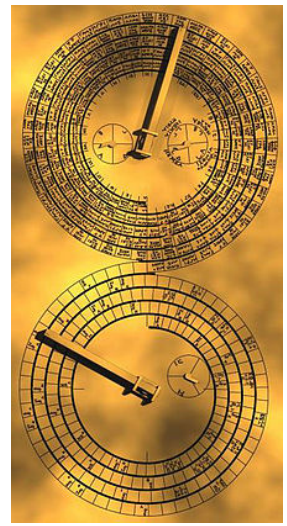
Automata and Formal Languages (1)

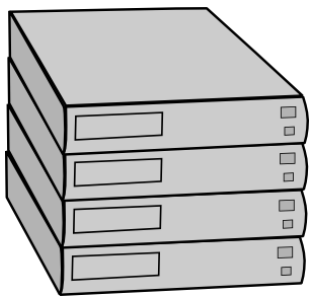


Antikythera automaton, 100 BC (Archimedes?)

Email: christian.urban at kcl.ac.uk

Office: S1.27 (1st floor Strand Building)

Slides: KEATS



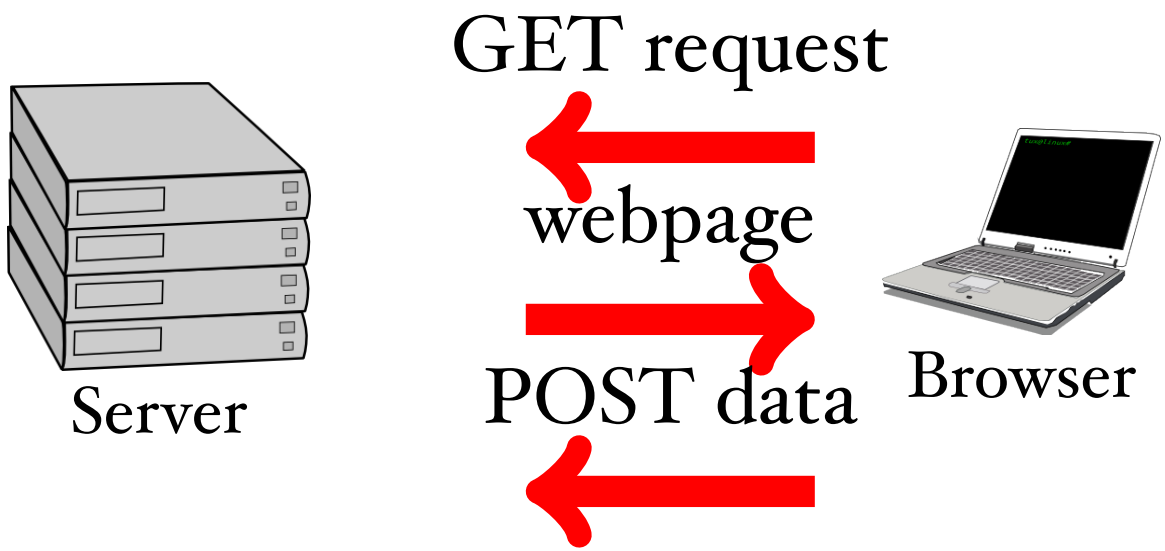
Server

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,

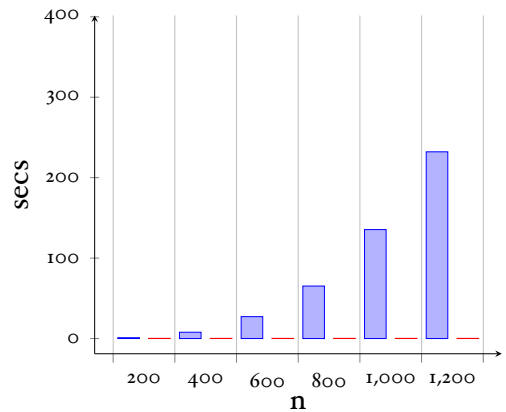
`http://www.youtube.com/watch?v=aZOxtURhfEU`)

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
2
3  def get_page(url: String) : String = {
4    Source.fromURL(url).take(10000).mkString
```

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get_page("""http://www.inf.kcl.ac.uk/staff/urbanc/""")
```

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```
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) getOrEl
3      { println(s"  Problem with: $url"); ""}
```

Why Scala?


twitter


LinkedIn


theguardian


Morgan Stanley


CREDIT SUISSE


EDF
ENERGY


Novell


foursquare


HSBC

...

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5 yrs {
- 2013: 1%
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- 2017: 81%
- 2018: 243% 😁

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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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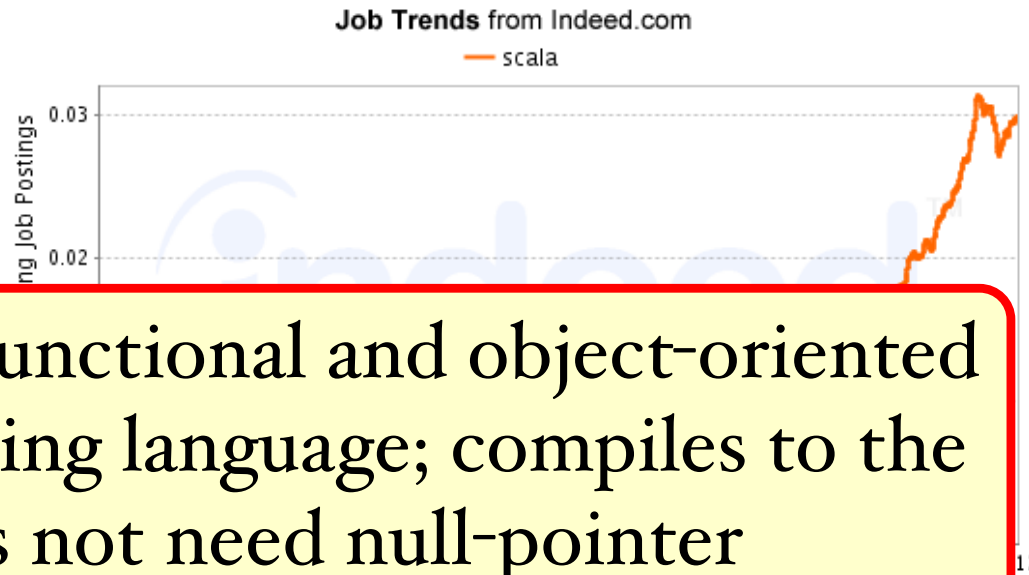

Scala is a functional and object-oriented programming language; compiles to the JVM; does not need null-pointer exceptions; a course on Coursera

http://www.scala-lang.org

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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

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).toSet
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 }

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\.]{2,6})""".r
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).mkString("\n"
12     for (u <- get_all_URLs(page))
13       crawl(u, n - 1)
14   }
15 }
```

http://net.tutsplus.com/tutorials/other/8-regular-expressions-you-should-know/

Regular Expressions

Their inductive definition:

r	$::=$	$\varnothing$	null
	$\mid$	ϵ	empty string / "" / []
	$\mid$	c	character
	$\mid$	$r_1 \cdot r_2$	sequence
	$\mid$	$r_1 + r_2$	alternative / choice
	$\mid$	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

$$
\begin{array}{rcl}
L(\varnothing) & \stackrel{\text{def}}{=} & \varnothing \\
L(\epsilon) & \stackrel{\text{def}}{=} & \{""\} \\
L(c) & \stackrel{\text{def}}{=} & \{"c"\} \\
L(r_1 + r_2) & \stackrel{\text{def}}{=} & L(r_1) \cup L(r_2) \\
L(r_1 \cdot r_2) & \stackrel{\text{def}}{=} & \{\, s_1 @ s_2 \mid s_1 \in L(r_1) \wedge s_2 \in L(r_2) \,\} \\
L(r^*) & \stackrel{\text{def}}{=} &
\end{array}
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$$
\begin{array}{rcl}
L(r)^0 & \stackrel{\text{def}}{=} & \{""\} \\
L(r)^{n+1} & \stackrel{\text{def}}{=} & L(r) @ L(r)^n
\end{array}
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\end{array}
$$

(append on sets)

$$\{\, s_1 @ s_2 \mid s_1 \in L(r) \wedge s_2 \in L(r)^n \,\}$$

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

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

Written Exam

- Accounts for 75%.
- You will understand the question "Is this relevant for the exam?" is very demotivating for the lecturer!
- Deal: Whatever is in the homework (and is not marked "optional") is relevant for the exam.

Coursework

- Accounts for 25%. Two strands. Choose **one**!

Strand 1

- four programming subtasks:
  - matcher (5%, 13.10.)
  - lexer (5%, 03.11.)
  - parser (5%, 27.11.)
  - compiler (10%, 12.12.)

Strand 2

- one task: prove the correctness of a regular expression matcher in the Isabelle theorem prover
- 25%, submission 12.12.

- Solving more than one strand will **not** give you more marks.
- The exam will contain in much, much smaller form elements from both (but will also be in lectures and HW).