\delta(q_i,a)=(q_j,b,L)$

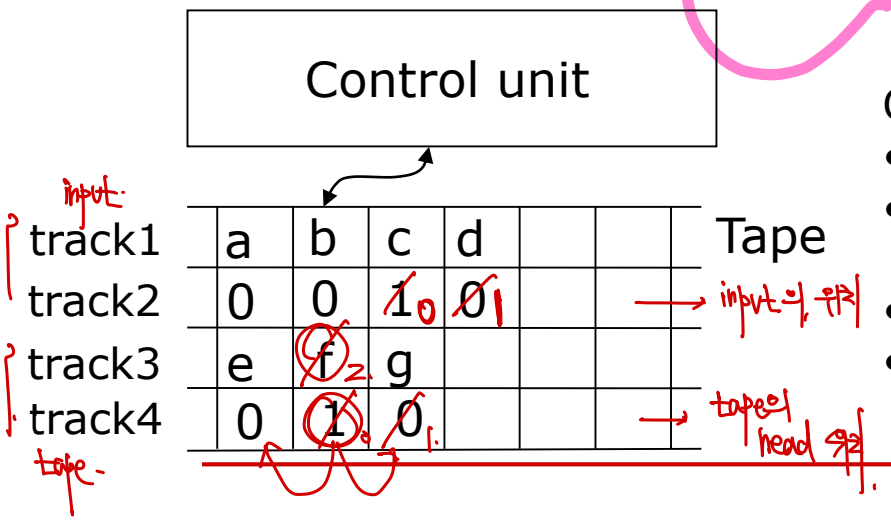


Turing Machine with minor variations (3/3)

- Off-line Turing machine
  - Turing machine with input file



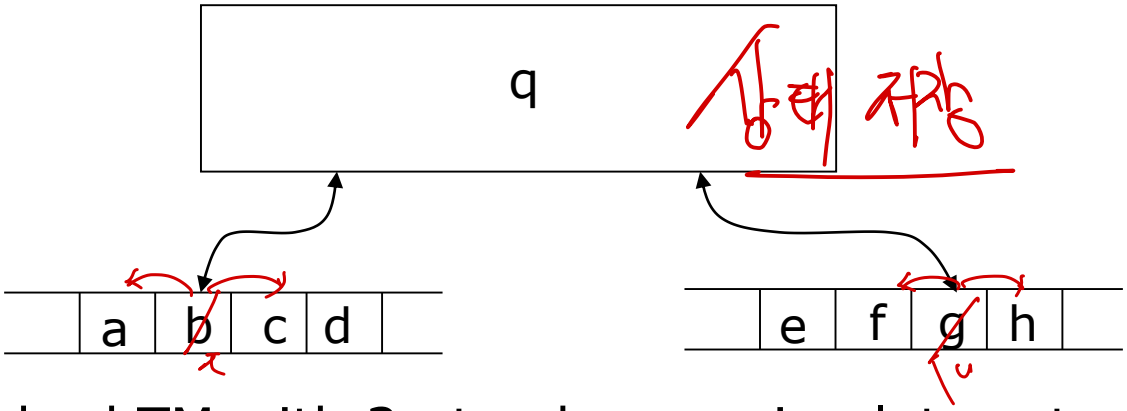
  - Standard TM with 4 tracks can simulate off-line TM.



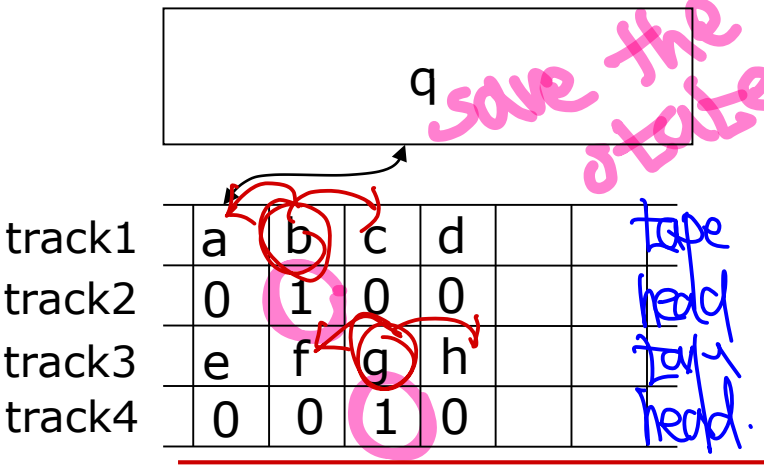
Operations:
- Find 1 on track 2
- Read input symbol, save state, change symbols on track 2
- Find 1 on track 4
- Read tape symbol, change state, and change symbols on track 3 & 4.

Multitape Turing Machine

- n-tape Turing machine
  - $\delta : Q \times \Gamma^n \rightarrow Q \times \Gamma^n \times \{L, R\}^n$



  - Standard TM with 2n tracks can simulate n-tape TM.

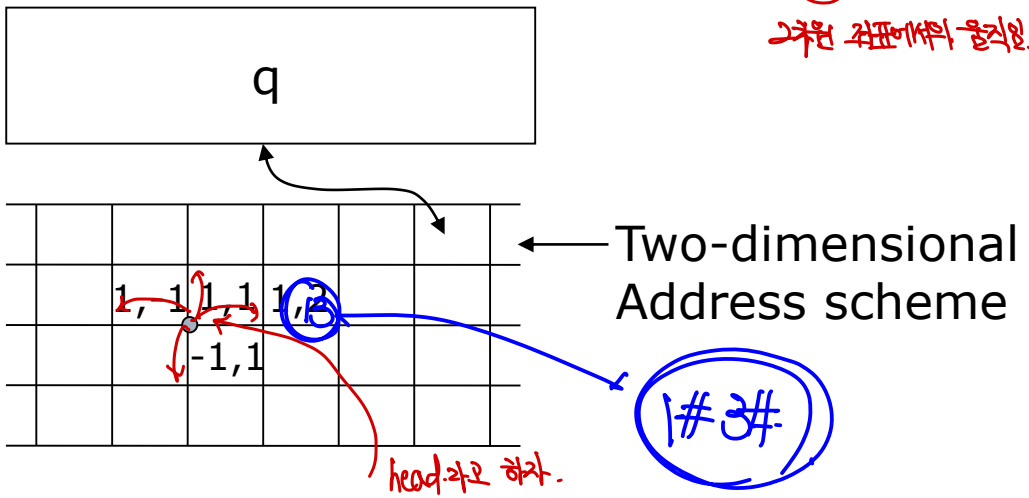


Operations:

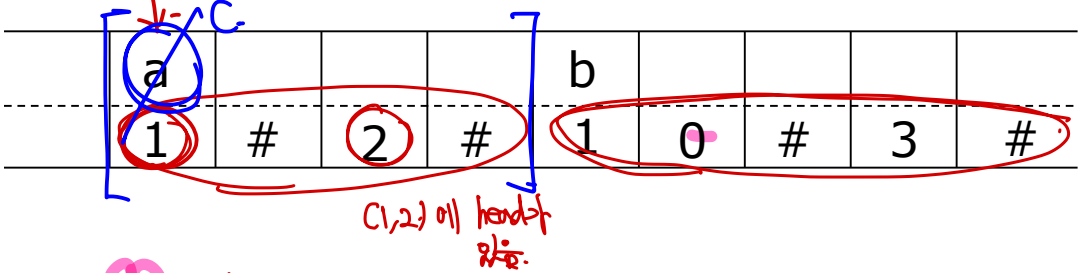
- Find 1 on track 2
- Read tape 1 symbol, save the state, and change symbol on track 1 & 2
- Find 1 on track 4
- Read tape 2 symbol, change state, and change symbols on track 3 & 4.

Multidimensional Turing Machine

- 2-dimensional Turing machine
  - $\delta : Q \times \Gamma \rightarrow Q \times \Gamma \times \{L, R, U, D\}$



- Standard TM with 2 tracks can simulate 2-dimensional TM.

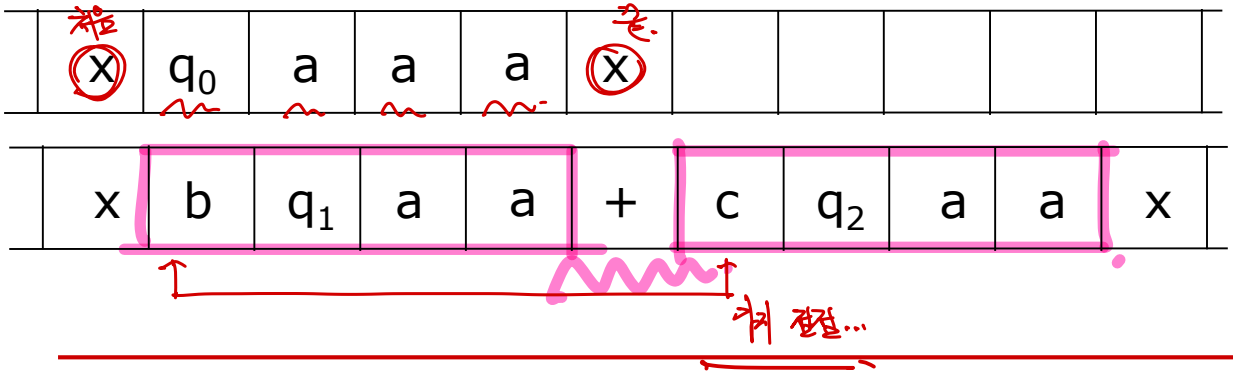


Operations:

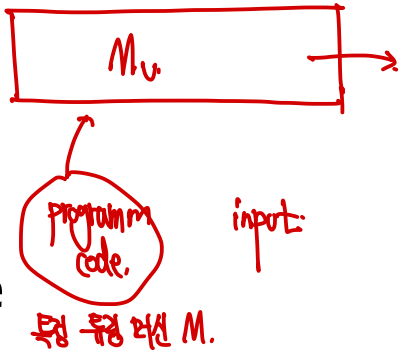
- Read symbol on track 1.
- Change tape symbol on track 1 and internal state.
- Move head to next position using information on track 2.

Nondeterministic Turing Machines

- Nondeterministic Turing machine
  - $\delta : Q \times \Gamma \rightarrow 2^{Q \times \Gamma \times \{L, R\}}$
  - Ex) $\delta(q_0,a)=\{(q_1,b,R), (q_2,c,R)\}$
  - Simulation using standard TM
    - Trace the movement using instantaneous descriptions
    - Use symbol X to delimit the area of interest
    - Use symbol + to separate individual instantaneous descriptions
  - Ex) $q_0aaa \vdash bq_1aa$, $q_0aaa \vdash cq_2aa$



Universal Turing Machine (1/2)



- Turing machine vs. Digital computer
  - Special purpose vs. general purpose.
- To overcome the objection
  - Design a reprogrammable Turing machine
- A universal Turing machine M_u
  - input : a description of any Turing Machine M and a string w
  - Simulate the computation of M on w
- Description of Turing machines.
  - Assumption

    $Q=\{q_1,q_2,\ldots,q_n\}$, q_1=initial state, $F=\{q_2\}$, $\Gamma=\{a_1,a_2,\ldots,a_m\}$, $a_1=\square$
  - Encoding

    q_i=11…1 ($|q_i|=i$), a_i=11…1 ($|a_i|=i$), 0 separator between 1's.

    Ex) $\delta(q_1,a_2) = (q_2, a_3, L)$ ➔ …10110110111010
    (q_1 a_2 q_2 a_3 L)

Universal Turing Machine (2/2)

- A universal Turing Machine M_u simulating an M with input w
  - Consider M_u with three tapes.
  - Operations of M_u
    1. Look at tapes 2 & 3.
    2. Consults tape 1 to see what M would do.
    3. Modify tapes 2 & 3.