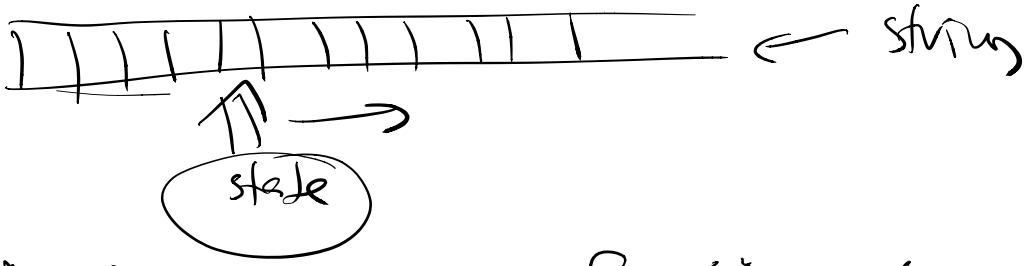
Today: Models of Computation
- Grammers
- λ-calculus
- automata
- RAM-machine

Exam 1: 7-9 pm Monday
Thu lecture: Optional review
Fri lab: exam Q's
Sun 2-4 pm: review session (1002 ~~ECEB~~)
Sat 1-3 pm: Sec A review session (1003 ECEB)

DFA compute $f: \Sigma^* \to \{0,1\}$



NFA compute $f: \Sigma^* \to \{0,1\}$

$\tilde{L}(NFA) = \tilde{L}(DFA)$

DFA simulates an NFA
(subset construction)

Thompson's alg RegEx → NFA

simulation requires exponential # of states

NFA → DFA

Q → 2^Q

$(0-9)^*(374|473)$

Some models of comp can simulate others — with a performance penalty

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Intel CPU → ARM CPU ↔ AIU CPU

L3 ↔ MIPS

simulator

$S \to SS \mid (S) \mid \epsilon$

$S \rightsquigarrow^* (())$ $G \to L(G)$

$S \rightsquigarrow (S) \rightsquigarrow ((S)) \to ((\epsilon))$

$RL \subsetneq CFL \subsetneq 2^{\Sigma^*}$

countable (CFL) — uncountable (2^{Σ^*})

"$A \to BC$ # $B \to C$ # $C \to \emptyset$"

$\to$

"[A] → [B][C]

[B] → [XX]

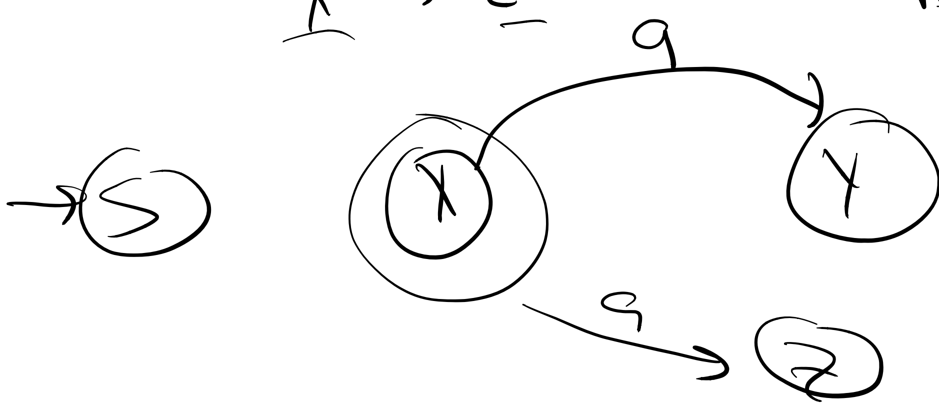
Q0, Q1, ..., Q99 ...

$a^n b^n$ CF but not regular

$a^n b^n c^n$ not CF

$S \to$ $X \to aY \mid aZ$ G_R – grammars with this restriction

$X \to \epsilon$



Chomsky normal form Grammar

$A \to BC$ non-terminals, $B, C \neq S$

$A \to a$

$S \to \epsilon$

CNF-L $\leftrightarrow$ CFL

$\subset$

$=$

~~$S \to A \mid \epsilon$~~

~~$A \to \emptyset A \mid \_$~~

$S \to BC \mid \epsilon$

$A \to BC$

$B \to \emptyset$

$C \to AD$

$D \to 1$

$\alpha \to \beta \qquad \alpha, \beta \in (\Sigma \cup N)^*$

$N \to 2n-1 \qquad |\alpha| = |\beta|$

$|\alpha| = |\beta| - 1$

$1 \xrightarrow{(n-1)} N_{non\text{-}t} \xrightarrow{(n)} N_{term}$

$S \to SS \mid (S) \mid \epsilon$

$S \to SS \to S\epsilon$

LL(1) grammar linear time

$RL \subsetneq LL(1) \subsetneq CFL$

Context free grammar

$$X \to \alpha \qquad X \in N,\ \alpha \in (N \cup \Sigma)^*$$

Context-sensitive grammar

$$\gamma X \delta \to \gamma \alpha \delta \qquad X \in N,\ \alpha, \beta, \gamma, \delta \in (N \cup \Sigma)^*$$

$$0X1 \to 0Y1$$

$$1X0 \to 1Z\emptyset$$

$$CFL \subsetneq CSL$$

$$\{a^n b^n c^n\}$$

Unrestricted grammars

$$\alpha \to \beta \qquad \alpha, \beta \in (N \cup \Sigma)^*$$

$$AB \to B1A$$

$$aBXc \to Zaaa$$

$$RL \subsetneq CFL \subsetneq CSL \subsetneq UGL \subsetneq \Sigma^*$$

RL ↓ DFA / NFA

CFL ↓ NPDA "NFA + stack"

UGL ↓ Turing machine: can read/write tape infinite ← move back or forward

λ - calculus

```
def f(x):
    return x * 2
print(f(7))
```

function call

```
def f(x)
return x*2
print(7*2)
```

LC ⟷ TM ⟷ UGL