Finite state machines. Syllabification

NTV Lecture 2

April 1, 2003

Last week

- **words**
  - ⋆ fundamental building block of language
- **regular expressions**
  - ⋆ specify text search strings
  - ⋆ define the language recognized by an automaton
  - ⋆ formally define a regular language
- **finite state automata** (FSA)
  - ⋆ used to implement regular expressions
  - ⋆ using finite alphabet may recognize infinite strings in a regular language

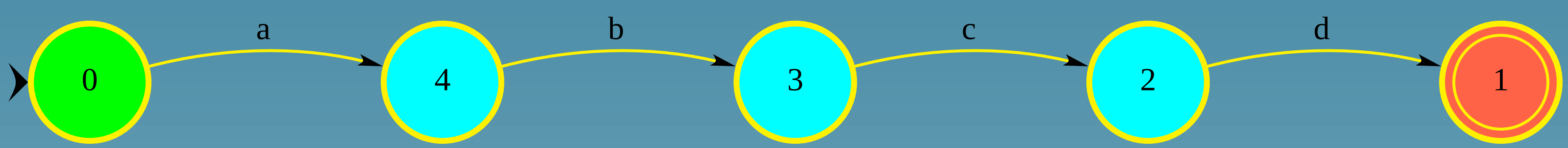
Finite state and syllabification

- Relation between regular expressions and automata
- **Deterministic and non-deterministic automata**
- **ϵ-transitions**
- **Syllabification**
  - ⋆ word splitting in order to justify paragraphs
- Part-of-speech tagging

From regular expressions to finite automata

- Concatenation
  - ⋆ $[A, B]$
  - ⋆ Link final state(s) of automaton A with initial state of automaton B

Concatenation

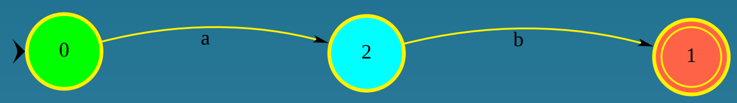


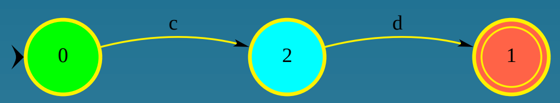
From regular expressions to finite automata

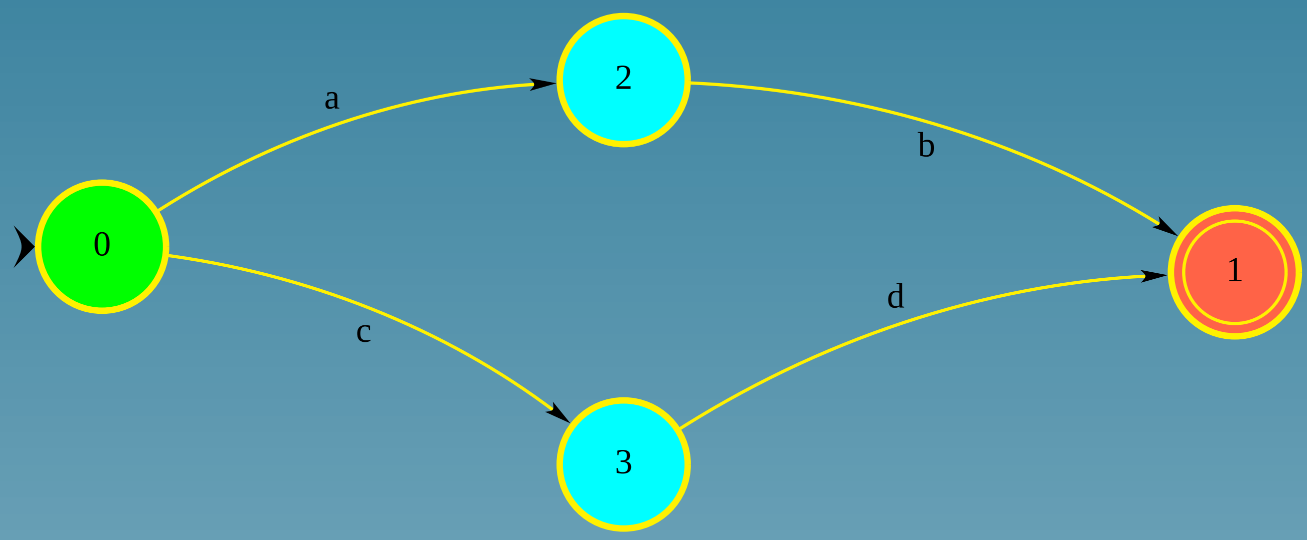
- Disjunction
  - ⋆ {A,B}

  - ⋆ Initial state A = Initial state B,
  - ⋆ Final state A = Final state B

Disjunction







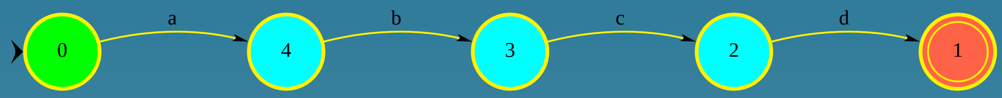
From regular expressions to finite automata

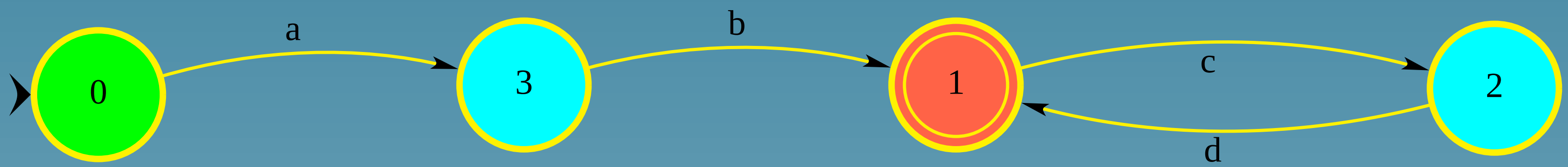
- Optional

  - ⋆ [A, B] → [A, B^]

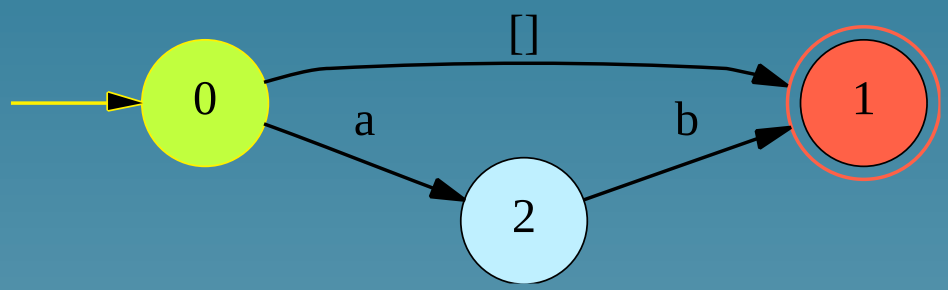
  - ⋆ Add an epsilon-transition (jump) from the initial state of B to the final state(s) of B.

Optional

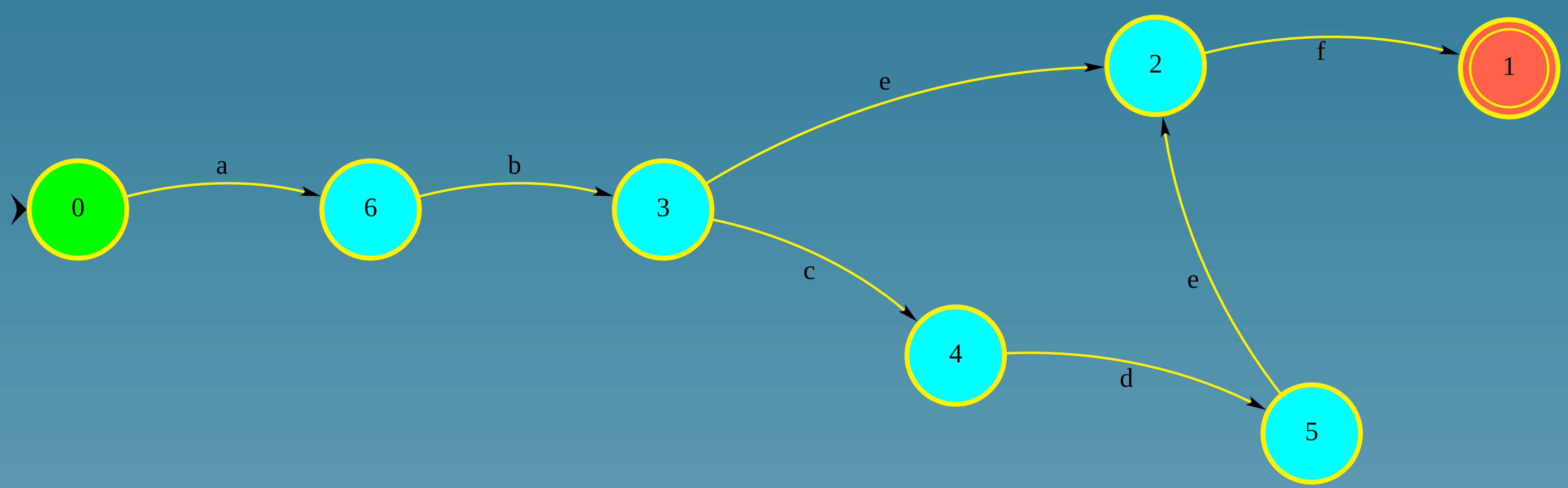




Epsilon-transitions (jumps)



Epsilon-transitions in fsa



From regular expressions to finite automata

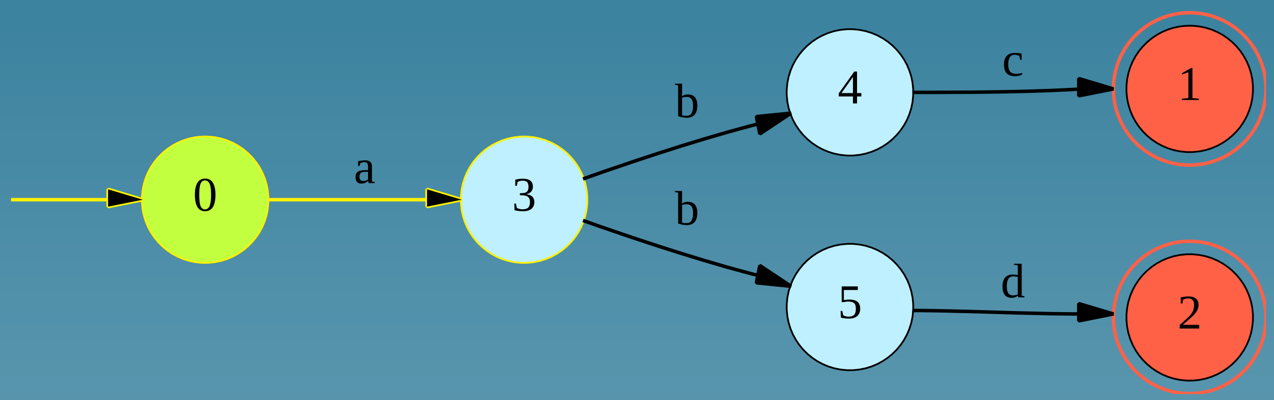
- Kleene Plus: A^+
  - ⋆ Add an epsilon-transition from the final state of A to the initial state of A.
- Kleene Star: A^*
  - ⋆ Add an epsilon-transition from the final state of A to the inital state of A.
  - ⋆ Make the initial state of A also a final state.

Determinism and Non-determinism

- An automaton is deterministic when being at any state Q looking at an input symbol S only one transition (move) is possible for the automaton.

- Automata with epsilon-transitions are non-deterministic.

Non-deterministic recognizer



Deterministic Recognizers

- For every recognizer with epsilon-transitions there is always an equivalent recognizer without jumps
- A non-deterministic recognizer can always be converted into a deterministic one.
- FSA produces deterministic recognizers

Syllabification (woorden afbreken)

- newspaper text fit into narrow columns
- long or complex words splitting
- hyphenation: (apparently) a simple typesetting problem
- in practice, not so simple (Volkskrant, 17-11-01)
  - ⋆ Schaat-sunie
  - ⋆ Bamboes-tok
  - ⋆ Blessures-pook

Hyphenation rules

- respect word boundaries
  - ⋆ Drugs-panden, drug-spanden
- Split syllables
  - ⋆ Al-fa-bet, a-lfa-bet
- Split as early as possible (maximum onset rule)
  - ⋆ Al-fa-bet, alf-a-bet, al-fab-et, alf-ab-et

What is a syllable? (lettergreep)

- A regular expression:
  - ⋆ [onset^, nucleus, coda^]
  - ⋆ Onset: {b, [b, r],[b, l], c,[c, h],. . . }
  - ⋆ Nucleus: {a, [a, a], [a, a, i], e,. . . }
  - ⋆ Coda: {b, c, [c, h], [c, h, t],...}

Simple syllabification program

- Set breaking points between syllables, as early as possible
- Gosse's algorithm evaluation :
  - ⋆ 290.000 words (10,8 letters long, 2,5 hyphens per word)
  - ⋆ 86% correct words
  - ⋆ 94,5% correct hyphenation points
  - ⋆ Errors are often compound words (samenstellingen)

A better syllabification program

- Machine learning algorithm helps to find hyphenation rules automatically
- Automatic syllabification of all words in Celex
- Comparison with correct syllabification
  - ⋆ Rule i-st → is-t (li-stig → lis-tig) corrects 2900 errors (and introduces 300 new errors)
  - ⋆ After learning 1400 rules 98,2% (words) and 99,2% (hyphens) correct

Regular expressions: macros

- Words with one syllable (monosyllable)
- Pattern:
  - ⋆ consonants,vowels,consonants (medeklinkers,klinkers,medeklinkers)
  - ⋆ macro(monosyllable,[cons$*$, vowel$_+$, cons$*$]).
  - ⋆ macro(cons, { b,c,d,. . . ,z }).
  - ⋆ macro(vowel, {,a,e,i,o,u,y}).

Macros 2

- In FSA macro is a label for a regular expression.
- macro(Name,RegExp).
- Macros can be used in the definition of other regular expressions
- To load macros in FSA use LoadAux.

Other applications: Part-of-speech tagging

- labelling of words with their word category
  - ⋆ fiets → common noun, verb (1st sg present)
  - ⋆ fietsen → common noun, verb (infinitive, 2nd–3rd pl present)
  - ⋆ De fietsen staan in de schuur.
  - ⋆ We fietsen naar school.
  - ⋆ vliegen
- Typically this is the first step in syntactic analysis (description of sentence constituency)
- In a corpus with pos tags we can seek syntactic patterns
  - ⋆ all sentences with 3 verbs, etc.
- POS-tagging : word recognition problem + word categorization problem

POS-tagging

- Word recognition problem:
  - ⋆ Proper names : $/[A\ldots Z, a\ldots z]^{*}/$
  - ⋆ Verbs
    - ∘ $/[a\ldots z, \{[e,n],[t],[de]\}]/$
    - ∘ $/[g,e,a\ldots z^{+}, \{[e,n],[t],[d]\}]/$
- Usefulness of recognizers is limited because they only return a binary classification: 'yes' or 'no'
- Word categorization: more complex finite state machines are needed (finite state transducers)