Computación y Estructuras Discretas III

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Agenda

1. **Regular languages and Automata theory**
   - Languages
   - Regular Languages
   - Regular expressions
   - Exercises
   - An overview of regular expressions
   - Regular expressions in Python

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Languages

What is a language?

Languages

What is a language?

- Is a **set** of strings formed with the symbols in a particular alphabet.
- Languages are denoted with capital letters.
- As sets, languages can be finite or infinite.
- there's two types of language operations
  - Set (also called boolean)
  - Linguistic (power, reverse, concat, closure)

Activity

Given the languages $L_1 = \{\lambda, 0, 10, 11\}$ and $L_2 = \{\lambda, 1, 01, 11\}$ over the alphabet $\Sigma = \{0, 1\}$, obtain: $L_1 \cdot L_2$, $L_1 \cup L_2$. $L_1 \cap L_2$, $L_1 - L_2$, L_1^2 y L_2^R.

Languages

What is the power of a language?

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Definition

Given a language A over Σ, ($A \subseteq \Sigma^*$), *and a natural numberl* $n \in \mathbb{N}$, A^n *is defined in the following way:*

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A^2 is the set of double string concatenations of A, A^3 the set of triple string concatenations of A and in general A^n is the set of n string concatenations of A.

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$$\begin{aligned} A^* &= \textit{set of all string concatenations of } A, \\ &\quad \textit{including } \lambda \\ &= \{u_1, \cdots u_n \mid u_i \in A,\ n \geq 0\} \end{aligned}$$

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$$\begin{aligned} A^+ &= \text{set of all string concatenations of } A, \\ &\quad \text{without including } \lambda \\ &= \{u_1, \cdots u_n \mid u_i \in A,\ n \geq 1\} \end{aligned}$$

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Given A, a language over Σ, we define A^R in the following way:

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A^R is the inverse of A.

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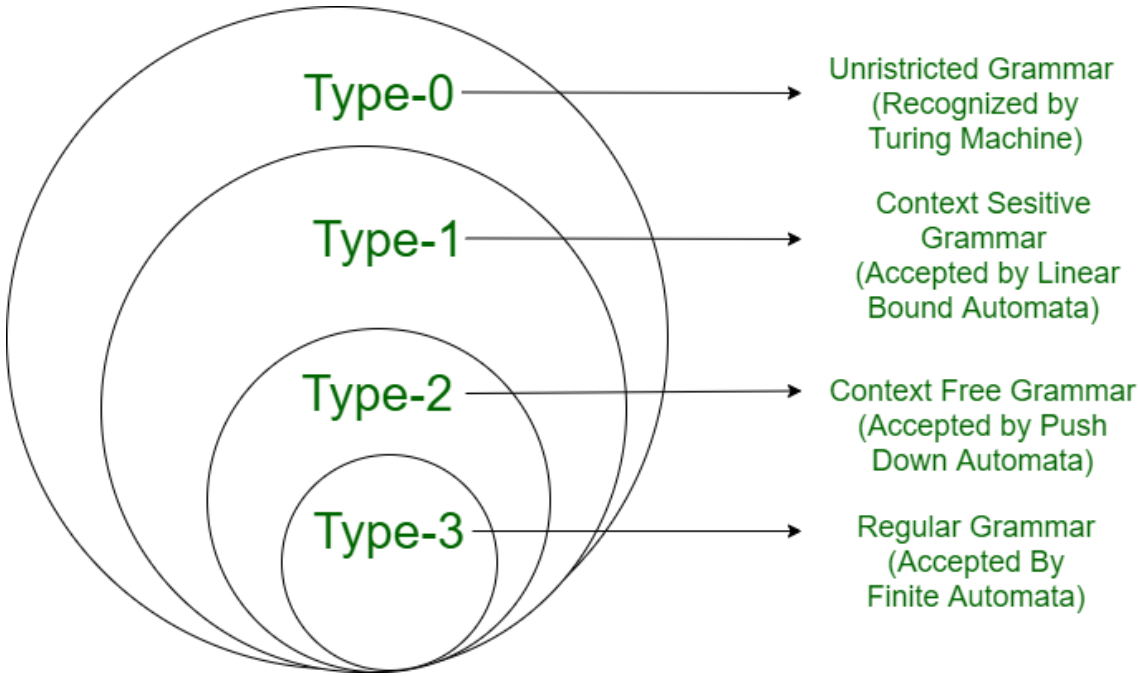

Languages

What are regular languages useful for?

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- Lexical analysis (Scanning): In compiler construction, regular languages are used to define the tokens of a programming language, and lexical analyzers (scanners) are built to recognize these tokens using regular expressions.
- Language engineering: building tools for developers (compilers, IDEs, etc). For instance, regular expressions are applied to perform syntax highlighting, making it easier for programmers to read and understand code.

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5. $[(\{a\}^* \cup \{b\}^*) \cdot \{b\}]^*$.

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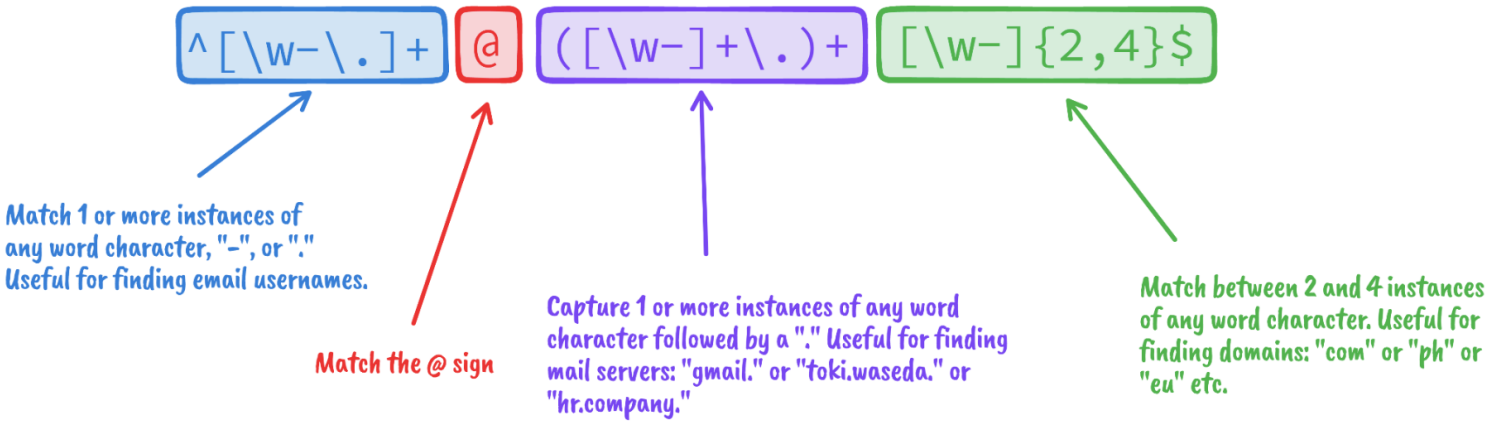

Languages

What can we do with these regular expressions?

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What can we do with these regular expressions?

- Check if an input honors a given pattern.
- Look for a pattern appearance in a piece of text.
- Extract specific portions of a text.
- Replace portions of text.
- Split a larger text into smaller pieces.

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$$(\{a\} \cup \{b\}^*) \cdot \{a\}^* \cdot \{bc\}^*$$

Activity

Give some examples of strings in the language defined by the regular expression

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Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1, 2\}$ *of all strings that start with* 2 *and end with* 1.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that start with two consecutive ones.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that have a number of zeros divisible by three.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that have at least two consecutive ones.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that have at most two zeros.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that only have one occurrence of three consecutive zeros.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that have length of five or less.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ *of all strings that start or end in* 00 *or* 11.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{a, b\}$ of all strings that have string ab an even number of times.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{a, b\}$ of all strings that have an even number of a's and an odd number of b's.

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Exercise

Find the regular expression for the language over $\Sigma = \{0, 1, 2\}$ of all strings that do not have two consecutive ones.

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Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings that have at most two consecutive ones.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ *of all strings which fifth symbol, from left to right, is a* 1.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ *of all strings which length is* ≥ 4.

Exercises

Exercise

Find the regular expression for the language over $\Sigma = \{0, 1\}$ of all strings which do not have four consecutive zeros.

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An overview of regular expressions

What else can we say about regular expressions?

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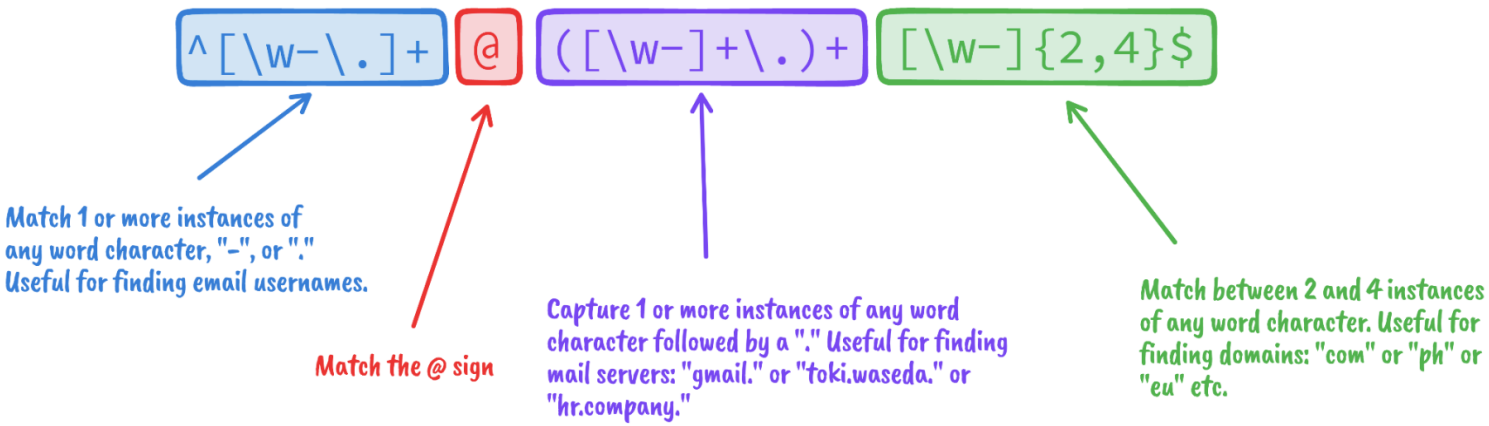
- A regular expression is a pattern of text that consists of ordinary characters **literals** and special characters known as **metacharacters**.



An overview of regular expressions

What are literals?

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- Are the simplest form of pattern matching in regular expression.
- They will simply succeed whenever that literal is found.
- If we apply the regular expression **fox** to search the phrase:
  The quick brown fox jumps over the lazy dog, we will find one match.
- We can also obtain several results instead of just one, if we apply the regular expression `be` to the following phrase:
  To be, or not to be.

What are character classes?

What are character classes?

- The character classes (also known as character sets) allow us to define a character that will match if any of the defined characters on the set is present.
- To define a character class, we should use the opening square bracket metacharacter [, then any accepted characters, and finally close with a closing square bracket].
- e.g. `licen[cs]e`
- It is possible to also use the range of a character. This is done by leveraging the hyphen symbol (-) between two related characters.
- e.g. To match any lowercase letter we can use `[a-z]`.
- e.g. To match any single digit we can define the character set `[0-9]`.

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- We just need to put one range after the other.
- e.g. If we want to match any lowercase or uppercase alphanumeric character, we can use `[0-9a-zA-Z]`
- This can be alternatively written using the union mechanism: `[0-9[a-z[A-Z]]]`.

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- We can invert the meaning of a character set by placing a caret (^) symbol right after the opening square bracket metacharacter ([).

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- We can invert the meaning of a character set by placing a caret (^) symbol right after the opening square bracket metacharacter ([).
- If we have a character class such as `[0-9]` meaning any digit, the negated character class `[^0-9]` will match anything that is not a digit.

An overview of regular expressions

Some character classes supported at this moment in Python

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- e.g. `yes|no|maybe`

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- `?` 0 or 1 repetitions
- `*` 0 or more times
- `+` 1 or more times
- `{n,m}` Between *n* and *m* times.

What are quantifiers?

- The mechanisms to define how a character, metacharacter, or character set can be repeated.

Which are the three basic quantifiers?

- `?` 0 or 1 repetitions
- `*` 0 or more times
- `+` 1 or more times
- `{n,m}` Between *n* and *m* times.
  - `{n}` Exactly *n* times.

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  - `{,n}` At most *n* times.
- e.g. `cars?` Singular or plural.

Example

How to match a telephone number that can be in the format 555-555-555, 555 555 555, or 555555555.

```
r'\b\d{3}[-\s]?\d{3}[-\s]?\d{3}\b'
```

What are boundary matchers?

- The boundary matchers are a number of identifiers that will correspond to a particular position inside of the input.
- `^` Matches at the beginning of a line
- `$` Matches at the end of a line
- `\b` Matches a word boundary
- `\B` The opposite of \b
- `\A` Matches the beginning of the input
- `\Z` Matches the end of the input

Example

Write a regular expression that will match lines that start with `Name:` *and make sure that after the name, there are only alphabetic characters or spaces until the end of the line.*

r'^Name:\s*[A-Za-z]*$'

Example

What is the difference between the regular expressions `hello` *and* `\bhello\b`*?*

- ‘hello’ is a pattern that matches the substring "hello" anywhere in the text, regardless of what characters come before or after it.
- r’\bhello\b’ uses the word boundary anchors \b to match the substring "hello" as a whole word, ensuring it is not part of another word.

Agenda

1. **Regular languages and Automata theory**
   - Languages
   - Regular Languages
   - Regular expressions
   - Exercises
   - An overview of regular expressions
   - Regular expressions in Python

Regular expressions in Python

How are regular expressions supported in Python?

- They are supported by the `re` module.
- We only need to import it to start using it.

How to start using them to match a pattern?

- We compile a pattern with `pattern = re.compile(r'foo')`
- We can try to match it against a string `pattern.match("foo bar")`

Regular expressions in Python

What are the building blocks for Python Regex?

- RegexObject
  - Also known as Pattern Object.
  - Represents a compiled regular expression.
- MatchObject
  - Represents the matched pattern.

What is a RegexObject?

- Before matching patterns we need to compile the regex.
- The compilation produces a reusable pattern object.
- This object provides all the operations that can be done (i.e. matching a pattern and finding all substrings that match a particular regex).
- e.g. `pattern = re.compile(r'<HTML>')`
- `pattern.match("<HTML>")`

Regular expressions in Python

What are two ways of matching a pattern?

- We can compile a pattern, which gives us a RegexObject.
- We can just use the module operations.
- If we compile a pattern we are able to reuse it.
- e.g. `pattern = re.compile(r'<HTML>')`
- `pattern.match("<HTML>")`
- e.g. `re.match(r'<HTML>', "<HTML>")`

How to search for string that match a pattern?

- In python we have two operations match and search.

How does match work?

- This method tries to match the compiled pattern only at the beginning of the string.
- If there is a match, then it returns a MatchObject.
- It has two optional parameters, pos and endpos.
- pos determines the position from where to search the pattern in the string.
- endpos determines the position until where the pattern is searched in the string.
- `pattern.match(string,pos,endpos)`

Example

Given `pattern = re.compile(r'^<HTML>')` *what is the result of:*

Example

Given `pattern = re.compile(r'^<HTML>')` *what is the result of:*

- `pattern.match("<HTML>")`

Example

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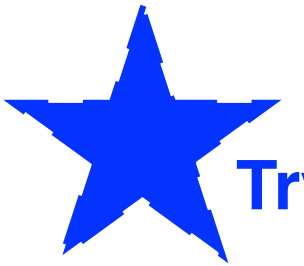
- `pattern.match("<HTML>")`
- `pattern.match(" <HTML>")`



Try the following instructions and find the answer

Example

Given `pattern = re.compile(r'^<HTML>')` *what is the result of:*

- `pattern.match("<HTML>")`
- `pattern.match(" <HTML>")`
- `pattern.match(" <HTML>"[2:])`

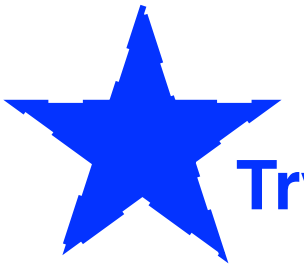
Example

Given `pattern = re.compile(r'<HTML>$')` *what is the result of:*

Example

Given `pattern = re.compile(r'<HTML>$')` *what is the result of:*

- `pattern.match("<HTML> ",0,6)`



Try the following instructions and find the answer

Example

Given `pattern = re.compile(r'<HTML>$')` *what is the result of:*

- `pattern.match("<HTML> ",0,6)`
- `pattern.match("<HTML> "[:6])`

Regular expressions in Python

How does search work?

How does search work?

- This operation would be like the match of many languages.
- It tries to match the pattern at any location of the string and not just at the beginning.
- If there is a match, then it returns a MatchObject.
- The pos and endpos parameters have the same meaning as that in the match operation.
- pos determines the position from where to search the pattern in the string.
- endpos determines the position until where the pattern is searched in the string.
- `pattern.match(string,pos,endpos)`

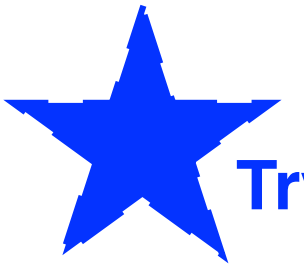
Example

Given `pattern = re.compile(r"world")` *what is the result of:*

Example

Given `pattern = re.compile(r"world")` *what is the result of:*

- `pattern.match("hello world")`



Try the following instructions and find the answer

Example

Given `pattern = re.compile(r"world")` *what is the result of:*

- `pattern.search("hello world")`
- `pattern.search("hola mundo ")`

Example

Given `pattern = re.compile(r'^<HTML>', re.MULTILINE)`
what is the result of:

Example

Given `pattern = re.compile(r'^<HTML>', re.MULTILINE)` *what is the result of:*

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Example

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- `pattern.search("<HTML>")`
- `pattern.search(" <HTML>")`
- `pattern.search(" \n<HTML>")`

Example

Given `pattern = re.compile(r'^<HTML>', re.MULTILINE)` *what is the result of:*

- `pattern.search("<HTML>")`
- `pattern.search(" <HTML>")`
- `pattern.search(" \n<HTML>")`
- `pattern.search(" \n<HTML>",3)`

Example

Given `pattern = re.compile(r'^<HTML>', re.MULTILINE)` *what is the result of:*

- `pattern.search("<HTML>")`
- `pattern.search(" <HTML>")`
- `pattern.search(" \n<HTML>")`
- `pattern.search(" \n<HTML>",3)`
- `pattern.search("</div></body>\n<HTML>",4)`

Try the following instructions and find the answer

Example

Given `pattern = re.compile(r'^<HTML>', re.MULTILINE)` *what is the result of:*

- `pattern.search("<HTML>")`
- `pattern.search(" <HTML>")`
- `pattern.search(" \n<HTML>")`
- `pattern.search(" \n<HTML>",3)`
- `pattern.search("</div></body>\n<HTML>",4)`
- `pattern.search(" \n<HTML>",4)`

How does findall work?

How does findall work?

- It returns a list with all the non-overlapping occurrences of a pattern and not the MatchObject like search and match do.

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- It returns a list with all the non-overlapping occurrences of a pattern and not the MatchObject like search and match do.
- e.g. `pattern = re.compile(r"\w+")`
- `pattern.findall("hello world")`
- `['hello', 'world']`

Regular expressions in Python

Example

- `pattern = re.compile(r"(\w+) (\w+)")`
- `pattern.findall("Hello world hola mundo")`
- `[('Hello', 'world'), ('hola', 'mundo')]`

How does finditer work?

How does finditer work?

- Works essentially as as findall.
- It returns an iterator in which each element is a MatchObject.
- We can use the operations provided by this object.
- Useful when you need information for every match.

Regular expressions in Python

Example

- `pattern = re.compile(r"(\w+) (\w+)")`
- `it = pattern.finditer("Hello world hola mundo")`
- `match = it.next()`
- `match.groups()`
- `('Hello','world')`
- `match.span()`
- `(0,11)`

Regular expressions in Python

Which are some operations to modify strings?

Which are some operations to modify strings?

- split(string, maxsplit=0): A string can be split based on the matches of the pattern.
- sub(repl, string, count=0): Returns the resulting string after replacing the matched pattern in the original string with the replacement.

Regular expressions in Python

Example

- `pattern = re.compile(r"\W")`
- `pattern.split("Beautiful is better than ugly", 2)`
- `['Beautiful', 'is', 'better than ugly']`

Example

- *pattern = re.compile(r'[0-9]+)*
- *pattern.sub("-","order0, order1 order13")*
- *'order- order- order-'*

What is a MatchObject?

What is a MatchObject?

- An object that represents the matched pattern.
- We will get one every time you execute one of these operations:
  - match
  - search
  - finditer
- Provides a set of operations for working with the captured groups.

Which are the main operations for a MatchObject?

Which are the main operations for a MatchObject?

- group
- groups
- groupdict
- start
- end
- span

What is the group operation?

What is the group operation?

- Gives the subgroups of the match.
- If invoked with no arguments or zero, returns the entire match.
- If one or more group identifiers are passed, the corresponding groups' matches will be returned.

Try the following instructions and find the answer

Example

- `pattern = re.compile("(\w+) (\w+)")`
- `match = pattern.search("Hello world")`
- `match.group()` → `'Hello world'`
- `match.group(0)` → `'Hello world'`
- `match.group(1)` → `'Hello'`
- `match.group(2)` → `'world'`
- `match.group(0,2)` → `('Hello world','world')`

Example

- *Groups can be named.*
- *If the pattern has named groups, they can be accessed using the names or the index:*
- `pattern = re.compile(r"(?P<first>\w+) (?P<second>\w+)")`
- `match = pattern.search("Hello world")`
- `match.group('first')` → `'Hello'`
- `match.group(1)` → `'Hello'`
- `match.group(0,'first',2)` → `('Hello world','Hello','world')`

What is the groups operation?

What is the groups operation?

- It returns a tuple with all the subgroups in the match instead of giving one or some of the groups.

Regular expressions in Python

Example

- `pattern = re.compile("(\w+) (\w+)")`
- `match = pattern.search("Hello world")`
- `match.groups()` → `('Hello', 'world')`

What is the groupdict operation?

What is the groupdict operation?

- It is used in the cases where named groups have been used.
- It will return a dictionary with all the groups that were found.
- `pattern = re.compile(r"(?P<first>\w+) (?P<second>\w+)")`
- `match = pattern.search("Hello world")`
- `{'first': 'Hello', 'second': 'world'}`
- If there aren't named groups, then it returns an empty dictionary.