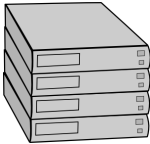


# Automata and Formal Languages (1)



Antikythera automaton, 100 BC (Archimedes?)

Email: christian.urban at kcl.ac.uk  
Office: S1.27 (1st floor Strand Building)  
Slides: KEATS



Server

GET request



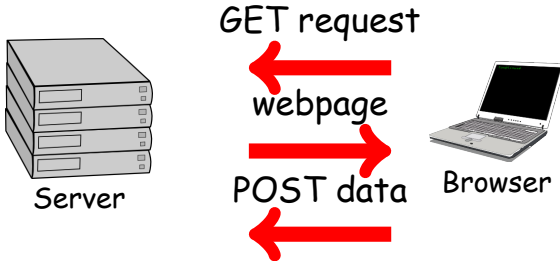
webpage



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 web-browser (really small one)

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

# A Web-Crawler

- 1 given an URL, read the corresponding webpage
- 2 if not possible print, out a problem
- 3 if possible, extract all links from it
- 4 call the web-crawler again for all these links



# A Web-Crawler

- 1 given an URL, read the corresponding webpage
- 2 if not possible print, out a problem
- 3 if possible, extract all links from it
- 4 call the web-crawler again for all these links

(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
```

# 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
5
6     get_page("http://www.inf.kcl.ac.uk/staff/urbanc/")
```

# 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
5
6     get_page("http://www.inf.kcl.ac.uk/staff/urbanc/")
7 }
```

slightly more complicated for handling errors properly:

```
1 def get_page(url: String) : String = {
2     try {
3         Source.fromURL(url).take(10000).mkString
4     }
5     catch {
6         case e => {
7             println(" Problem with: " + url)
8             ""
9         }
10    }
11 }
```

# 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("Visiting: " + n + " " + url)
13    for (u <- get_all_URLs(get_page(url))) crawl(u, n - 1)
14  }
15 }
```

```
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("Visiting: " + n + " " + url)
8     for (u <- get_all_URLs(get_page(url))) crawl(u, n - 1)
9   }
10 }
```

## 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("Visiting: " + n + " " + url)
10    val page = get_page(url)
11    println(email_pattern.findAllIn(page).mkString("\\n"))
12    for (u <- get_all_URLs(page)) crawl(u, n - 1)
13  }
14 }
```

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

# Regular Expressions

Their inductive definition:

$r ::=$	$\emptyset$	null
	$\epsilon$	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

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

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

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

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

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

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

# The Meaning of a Regular Expression

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

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

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

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

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

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

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

$$L(r)^{n+1} \stackrel{\text{def}}{=} L(r) @ L(r)^n$$

# The Meaning of a Regular Expression

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

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

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

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

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

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

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

$$L(r)^{n+1} \stackrel{\text{def}}{=} L(r) @ L(r)^n \quad (\text{append on sets})$$
$$\{ s_1 @ s_2 \mid s_1 \in L(r) \wedge s_2 \in L(r)^n \}$$

# The Meaning of a Regular Expression

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

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

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

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

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

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

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

$$L(r)^{n+1} \stackrel{\text{def}}{=} L(r) @ L(r)^n \quad (\text{append on sets})$$
$$\{s_1 @ s_2 \mid s_1 \in L(r) \wedge s_2 \in L(r)^n\}$$



# 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
- automata
- the Myhill-Nerode theorem
- parsing
- grammars
- a small interpreter / web browser

# 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.