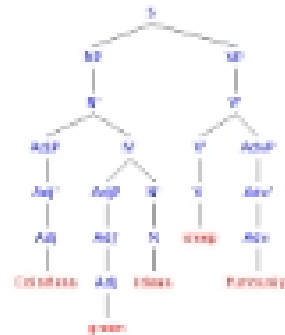


## Lecture 8: Context-Free Languages



## Menu

- Review Machine Models of Computing
- Linguistic Model of Computing
- Challenge Problem Near-Solution - Liuyi (Eric) Zhang
- Context-Free Grammars

## Deterministic Machine Models



**Memory**  
Finite States  
+ Stack  
+ Tape

**Machine**  
DFA  
DPDA  
TM

**Languages**  
Regular  
[this week]  
[later]

## Nondeterministic Machine Models



**Memory**  
Finite States  
+ Stack  
+ Tape

**Machine**  
NFA  
NDPDA  
NDTM

**Languages**  
Regular  
[this week]  
[later]

## Where did these models come from?

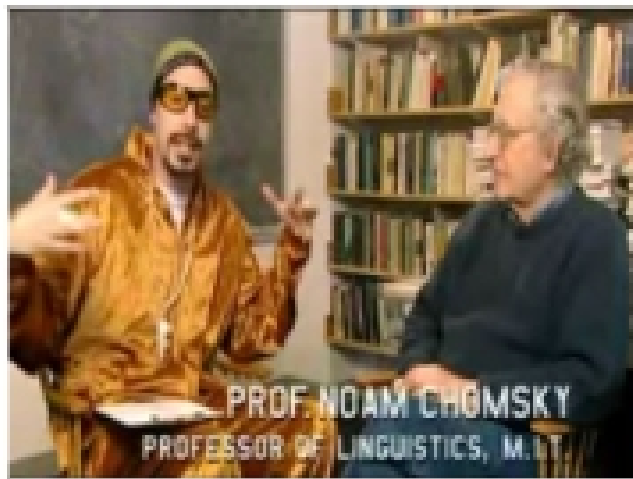
## Modeling Human Intellect

- Turing Machine (Alan Turing, 1936)
  - Modeling Human Computers
- DFAs
  - McCulloch and Pitts, "A logical calculus of the ideas immanent in nervous activity", 1943
  - S. C. Kleene, *Representation of Events in Nerve Nets and Finite Automata*, 1956
  - Claude Shannon and John McCarthy, *Automata Studies*, 1956

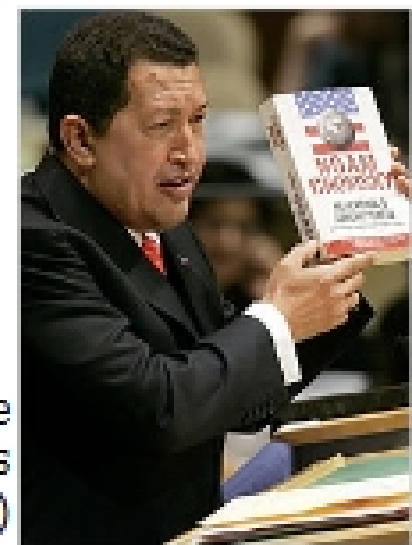
Our theoretical objective is not dependent on the assumptions fitting exactly. It is a familiar strategem of science, when faced with a body of data too complex to be mastered as a whole, to select some limited domain of experiences, some simple situations, and to undertake to construct a model to fit these at least approximately. Having set up such a model, the next step is to seek a thorough understanding of the model itself.

S. C. Kleene, *Representation of Events in Nerve Nets and Finite Automata*, 1956

## Language-Based Models of Computation



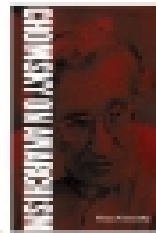
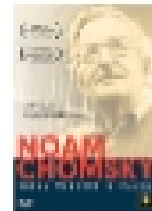
Prof. Noam Chomsky  
Professor of Linguistics, MIT  
Noam Chomsky (born 1928), MIT Linguistics Professor and Leftist Political Activist



Hugo Chávez at the United Nations  
(20 Sept 2006)

*I don't know anybody who's ever read a Chomsky book. He does not write page turners, he writes page stoppers. There are a lot of bent pages in Noam Chomsky's books, and they are usually at about Page 16.*

Alan Dershowitz



"I must admit to taking a copy of Noam Chomsky's *Syntactic Structures* along with me on my honeymoon in 1961. During odd moments, while crossing the Atlantic in an ocean liner and while camping in Europe, I read that book rather thoroughly and tried to answer some basic theoretical questions. Here was a marvelous thing: a mathematical theory of language in which I could use a computer programmer's intuition! The mathematical, linguistic, and algorithmic parts of my life had previously been totally separate. During the ensuing years those three aspects became steadily more intertwined; and by the end of the 1980s I found myself a Professor of Computer Science at Stanford University, primarily because of work that I had done with respect to languages for computer programming."

Donald Knuth



## Replacement Grammars

### *Left* $\rightarrow$ *Right*

Anything that matches the left side can be replaced by what is on the right side.

*Left* and *Right* can be any sequence of variables (nonterminals) and symbols (terminals)

## Restricted Replacement Grammars

Unrestricted:  $\alpha \rightarrow \beta$   
(left and right sides can be any sequence of symbols and variables)

Context-Sensitive:  $\alpha A \beta \rightarrow \alpha \gamma \beta$   
( $A$  is a variable)

Context-Free:  $A \rightarrow \alpha \gamma \beta$

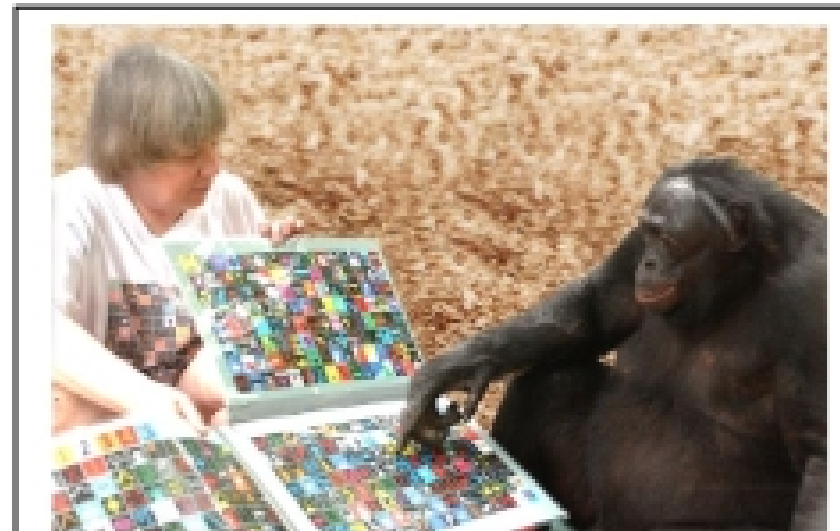
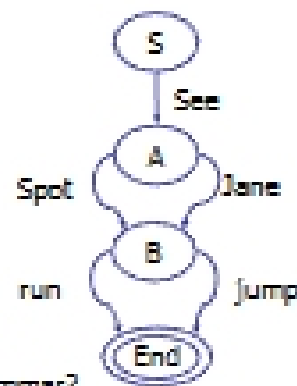
Regular:  $A \rightarrow aB ; A \rightarrow a$

## Example Regular Grammar

$S \rightarrow \text{See } A$   
 $A \rightarrow \text{Spot } B$   
 $A \rightarrow \text{Jane } B$   
 $B \rightarrow \text{run}$   
 $B \rightarrow \text{jump}$

How many possible sentences?

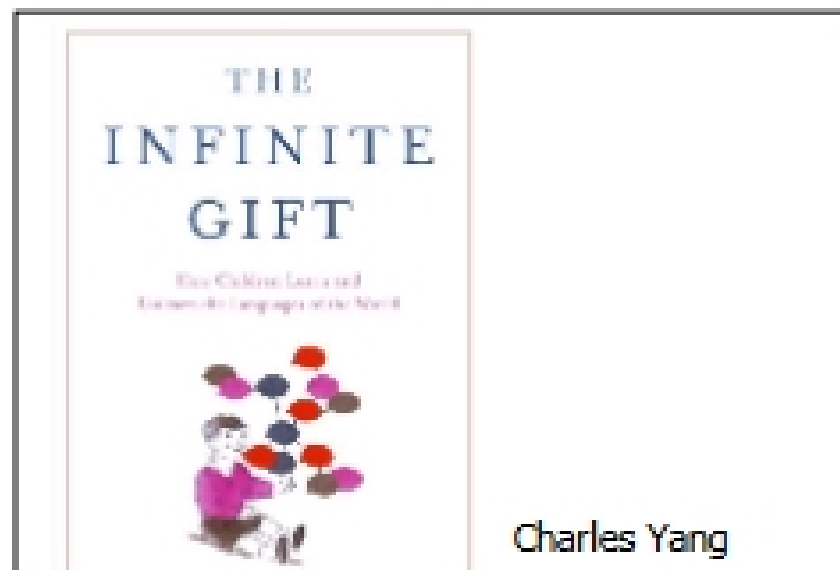
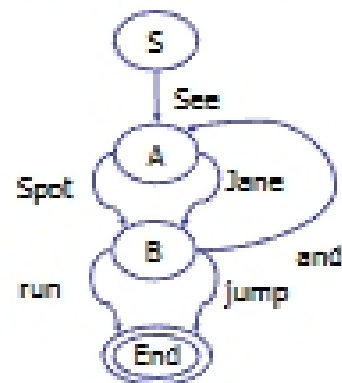
Why do we call it a *Regular* Grammar?



Kanzi and Sue Savage-Rumbaugh

## Example Regular Grammar

$S \rightarrow \text{See } A$   
 $A \rightarrow \text{Spot } B$   
 $A \rightarrow \text{Jane } B$   
 $B \rightarrow \text{run}$   
 $B \rightarrow \text{jump}$   
 $B \rightarrow \text{and } A$



Charles Yang