

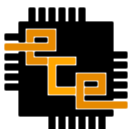


ECE 364

Software Engineering Tools Laboratory

Lecture 6

Python: Regular Expressions



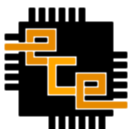
Lecture Summary

- Regular Expressions in Python



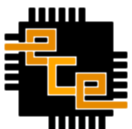
Python Regular Expressions

- Python provides very sophisticated regular expression functionality
 - Searching and matching
 - Ability to specify named “groups” to get values of matched strings
 - Substitution/Find-Replace
 - Pattern Splitting



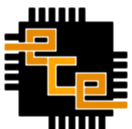
Regular Expressions (2)

- The most basic regex is just the characters of a string we want to match
- A very simple regex: `blue`
 - Will match the string “blue”
- Another very simple regex: `1a2b3c`
 - Will match the string “1a2b3c”



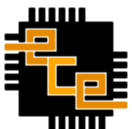
Regular Expressions (3)

- **Boolean “or”**: Choose between 2 or more alternatives
 - A vertical bar (pipe) “|” indicates an “or”
- **Example**: `red|green|blue`
 - Will match “red” or “green” or “blue”



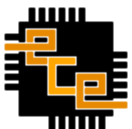
Regular Expressions (4)

- **Grouping**: Assign precedence and scope to regular expressions
 - Use parenthesis “(`<regex>`)” to form a group
- Example `can | r | t`
 - Matches string “can” or “r” or “t”
- Example: `ca (n | r | t)`
 - Matches strings “can” or “car” or “cat”



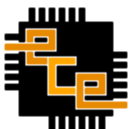
Regular Expressions (5)

- **Quantifiers:** Express the number of repetitions of a preceding element
 - Zero or one repetitions: `?`
 - Zero or more repetitions: `*`
 - One or more repetitions: `+`
- Example: `card?`
 - Matches “**car**” or “**card**”
- Example: `ab*c`
 - Matches “**ac**” or “**abc**” or “**abbc**” or “**abbbc**” or ...
- Example: `be+f`
 - Matches “**bef**” or “**beef**” or “**beeef**” or “**beeeef**” or...



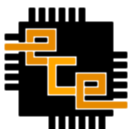
Regular Expressions (6)

- **Range Quantifier:** Express the number of repetitions of a preceding element
 - $\{m, n\}$ – between m and n repetitions
 - $\{m, \}$ – at least m repetitions
 - $\{n\}$ – exactly n repetitions
- Example: $fo\{1, 5\}$
 - Will match “fo” or “foo” or “fooo” or “foooo” or “fooooo”
- Example: $60\{3, \}$
 - Will match “6000” or “60000” or “600000” or ...
- Example: $60\{2\}$
 - Will match “600”



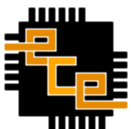
Regular Expressions (7)

- Quantifiers and groups can be used together
- Example: `(ca(t|r))+`
 - Matches “cat” or “car” or “catcat” or “catcar” or “carcar” or “catcarcat” or ...
- Example: `EC?E((1|2|3)+) *`
 - Matches “EE” or “ECE” or “EE 111” or “ECE 2” or “EE 13 2” or “ECE 123 32 1” or ...



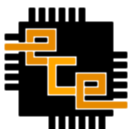
Regular Expressions (8)

- **Character Set:** A compact representation to represent a set of characters to match
 - Use square brackets to denote a set: `[<characters>]`
- How could we match all integers?
 - `(0|1|2|3|4|5|6|7|8|9) +`
- Another way is to match characters in a set
 - `[0123456789] +`
- An even shorter way is to take advantage of the regular ordering of the digits
 - `[0-9] +`



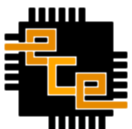
Regular Expressions (9)

- If a set of characters can form a natural range (e.g. 0 – 9, a-z) then you can use `<start><dash><end>` notation
 - Multiple ranges can be placed inside the square brackets
 - Ranges can be used in conjunction with single characters
 - Can invert the set using a `^` character at the beginning
- Example: `[a-z0-9]+`
 - Will match any alphanumeric string
- Example: `[aeiou0-9]*`
 - Will match any string containing only vowels and numbers
- Example `[^a-z0-9]+`
 - Will match 1 or more characters that are **NOT** a-z or 0-9.



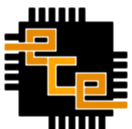
Regular Expressions (10)

- To match any single character use a period “.”
 - Will match all characters including whitespace
- Example: ...
 - Will match “abc” or “a 1” or “ 3” or ...
- Example: .*
 - Will match: “any string of any length”



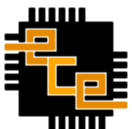
Regular Expressions (11)

- **Escaping**: Characters that have special meaning must be escaped when used in a regex
 - Prepend a backslash character (\)
- Example: `[0-9]*\.[0-9]+`
 - Will match “.345” or “12.4” or “9.11111” or ...
- Example: `[a-f0-9]+(\+[a-f0-9]+)?`
 - Will match: “a4f” or “beef+a6b” or ...



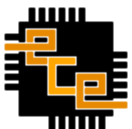
Regular Expressions (12)

- **Search vs. Match:** An implementation detail of the regex functionality provided
 - Search refers to finding a match somewhere in a string (substring)
 - Match refers to checking if the entire string matches
- Some regex engines will preform search by default
 - Check documentation to find out
 - Try out some basic examples



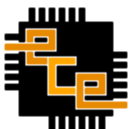
Regular Expressions (13)

- **Start of String**: the position right before the first character
 - Can be matched using the '^' character
- **End of String**: the position right after the last character
 - Can be matched using the '\$' character
- **Example**: `[0-9]+`
 - A **search** would match: “**abc 012 def**” or “**999 bbb**” or ...
 - A **match** would match: “**123**” or “**999**” or ...
- **Example**: `^[0-9]+$`
 - Will match only strings that contain digits 0 to 9 and nothing else
 - A **match** would match: “**123**” or “**999**” or ...
 - A **search** would match: “**123**” or “**999**” or ...



Symbol Summary

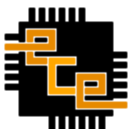
- Or: |
- Grouping: ()
- Quantifiers: ? * +
- Range Quantifiers: { , }
- Character Set: []
- A Single Character: .
- Start & End: ^ \$



Special Sequences in Python

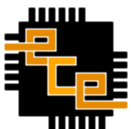
- Commonly used expressions have shorthand sequences

<code>\d</code>	Equivalent to <code>[0-9]</code>
<code>\D</code>	Equivalent to <code>[^0-9]</code>
<code>\w</code>	Equivalent to <code>[a-zA-Z0-9_]</code>
<code>\W</code>	Equivalent to <code>[^a-zA-Z0-9_]</code>
<code>\s</code>	Equivalent to any whitespace character
<code>\S</code>	Equivalent to any non whitespace character
<code>\\</code>	Matches a literal backslash
<code>\b</code>	Match the empty string the forms the boundary of a word



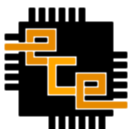
Special Sequences (2)

- Special sequences in Python regex conflict with escaped characters
 - `\b` Backspace in a string literal
 - `\b` Word boundary in a regex
- To avoid this conflict, regular expressions are written as “**raw**” strings
 - Typical String: `"this is a string"`
 - Raw String: `r"this is a raw string"`



Groups

- A group is formed by parenthesizing (part of) the regular expression
 - `([a-z]+|[0-9]+)`
 - `hello (world|ee364)`
- In Python, a group also **specifies the text you want to extract** from a matched string
 - Python reserves the **0th group as the entire string** that matches the regular expression



Groups (2)

- Example: Search for an email address and get the username and domain

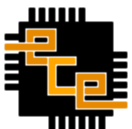
Regex: `([\w.-]+)@([\w.-]+)`

Input: `"foo mgoldfar@purdue.edu baz"`

Group 0: `mgoldfar@purdue.edu`

Group 1: `mgoldfar`

Group 2: `purdue.edu`



Groups (3)

- Groups can be given names

(?P<GroupName> ...)

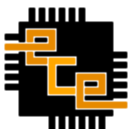
Regex: (?P<user>[\w.-]+)@(?P<domain>[\w.-]+)

Input: "foo mgoldfar@purdue.edu baz"

Group 0: mgoldfar@purdue.edu

Group "user": mgoldfar

Group "domain": purdue.edu



Greedy and Non-greedy

- Quantifiers in a regex match **as much as possible**
- **?** is appended to the quantifier to indicate non-greedy behaviour
 - A non-greedy match will match **as little as possible**

Greedy

`(pattern) +`

`(pattern) *`

`(pattern) ?`

`(pattern) {n}`

`(pattern) {n,m}`

Non-Greedy

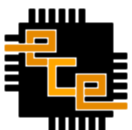
`(pattern) +?`

`(pattern) *?`

`(pattern) ??`

`(pattern) {n}?`

`(pattern) {n,m}?`



Greedy vs. Non-greedy (2)

- Example: Match an HTML tag name:

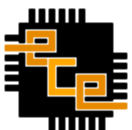
Regex: `<(.*>`

Input: `"<h1>ECE 364</h1>"`

Group 0: `"<h1>ECE 364</h1>"`

Group 1: `"h1>ECE 364</h1"`

- None of the groups contain what we want because the `*` is greedy



Greedy vs. Non-greedy (3)

- Example: Match an HTML tag name:

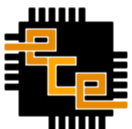
Regex: `<(.*?)>`

Input: `"<h1>ECE 364</h1>"`

Group 0: `"h1"`

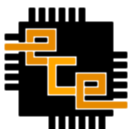
Group 1: `"h1"`

- Non-greedy `*?` operator results in the correct behavior



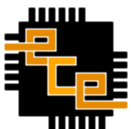
`re` Module

- The `re` module provides access to regular expression functionality
- Always remember to `import re` before using any regular expressions



Match and Search

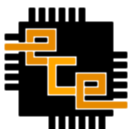
- `re.match(<pattern>, <string>)`
 - If zero or more characters at the beginning of `<string>` match the regex `<pattern>`, return a **MatchObject**
 - Return **None** if the string does not match the pattern
- `re.search(<pattern>, <string>)`
 - Scan through `<string>` looking for a location where the regex `<pattern>` produces a match, and return a corresponding **MatchObject**
 - Return **None** if no position in the string matches the pattern



Match and Search (2)

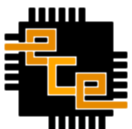
```
input = "foo bar@baz.bin 923"
expr = r"([\w.-]+)@([\w.-]+)"

if re.match(expr, input):
    print("The input starts with an email!")
elif re.search(expr, input):
    print("The input contains an email.")
else:
    print("No email found.")
```



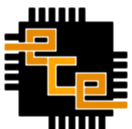
The `MatchObject`

- When a regular expression finds a match, a `MatchObject` is returned
 - `None` is returned if there is no match
- This object contains information about the matched string



The `MatchObject` (2)

- `m.group(g)`
 - Returns the string contained in the g^{th} group
- `m.group(g1, g2, g3, ...)`
 - Returns a tuple containing the $g1^{\text{th}}$, $g2^{\text{nd}}$, $g3^{\text{rd}}$, ... groups
- `m.groupdict()`
 - Returns the a dictionary of all named groups keyed by group name
- Arguments to `m.group()` can be an **index** or a **string** representing the group name



The MatchObject (3)

```
m = re.match(r"(?P<int>\d+)\.(\d*)", "3.14")
```

```
m.group(0) returns "3.14"
```

```
m.group(1) returns "3"
```

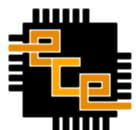
```
m.group(2) returns "14"
```

```
m.group("int") returns "3"
```

```
m.group(0, "int", 2) returns ("3.14", "3", "14")
```

```
m.groups() returns the tuple ("3", "14")
```

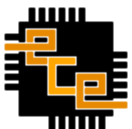
```
m.groupdict() returns {"int" : "3"}
```



The MatchObject (4)

```
pattern = r"[0-9]+(?P<foo>\.[0-9]+)"
m = re.search(pattern, "Hello 56.43 World")

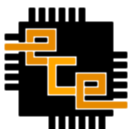
if m:
    gp = m.groupdict()
    print(gp["foo"])
else:
    print("Not found")
```



Split

- `re.split(pattern, string, maxsplit=0)`
 - Split *string* by the occurrences of *pattern*
 - If *maxsplit* is nonzero, at most *maxsplit* splits occur, and the remainder of the string is returned as the final element of the list

```
>>> re.split(r"\W+", "foo, bar, baz.")  
['foo', 'bar', 'baz', '']
```

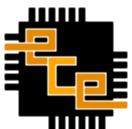


Find

- `re.findall(pattern, string)`
 - Return all non-overlapping matches of *pattern* in *string*, as a list of strings
 - The *string* is scanned left-to-right, and matches are returned in the order found.

```
>>> re.findall(r"[0-9]+", "hello 56.78 world 25")  
['56', '78', '25']
```

```
>>> re.findall(r"[\w.]+@[ \w.]+", "26 bar@biz.com baz@foo 99")  
['bar@biz.com', 'baz@foo']
```

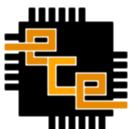


Substitution

- `re.sub(pattern, repl, string, count=0)`
 - Return the string obtained by replacing the leftmost non-overlapping occurrences of *pattern* in *string* by the replacement *repl*
 - If the pattern isn't found, *string* is returned unchanged

```
>>> re.sub(r"[0-9]+", "NUM", "Hello 267 World 8")  
'Hello NUM World NUM'
```

```
>>> re.sub(r"[0-9]+", "NUM", "Hello 267 World 8", 1)  
'Hello NUM World 8'
```

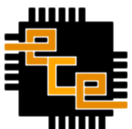


Substitution (2)

- `re.subn(pattern, repl, string, count=0)`
 - Performs the substitution in the same way `re.sub()` does
 - Returns a tuple containing the new string and the number of occurrences of `pattern` replaced

```
>>> re.subn(r"[0-9]+", "NUM", "Hello 267 World 8")  
('Hello NUM World NUM', 2)
```

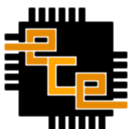
```
>>> re.subn(r"[0-9]+", "NUM", "Hello 267 World 8", 1)  
('Hello NUM World 8', 1)
```



Flags

- Flags can be used to modify how the regular expression engine behaves.
 - Passed to the functions covered in the previous slides
 - Combine flags with a bit-wise or operator

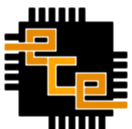
<code>re.I</code> or <code>re.IGNORECASE</code>	Perform non case-sensitive matching
<code>re.M</code> or <code>re.MULTILINE</code>	Make <code>^</code> and <code>\$</code> apply to each line (not the entire string)
<code>re.S</code> or <code>re.DOTALL</code>	Make <code>.</code> match all characters, even newline
<code>re.X</code> or <code>re.VERBOSE</code>	Ignore un-escaped whitespace and comments.



Flags (2)

```
input = "foo bar@BAZ.com 923"
expr = r"([\w.-]+)@([\w.-]+)"

if re.match(expr, input, re.I):
    print("The input starts with an email!")
elif re.search(expr, input, re.I):
    print("The input contains an email.")
else:
    print("No email found.")
```

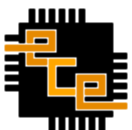


Compiled Regular Expressions

- A regular expression can be *compiled* into a special object.
 - Improves the performance when performing lots of repeated matches or searches
 - You should compile your regular expression if it is going to be used multiple times (i.e. in a loop)

```
Reg_Exp = re.compile(expression[, flags])
```

- The regular expression can then be passed around like any other Python value.



Compiled RegEx (2)

- Functions of a compiled regex are identical to the module level functions

```
Reg_Exp = re.compile(expression[, flags])
```

```
Reg_Exp.search(string)
```

```
Reg_Exp.match(string)
```

```
Reg_Exp.findall(string)
```

```
Reg_Exp.split(string[, maxsplit])
```

```
Reg_Exp.sub(replacement, string[, count])
```

```
Reg_Exp.subn(replacement, string[, count])
```

