Regular Expression and Automata

Lec-2

Regular expression

- Everybody does it
  - Emacs, vi, perl, grep, etc..
- Regular expressions are a compact textual representation of a set of strings representing a language.
- Regular expression search
  - grep – line of the document

Regular expression

RE	Example Patterns Matched
`/woodchucks/`	"interesting links to woodchucks and lemurs"
`/a/`	"Mary Ann stopped by Mona's"
`/Claire␣says,/`	" "Dagmar, my gift please," Claire says,"
`/DOROTHY/`	"SURRENDER DOROTHY"
`/!/`	"You've left the burglar behind again!" said Nori

Regular expression

RE	Match	Example Patterns
`/[wW]oodchuck/`	Woodchuck or woodchuck	"Woodchuck"
`/[abc]/`	'a', 'b', *or* 'c'	"In uomini, in soldati"
`/[1234567890]/`	any digit	"plenty of 7 to 5"

Regular expression

RE	Match	Example Patterns Matched
`/[A-Z]/`	an upper case letter	"we should call it 'Drenched Blossoms' "
`/[a-z]/`	a lower case letter	"my beans were impatient to be hoed!"
`/[0-9]/`	a single digit	"Chapter 1: Down the Rabbit Hole"

Regular expression

RE	Match (single characters)	Example Patterns Matched
`[^A-Z]`	not an upper case letter	"Oyfn pripetchik"
`[^Ss]`	neither 'S' nor 's'	"I have no exquisite reason for't"
`[^\.]`	not a period	"our resident Djinn"
`[e^]`	either 'e' or '^'	"look up ^ now"
`a^b`	the pattern '`a^b`'	"look up a^ b now"

Regular Expressions: ? * + .

Pattern	Matches	
colou?r	Optional previous char	color colour
oo*h!	0 or more of previous char	oh! ooh! oooh! ooooh!
o+h!	1 or more of previous char	oh! ooh! oooh! ooooh!
baa+		baa baaa baaaa baaaaa
beg.n		begin begun begun beg3n

Regular Expressions: Anchors ^ $ \b

Pattern	Matches
^[A-Z]	Palo Alto
^[^A-Za-z]	1 "Hello"
\.$	The end.
.$	The end? The end!

Disjunction and Grouping

<table>
<tr><th>Patterns</th><th>Match</th></tr>
<tr><td>guppy|ies</td><td>guppy and ies</td></tr>
<tr><td>gupp(y|ies)</td><td>guppy and guppies</td></tr>
<tr><td>/Column [0-9]+ */</td><td>??</td></tr>
<tr><td>/(Column [0-9]+ *)*/</td><td>??</td></tr>
</table>

Regular expression

RE	Expansion	Match	Examples
\d	[0-9]	any digit	Party␣of␣5
\D	[^0-9]	any non-digit	Blue␣moon
\w	[a-zA-Z0-9_]	any alphanumeric/underscore	Daiyu
\W	[^\w]	a non-alphanumeric	!!!!
\s	[␣\r\t\n\f]	whitespace (space, tab)	
\S	[^\s]	Non-whitespace	in␣Concord

Regular expression

RE	Match	Example Patterns Matched
`\*`	an asterisk "*"	"K*A*P*L*A*N"
`\.`	a period "."	"Dr. Livingston, I presume"
`\?`	a question mark	"Why don't they come and lend a hand?"
`\n`	a newline	
`\t`	a tab	

Example

Find all the instances of the word “the” in a text.

- `/the/`
- `/[tT]he/`
- `/\b[tT]he\b/`
- `[^a-zA-Z][tT]he[^a-zA-Z]`
- `(^|[^a-zA-Z])[tT]he($|[^a-zA-Z])`

Errors

- The process we just went through was based on fixing two kinds of errors
  - Matching strings that we should not have matched (there, then, other)
    - False positives (Type I)
  - Not matching things that we should have matched (The)
    - False negatives (Type II)

Error

- We'll be telling the same story for many tasks, all semester.
- Reducing the error rate for an application often involves two antagonistic efforts:
  - Increasing accuracy, or precision, (minimizing false positives)
  - Increasing coverage, or recall, (minimizing false negatives).

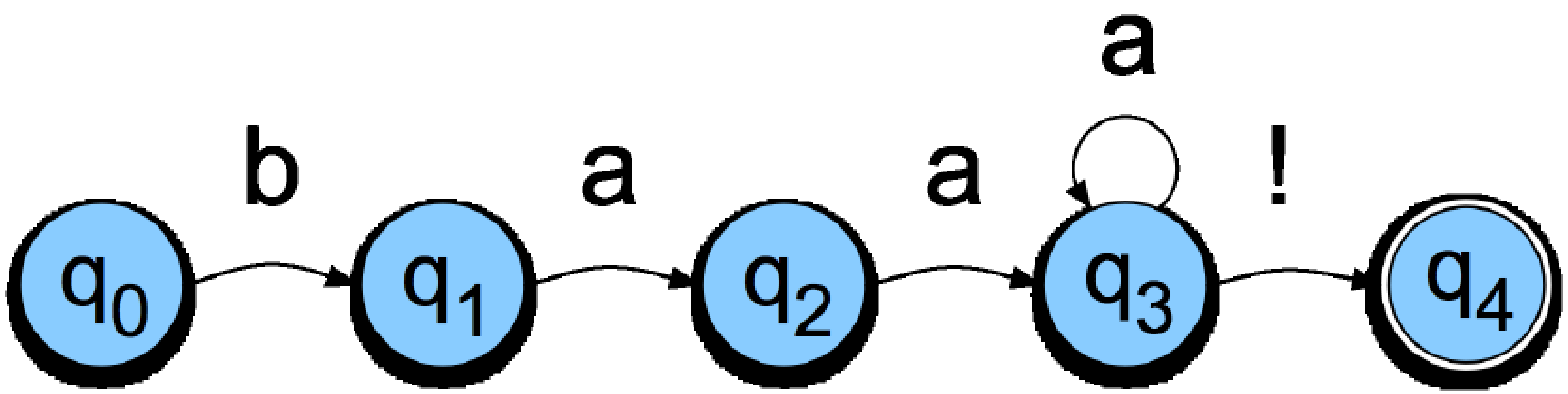
Finite State Automata

- Regular expression is one way of describing FSA
- Regular expressions can be viewed as a textual way of specifying the structure of finite-state automata.
- FSAs capture significant aspects of what linguists say we need for morphologyand parts of syntax.
- Regular expression is one way of characterizing a regular language (formal language).
- FSAs and Res both are used to describe RL

FSAs as Graphs

Let's start with the sheep language from

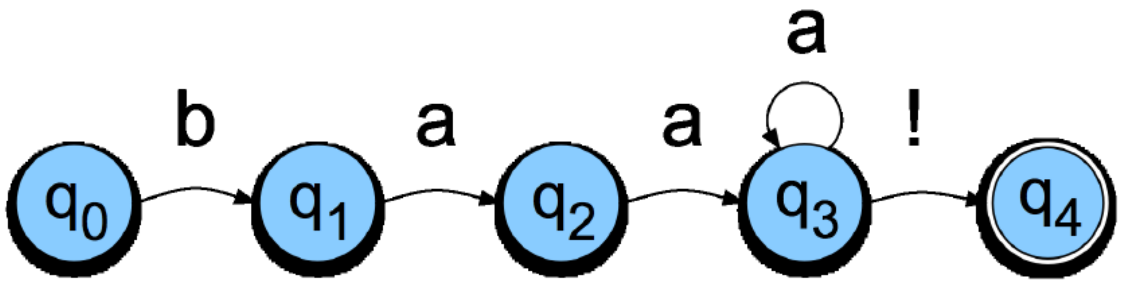
- **/baa+!/**



FSA : Sheep language

We can say the following things about this machine

- It has 5 states
- b, a, and !are in its alphabet
- q_0 is the start state
- q_4 is an accept state
- It has 5 transitions



More Formally

You can specify an FSA by enumerating the following things.

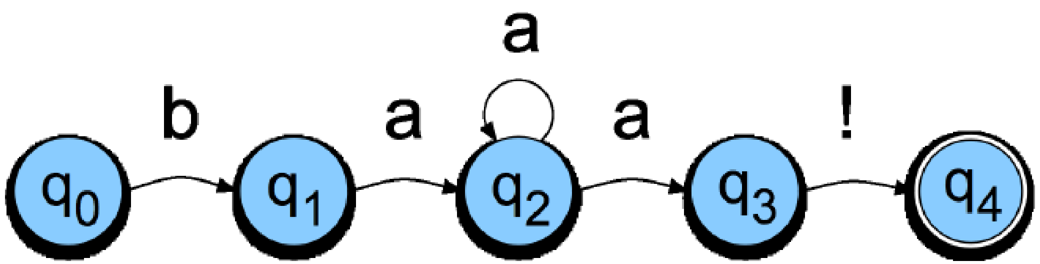
- The set of states: Q
- A finite alphabet: Σ
- A start state
- A set of accept/final states
- A transition function that maps $Q \times \Sigma$ to Q

Yet Another View

The guts of FSAs can ultimately be represented as tables

	b	a	!	e
0	1			
1		2		
2		2,3		
3			4	
4				

If you're in state 1 and you're looking at an a, go to state 2

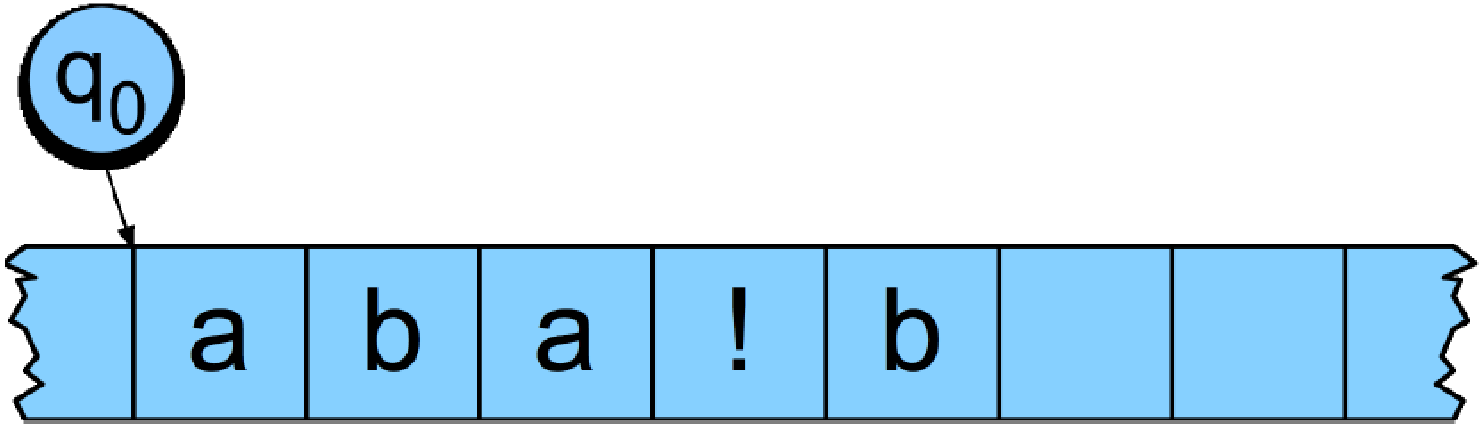


Recognition

- Recognition is the process of determining if a string should be accepted by a machine
- Or… it’s the process of determining if a string is in the language we’re defining with the machine
- Or… it’s the process of determining if a regular expression matches a string
- Those all amount the same thing in the end

Recognition

- Traditionally, (Turing's notion) this process is depicted with a tape.



Recognition

- Simply a process of starting at the start state
- Examining the current input
- Consulting the table
- Going to a new state and updating the tape pointer.
- Until you run out of tape.

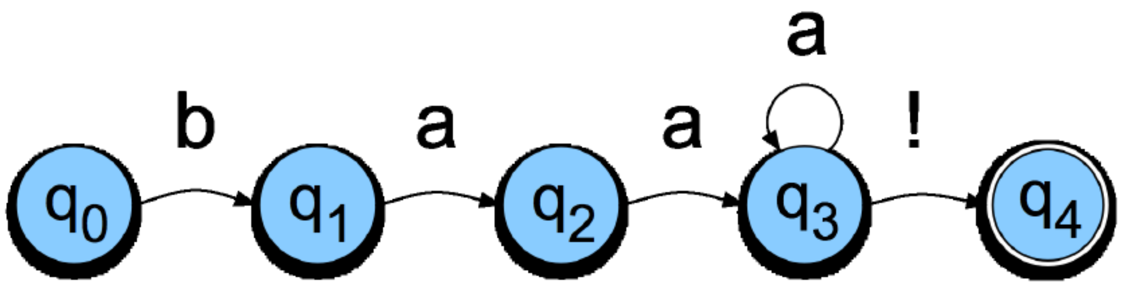
D-Recognize

```
function D-RECOGNIZE(tape, machine) returns accept or reject

  index ← Beginning of tape
  current-state ← Initial state of machine
  loop
    if End of input has been reached then
      if current-state is an accept state then
        return accept
      else
        return reject
    elsif transition-table[current-state,tape[index]] is empty then
      return reject
    else
      current-state ← transition-table[current-state,tape[index]]
      index ← index + 1
  end
```

Example

- baaa!



Key Points

- Deterministic means that at each point in processing there is always one unique thing to do (no choices).
- D-recognize is a simple table-driven interpreter
- The algorithm is universal for all unambiguous regular languages.
  - To change the machine, you simply change the table.
- Crudely therefore… matching strings with regular expressions (ala Perl, grep, etc.) is a matter of
  - translating the regular expression into a machine (a table) and
  - passing the table and the string to an interpreter

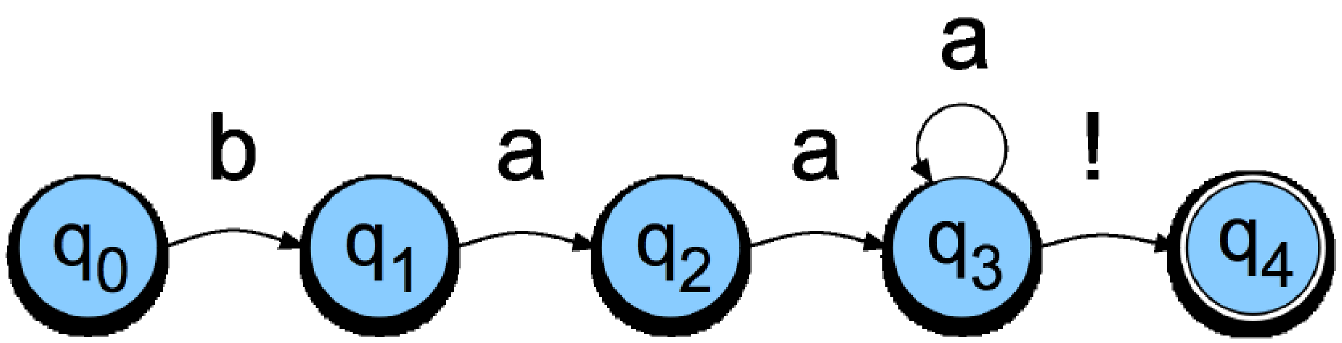
Generative Formalisms

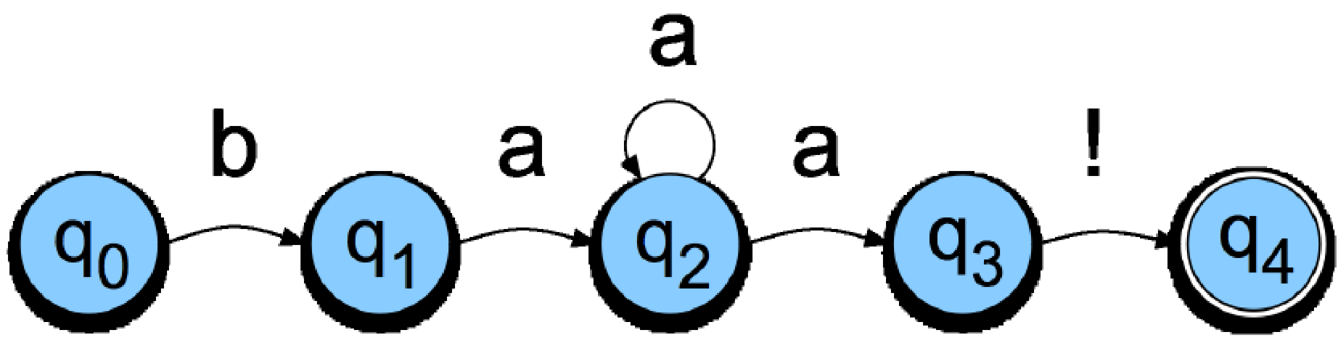
- Formal Languages are sets of strings composed of symbols from a finite set of symbols.
- Finite-state automata define formal languages (without having to enumerate all the strings in the language)
- The term Generative is based on the view that you can run the machine as a generator to get strings from the language.

Generative Formalisms

- FSAs can be viewed from two perspectives:
  - Acceptors that can tell you if a string is in the language
  - Generators to produce all and onlythe strings in the language

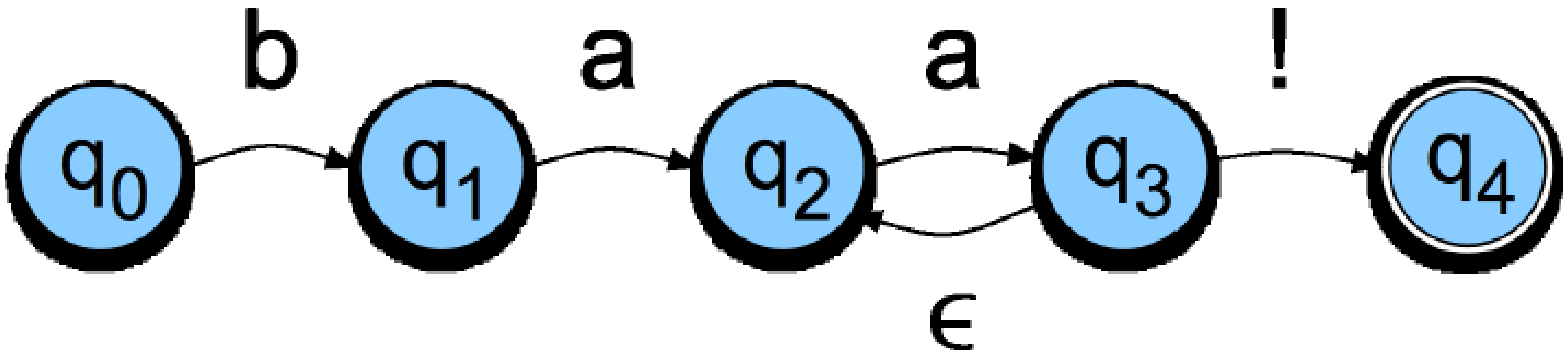
Non- Determinism





Non- Determinism

- Yet another technique
  - Epsilon transitions
  - Key point: these transitions do not examine or advance the tape during recognition



Equivalence

- Non-deterministic machines can be converted to deterministic ones with a fairly simple construction
- That means that they have the same power; non-deterministic machines are not more powerful than deterministic ones in terms of the languages they can accept

ND Recognition

- Two basic approaches (used in all major implementations of regular expressions, see Friedl 2006)
- 1.Either take a ND machine and convert it to a D machine and then do recognition with that.
- 2.Or explicitly manage the process of recognition as a state-space search (leaving the machine as is).

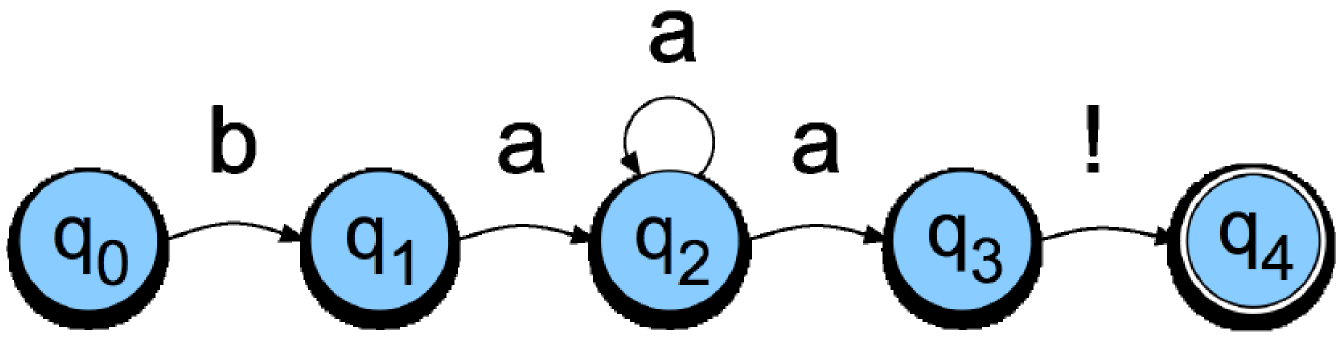
Non-Deterministic Recognition: Search

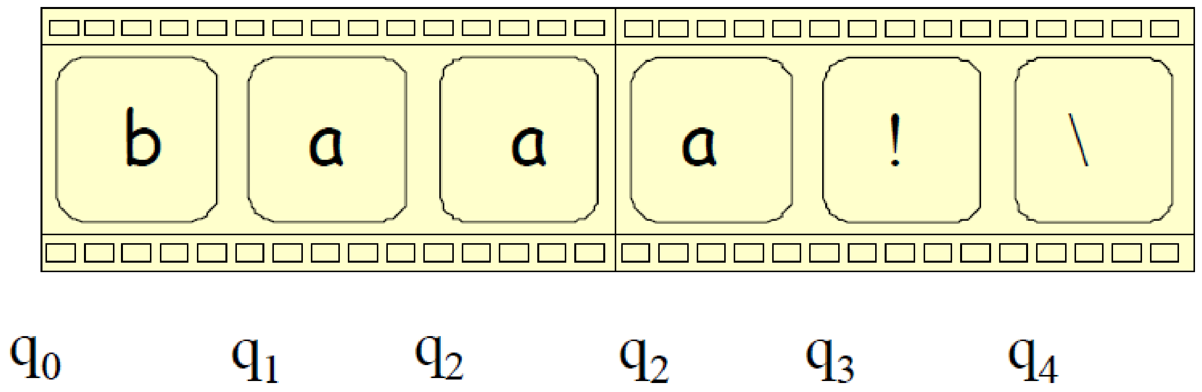
- In a ND FSA there exists at least one path through the machine for a string that is in the language defined by the machine.
- •But not all paths directed through the machine for an accept string lead to an accept state.
- •No paths through the machine lead to an accept state for a string not in the language.

Non-Deterministic Recognition

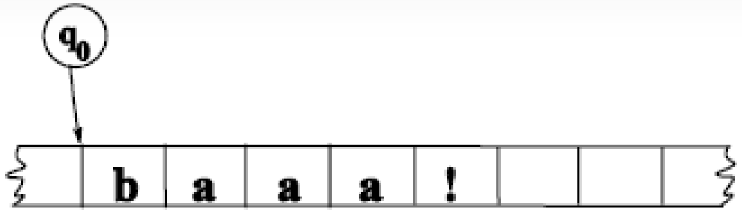
- So success in non-deterministic recognition occurs when a path is found through the machine that ends in an accept.
- •Failure occurs when all of the possible paths for a given string lead to failure.

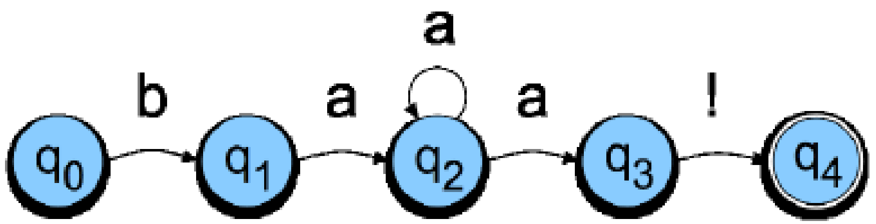
Example

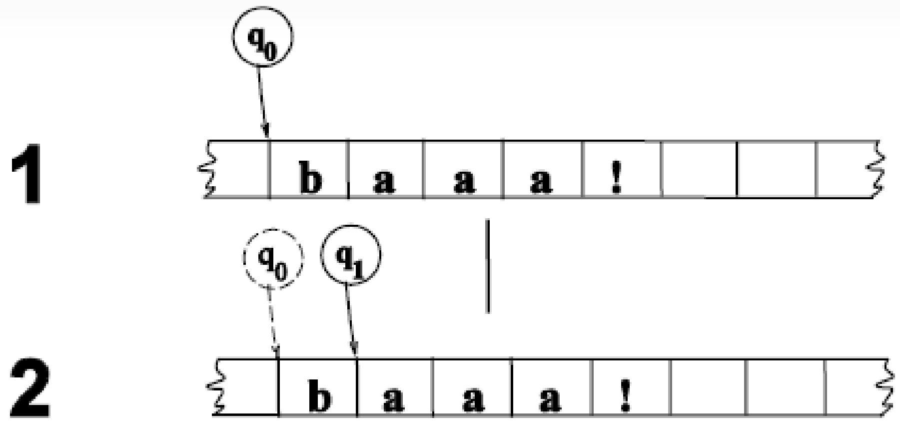


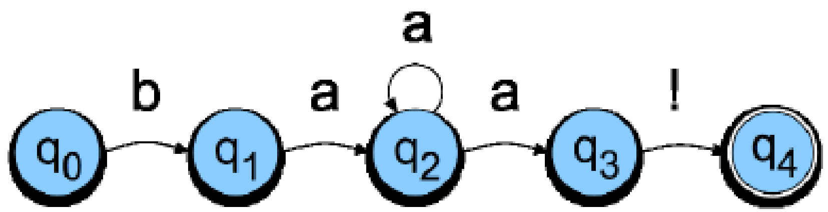


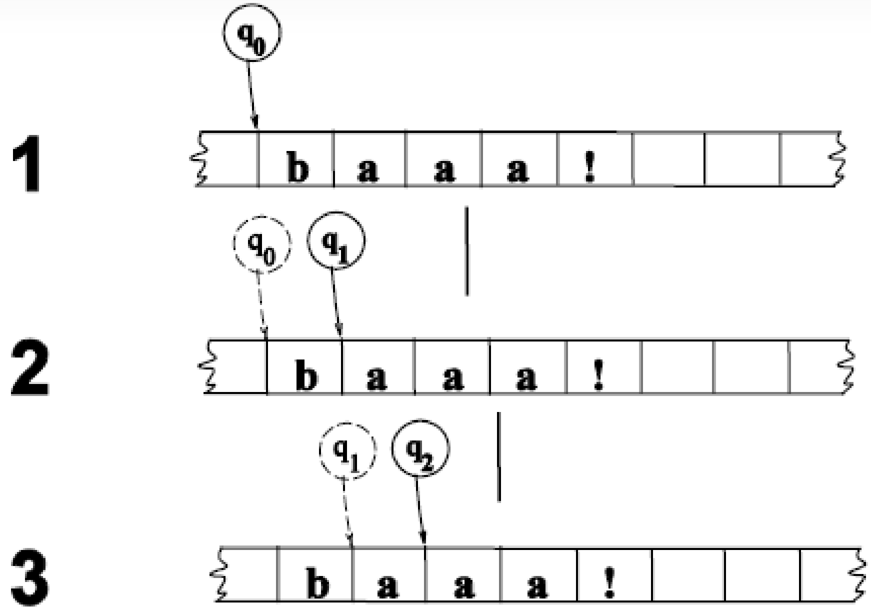
1

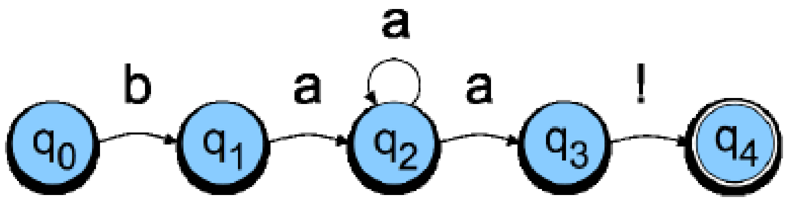


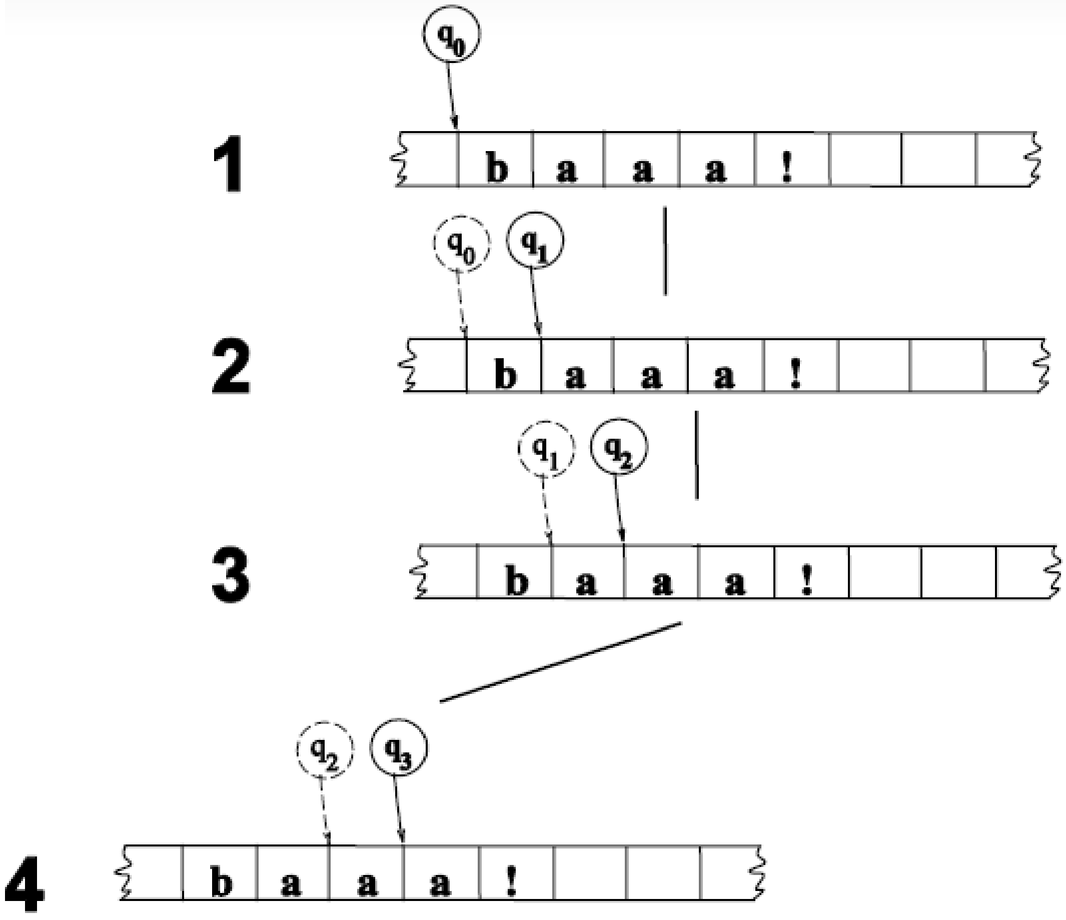


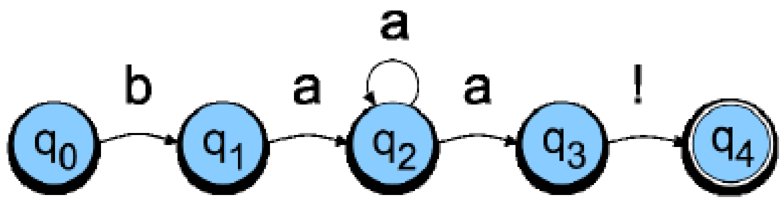

1
2
q0
q0
q1
b a a a !
b a a a !

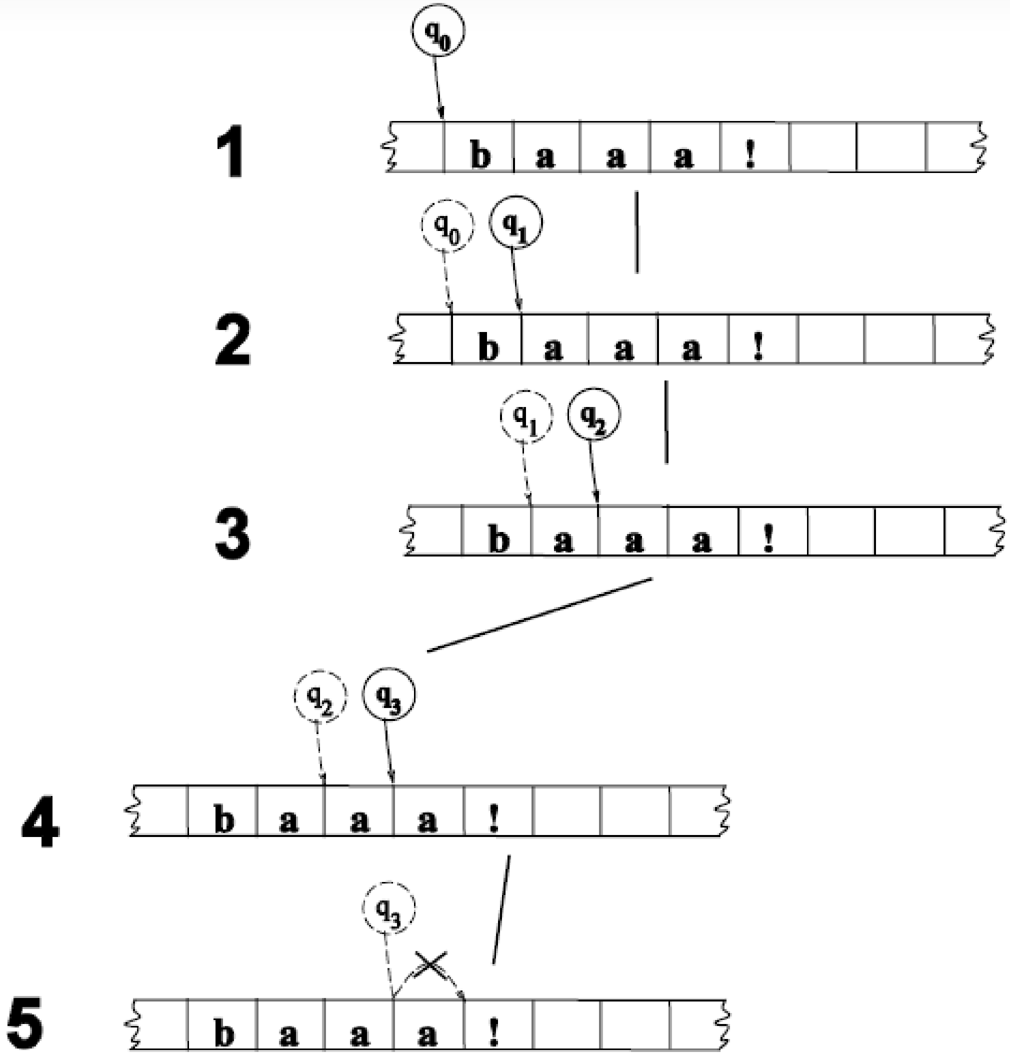

b
a
a
a
!
q0
q1
q2
q3
q4

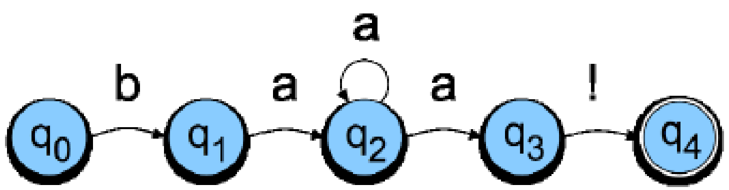

1
2
3
b a a a !
b a a a !
b a a a !

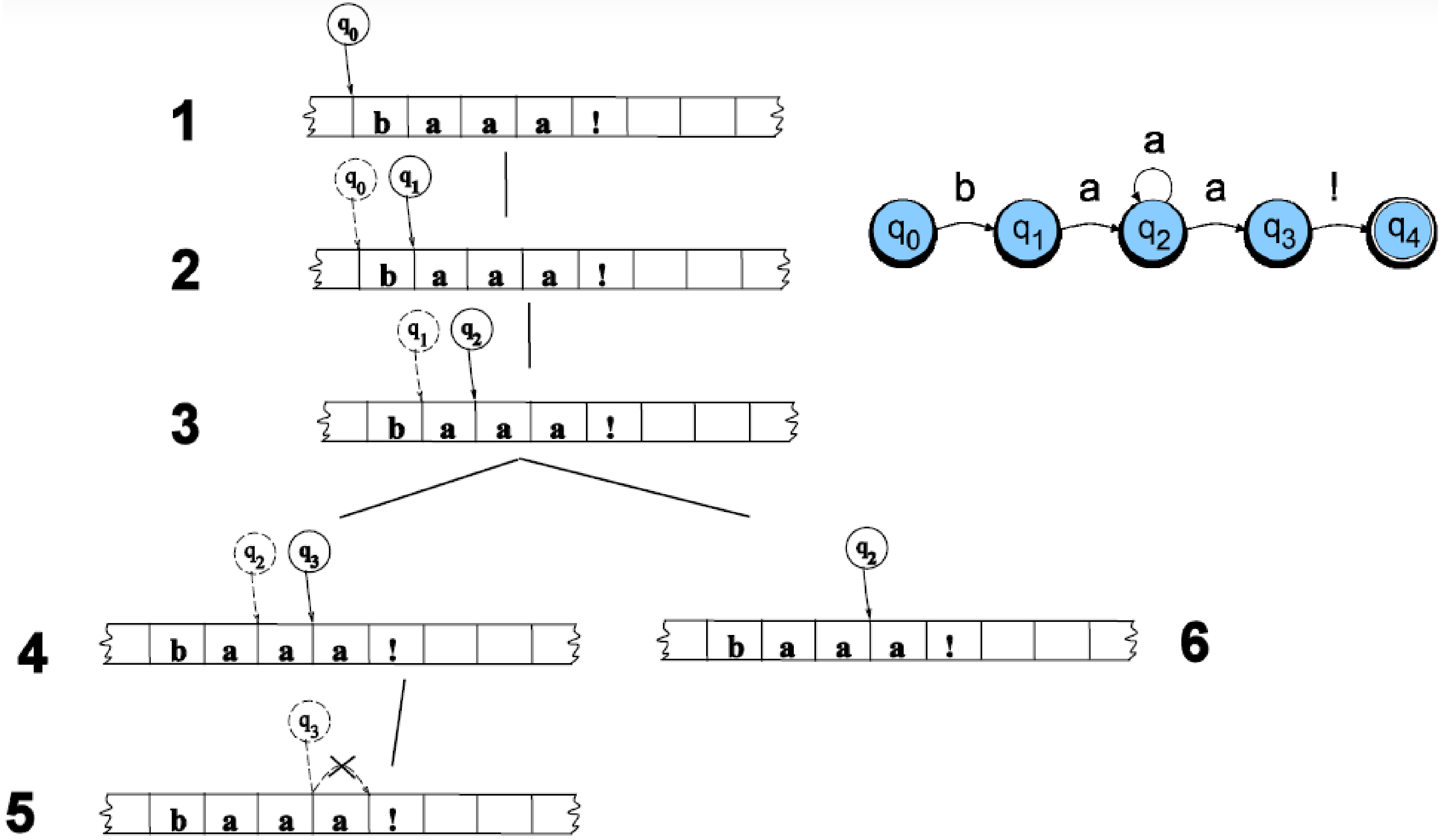

b
a
a
a
!

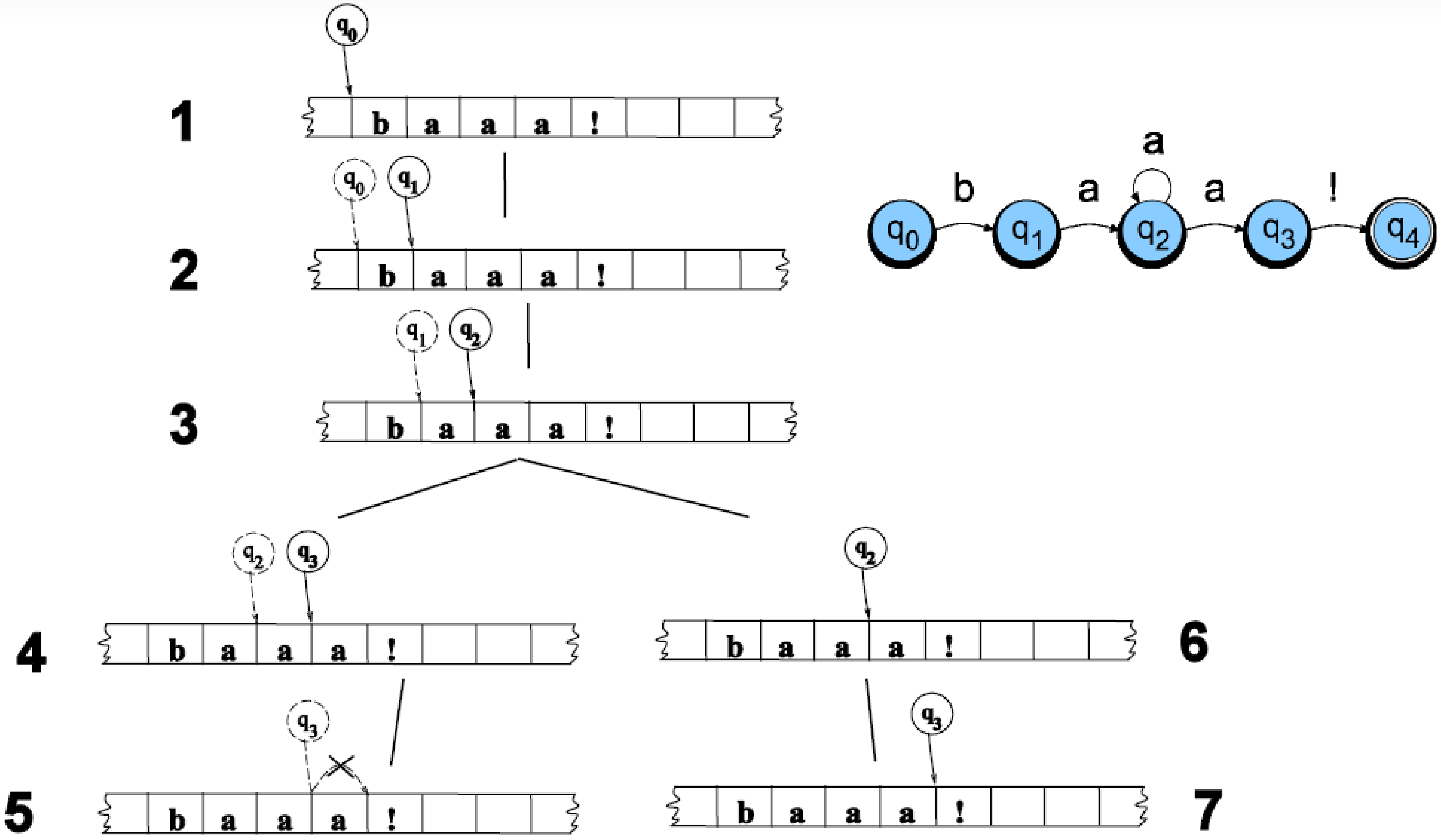

1
q_0
b a a a !
2
q_0 q_1
b a a a !
3
q_1 q_2
b a a a !
4
q_2 q_3
b a a a !


q_0 q_1 q_2 q_3 q_4
b
a
a
a
!

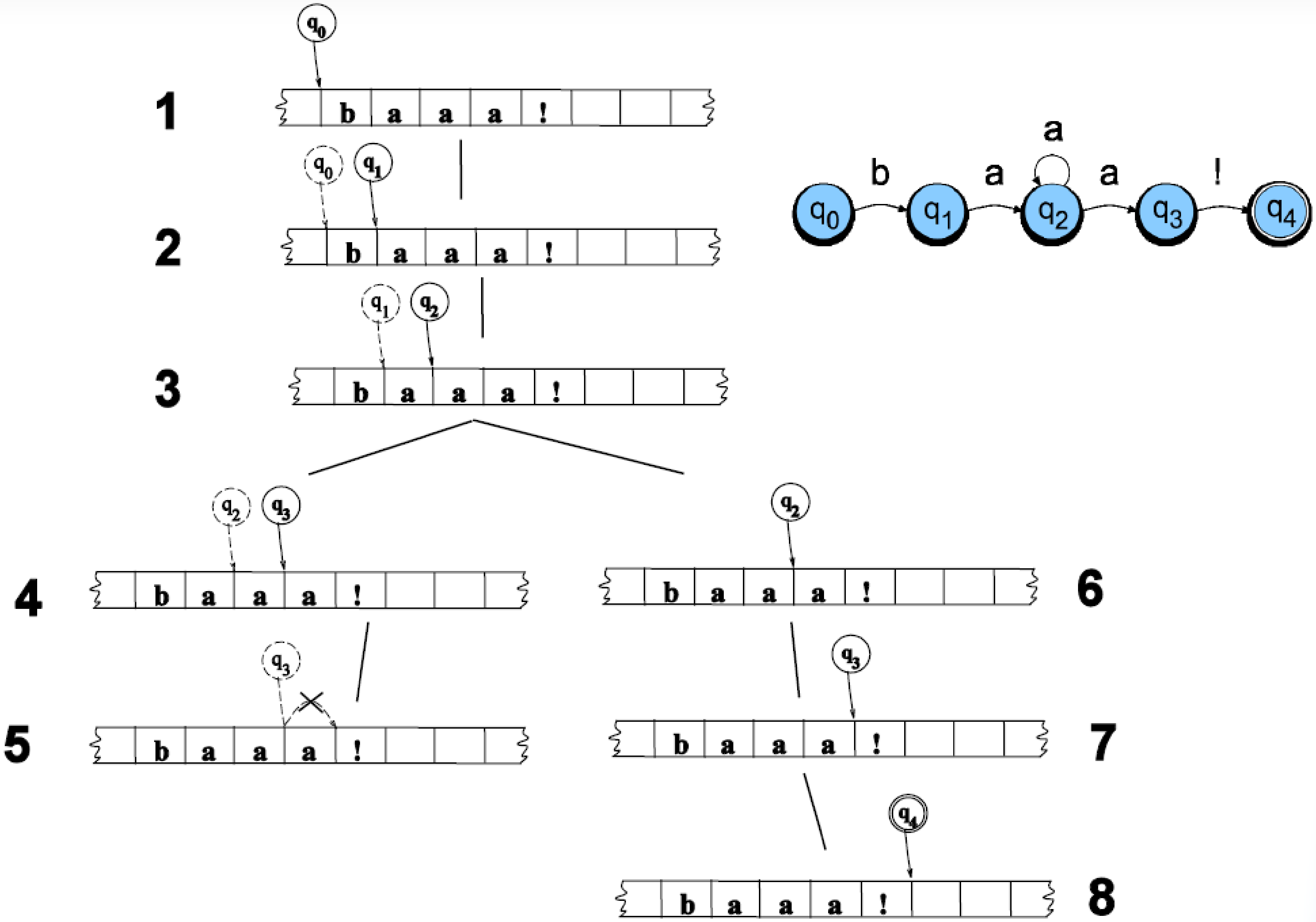

1
2
3
4
5
b a a a !
q0
q0 q1
q1 q2
q2 q3
q3


b
a
a
a
!
q0
q1
q2
q3
q4


1
2
3
4
5
6
q0
q1
q2
q3
q4
b a a a !
b
a
a
a
!



1
2
3
4
5
6
7
b a a a !
q0 q1 q2 q3 q4
b a a a !


1
2
3
4
5
6
7
8
b a a a !
q_0
q_1
q_2
q_3
q_4
b
a
a
a
!

Key Points

- States in the search space are pairings of tape positions and states in the machine.
- •By keeping track of as yet unexplored states, a recognizer can systematically explore all the paths through the machine given an input.

Uses of Regexes

- Observing simple subcomponents
  - Dollars and cents
  - Date, Time
  - Chemical compounds
  - Mathematical formulas
  - Word search in crossword puzzles
  - Noun compounds, Lexico-POS patterns
- Use regexes in low-data setting
- Use regexes as features in ML

Conclusion

- Regular expressions and FSAs can represent subsets of natural language as well as regular languages
  - Both representations may be difficult for humans to use for any real subset of a language
  - But quick, powerful and easy to use for small problems
- Finite state transducers and rules are common ways to incorporate linguistic ideas in NLP for small applications
- Particularly useful for no data setting