Afternoon

Turing Machine

- Enumerating
- Coding of TM
- Recursive language
- Chomsky Grammar

Enumerating Strings

All $w \in \{0,1\}^*$, in order of the length :

ε, 0, 1, 00, 01, 10, 11, 000, 001, 010, 011, …

1, 10,11,100,101,110,111,1000,1001,1010,1011, …

To take 1w as a binary integer, where 1w = i, w is called the *i*th string.

Coding of Turing machine

Let TM $M = (Q, \{0,1\}, \Gamma, \delta, q_1, B, \{q_2\})$

Where $Q = \{q_1, q_2, \ldots, q_r\}$, $\Gamma = \{X_1, X_2, X_3, \ldots, X_s\}$

$$X_1 : 0,\ X_2 : 1,\ X_3 : B,\ D_1 : \leftarrow,\ D_2 : \rightarrow$$

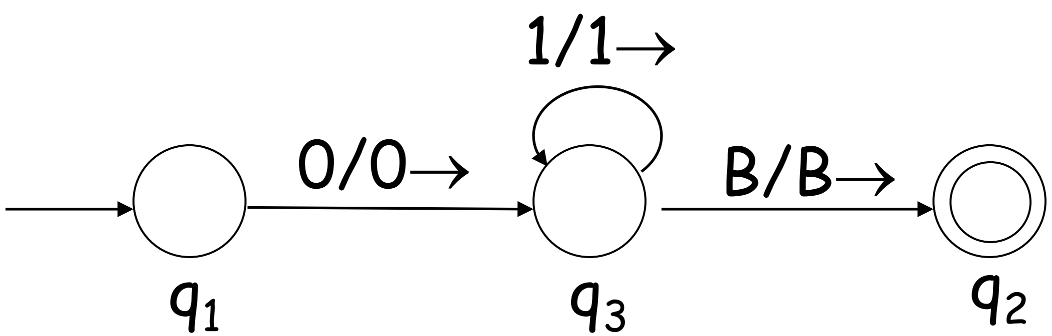
Coding :

$$\delta(q_i, Xj) = (q_k, X_m, D_n)$$

$$\Rightarrow 0^i 1 0^j 1 0^k 1 0^m 1 0^n$$

$$M \Rightarrow C_1 11\ C_2 11\ C_3 11 \ldots C_{n-1} 11\ C_n$$

Example 1 Coding of TM



$\delta(q_1,0) = (q_3,0,\rightarrow) \Rightarrow 010100010100$

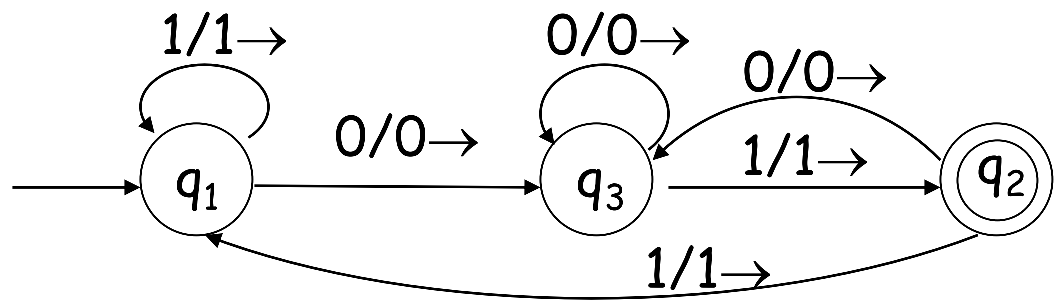
$\delta(q_3,1) = (q_3,1,\rightarrow) \Rightarrow 0001001000100100$

$\delta(q_3,B) = (q_2,B,\rightarrow) \Rightarrow 00010001001000100$

TM $\Rightarrow$ 010100010100 11 0001001000100100 11

00010001001000100

Example 2 Coding of TM



$\delta(q_1,0) = (q_3,0,\rightarrow)$

$\Rightarrow$ 010100010100

$\delta(q_1,1) = (q_1,1,\rightarrow)$ $\Rightarrow$ 010010100100

$\delta(q_3,0) = (q_3,0,\rightarrow)$ $\Rightarrow$ 00010100010100

$\delta(q_3,1) = (q_2,1,\rightarrow)$ $\Rightarrow$ 000100100100100

$\delta(q_2,0) = (q_3,0,\rightarrow)$ $\Rightarrow$ 0010100010100

$\delta(q_2,1) = (q_1,1,\rightarrow)$ $\Rightarrow$ 0010010100100

TM $\Rightarrow$ 01010001010011010010100100110001010001010011

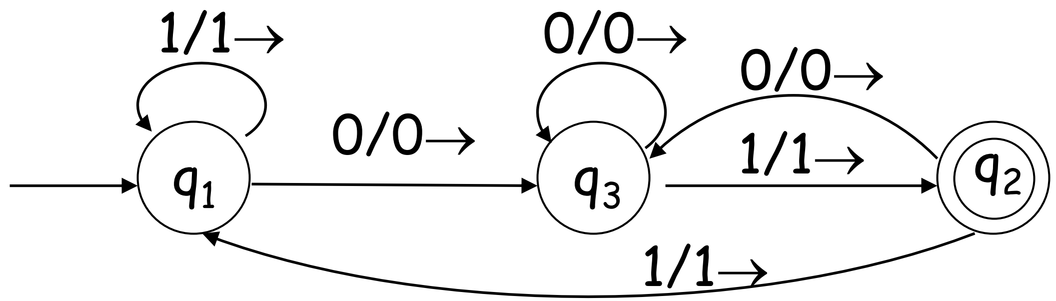
0001001001001001100101000101001100100101000100

Not - *RecuEnuLang*

$$L_d = \{\, w_i \mid w_i \notin L(M_i) \,\}$$

	1	2	3	4	...
1	0	1	1	0	...
2	1	0	0	0	...
3	0	0	0	1	...
4	0	1	0	1	...
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

Not - RecuEnuLang



TM ⇒ 01010001010011010010100100110001010001010011

000100100100100110010100010100110010010100100

$$w_i \notin L(M_i)$$

L_d is not *RecuEnuLang*

Theorem L_d is not a recursively enumerable language.
That is there is no TM to accept L_d .

Proof : Suppose L_d were L(M) for some TM M.

$\Rightarrow$ There is at least one code for M, say i,that $M=M_i$

Now, ask if w_i is in L_d .

- w_i is in $L_d \Rightarrow M_i$ accepts $w_i \Rightarrow w_i$ is not in L_d
- w_i is not in $L_d \Rightarrow M_i$ does not accept $w_i \Rightarrow w_i$ is in L_d

Recursive languages

L is recursive if $L=L(M)$ for some TM M such that

1. $w \in L \Rightarrow$ M accepts w and halts

2. $w \notin L \Rightarrow$ M eventually halts

Recursive languages

If L is recursive language, so is $\overline{L}$.

Suppose $L=L(M)$, $M=(Q, \Sigma, \Gamma, \delta, q_0, B, F)$

Let $\overline{M}=(Q \cup \{r\}, \Sigma, \Gamma, \delta, q_0, B, \{r\})$ such that

1. r is a new state which is not in Q
2. if $\delta(q,a) = \phi$ for any $q \in Q-F$ and $a \in \Sigma$

   then $\delta(q,a) = (r, a, \rightarrow)$

Recursive languages

If both L and its complement $\overline{L}$ are RE, then L is recursive.

Suppose $M_1 = (Q_1, \Sigma, \Gamma, \delta_1, q_1, B, F_1)$

$M_2 = (Q_2, \Sigma, \Gamma, \delta_2, q_2, B, F_2)$

$M = (Q_1 \times Q_2, \Sigma, \Gamma, \delta, (q_1,q_2), B, F_1 \times (Q_2 - F_2))$

$\delta((p,q),(a,b)) = (\delta_1(p,a), \delta_2(q,b))$

Universal TM

$$L_u = \{\ (M,w) \mid w \in L(M)\ \}$$

Universal language

Let $L(M) = \{0\}\{1\}^*$

Tape 1 : 010100010100 11 0001001000100100 11

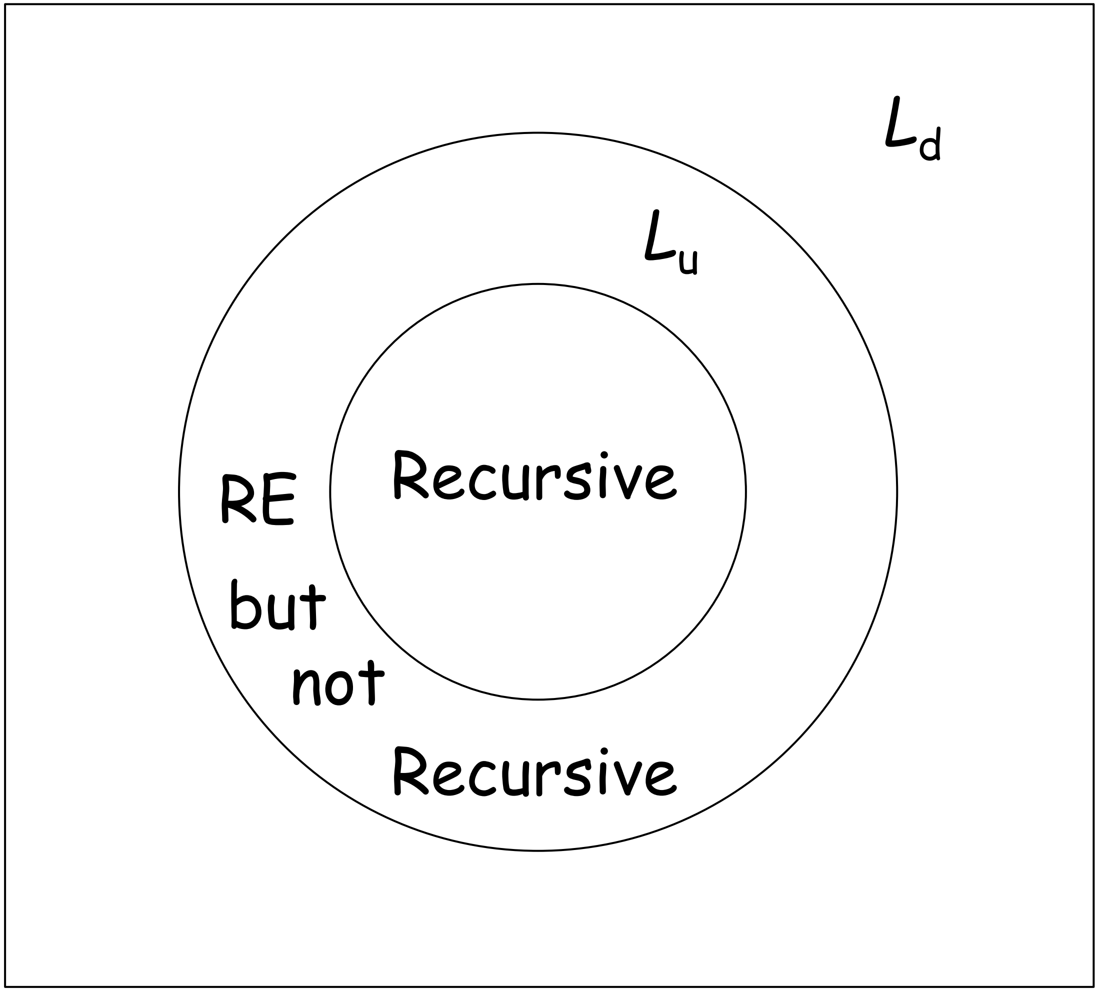
0001000100100010011011

Tape 2 : 10100100

Tape 3 : 0

Tape 4 :

Recursive languages



Chomsky Grammar

Type 0: phrase structure grammar(PSG)

$\alpha \to \beta$; $\alpha \in (V \cup T)^* V (V \cup T)^*$, $\beta \in (V \cup T)^*$

Type 1: context sensitive grammar(CSG)

$\alpha A \beta \to \alpha \omega \beta$; $A \in V$, $\alpha, \omega, \beta \in (V \cup T)^*$

Type 2: context free grammar(CFG)

$A \to \omega$; $A \in V$, $\omega \in (V \cup T)^*$

Type 3: regular grammar(RG)

$A \to \alpha \mid \alpha B$; $A, B \in V$, $\alpha \in T^*$

Phrase Short Grammar

$W = aaabbbccc$

$S \to abc \mid aAbc$
$Ab \to bA$
$Ac \to Bbcc$
$bB \to Bb$
$aB \to aa \mid aaA$

S
$aAbc$
$abAc$
$abBbcc$
$aBbbcc$
$aaAbbcc$
$aabAbcc$
$aabbAcc$
$aabbBbccc$
$aabBbbccc$
$aaBbbbccc$
$aaabbbccc$

$S \to aAbc$
$Ab \to bA$
$Ac \to Bbcc$
$bB \to Bb$
$aB \to aaA$
$Ab \to bA$
$Ab \to bA$
$Ac \to Bbcc$
$bB \to Bb$
$bB \to Bb$
$aB \to aa$

Context Sensitive Grammar

$S \rightarrow aDc$

$D \rightarrow aDE \mid b$

$bEc \rightarrow bbcc$

$bEE \rightarrow bbFE$

$FE \rightarrow FF$

$FFc \rightarrow GFc \rightarrow Gcc$

$FG \rightarrow GG$

$bGc \rightarrow bbcc$

$bGG \rightarrow bbHG$

$HG \rightarrow HH$

$HHc \rightarrow EHc \rightarrow Ecc$

$HE \rightarrow EE$

<u>W=aaabbbccc</u>

S	$S \rightarrow aDc$
$a\underline{D}c$	$D \rightarrow aDE$
$a\underline{aDE}c$	
$aa\underline{aDE}Ec$	
$aaa\underline{bEE}c$	$D \rightarrow b$
$aaab\underline{bFE}c$	$bEE \rightarrow bbFE$
$aaabb\underline{FFc}$	$FE \rightarrow FF$
$aaabb\underline{GFc}$	$FFc \rightarrow GFc$
$aaab\underline{bGcc}$	$GFc \rightarrow Gcc$
$aaabbbccc$	$bGc \rightarrow bbcc$

Right Linear Grammars

A grammar $G = (V, T, S, P)$ is said to be right linear if all productions are of the form

$$A \to xB$$

$$A \to x$$

where $A, B \in V$, and $x \in T^*$

Left Linear Grammars

A grammar $G = (V, T, S, P)$ is said to be left linear if all productions are of the form

$$A \to Bx$$

$$A \to x$$

where $A, B \in V$, and $x \in T^*$

Example 3

$G = (\{S\}, \{a, b\}, S, P)$

$S \rightarrow abS \mid a$

$S \rightarrow Sba \mid a$

Example 4

$L=\{w \mid w \in \{0, 1\}^*$ and ending with $01\}$

$L = \{0, 1\}^* \{01\}$

$S \rightarrow A\ 01$

$A \rightarrow A0 \mid A1 \mid \varepsilon$

ie, $S \Rightarrow A01$

$\Rightarrow A001$

$\Rightarrow A0001$

$\Rightarrow A10001$

$\Rightarrow 10001$

$G=(\{S, A\}, \{0, 1\}, S, P)$

What is the right linear grammar for L ?

Example 5

$L = \{ w \mid w \in \{0, 1\}^* \text{ and } w \text{ contains } 01 \}$

$L = \{0, 1\}^* \quad \{01\} \quad \{0, 1\}^*$

$S \rightarrow 0S \mid 1S, \quad S \rightarrow 01A, \quad A \rightarrow 0A \mid 1A \mid \varepsilon$

$G = (\{S, A\}, \{0, 1\}, S, P)$

$P: \quad S \rightarrow 0S \mid 1S \mid 01A, \quad A \rightarrow 0A \mid 1A \mid \varepsilon$

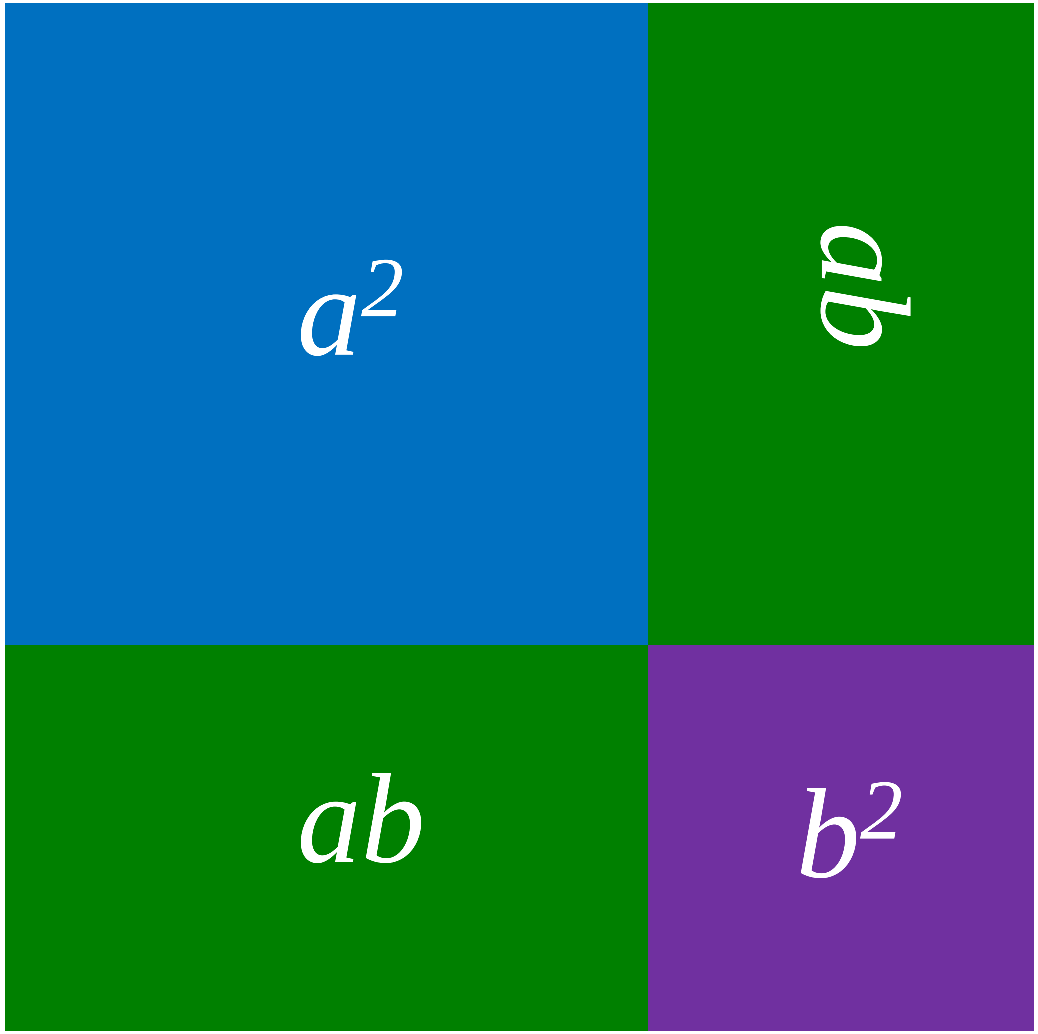
Linear Bounded Automata

A linear bounded automata is a nondeterministic Turing machine $M = (Q, \Sigma, \Gamma, \delta, q_0, B, F)$

that Σ must contain two special symbols [and], such that $\delta(q_i,[)$ can contain only elements of the $(q_j,[, \rightarrow)$, and $\delta(q_i,])$ can contain only elements of the $(q_j,], \leftarrow)$

Good good study

day day up !



a²
ab
ab
b²