CS 302 Automata Theory Fall 2017

Text :

Introduction to Automata Theory, Languages and Computation

Third edition, Pearson 2006

Instructor :

Kemal İnan, inan@sabanciuniv.edu

PREMODERN AUTOMATION

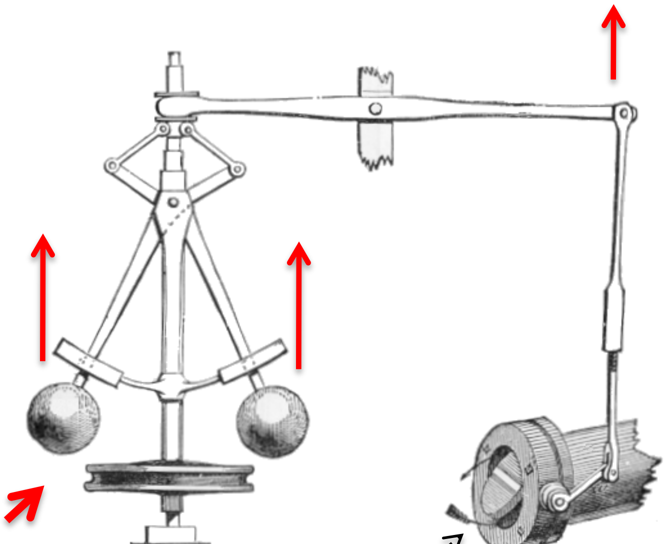
James Watt's Governor (Speed regulator) 1788

James Clerk Maxwell's famous paper (1868) : On Governors

First mathematical treatment of stability

Classical Example of Negative Feedback

flyball operating
with centrifugal force

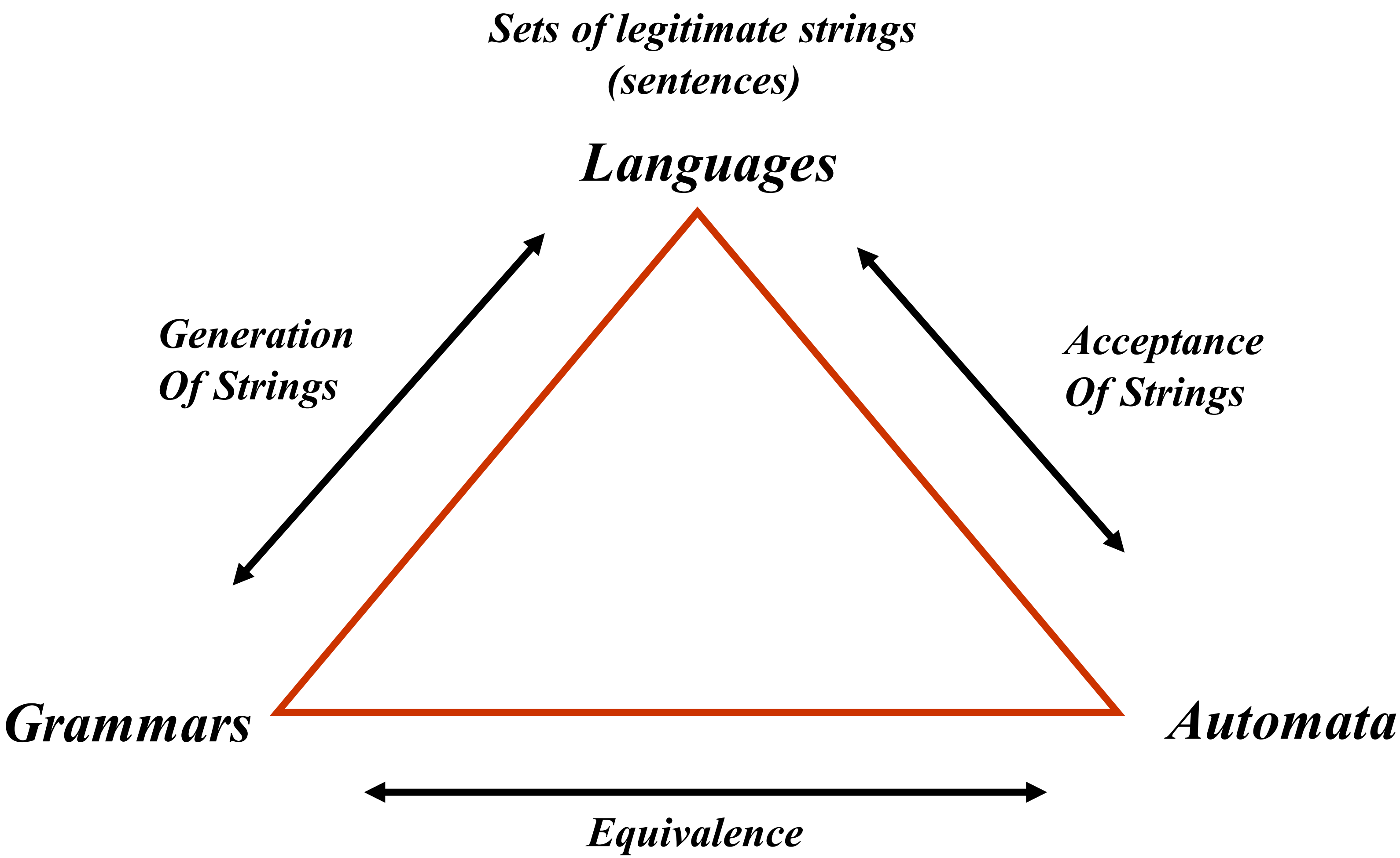


sensing

Steam Valve Opening

action

Topic of the Course → MODERN : LINGUISTIC BASED AUTOMATION



Definition of a Language

(1) A finite set $\boldsymbol{\Sigma}$***,*** *called the* ***alphabet*** *set.*

(2) A ***set*** *of strings with elements in* $\boldsymbol{\Sigma}$ *is called a* ***language*** *over* $\boldsymbol{\Sigma}$

Formal Definition of a Language $L \subseteq \Sigma^*$ *where :*

empty string

$$\Sigma^* := e \cup \Sigma^+$$

$$\Sigma^+ := \Sigma \cup \Sigma^2 \cup \ldots \cup \Sigma^n \cup \ldots = \cup_{k=1,+\infty} \Sigma^k$$

Σ^n := *Set of all strings with elements in* Σ *of length* n

String Operations and Terminology

String Concatenation : $u \in \Sigma^*$, $v \in \Sigma^*$: $u.v \in \Sigma^*$

$u \in \Sigma^+$, $v \in \Sigma^+$ *and* $w \in \Sigma^+$; $\mathbf{s} = \mathbf{u} \,.\, \mathbf{v} \,.\, \mathbf{w}$;

each ***u*****,*****v*** *or* ***w*** *is called a substring of s ;*

u *is called a prefix of s*

w *is called a postfix of s*

$\mathbf{s} \in \boldsymbol{\Sigma}^*$

$\mathbf{s}^n$ *denotes* ***s*** *concatenated* ***n*** *times*

length (***s***) = # *characters in* ***s*** = |***s***|

*How can we define a language **L** ?*

$$L := \{ s \in \Sigma^* \mid F(s) \}$$

*A logical condition on **s** ; **F** is a truth valued function*

There is a problem in this definition :
*Is **F** computable ?*
*What does **computable** mean ?*

Two computable tools are introduced :
(1) Grammars ; (2) Automata

Examples of languages :

(1) Natural Languages *; strings of characters from a keyboard that are* ***syntactically*** *correct in* ***English*** *e.g.* ***The chair ate the elephant*** *is a syntactically correct string (sentence) in the English language ;* ***The ate elephant chair the*** *is not correct !*

(2) Formal *(Computer)* ***Languages :*** *e.g. strings of symbols that are syntactically correct. such as a C++ program for which the compiler does not give a syntax error*

Simpler examples of languages

(*3***)** *Well-defined expressions. Eg. Arithmetic expressions*

using the operators **+** *and* ***x*** *and nonnegative integers*

(32 + 560) x (3 +54x7) *is correct whereas* ***32(+056x7(3))*** *is not correct*

(4) *Problems :* ***encoding ?*** *of* ***decision ?*** *problems*

Examples :

(i) Decision problem : $\boldsymbol{E = \{ (n, m, k) \in Z \times Z \times Z \mid n+m = k\ ?\ \}\ ;\ E \subseteq Z^3}$

(ii) Encoding of a graph ***G*** *that solves the decision problem of connectedness !*

Context Free Grammars

$$G = (\quad V \quad , \quad T \quad , \quad P \quad , \quad S \quad)$$

Terminal symbols $T \subseteq V$

Start symbol $S \in V\text{-}T$

Finite set of symbols

Finite set of production rules
$P \subseteq (V\text{-}T) \times V^*$

Example : generation of integers in decimal notation

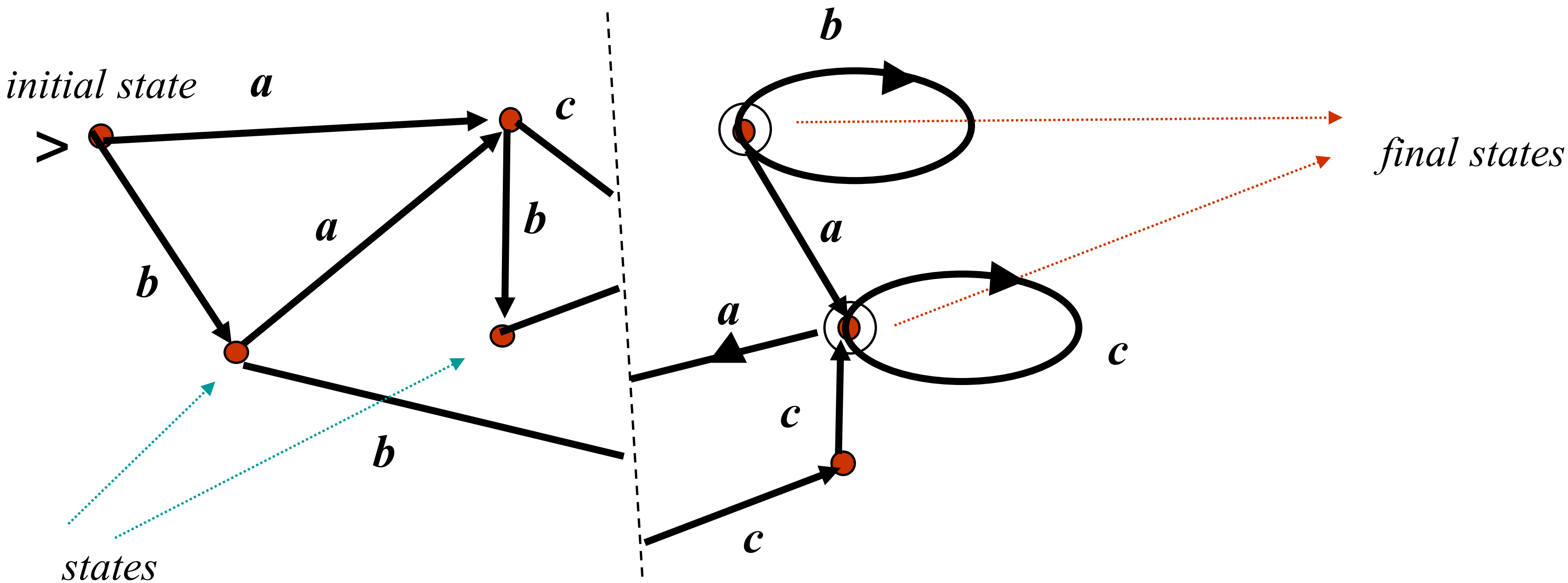
-108970 and +67 and 564 are legitimate strings but 034

and 1-3 and 90+1 are not!

Find a grammar that generates integers in decimal notation !

(Deterministic Finite) Automata over a set $\Sigma = \{a ,b, c , \ ... \}$

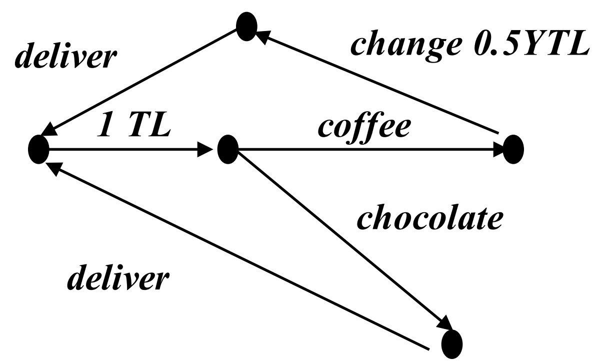
Simple way to define is by directed graphs where edges are labeled by symbols in Σ



*In **CS 302** we use **Automata** as a language acceptor (or generator)*

But there are other uses in modeling real systems :

(1) Coffee & Chocolate Machine



(2) Digital Integrated Circuits with input and output