Introduction to pattern matching

Using Regexes

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Typical Linux problem

```
$ cat files.txt
readme.md
document.pdf
image.png
music.mp3
video.mp4
manual.pdf
```

Objectives: List only PDF files

$ man grep

```
GREP(1)                     User Commands                    GREP(1)

NAME
    grep, egrep, fgrep, rgrep - print lines that match
   patterns

SYNOPSIS
    grep [OPTION...] PATTERNS [FILE...]
    grep [OPTION...] -e PATTERNS ... [FILE...]
    grep [OPTION...] -f PATTERN_FILE ... [FILE...]

DESCRIPTION
    grep searches for PATTERNS in each FILE.  PATTERNS
   is one or more patterns separated  by  newline
   characters,  and  grep prints each line that matches
    a pattern.  Typically PATTERNS should be quoted
   when grep is used in a shell command.
```

Using grep

```
$ cat files.txt | grep ’pdf’
document.pdf
manual.pdf
```

Easy! However...

Using grep

```
$ cat files.txt | grep ’pdf’
document.pdf
manual.pdf
```

Easy! However...

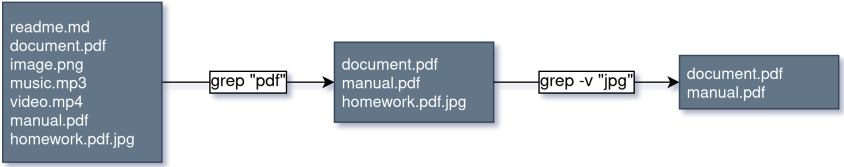
```
$ cat files-2.txt | grep ’pdf’
document.pdf
manual.pdf
homework.pdf.jpg
```

How can we filter out `homework.pdf.jpg`?

Using grep

```
$ cat files-2.txt | grep 'pdf' | grep -v 'jpg'
document.pdf
manual.pdf
```

−v allows us to perform an in**V**ert match



Using grep

```
$ cat files-3.txt | grep ’pdf’ | grep -v ’jpg’
document.pdf
manual.pdf
adobe_pdf_reader.exe
i_hate_pdf.mp3
this.is.a.weird.pdf.filename.zip
filename with spaces are evil.pdf
```

Using invert match is not going to scale...

Other commonly encountered problems

- Matching valid email addresses
- Matching valid IBAN number
- Matching valid IPv4 addresses

→ Regular Expressions (**Regex**) to the rescue

Regular Expression

A **regular expression** (shortened as **regex** or **regexp**) is a sequence of characters that specifies a search pattern in text.

Regexes are extremely useful in extracting information from text.

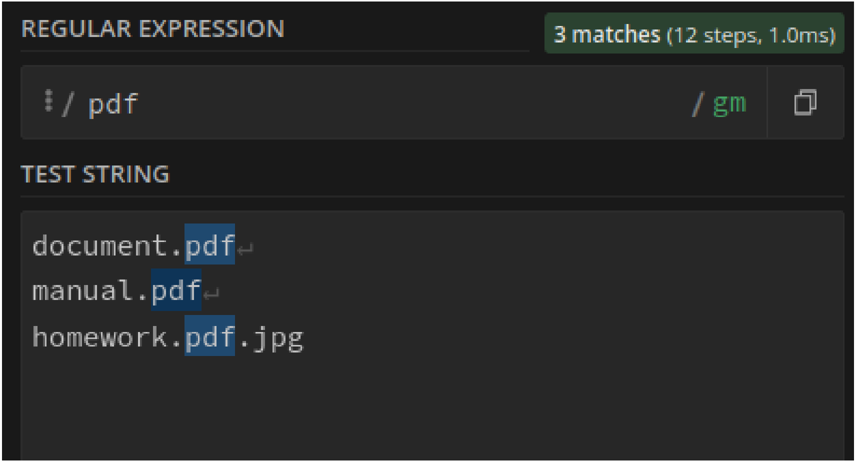
Regular Expression Basics

- What ?
  - Literal characters: `abc`
  - Quantifiers: `ab+c`
  - Operator OR: `(abc|cba)`
  - Bracket expressions: `[a-z]`
  - Meta sequences: `\S`
  - Capture group: `(abc)`
  - Anchors: `^abc$`
- New skill ?

```
/ <([a-z]+)(>(.*)<\/\1>|\s+\/>) /
```

Regular Expression Basics: Literal characters

Letters and digits from the ASCII character set match their respective value

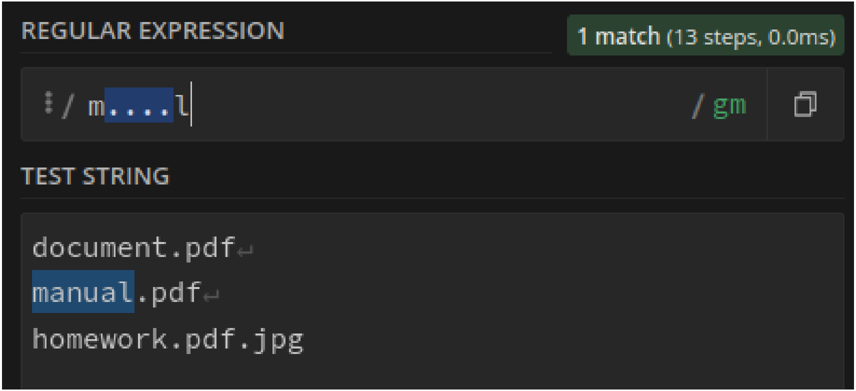


```
/ pdf / gm
```

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: The Dot

- `.` is a *joker* or *wildcard* that can match any single character



REGULAR EXPRESSION

1 match (13 steps, 0.0ms)

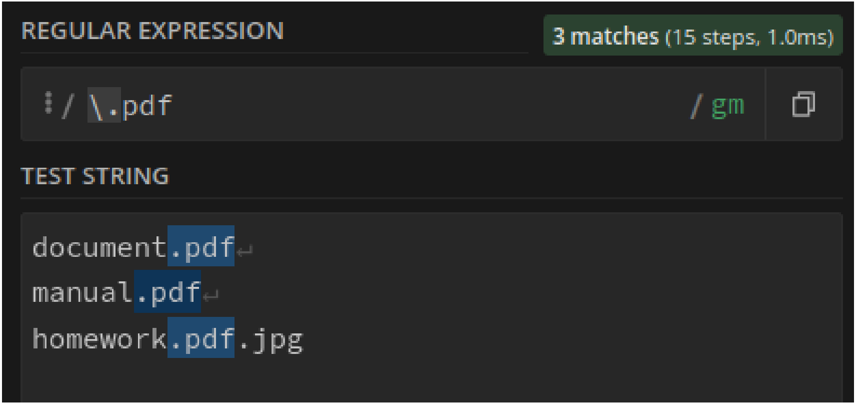
```
/ m....l / gm
```

TEST STRING

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: The Period

The period character `.` can be matched using the escape character `\.`



REGULAR EXPRESSION

3 matches (15 steps, 1.0ms)

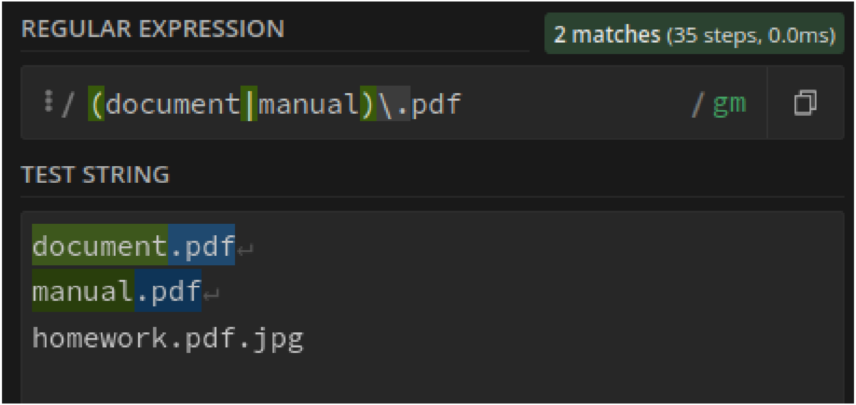
```
/ \.pdf / gm
```

TEST STRING

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: OR Operator

The (|) structure can be used as a logical operator to match one sequence or the other



REGULAR EXPRESSION

2 matches (35 steps, 0.0ms)

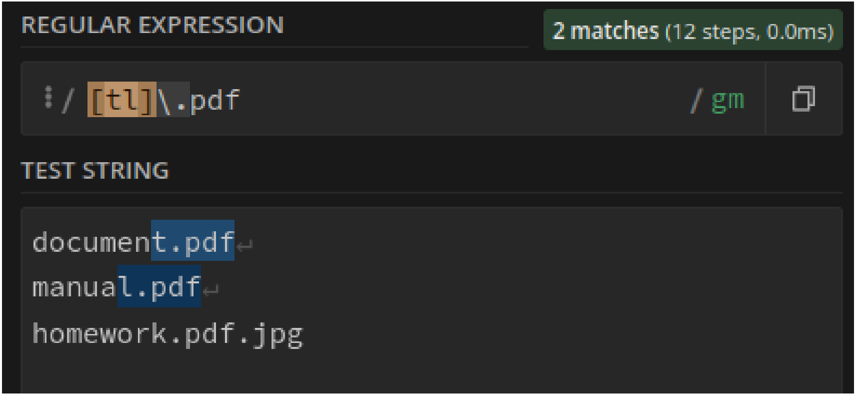
```
/ (document|manual)\.pdf / gm
```

TEST STRING

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Bracket Expression (1)

The [ ] structure can be used to specifiy a set of characters that can match

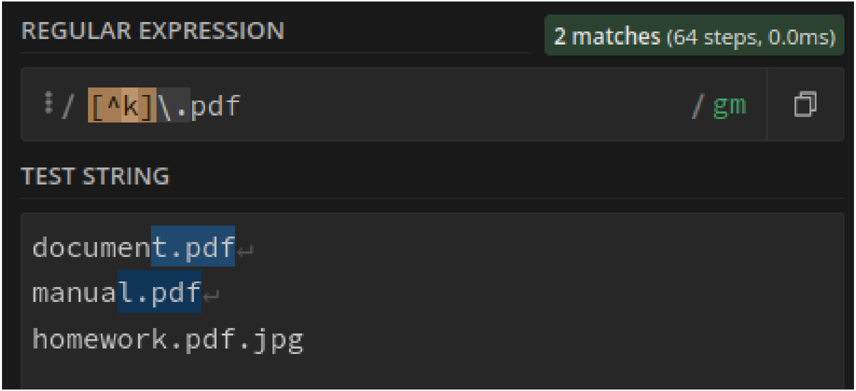


```
/ [tl]\.pdf / gm
```

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Bracket Expression (2)

The `[^ ]` structure can be used to exclude a specific set of characters

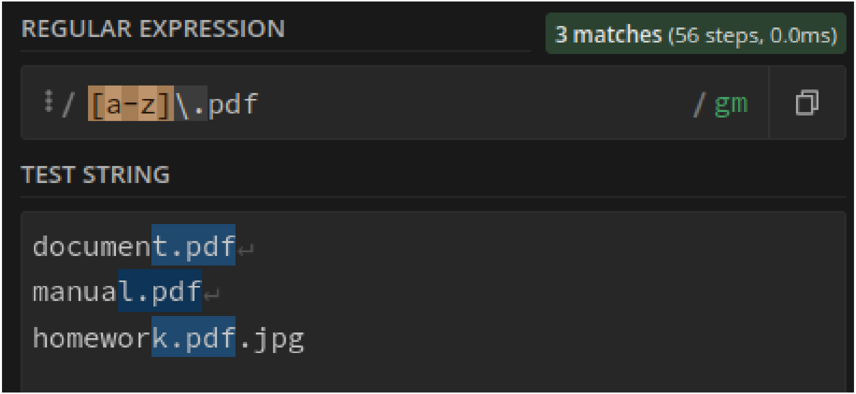


```
/ [^k]\.pdf / gm
```

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Bracket Expression (3)

The [-] structure can be used to specifiy a range of sequential characters



REGULAR EXPRESSION

3 matches (56 steps, 0.0ms)

```
/ [a-z]\.pdf / gm
```

TEST STRING

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Meta Sequences (1)

- `/ . /`
  - Any single character
- `/ \w /`
  - Any word character
  - `/ [a-zA-Z0-9_] /`
  - **Match**: `any non-whitespace character $!-:;`
- `/ \W /`
  - Any non-word character
  - `/ [^a-zA-Z0-9_] /`
  - **Match**: `any whitespace character $!-:;`

Regular Expression Basics: Meta Sequences (2)

- `/ \d /`
  - Any digit
  - **Match**: `one: 1, two: 2;`
- `/ \s /`
  - Any whitespace character
  - **Match**: `any whitespace character $!-:;`
- `/ \S /`
  - Any non-whitespace character
  - **Match**: `any non-whitespace character $!-:;`

Regular Expression Basics: Reading Exercises (1)

1. `/ facebo.k /`

Regular Expression Basics: Reading Exercises (1)

1. `/ facebo.k /`
   - ○ **Match**: `facebook`, `faceboak`, `facebo&k`
2. `/ 4\.2 /`

Regular Expression Basics: Reading Exercises (1)

1. `/ facebo.k /`
    - **Match**: `facebook`, `faceboak`, `facebo&k`
2. `/ 4\.2 /`
    - **Match**: `4.2`
    - **Match**: `Nice number:  4.2`
3. `/ drink (beer|wine) ! /`

Regular Expression Basics: Reading Exercises (1)

1. `/ facebo.k /`
    - **Match**: `facebook`, `faceboak`, `facebo&k`
2. `/ 4\.2 /`
    - **Match**: `4.2`
    - **Match**: `Nice number:  4.2`
3. `/ drink (beer|wine) ! /`
    - **Match**: `I drink beer !`
    - **Match**: `I drink wine !`
4. `/ [e-h] /`

Regular Expression Basics: Reading Exercises (1)

1. `/ facebo.k /`
   - **Match**: `facebook`, `faceboak`, `facebo&k`
2. `/ 4\.2 /`
   - **Match**: `4.2`
   - **Match**: `Nice number:  4.2`
3. `/ drink (beer|wine) ! /`
   - **Match**: `I drink beer !`
   - **Match**: `I drink wine !`
4. `/ [e-h] /`
   - **Match**: `fefe`, `hehe`
   - **No match**: ~~haha~~

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*

   ```
   / _light /
   ```

2. **Match**: *red_light* and *green_light* **but not** *white_light*

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*

   ```
   / _light /
   ```

2. **Match**: *red_light* and *green_light* **but not** *white_light*

   ```
   / (red|green)_light /
   ```

3. **Match**: **_light* where ∗ is any digit

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*

   ```
   / _light /
   ```
2. **Match**: *red_light* and *green_light* **but not** *white_light*

   ```
   / (red|green)_light /
   ```
3. **Match**: **_light* where ∗ is any digit

   ```
   / [0-9]_light /
   ```
4. **Match**: *?_light* where `?` is 4-letters color name

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*
   ```
   / _light /
   ```
2. **Match**: *red_light* and *green_light* **but not** *white_light*
   ```
   / (red|green)_light /
   ```
3. **Match**: *_light where `*` is any digit
   ```
   / [0-9]_light /
   ```
4. **Match**: *?_light* where `?` is 4-letters color name
   ```
   / [a-z][a-z][a-z][a-z]_light /
   ```

Regular Expression Basics: Writing Exercises (1)

1. **Match**: *red_light*, *green_light* and *!=_light*

   ```
   / _light /
   ```

2. **Match**: *red_light* and *green_light* **but not** *white_light*

   ```
   / (red|green)_light /
   ```

3. **Match**: **_light* where ∗ is any digit

   ```
   / [0-9]_light /
   ```

4. **Match**: *?_light* where `?` is 4-letters color name

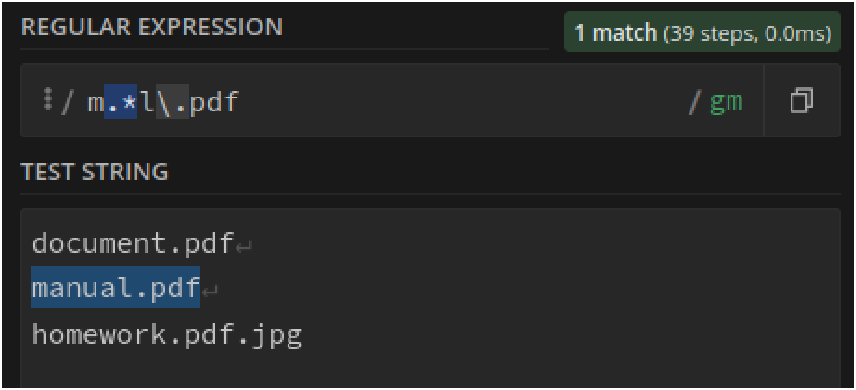
   ```
   / [a-z][a-z][a-z][a-z]_light /
   ```

Question: *?_light* where `?` is any color between 3 and 6 letters

We need a way to express occurences... Introducing **quantifiers**

Regular Expression Basics: Quantifiers (1)

The ∗ control character can be used to describe **zero or more** occurences

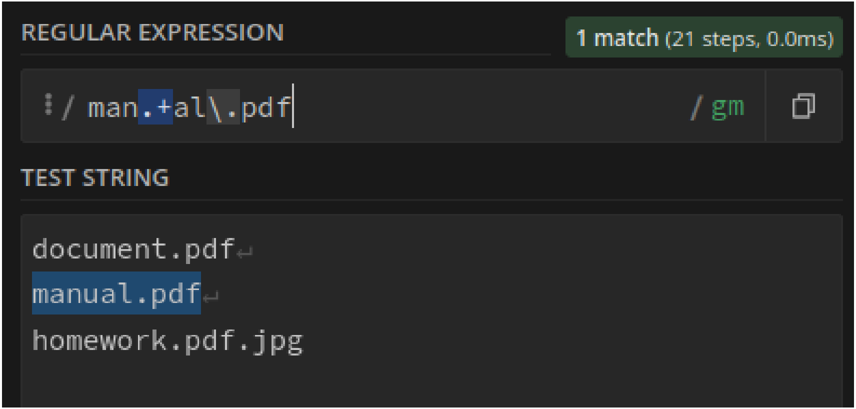


```
/ m.*l\.pdf / gm
```

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Quantifiers (2)

The + control character can be used to describe **one or more** occurences



1 match (21 steps, 0.0ms)

```
/ man.+al\.pdf / gm
```

```
document.pdf
manual.pdf
homework.pdf.jpg
```

Regular Expression Basics: Quantifiers (3)

- `/ a? /`
  - Match 0 or one `a` character
- `/ a{3} /`
  - Match exactly 3 `a` character
- `/ a{3,} /`
  - Match 3 or more `a` character
- `/ a{3,6} /`
  - Match between 3 and 6 `a` character

Regular Expression Basics: Reading Exercises (2)

1. `/ colou?r /`

Regular Expression Basics: Reading Exercises (2)

1. `/ colou?r /`
   - **Match**: `colour` and `color`
2. `/ go*gle /`

Regular Expression Basics: Reading Exercises (2)

1. `/ colou?r /`
    - **Match**: `colour` and `color`
2. `/ go*gle /`
    - **Match**: `gogle`, `goooooogle`, `ggle`, ...
3. `/ waz+up /`

Regular Expression Basics: Reading Exercises (2)

1. / `colou?r` /
   - **Match**: `colour` and `color`
2. / `go*gle` /
   - **Match**: `gogle`, `goooooogle`, `ggle`, ...
3. / `waz+up` /
   - **Match**: `wazup`, `wazzzzzup`, ...
4. / `+352[0-9]{6,8}` /

Regular Expression Basics: Reading Exercises (2)

1. `/ colou?r /`
   - **Match**: `colour` and `color`
2. `/ go*gle /`
   - **Match**: `gogle`, `goooooogle`, `ggle`, ...
3. `/ waz+up /`
   - **Match**: `wazup`, `wazzzzzup`, ...
4. `/ +352[0-9]{6,8} /`
   - **Match**: +352791648, +35226791349

Regular Expression Basics: Writing Exercises (2)

1. **Match**: The time (16:42, 03:59)

Regular Expression Basics: Writing Exercises (2)

1. **Match**: The time (16:42, 03:59)

   `/ [0−9][0−9]:[0−9][0−9] /`

   (not perfect but good enough for the exercise)
2. **Match**: Luxembourg postal code (L-4253, L-1110)

Regular Expression Basics: Writing Exercises (2)

1. **Match**: The time (16:42, 03:59)

   `/ [0-9][0-9]:[0-9][0-9] /`

   (not perfect but good enough for the exercise)

2. **Match**: Luxembourg postal code (L-4253, L-1110)

   `/ L-[0-9]{4} /`

3. **Match**: *_light where * is any color?

Regular Expression Basics: Writing Exercises (2)

1. **Match**: The time (16:42, 03:59)

   `/ [0-9][0-9]:[0-9][0-9] /`

   (not perfect but good enough for the exercise)
2. **Match**: Luxembourg postal code (L-4253, L-1110)

   `/ L-[0-9]{4} /`
3. **Match**: **_light* where ∗ is any color?

   `/ [a-z]+_light /`
4. **Match**: any hexadecimnal color (#ff0000, #f7f8f9)

Regular Expression Basics: Writing Exercises (2)

1. **Match**: The time (16:42, 03:59)

   `/ [0-9][0-9]:[0-9][0-9] /`

   (not perfect but good enough for the exercise)

2. **Match**: Luxembourg postal code (L-4253, L-1110)

   `/ L-[0-9]{4} /`

3. **Match**: *_light where * is any color?

   `/ [a-z]+_light /`

4. **Match**: any hexadecimnal color (#ff0000, #f7f8f9)

   `/ #[a-f0-9]{6} /`

Regular Expressions: Tag matching (1)

Create a Regex that validates the following tags:

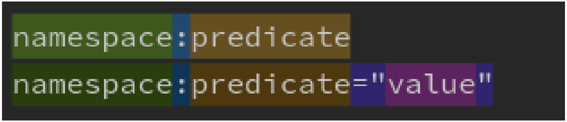
```
namespace:predicate
namespace:predicate="value"
name_space:pred_icate="value"
namespace:predicate="qwert _+$- yuiop"
namespace:predicate="qwert=:yuiop"
```

But not these:

```
tag
name space:pred icate="value"
name-space:predicate="value"
namespace:predicate="qwert"yuiop"
```

Regular Expressions: Tag matching (2)

A valid tag is composed of 2 or 3 parts



```
namespace:predicate
namespace:predicate="value"
```

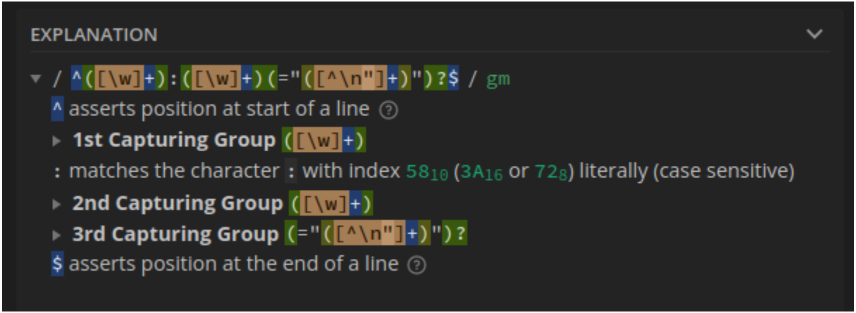
1. The `namespace`
2. The `predicate`
3. The optional `value`

Regular Expressions: Tag matching (3)

Tag validator

```
/ ^([\w]+):([\w]+)(="([^\n"]+)")?$ /
```

Regular Expressions: Tag matching (4)



EXPLANATION

```
/ ^([\w]+):([\w]+)(="([^\n"]+)")?$ / gm
```

^ asserts position at start of a line

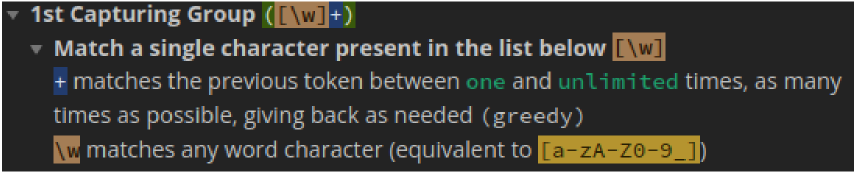
- 1st Capturing Group `([\w]+)`

`:` matches the character `:` with index 58_{10} ($3A_{16}$ or 72_{8}) literally (case sensitive)

- 2nd Capturing Group `([\w]+)`
- 3rd Capturing Group `(="([^\n"]+)")?`

$ asserts position at the end of a line

Regular Expressions: Tag matching (5)



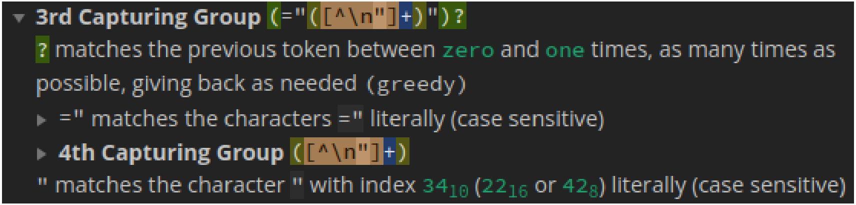
1st Capturing Group `([\w]+)`

Match a single character present in the list below `[\w]`

`+` matches the previous token between `one` and `unlimited` times, as many times as possible, giving back as needed `(greedy)`

`\w` matches any word character (equivalent to `[a-zA-Z0-9_]`)

Regular Expressions: Tag matching (5)



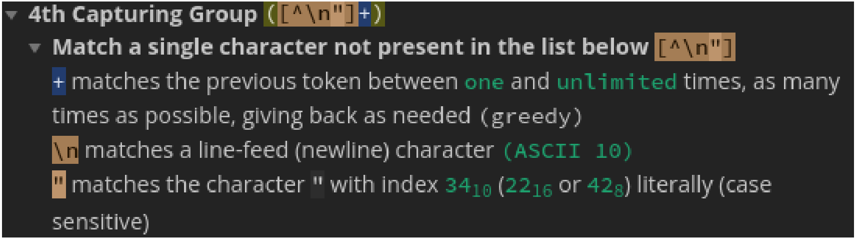
▼ **3rd Capturing Group** `(="([^\n"]+)")?`

`?` matches the previous token between `zero` and `one` times, as many times as possible, giving back as needed `(greedy)`

▶ `="` matches the characters `="` literally (case sensitive)

▶ **4th Capturing Group** `([^\n"]+)`

`"` matches the character `"` with index 34_{10} (22_{16} or 42_{8}) literally (case sensitive)



▼ **4th Capturing Group** `([^\n"]+)`

▼ **Match a single character not present in the list below** `[^\n"]`

`+` matches the previous token between `one` and `unlimited` times, as many times as possible, giving back as needed `(greedy)`

`\n` matches a line-feed (newline) character `(ASCII 10)`

`"` matches the character `"` with index 34_{10} (22_{16} or 42_{8}) literally (case sensitive)

Regular Expressions: Final question

What does these regexes do?

1. `/ ([12]\d{3}-(0[1-9]|1[0-2])-(0[1-9]|[12]\d|3[01])) /`

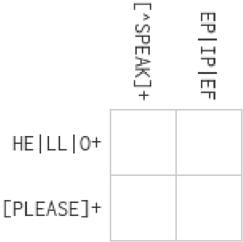
2. `/ <([a-z]+)(>(.*)<\/\1>|\s+\/>) /`
   - \1 is used to reference the first capturing group
   - First capturing group is `([a-z]+)`

Regexes: Going further

- ˆ and **$** anchors
- Capture **groups**
- **Greedy** and **Lazy** quantifiers
- **Possessive** quantifier

Fun with Regular Expressions

`https://regexcrossword.com/`



Fun with Regular Expressions

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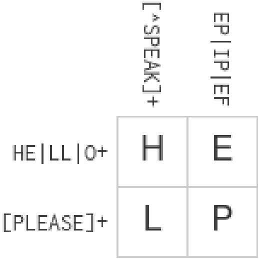
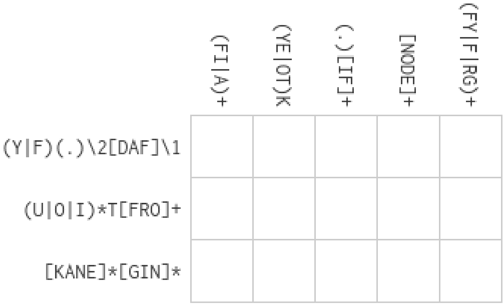


	[^SPEAK]+	EP|IP|EF
HE|LL|O+	H	E
[PLEASE]+	L	P

Fun with Regular Expressions

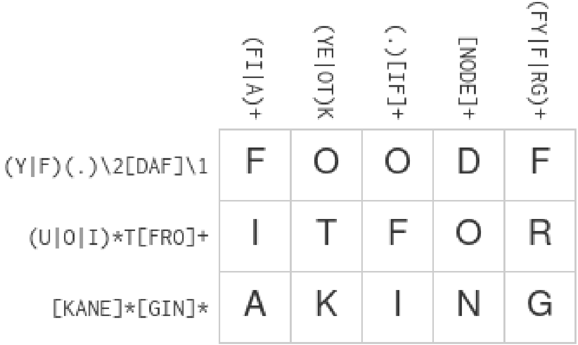
https://regexcrossword.com/



	(FI|A)+	(YE|OT)K	(.)[IF]+	[NODE]+	(FY|F|RG)+
(Y|F)(.)\2[DAF]\1					
(U|O|I)*T[FRO]+					
[KANE]*[GIN]*					

Fun with Regular Expressions

https://regexcrossword.com/



<table>
<tr><th></th><th>(FI|A)+</th><th>(YE|OT)K</th><th>(.)[IF]+</th><th>[NODE]+</th><th>(FY|F|RG)+</th></tr>
<tr><td>(Y|F)(.)\2[DAF]\1</td><td>F</td><td>O</td><td>O</td><td>D</td><td>F</td></tr>
<tr><td>(U|O|I)*T[FRO]+</td><td>I</td><td>T</td><td>F</td><td>O</td><td>R</td></tr>
<tr><td>[KANE]*[GIN]*</td><td>A</td><td>K</td><td>I</td><td>N</td><td>G</td></tr>
</table>