Regular Expressions

Principles of Programming Languages

Colorado School of Mines

`https://lambda.mines.edu`

Learning Group Activity

You should have researched one of these topics on the LGA:

- Reference Couting
- Smart Pointers
- Valgrind

Explain to your group!

Regular Expressions

Regular expression languages describe a search pattern on a string.

- They are called *regular*, since they implement a **regular language**: a language which can be described using a finite state machine.
- Typically used for determining if a string matches a pattern, replacing a pattern in a string, or extracting information from a string.
- Regular expression languages are a *family of languages*, rather than just a single language. Many modern regular expression languages were inspired by Perl's regular expression syntax.

Python's Regular Expressions

Python's regular expression language can be accessed using the `re` module:

```
>>> import re
```

Regular expressions can be compiled using `re.compile`. This returns a regular expression object:

```
>>> p = re.compile(r'ab[cd]')
```

There's a number of things we might want to do with p here:

- `p.match`: Match the beginning of a string
- `p.fullmatch`: Match the whole string, without allowing characters at the end
- `p.search`: Match anywhere in the string
- `p.finditer`: Iterate over all of the matches in the string

Character Sets

- [abcd] is a character set. It matches a single a, b, c, or d, only once.
- Character sets also support a shorthand for ranges of characters, for example:
  - [0-9] matches a single digit
  - [a-z] matches a lowercase letter
  - [A-Z] matches an uppercase letter
- These can even be combined:
  - [a-zA-Z2] will match a single lowercase letter, uppercase letter, or the digit 2.
- A ^ (caret) at the beginning of a character set *negates* the set:
  - [^0-9] will match a single character that is **not** a digit.

Special Character Sets

As a convenience, Python gives us access to a few nice character sets:

- `\s` matches any whitespace character
- `\S` matches any non-whitespace character
- `\d` matches any digit
- `\D` matches any non-digit
- `\w` matches any "word" character (capital letters, lowercase letters, digits, and underscores)
- `\W` matches any non-word character

Any character

The `.` matches any character, exactly once.

- `t.ck` will match `tick`, `tock`, and `tuck`, but not `truck`.

To match a literal period, write "`\.`".

Match Objects

When we call `match`, `fullmatch`, or `search`, we get back a **match object**, or `None` if it did not match. When we iterate over `finditer`, we iterate on all of the match objects found.

```
>>> p = re.compile(r'[cd][ao][tg]')
>>> for word in 'cat', 'dog', 'cog', 'dat', 'datt':
...     print(bool(p.match(word)))
True
True
True
True
True
>>> for word in 'orange', 'apple', 'datum':
...     print(bool(p.match(word)))
False
False
True
```

How Many?

Often times, we want to match the previous group a certain number of times:

- `?` will match 0 or 1 times
- `+` will match 1 or more times
- `*` will match 0 or more times
- `{n}` will match `n` times, exactly
- `{m,n}` will match between `m` and `n` times

For example:

- `a?b` matches `ab` as well as `b`
- `[A-Z]*` matches any amount of capital letters, including none at all
- `[0-9]+` matches one or more digits
- `.*` matches any character, zero or more times

Grouping

Grouping allows us to:

- Specify groups of characters to repeat
- Alternate on different sets of characters
- Capture the matched group and retrieve it in our match object

Groups are written in parentheses, and alternation is specified using a vertical bar (`|`):

- `Thanks?( you)?` matches:
  - `Thanks`
  - `Thank`
  - `Thank you`
  - `Thanks you`
- `Thank(s| you)` matches:
  - `Thanks`
  - `Thank you`

Grouping: Using Captures

On our match objects, we can obtain the result of a capture by calling `.group`:

```
>>> p = re.compile(r'My name is (\w+) and I like (\w+)')
>>> m = p.match('My name is Jack and I like computers')
>>> m.group(1)
'Jack'
>>> m.group(2)
'computers'
>>> m.group(0)      # the whole match
'My name is Jack and I like computers'
```

Non-capturing Groups

Groups which begin with `?:` are **non-capturing groups.** This means that they will not provide any visible group in the match object:

```
>>> p = re.compile(r'My name is (\w+)(?:, | and) I like (\w+)
>>> m = p.match('My name is Jack and I like computers')
>>> m.group(1)
'Jack'
>>> m.group(2)
'computers'
>>> m = p.match('My name is Jack, I like computers')
>>> m.group(1)
'Jack'
>>> m.group(2)
'computers'
```

Greedyness

+, *, and ? are called *greedy operators* since they will try and match **as many characters as possible**, this may lead to undesired results:

```
>>> p = re.compile(r'#(.*)#')
>>> for m in p.finditer('#hello# a b c #world#'):
...     print(m.group(1))
hello# a b c #world
```

If we wanted to match **as little as possible**, we can use the *non-greedy* version of the operator, which would be +?, *?, or ??.

```
>>> p = re.compile(r'#(.*?)#')
>>> for m in p.finditer('#hello# a b c #world#'):
...     print(m.group(1))
hello
world
```

Anchors

Anchors match a certain kind of occurrence in a string, but not necessarily any characters.

- `^` anchors to the beginning of a string, or to the beginning of a line when `re.MULTILINE` is passed to `re.compile`
- `$` anchors to the end of a string, or to the end of a line when `re.MULTILINE` is passed to `re.compile`
- `\b` anchors to the boundary of a word: the transition from a `\w` to a `\W`, or visa versa. Also anchors to the beginning or end of a string.

Examples:

- `foo\b.*` matches `foo` and `foo-dle`, but not `foodle`
- `^$` matches the empty string
- `//.*(\n$|$)` matches `// hello` and `// hello\n`, but not `// hello\n\n`

Tip: Making Long REs Readable

Sometimes, when regular expressions get long, you need a way to comment them and break up sections to let other programmers (or yourself) know what's going on.

When you pass `re.VERBOSE` to `re.compile`, whitespaces are ignored, and # starts a comment until the end of line:

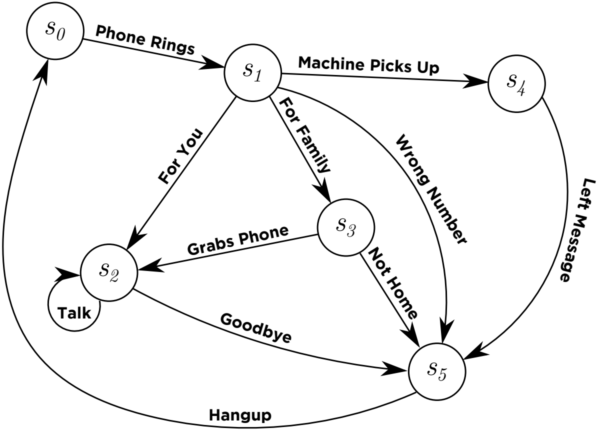
```
p = re.compile(r'''
    (\w+)                               # first name
    \s+
    (\w+)                               # last name
    \s+
    ([2-9]\d{2}-[2-9]\d{2}-\d{4})  # phone number
''', re.VERBOSE)
```

RE Examples, and any Questions?

- Matching a decimal number:
  `[0-9]+\.?[0-9]*`
- Matching a C/C++ identifier:
  `[A-Za-z_][A-Za-z0-9_]*`
- Matching a Mines Email address:
  `([A-Za-z0-9.+-]+)@(mymail\.)?mines\.edu`

Finite State Machines

A **finite state machine** is any machine which has a finite number of states, and can only be in one state at a time. The machine has *transitions* that move it from one state to another.

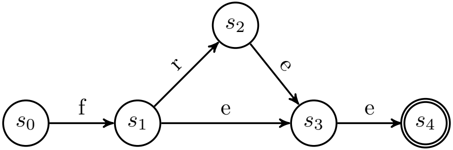


Regular Expressions as Finite State Machines

Regular expressions can be represented as finite state machines as well. Consider the following regular expression:

```
^fr?ee$
```

This matches both `free` and `fee`, we can write this in a state diagram like this:



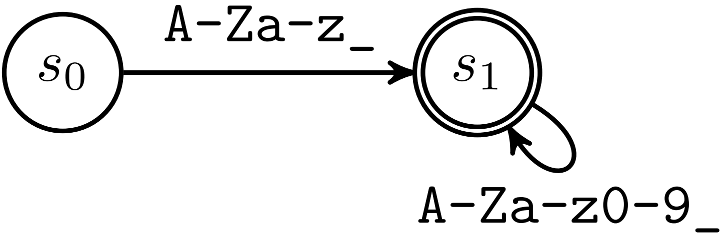
Required Formalisms

- Any state which *could* be a terminating state should be placed in **double circles**.
- The transitions have the letters on them. The states do not.

Another Example: C/C++ identifiers

Recall the regular expression for C and C++ identifiers:

`[A-Za-z_][A-Za-z0-9_]*`



Regess!

This is an open source tool developed by Sam Sartor (took CSCI-400 last semester) to help you visualize regular expressions using finite state graphs:

`http://gh.samsartor.com/regess/`

Translating REs to State Diagrams

With your learning group, translate each of these REs to a state diagram:

- `[A-Z]+`
- `[A-Z]?x` (try using ϵ for the "no character" transition)
- `([A-Z][1-5])+` (hint: draw a transition going backwards)

Write your names on your paper and turn in for **bonus** learning group participation points.