Theory and Practice of Data Cleaning

Regular Expressions: From Theory to **Practice**

Theory of Regular Expressions

- Base elements:
  - ∅ ***empty set***, ε ***empty string***, and Σ ***alphabet*** *of* characters
- For regular expressions *R*, *S*, the following are **regular expressions**:
  - *R* | *S* ***alternation***
  - *R S* ***concatenation***
  - *R** ***Kleene star***
  - *(R)* ***parentheses*** (can be omitted with *precedence rules*)

- **Regular languages** …
  - *generated* by regular (Type-3) grammars
  - *recognized* (accepted) by a finite automaton
  - *expressed* by regular expressions

Regular Grammars

Example: **floating point numbers** such as **`-0.314159265e+1`**
… can be **generated** by a ***right regular grammar G*** with
N = {**S**, A,B,C,D,E,F}, **Σ** = {0,1,2,3,4,5,6,7,8,9,+,-,.,e},

***Production rules P* =**

S → +A	A → 0A	B → 0C	C → 0C	D → +E	E → 0F	F → 0F
S → -A	A → 1A	B → 1C	C → 1C	D → -E	E → 1F	F → 1F
S → A	A → 2A	B → 2C	C → 2C	D → E	E → 2F	F → 2F
	A → 3A	B → 3C	C → 3C		E → 3F	F → 3F
	A → 4A	B → 4C	C → 4C		E → 4F	F → 4F
	A → 5A	B → 5C	C → 5C		E → 5F	F → 5F
	A → 6A	B → 6C	C → 6C		E → 6F	F → 6F
	A → 7A	B → 7C	C → 7C		E → 7F	F → 7F
	A → 8A	B → 8C	C → 8C		E → 8F	F → 8F
	A → 9A	B → 9C	C → 9C		E → 9F	F → 9F
	A → .B		C → eD			F → ε
	A → B		C → ε			

- Not very handy in practice …
- **Regular expressions** to the rescue!

[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?

Introduction to Regular Expressions (Regex)
Theory & Practice

- **Theory of regular expressions:**
  - Brief introduction where regular expressions come from …
- **Practice of regular expressions:**
  - What you need to know to get started with regex in practice!
- **Demonstration of regular expressions**

Practice of Regular Expressions

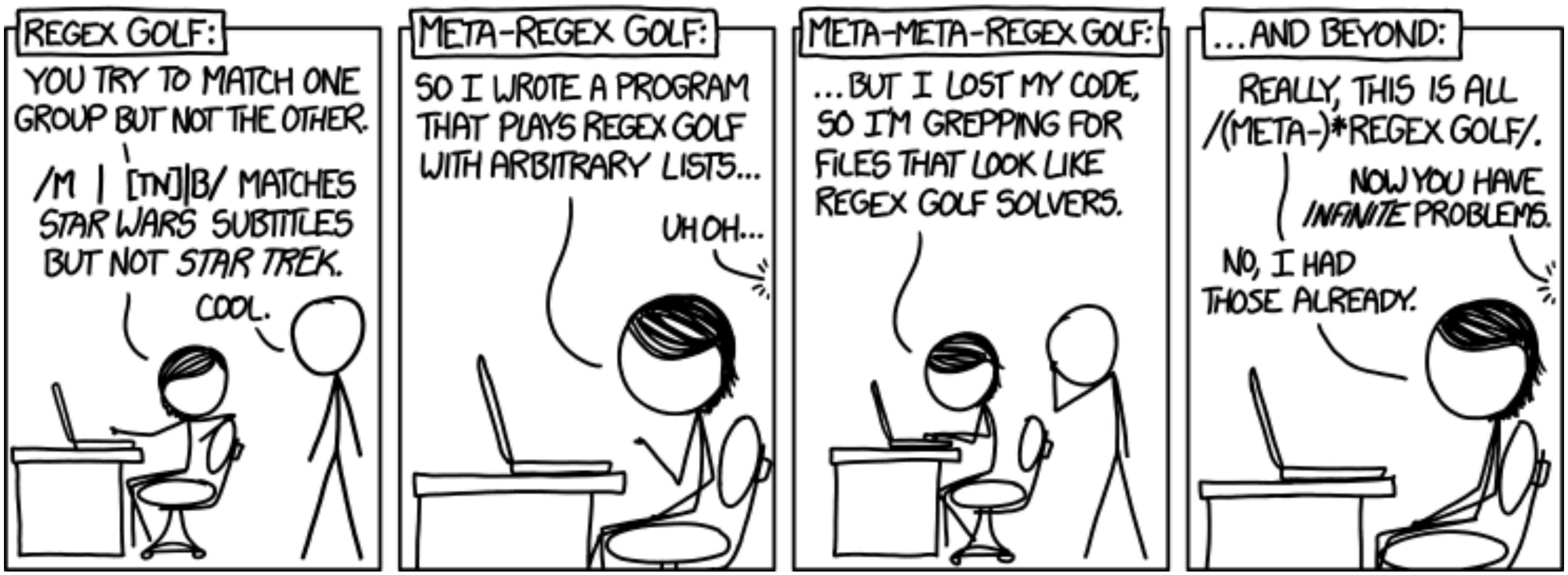
- Use case: Extract (then transform) data from text
  - `pi = -0.314159265e+1`
  - `e  =  0.2718281828E+1`
- This regex will do the trick: **[-+]?[0-9]*\.?[0-9]+([eE][-+]?[0-9]+)?**
  - **Character set […]** matches any single character
  - **Optional element ... ?** matches 0 or 1 occurrence
  - **Range [0-9]** matches any single character in this range
  - **(Kleene) Star ... *** matches 0 or more occurrences
  - **Dot .** matches any character (execept line breaks)
  - **Escape character \ ...** take next character literally (**no** special meaning)
  - **Capturing group (...)** group multiple tokens; capture group for backreference

Beware of False Negatives and False Positives

- **False Negative**
  - your pattern doe **not** match … although it should!
  - you will notice this problem first (missing match results)
  - Remedy: you need to “relax” the regex, so it matches the desired strings

- **False Positive**
  - your pattern **does** match … although it shouldn’t!
  - you might not notice this at first (false matches may occur sporadically)
  - Remedy: you need to “tighten” the regex, so it matches fewer strings (avoiding the false matches)

RegEx Matching as a Sport: RegEx Golf



https://xkcd.com/1313/

Division of Labor:
RegEx for Syntax; Code for Semantics

- Getting “the right” regex can be quite a balancing act
  - … making RegEx Golf a real sport

- Even if there is a (near) exact regex solution, it might be really difficult to get right, debug, maintain, etc.

Division of Labor:
RegEx for Syntax; Code for Semantics

- Better: allow some false positives, then use code to check the semantics
  - ➔ keep regex for what they're best: **syntactic patterns**
  - ➔ use some **code to check the semantics** of the match
- Usually much better in practice
  - and sometimes the only option, even in theory
- Example: 02/29/2000 . Is that a valid (even if non-standard) date?
  - ```
    if (year is not divisible by 4) then (it is a common year)
    else if (year is not divisible by 100) then (it is a leap year)
    else if (year is not divisible by 400) then (it is a common year)
    else (it is a leap year)
    ```
    ```

Character Classes

- **.** match any character except newline
- **\w \d \s** match a word, digit, whitespace character, respectively
- **\W \D \S** match a non-word, non-digit, non-whitespace character
- **[abc]** any of a, b, or c
- **[^abc]** match a character other than a, b, or c
- **[a-g]** match a character between a, b, …, g

Anchors

- **^abc** match abc at the start of the string
- **abc$** match abc at the end of the string
- **xyz\b** match xyz at a word boundary
- **xyz\B** match xyz if not at a word boundary

Escaped Characters

- **\. * **   escaped special characters
- **\t \n \r**   match a tab, linefeed, carriage return
- **\u00A9**   unicode escaped ©

Groups

- **([0-9]+)\s*([a-z]+)** two capture group s
- **\1** backreference to group #1
- **\2 \1** first group #2, then #1 (simple palindrome)

Using Groups for Transformations

- Groups and backreferences are often used in **transformations**
- **(\d{2})/(d{2})/(d{4})** three capture groups for **MM/DD/YYYY**
- **$3-$1-$2** insert captured results as: **YYYY-MM-DD**
-
- Use for example in Python, OpenRefine, …

Summary Regular Expressions

- Powerful language for pattern matching, extraction, transformation
- Roots in computer science theory (formal languages)
- Widely used in practice and may "save the day"
  - Data extraction, Data transformation ➔ Data quality assessment & cleaning
- … acquired taste... addictive ... special powers

https://xkcd.com/208/