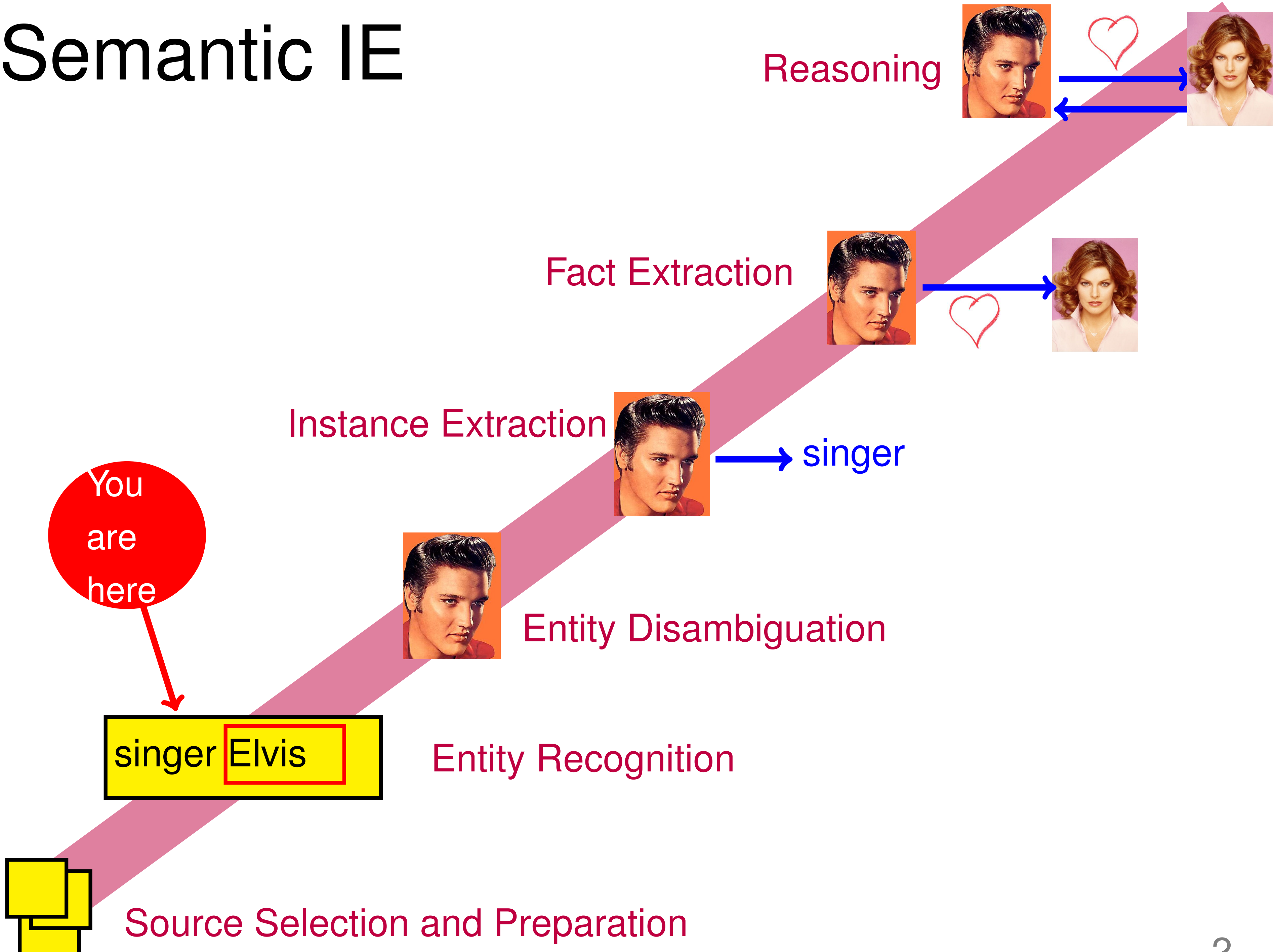
Named Entity Recognition

Fabian M. Suchanek

Semantic IE



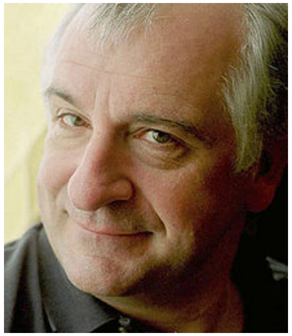
Reasoning
Fact Extraction
Instance Extraction
singer
You are here
Entity Disambiguation
singer Elvis
Entity Recognition
Source Selection and Preparation

Overview

- Named Entity Recognition
- ...by dictionary
- ...by regex

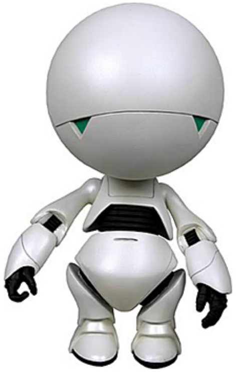
Named Entity

A named entity is an entity that has a name (and is not a literal, class, relation, fact id, or reified statement).



Douglas Adams

Télécom ParisTech



Marvin

Def: Named Entity Recognition

Named entity recognition (NER) is the task of finding entity names in a corpus.

In Douglas Adams' book "The Hitchhiker's Guide to the Galaxy" the robot Marvin says: "I didn't ask to be made. No one consulted me or considered my feelings in the matter."

(In its basic form, NER does not care to which entity the name belongs. It just finds names.)

NER is difficult

Deposit a penny at the All American Bank...

All State Police helped evacuate...

Cable and Wireless, a major company...

Microsoft and Dell both agreed...

?

?

Marvin the Paranoid Android

Def: Dictionary

A dictionary (also: gazetteer, lexicon) is a set of entity names.

NER by dictionary finds only names of the dictionary.

It can be used if the entities are known upfront.

US states: {Alabama, Alaska, California, ...}

...lived in Los Angeles, $\boxed{\text{California}}$, while...

- US states
- countries
- Dow Jones companies
- Actors of a given movie
- ...

Naive Dictionary NER is slow

?

Books by Douglas Adams: {

Life, the Universe and Everything

Hitchhiker's Guide to the Galaxy

Mostly Harmless

... }

The Hitchhiker's Guide to the Galaxy has "Don't Panic" on it, in large, mostly friendly letters.

Naive Dictionary NER is slow

Books by Douglas Adams: $\{$

Life, the Universe and Everything

Hitchhiker's Guide to the Galaxy

Mostly Harmless

... $\}$

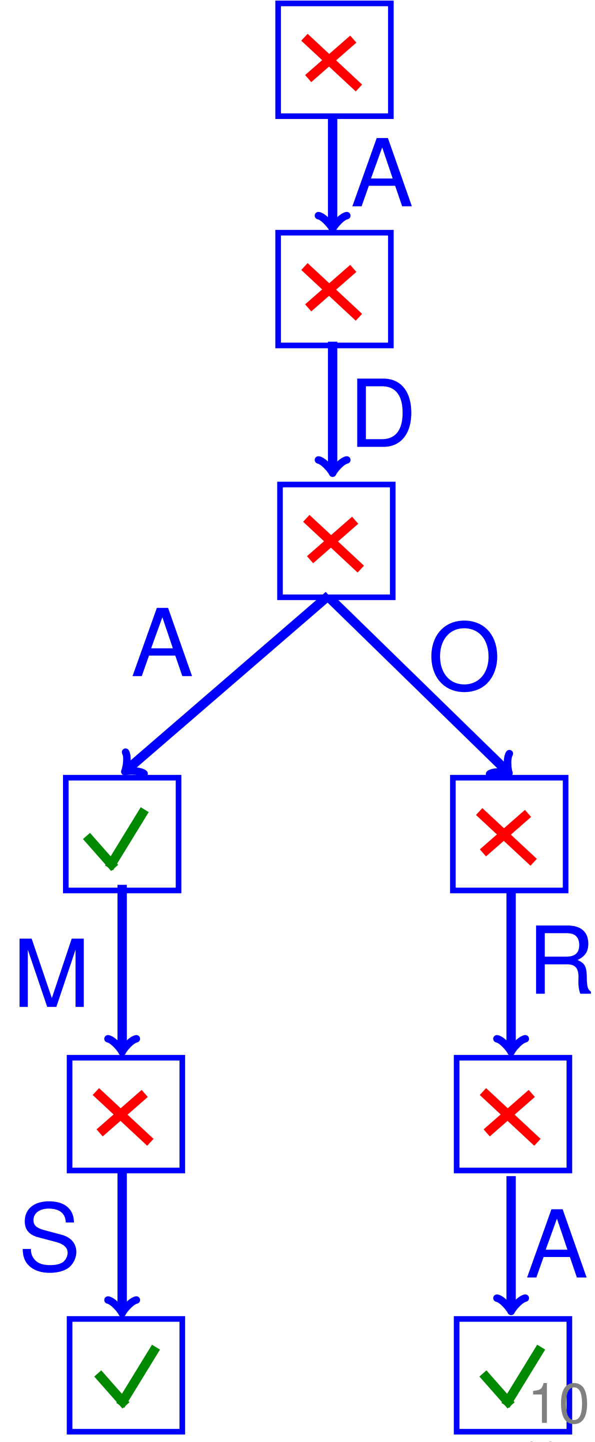
?

The Hitchhiker's Guide to the Galaxy has "Don't Panic" on it, in large, mostly friendly letters.

$$O(textLength \times dictSize \times maxWordLength)$$

Def: Trie

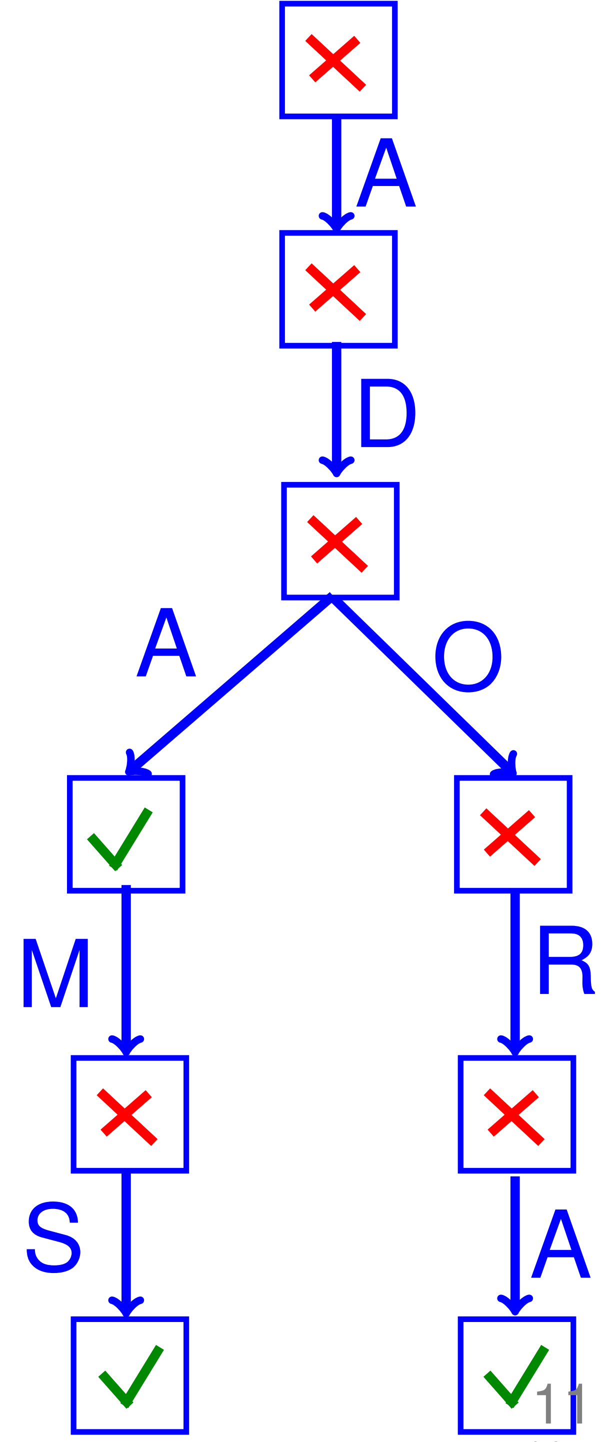
A trie is a tree, where nodes are labeled with booleans and edges are labeled with characters.



A trie contains strings

A trie contains a string, if the string denotes a path from the root to a node marked with “true”.

$\{$ADA, ADAMS, ADORA$\}$

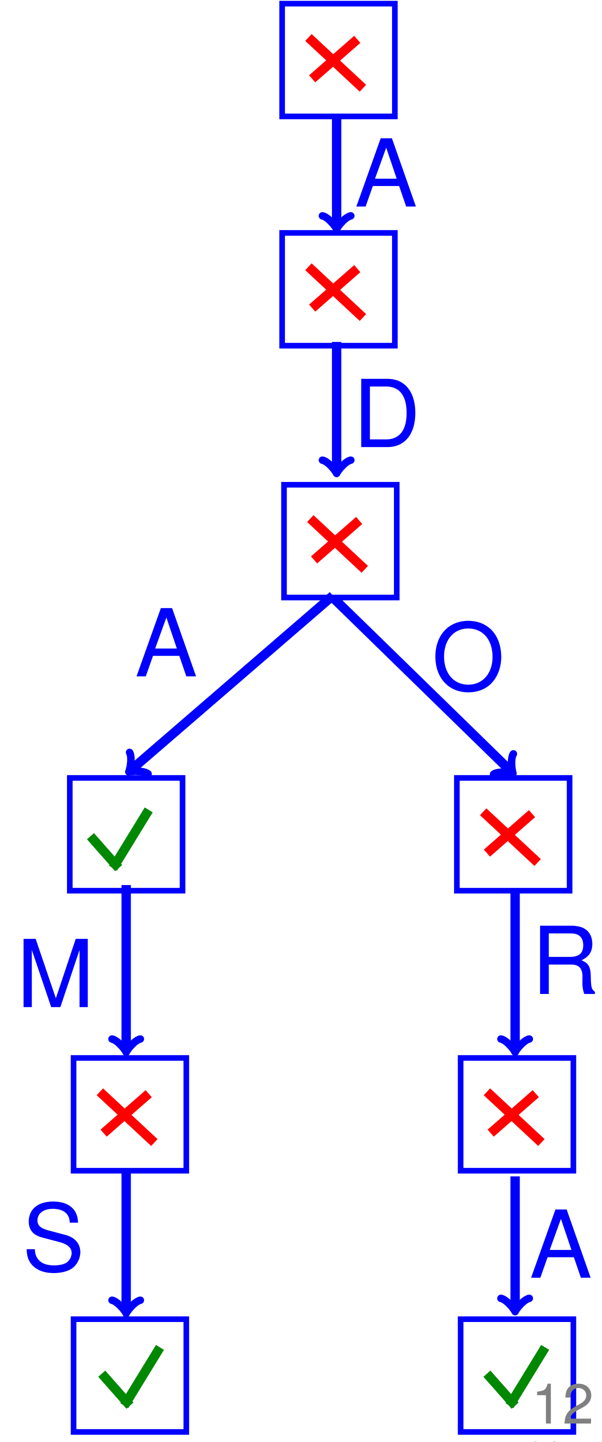


Adding strings (1)

To add a string that is a prefix of an existing string, switch node to “true”.

{ADA, ADAMS, ADORA}

+ ADAM



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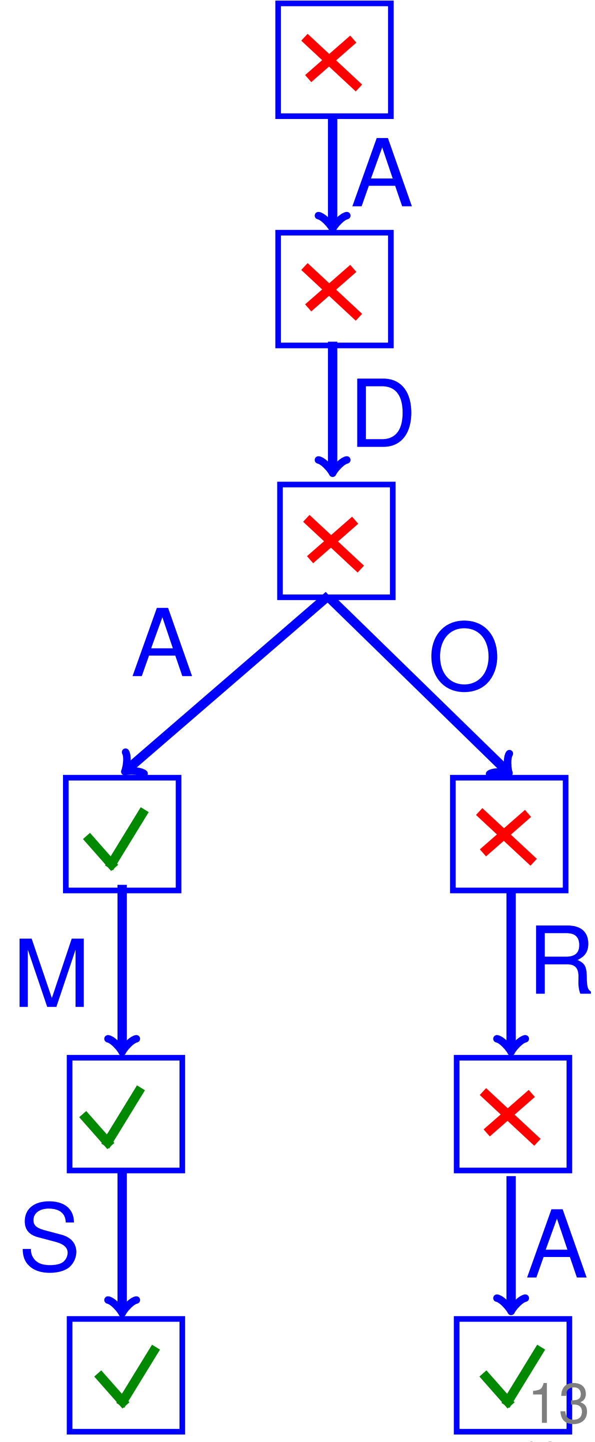
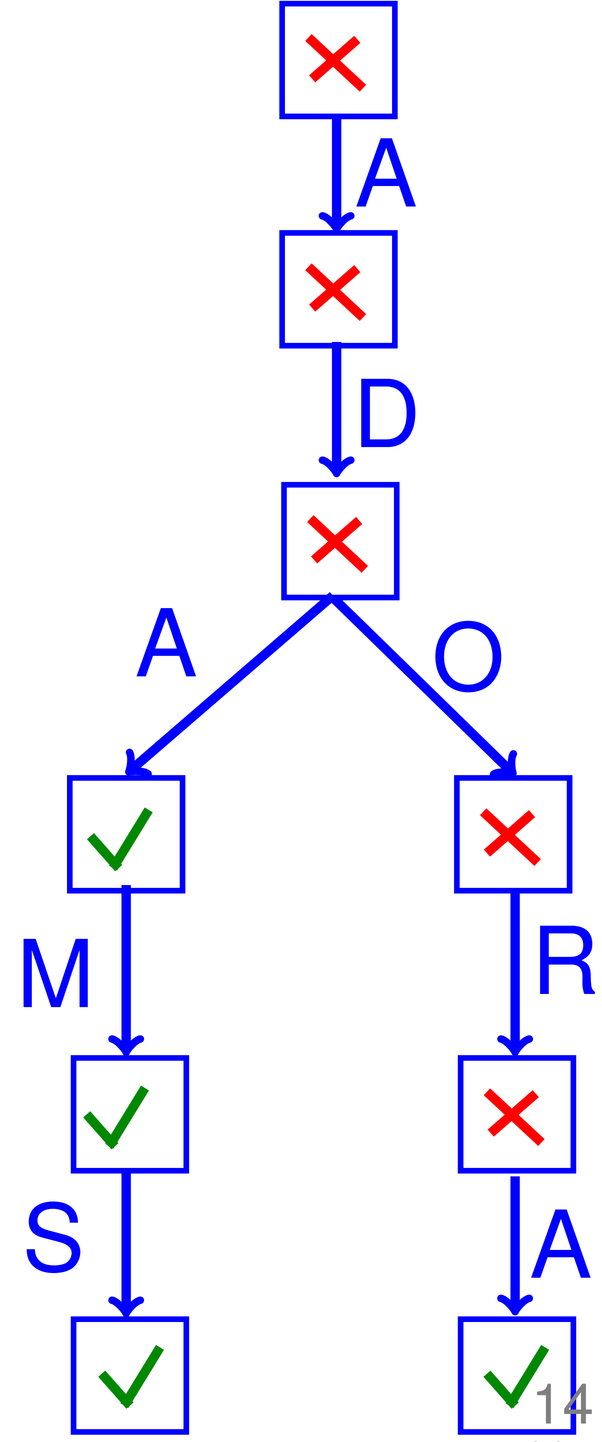
{ADA, ADAM, ADAMS, ADORA}



Adding strings (2)

To add another string, make a new branch.

{ADA, ADAM, ADAMS, ADORA} + ART

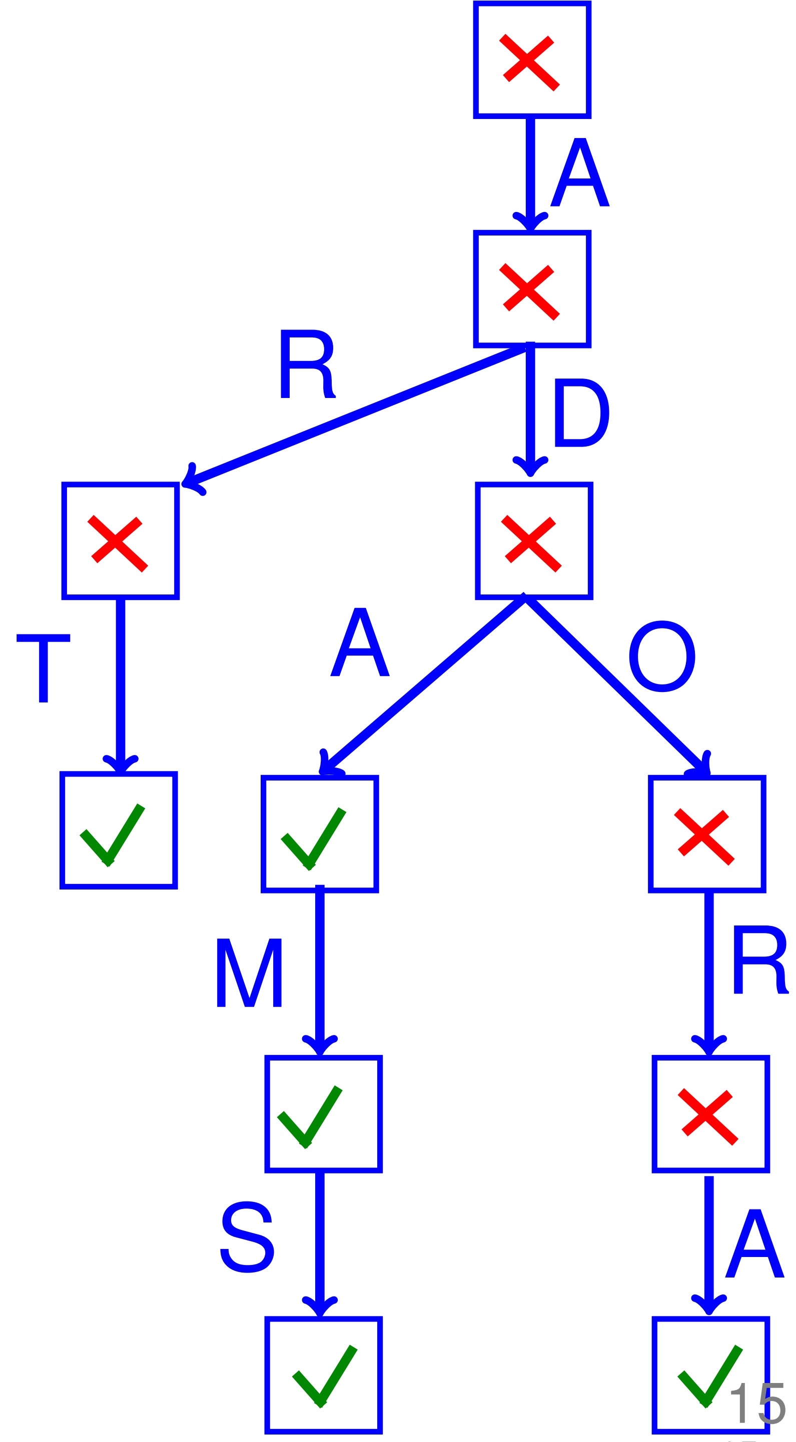


Adding strings (2)

To add another string, make a new branch.

{ADA, ADAM,

ADAMS, ADORA, ART}

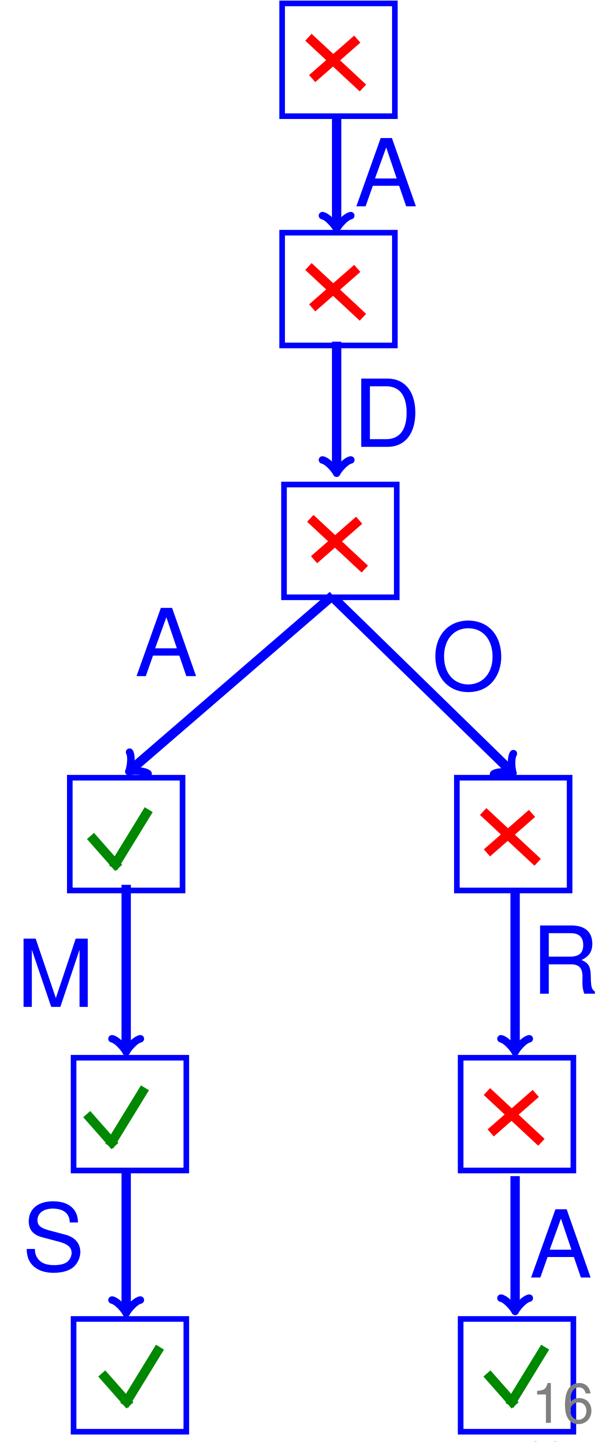


Task: Tries

Start with an empty trie.

Add

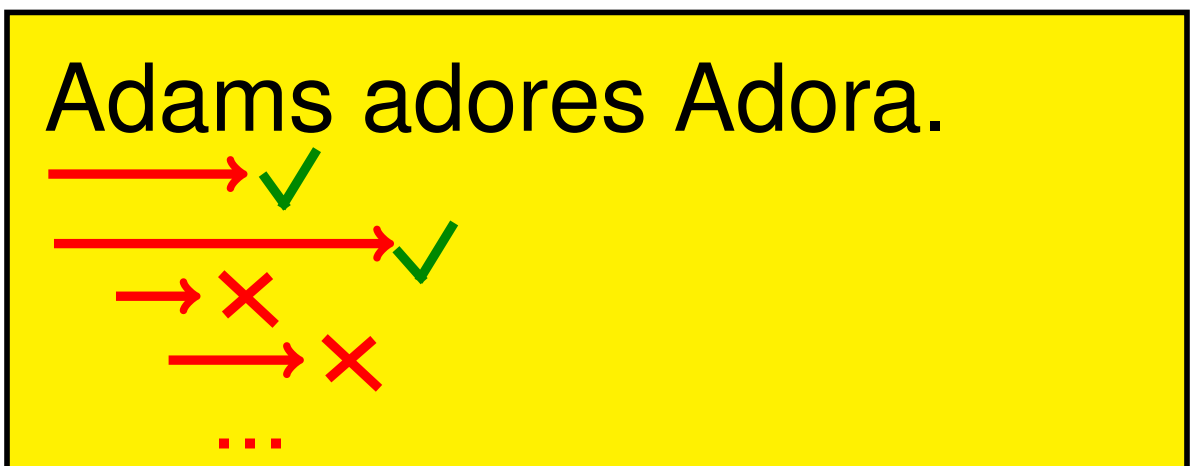
- bon
- bonbon
- on

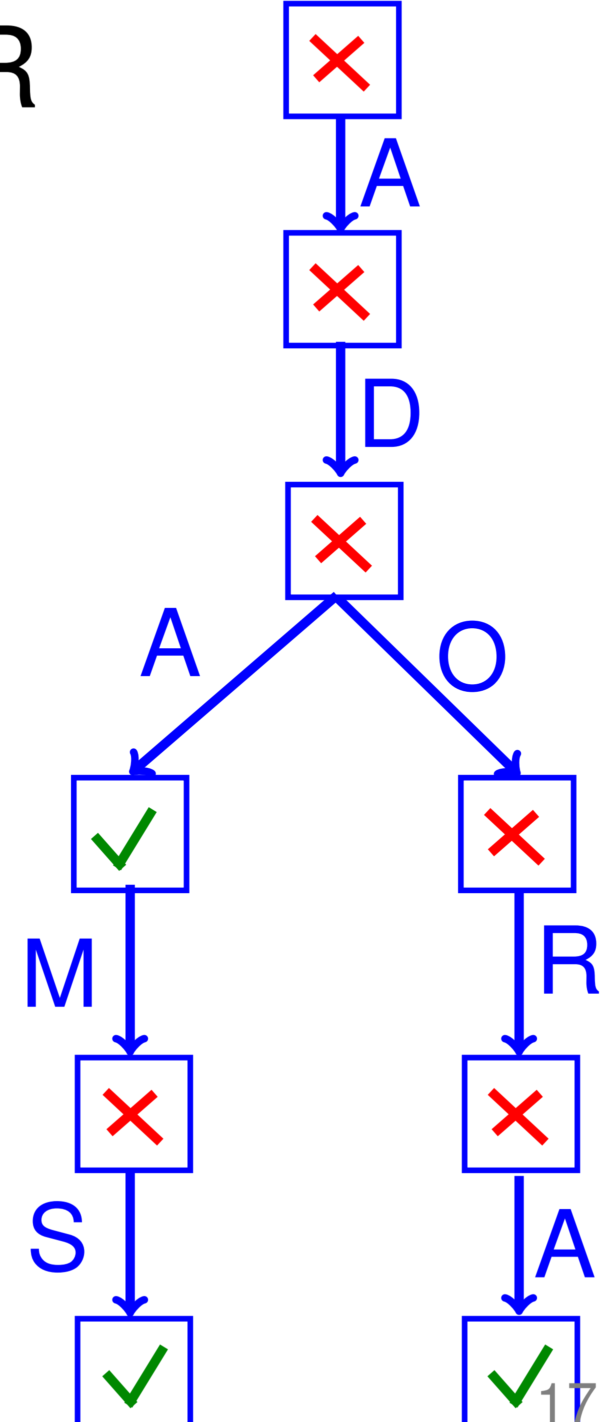


Tries can be used for NER

For every character in the doc

- advance as far as possible in the trie and
  - report match whenever you meet a "true" node





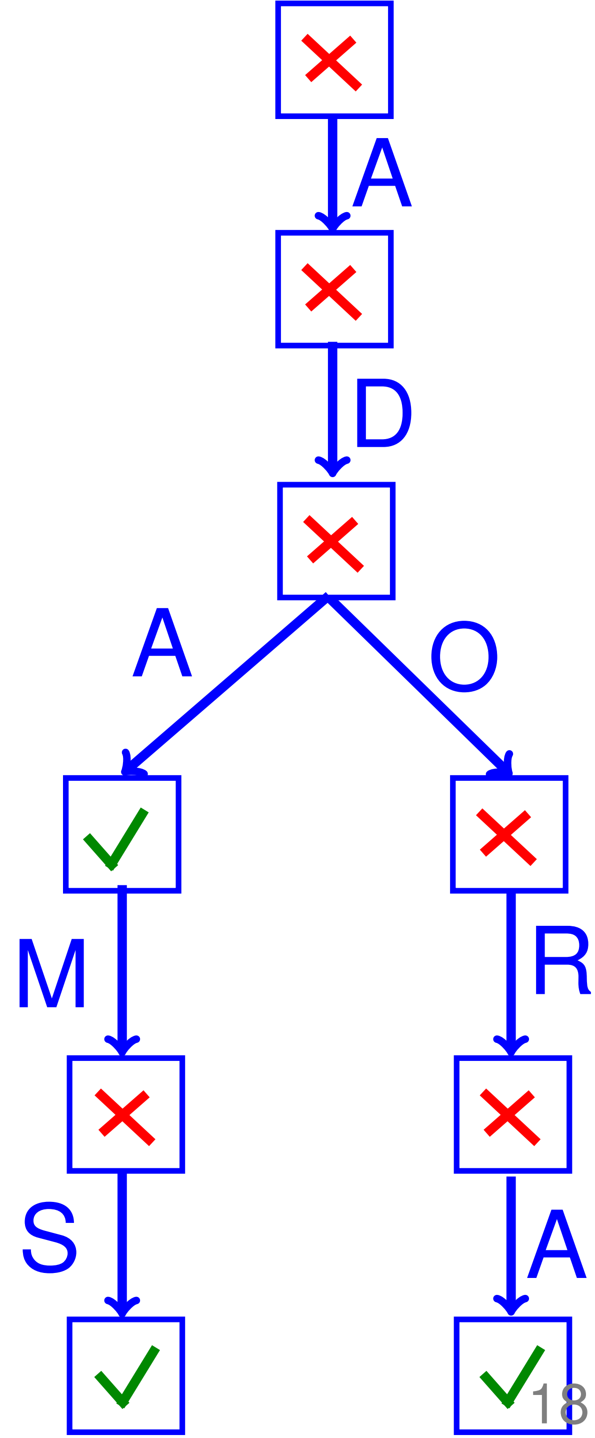
Tries have good runtime

$$O(textLength \times maxWordLength)$$

x phuong add « bon »
B
—>
x Waad add « on »
O
—>
x Issa
N
—>
bingo

Adams adores Adora.

...

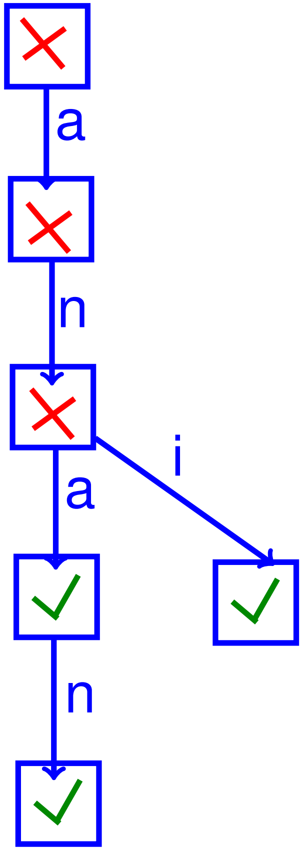


Task: NER with tries

Do NER with the trie from the last task
on the document

on aime un bon bonbon.

One more example

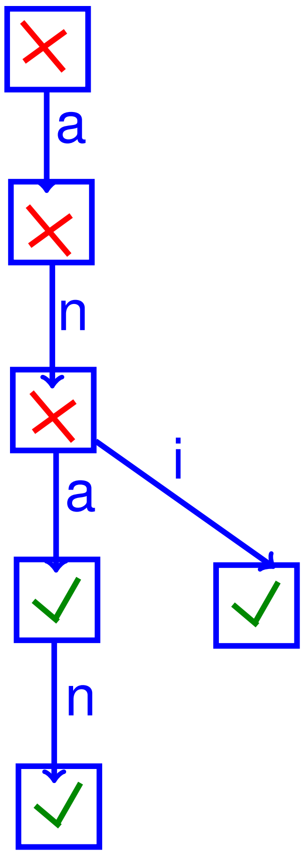


kofi anan eats an ananas in panama, ana!

Tricks with Tries

In practice, you can

- force tries to respect word boundaries
- ignore upcase/lowcase
- preprocess the string
- ignore nested words
- ...



kofi anan eats an ananas in panama, ana!

Dictionary NER

Advantages:

- very efficient,

Disadvantages: dictionaries

- have to be given upfront
- have to be maintened to accommodate new names
- cannot deal with name variants
- cannot deal with infinite or unknown sets of names
  (e.g., people's names)

Overview

- Named Entity Recognition
- ...by dictionary
- ...by regex

Some names follow patterns

The trilogy consist of 5 books, written in 1979, 1980, 1982, 1984, and 1992, respectively.

Years

Dr. Frankie and Dr. Benjy discuss how to best extract the data from Arthur's brain.

People with titles

Main street 42
West Country

Addresses

>alphabet

Def: Alphabet, Word

An alphabet is a set of symbols.

A={a,b,c,d,e,f,0,1,2,3,4,5,6,7,8,9}

We will use as alphabet always implicitly the set of all unicode characters.

A={0,...9,a...,z,A...Z,!,?,...}

A word over an alphabet A is a sequence of symbols from A.

Since we use the alphabet of unicode characters, words are just strings.

hello!, 42, 3.141592, Douglas and Sally

also with spaces!

Def: Language

A language over an alphabet S is a set of words over S.

L1 = {Arthur Dent, Ford Prefect, Marvin}

L2 = {1900, 1901, 1982, 2013, 2017, ...}

L3 = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}

L4 = {a, ab, abb, bbba, aaabbab, ababa, ...}

L5 = {a, b, aa, bb, aaa, bbb, ...}

L6 = {a, aa, aaa, ...}

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L8 = {c, ca, caa, caaa, ...}

L9 = { , a, aa, aaa, ...}

Set of strings
we want to describe

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Set of strings we want to describe

Our description (much shorter than the original set!)

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L5 = {a, b, aa, bb, aaa, bbb, ...}

L6 = {a, aa, aaa, ...} aa* = a+

L7 = { , ab, abab, ababab, ...} (ab)*

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L4 = {a, ab, abb, bbba, aaabbab, ababa, ...}

L5 = {a, b, aa, bb, aaa, bbb, ...} a+ — b+

L6 = {a, aa, aaa, ...} aa* = a+

L7 = { , ab, abab, ababab, ...} (ab)*

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L3 = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9} (0 — 1 — ... — 9) = [0-9]

L4 = {a, ab, abb, bbba, aaabbab, ababa, ...} (a — b)+

L5 = {a, b, aa, bb, aaa, bbb, ...} a+ — b+

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L1 = {Arthur Dent, Ford Prefect, ...}

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L3 = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9} (0 — 1 — ... — 9) = [0-9]

L4 = {a, ab, abb, bbba, aaabbab, ababa, ...} (a — b)+

L5 = {a, b, aa, bb, aaa, bbb, ...} a+ — b+

L6 = {a, aa, aaa, ...} aa* = a+

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Set of strings
we want to describe

Our description
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Def: Language

A language over an alphabet S is a set of words over S.

L1 = {Arthur Dent, Ford Prefect, ...} [A-Z][a-z]+ [A-Z][a-z]+

L2 = {1900, 1901, 1982, 2013, 2017, ...} [0-9][0-9][0-9][0-9] = [0-9]{4}

L3 = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9} (0 — 1 — ... — 9) = [0-9]

L4 = {a, ab, abb, bbba, aaabbab, ababa, ...} (a — b)+

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Set of strings
we want to describe

Our description
(much shorter than the original set!)

Regular expressions

A regular expression (regex) describes a language.

L1 = {Arthur Dent, Ford Prefect, ...}   [A-Z][a-z]+ [A-Z][a-z]+

L2 = {1900, 1901, 1982, 2013, 2017, ...}   [0-9][0-9][0-9][0-9] = [0-9]{4}

L3 = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}   (0 — 1 — ... — 9) = [0-9]

L4 = {a, ab, abb, bbba, aaabbab, ababa, ...}   (a — b)+

L5 = {a, b, aa, bb, aaa, bbb, ...}   a+ — b+

L6 = {a, aa, aaa, ...}   aa* = a+

L7 = { , ab, abab, ababab, ...} $L(E|F) = L(E) \cup L(F)$

L8 = {c, ca, caa, caaa, ...}   ca* $L(EF) = \{w_1 w_2 : w_1 \in L(E), w_2 \in L(F)\}$

L9 = { , a, aa, aaa, ...}   a* $L(E*) = \{w_1 w_2 ... w_n : w_i \in L(E), n \geq 0\}$

$L(x) = \{x\}$ for symbols x

The language of a regular expression

Def: Regular expressions

A regular expression (regex) over an alphabet S is one of the following:

- the empty string
- an element of S
- a string of the form XY
- a string of the form (X—Y)
- a string of the form (X)*

where X and Y are regexes

A regex is associated to a language:

$$L(E|F) = L(E) \cup L(F)$$

$$L(EF) = \{w_1 w_2 : w_1 \in L(E), w_2 \in L(F)\}$$

$$L(E*) = \{w_1 w_2 ... w_n : w_i \in L(E), n \geq 0\}$$

$L(x) = \underline{\{x\}}$ for symbols x

the regular expression

its language

(0 is a special regex that cannot appear as part of other regexes. It represents the empty language and does not match any string.)

Regular expressions cheat sheet

L(a) = {a}	Simple symbol
L(ab) = {ab}	Concatenation
L(a — b) = {a, b}	Disjunction
L(a*) = {, a, aa, aaa, ...}	Kleene star
L(a+) := L(aa*)	shorthand for “one or more”
L([a-z]) := L(a—b—...—z)	shorthand for a range
L(a{2,4}) := L(aa—aaa—aaaa)	shortand for a given number
L(a{3}) := L(aaa)	shortand for a given number
L(a?) := L(— a)	shorthand for “optional”
L(.) := {a—b—..—A—...—0—...—!—$—...}	shorthand for “any symbol”
L(.) := {.}	escape sequence for special symbols

Task: Regexes

L(a) = {a}	Simple symbol
L(ab) = {ab}	Concatenation
L(a — b) = {a, b}	Disjunction
L(a*) = {, a, aa, aaa, ...}	Kleene star
L(a+) := L(aa*)	shorthand for “one or more”
L([a-z]) := L(a—b—...—z)	shorthand for a range
L(a{2,4}) := L(aa—aaa—aaaa)	shortand for a given number
L(a{3}) := L(aaa)	shortand for a given number
L(a?) := L(— a)	shorthand for “optional”
L(.) := {a—b—..—A—...—0—...—!—$—...}	shorthand for “any symbol”
L(.) := {.}	escape sequence for special symbols

Define regexes for

- numbers
- phone numbers
- HTML tags
- Names of the form “Dr. Blah Blub”

Try it

Helpful Web page

https://regex101.com/

REGULAR EXPRESSION

`/ ([A-Z][a-z]* )+`

TEST STRING

`Elvis Presley`

EXPLANATION

- `/ ([A-Z][a-z]* )+ / g`
  - **1st Capturing Group** `([A-Z][a-z]* )+`
    - `+` **Quantifier** — Matches between `one` and `unlimited` times, as many times as possible, giving back as needed `(greedy)`

A repeated capturing group will only capture the last

MATCH INFORMATION

Match 1

Full match	0-14	`Elvis Presley `
Group 1.	6-14	`Presley `

Real-world example

Example from Wipolo via Dhouha Bouamor

Named regexes

When using regular expressions in a program, it is a good idea to name them:

```
String digits = ”[0-9]+”;
String separator = ”( —-)”;
String pattern = digits+separator+digits;
```

But: Human beings, who are almost unique in having the ability to learn from the experience of others, are also remarkable for their apparent disinclination to do so. (Douglas Adams)

Regex groups

A regex group is a sequence of the form (...) in a regex.

1st group

the answer to ([a-z]+),

the (([a-z]+) and ([a-z]+))

Regex groups

A regex group is a sequence of the form (...) in a regex.

1st group

the answer to ([a-z]+),
the (([a-z]+) and ([a-z]+))

2nd group

4th group

3rd group

Regex groups

He found the answer to life,
the universe, and everything

the answer to ([a-z]+),
the (([a-z]+) and ([a-z]+))

1st group: life
2nd group: universe and everything
3rd group: universe
4th group: everything

Try it out!

FSM>90

How can we match regexes?

Douglas Adams fictional character names:

[A-Z][a-z]*ch[a-z]*

?

The Hitchhiker meets the Golgafrinchan civilisation,
but falls in love with a girl named Fenchurch.

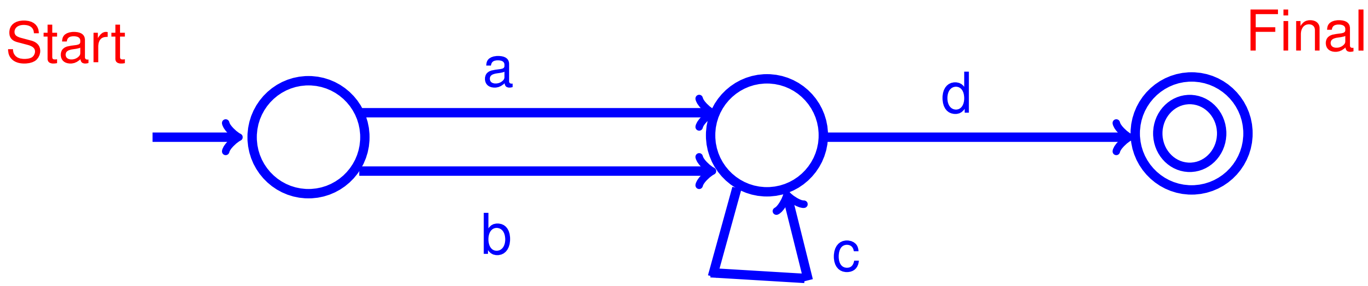
Def: Finite State Machine

A finite state machine (FSM) is a directed multi-graph,

where each edge is labeled with a symbol or the empty symbol ϵ.

One node is labeled “start” (typically by an incoming arrow).

Zero or more nodes are labeled “final” (typically by a double circle).

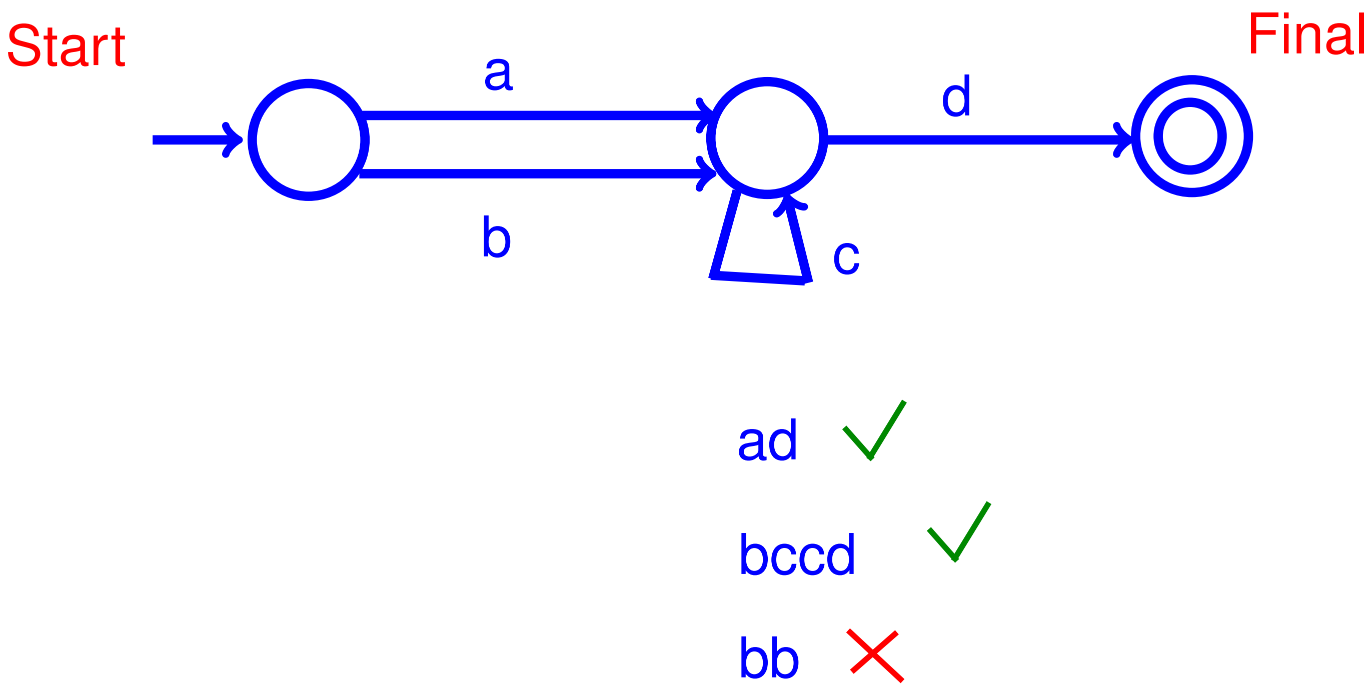


details>91

See a more formal definition in Wikipedia

Def: Acceptance

An FSM accepts (also: generates) a string, if there is a path from the start node to a final node whose edge labels are the string.



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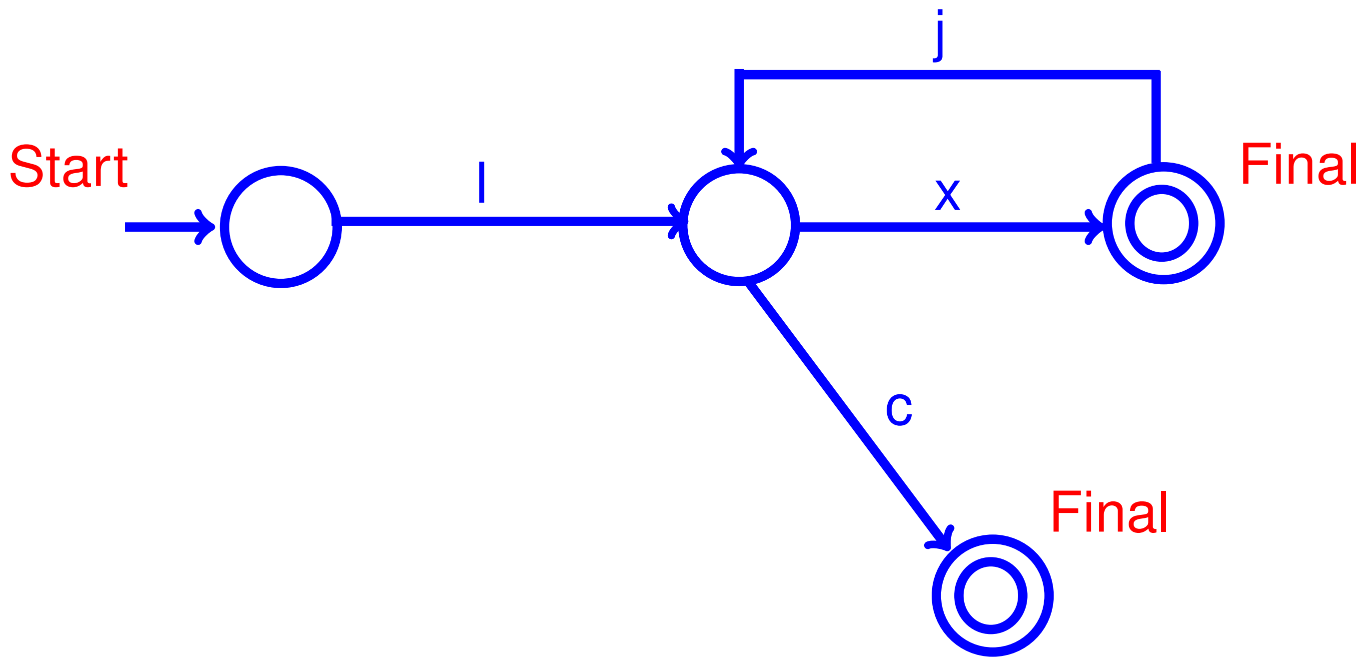
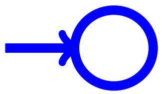
Task: FSM

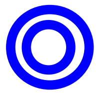
Find strings generated by the following FSM (Betelgeuse 7 language):



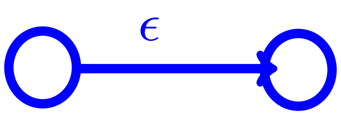
details>91

Notation

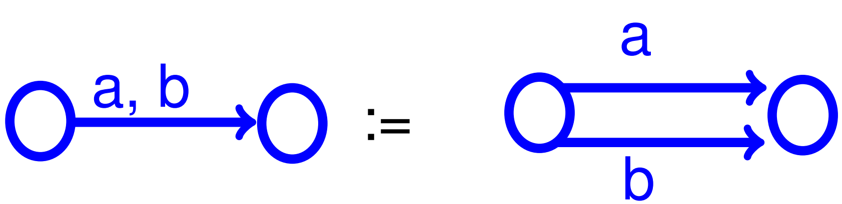
- start node 

- final node 

- empty transition (can be walked without accepting a symbol)



- multiple edges



details>91
task>85
trafo>87

Task: FSM

Draw an FSM that accepts the following strings

br kbr brbr kbrbr

brbrbr kbrbrbr ...

Draw an FSM that accepts the following strings

ling ping pong long

lingping lingpong pingpong

trafo>87

Transforming a regex to a FSM (1)

1. Simplify the regex to contain only concatenation, alternation, kleene star

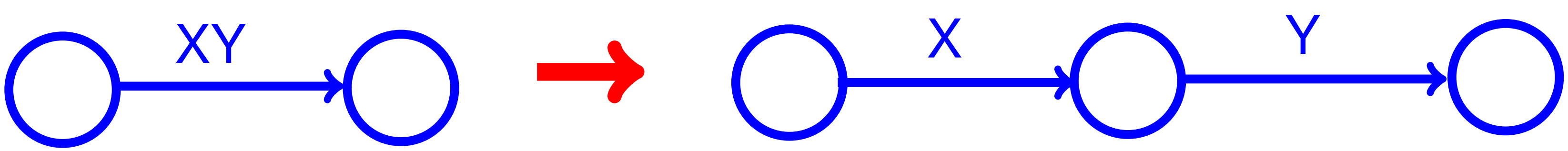
2. Start with this configuration:

3. Handle alternation:

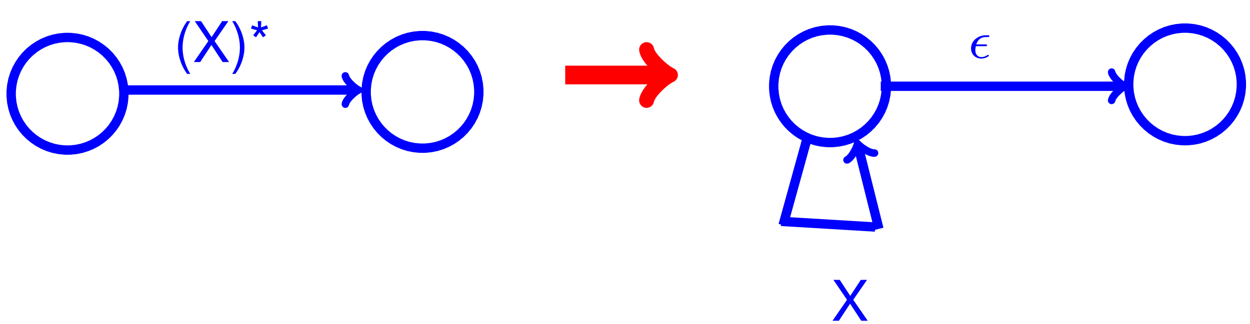
details>91

Transforming a regex to a FSM (2)

4. Handle concatenation:



5. Handle Kleene star:



6. Proceed recursively, until all edges are single symbols

details>91

FSM = Regex

For every regex, there is an FSM that accepts exactly the words of the language of the regex (and vice versa).

Examples:

- k?(br)+
- ((l—p)(i—o)ng)*
- f{2,3}

details>91

Runtime of regexes

Given a word of length l and given an FSM with n states, determining whether the FSM accepts the word

- takes $O(l)$ time if no state has several outgoing edges with the same label
- $O(l \times 2^n)$ else

There is a looooot more to say about FSMs, e.g.:

- making them deterministic
- compressing them
- making them more powerful
- learning FSMs from examples

Here, we only use them for IE

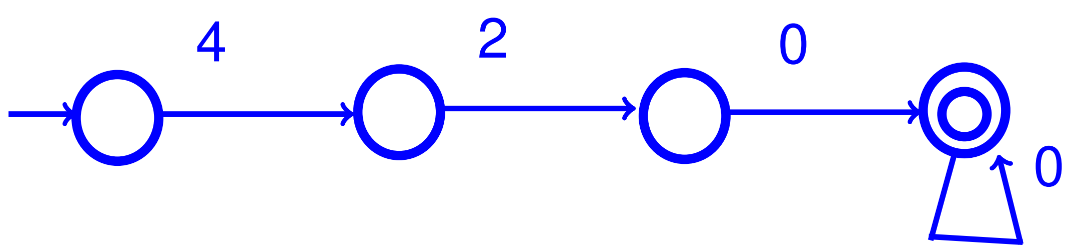
Regexes in programming

Regex 42(0)+

you

Simplified regex 420(0)*

FSM



your programming language

Matcher

His favorite numbers
are 42, 4200, and 19.

Example: Regexes in Java

```
Pattern pattern = Pattern.compile(”42(0)+”);
Matcher matcher = pattern.matcher(”His favorite numbers are...”);
while(matcher.find())
  System.out.println(matcher.group());
```

→ 4200

His favorite numbers are 42, 4200, and 19.

Entity Recognition

We have seen 2 methods to do entity recognition:

- Tries (if the set of names is known)
- Regexes (if the names follow a pattern)

$\boxed{\text{Douglas N. Adams}}$ had the idea for the “$\boxed{\text{Hitchhiker's Guide”}}$ while lying drunk in a field near Inn$\boxed{\text{sbruck.}}$

->evaluation

->named-entity-annotation

->disambiguation

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References

Sunita Sarawagi: Information Extraction

->evaluation

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->disambiguation