

Automata and Formal Languages (I)

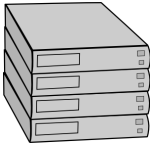


Antikythera automaton, 100 BC (Archimedes?)

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Office: SI.27 (1st floor Strand Building)

Slides: KEATS



Server

GET request



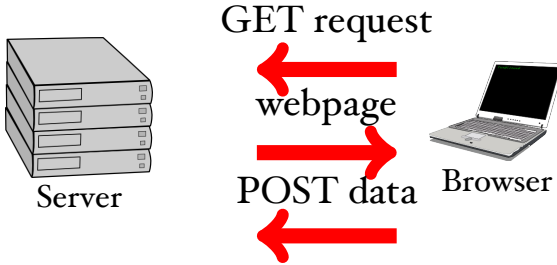
webpage



POST data



Browser



- programming languages, compilers

transforming strings into structured data

Lexing

(recognising “words”)

Parsing

(recognising “sentences”)

The subject is quite old:

- Turing Machines, 1936
- first compiler for COBOL, 1957 (Grace Hopper)
- but surprisingly research papers are still published now



Grace Hopper

(she made it to David Letterman's Tonight Show,

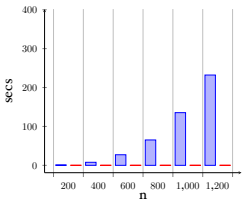
<http://www.youtube.com/watch?v=aZ0xtURhfEU>)

This Course

- the ultimate goal is to implement a small compiler (a really small one for the JVM)

Let's start with:

- a web-crawler
- an email harvester
- a web-scraper



A Web-Crawler

- 1 given an URL, read the corresponding webpage
- 2 extract all links from it
- 3 call the web-crawler again for all these links

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(we need a bound for the number of recursive calls)
(the purpose is to check all links on my own webpage)

Scala

a simple Scala function for reading webpages

```
1 import io.Source
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3 def get_page(url: String) : String = {
4     Source.fromURL(url).take(10000).mkString
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6     get_page("""http://www.inf.kcl.ac.uk/staff/urbanc/""")
7 }
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6     get_page("""http://www.inf.kcl.ac.uk/staff/urbanc/""")
```

slightly more complicated for handling errors properly:

```
1 def get_page(url: String) : String =
2     Try(Source.fromURL(url).take(10000).mkString) getOrElse
3     { println(s" Problem with: $url"); "" }
```

Why Scala?

twitter 

Linked 

theguardian

Morgan Stanley

CREDIT SUISSE 



edf
ENERGY

Novell.

foursquare™

HSBC 

...

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5 yrs {

- 2013: 1%
- 2014: 3%
- 2015: 9%
- 2016: 27%
- 2017: 81%
- 2018: 243% 😊

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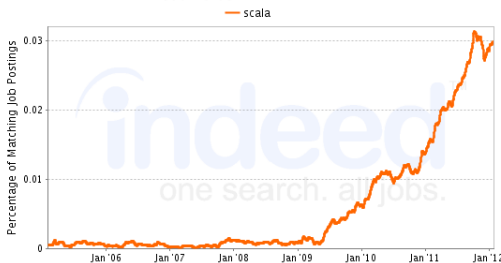
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Job Trends from Indeed.com



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in London today: 1 Scala job for every 30 Java jobs;
Scala programmers seem to get up to 20% better salary

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Job Trends from Indeed.com



Scala is a functional and object-oriented programming language; compiles to the JVM; does not need null-pointer exceptions; a course on Coursera

<http://www.scala-lang.org>

2016: 27%

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in London today: 1 Scala job for every 30 Java jobs;
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A Regular Expression

- ... is a pattern or template for specifying strings

”https?://[^\"]*”

matches for example

”http://www.foobar.com”

”https://www.tls.org”

A Regular Expression

- ... is a pattern or template for specifying strings

```
""""\”https?:\/\/[^\”]*\”"""".r
```

matches for example

```
”http://www.foobar.com”
```

```
”https://www.tls.org”
```

rexp.findAllIn(string)

returns a list of all (sub)strings that match the regular expression

rexp.findFirstIn(string)

returns either **None** if no (sub)string matches or **Some(s)** with the first (sub)string

```
1 val http_pattern = """\"https?://[^\"]*\".r
2
3 def unquote(s: String) = s.drop(1).dropRight(1)
4
5 def get_all_URLs(page: String) : Set[String] =
6     http_pattern.findAllIn(page).map(unquote).toS
7 }
8
9 def crawl(url: String, n: Int) : Unit = {
10     if (n == 0) ()
11     else {
12         println(s"Visiting: $n $url")
13         for (u <- get_all_URLs(get_page(url)))
14             crawl(u, n - 1)
15     }
16 }
17
18 crawl(some_start_URL, 2)
```

a version that only “crawls” links in my domain:

```
1  val my_urls = """urbanc""".r
2
3  def crawl(url: String, n: Int) : Unit = {
4    if (n == 0) ()
5    else if (my_urls.findFirstIn(url) == None) ()
6    else {
7      println(s"Visiting: $n $url")
8      for (u <- get_all_URLs(get_page(url)))
9        crawl(u, n - 1)
10   }
11 }
```

a little email “harvester”:

```
1 val http_pattern = """\"https?://[^\"]*\".r
2 val my_urls = """urbanc\".r
3 val email_pattern =
4     """([a-z0-9_\\.-]+)@([\\da-z\\.-]+)\\.([a-z\\.]{2,}
5
6 def crawl(url: String, n: Int) : Unit = {
7     if (n == 0) ()
8     else {
9         println(s\"Visiting: $n $url\")
10        val page = get_page(url)
11        println(email_pattern.findAllIn(page).mkStr
12        for (u <- get_all_URLs(page))
13            crawl(u, n - 1)
14    }
15 }
```

Regular Expressions

Their inductive definition:

$r ::=$	\emptyset	null
	ϵ	empty string / "" / []
	c	character
	$r_1 \cdot r_2$	sequence
	$r_1 + r_2$	alternative / choice
	r^*	star (zero or more)

Regular Expressions

In Scala:

```
1  abstract class Rexp
2
3  case object NULL extends Rexp
4  case object EMPTY extends Rexp
5  case class CHAR(c: Char) extends Rexp
6  case class ALT(r1: Rexp, r2: Rexp) extends Rexp
7  case class SEQ(r1: Rexp, r2: Rexp) extends Rexp
8  case class STAR(r: Rexp) extends Rexp
```

The Meaning of a Regular Expression

$$L(\emptyset) \stackrel{\text{def}}{=} \emptyset$$

$$L(\epsilon) \stackrel{\text{def}}{=} \{""\}$$

$$L(c) \stackrel{\text{def}}{=} \{ "c" \}$$

$$L(r_1 + r_2) \stackrel{\text{def}}{=} L(r_1) \cup L(r_2)$$

$$L(r_1 \cdot r_2) \stackrel{\text{def}}{=} \{ s_1 @ s_2 \mid s_1 \in L(r_1) \wedge s_2 \in L(r_2) \}$$

$$L(r^*) \stackrel{\text{def}}{=}$$

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$$L(r^*) \stackrel{\text{def}}{=} \bigcup_{n \geq 0} L(r)^n$$

$$L(r)^0 \stackrel{\text{def}}{=} \{""\}$$

$$L(r)^{n+1} \stackrel{\text{def}}{=} L(r) @ L(r)^n \quad (\text{append on sets})$$
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The Meaning of Matching

a regular expression r matches a string s is defined as

$$s \in L(r)$$

This Course

We will have a look at:

- regular expressions / regular expression matching
- derivatives
- automata
- parsing
- grammars
- a small interpreter / compiler

Exam

- The question “Is this relevant for the exam?” is not appreciated!

Whatever is in the homework sheets (and is not marked “optional”) is relevant for the exam.
No code needs to be written in the exam.