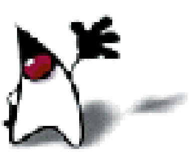
Regular Expressions in Java



Regular Expressions

- A regular expression is a kind of pattern that can be applied to text (`String`s, in Java)
- A regular expression either matches the text (or part of the text), or it fails to match
  - If a regular expression matches a part of the text, then you can easily find out which part
  - If a regular expression is complex, then you can easily find out which parts of the regular expression match which parts of the text
  - With this information, you can readily extract parts of the text, or do substitutions in the text
- Regular expressions are an extremely useful tool for manipulating text
  - Regular expressions are heavily used in the automatic generation of Web pages

Perl and Java

- The Perl programming language is heavily used in server-side programming, because
  - Much server-side programming is text manipulation
  - Regular expressions are built into the syntax of Perl
- Beginning with Java 1.4, Java has a regular expression package, `java.util.regex`
  - Java's regular expressions are almost identical to those of Perl
  - This new capability greatly enhances Java 1.4's text handling
- Regular expressions in Java 1.4 are just a normal package, with no new syntax to support them
  - Java's regular expressions are just as powerful as Perl's, but
  - Regular expressions are easier and more convenient in Perl

A first example

- The regular expression "[a-z]+" will match a sequence of one or more lowercase letters
  - [a-z] means any character from a through z, inclusive
  - + means "one or more"
- Suppose we apply this pattern to the String "Now is the time"
  - There are *three ways* we can apply this pattern:
    - To the *entire string:* it fails to match because the string contains characters other than lowercase letters
    - To the *beginning of the string:* it fails to match because the string does not begin with a lowercase letter
    - To *search the string:* it will succeed and match ow
      - If applied repeatedly, it will find is, then the, then time, then fail

Doing it in Perl and Ruby

- In both Perl and Ruby, a regular expression is written between forward slashes, for example, `/[a-z]+/`
- Regular expressions are values, and can be used as such
  - For example, `line.split(/\s+/)`
- We can search for matches to a regular expression with the `=~` operator
  - For example, `name = "Dave"; name =~ /[a-z]/;` will find `ave`

Doing it in Java, I

- First, you must *compile* the pattern

```
import java.util.regex.*;
Pattern p = Pattern.compile("[a-z]+");
```

- Next, you must create a *matcher* for a specific piece of text by sending a message to your pattern

```
Matcher m = p.matcher("Now is the time");
```

- Points to notice:
  - `Pattern` and `Matcher` are both in `java.util.regex`
  - Neither `Pattern` nor `Matcher` has a public constructor; you create these by using methods in the `Pattern` class
  - The matcher contains information about *both* the pattern to use *and* the text to which it will be applied

Doing it in Java, II

- Now that we have a matcher m,
  - m.matches() returns true if the pattern matches the entire text string, and false otherwise
  - m.lookingAt() returns true if the pattern matches at the beginning of the text string, and false otherwise
  - m.find() returns true if the pattern matches any part of the text string, and false otherwise
    - If called again, m.find() will start searching from where the last match was found
    - m.find() will return true for as many matches as there are in the string; after that, it will return false
    - When m.find() returns false, matcher m will be *reset* to the beginning of the text string (and may be used again)

Finding what was matched

- *After a successful match,* `m.start()` will return the index of the first character matched
- *After a successful match,* `m.end()` will return the index of the last character matched, *plus one*
- If no match was attempted, or if the match was unsuccessful, `m.start()` and `m.end()` will throw an `IllegalStateException`
  - This is a `RuntimeException`, so you don't have to catch it
- It may seem strange that `m.end()` returns the index of the last character matched plus one, but this is just what most String methods require
  - For example, `"Now is the time".substring(m.start(), m.end())` will return exactly the matched substring

A complete example

```
import java.util.regex.*;

public class RegexTest {
    public static void main(String args[]) {
        String pattern = "[a-z]+";
        String text = "Now is the time";
        Pattern p = Pattern.compile(pattern);
        Matcher m = p.matcher(text);
        while (m.find()) {
            System.out.print(text.substring(m.start(), m.end()) + "*");
        }
    }
}
```

Output: ow*is*the*time*

Additional methods

- If m is a matcher, then
  - m.replaceFirst(***replacement***) returns a new String where the first substring matched by the pattern has been replaced by ***replacement***
  - m.replaceAll(***replacement***) returns a new String where every substring matched by the pattern has been replaced by ***replacement***
  - m.find(***startIndex***) looks for the next pattern match, starting at the specified index
  - m.reset() resets this matcher
  - m.reset(***newText***) resets this matcher and gives it new text to examine (which may be a String, StringBuffer, or CharBuffer)

Some simple patterns

abc	exactly this sequence of three letters
[abc]	any *one* of the letters a, b, or c
[^abc]	any character *except* one of the letters a, b, or c (immediately within an open bracket, ^ means "not," but anywhere else it just means the character ^)
[a-z]	any *one* character from a through z, inclusive
[a-zA-Z0-9]	any *one* letter or digit

Sequences and alternatives

- If one pattern is followed by another, the two patterns must match consecutively
  - For example, [A-Za-z]+[0-9] will match one or more letters immediately followed by one digit
- The vertical bar, |, is used to separate alternatives
  - For example, the pattern abc|xyz will match either abc or xyz

Some predefined character classes

.	any one character except a line terminator
\d	a digit: [0-9]
\D	a non-digit: [^0-9]
\s	a whitespace character: [\t\n\x0B\f\r]
\S	a non-whitespace character: [^\s]
\w	a word character: [a-zA-Z_0-9]
\W	a non-word character: [^\w]

Notice the space.
Spaces are **significant** in regular expressions!

Boundary matchers

- These patterns match the *empty string* if at the specified position:

`^`	the beginning of a line
`$`	the end of a line
`\b`	a word boundary
`\B`	not a word boundary
`\A`	the beginning of the input (can be multiple lines)
`\Z`	the end of the input except for the final terminator, if any
`\z`	the end of the input

Greedy quantifiers

(The term "greedy" will be explained later)
Assume *X* represents some pattern

X? optional, *X* occurs once or not at all

X* *X* occurs zero or more times

X+ *X* occurs one or more times

X{n} *X* occurs exactly *n* times

X{n,} *X* occurs *n* or more times

X{n,m} *X* occurs at least *n* but not more than *m* times

Note that these are all *postfix* operators, that is, they come *after* the operand

Types of quantifiers

- A greedy quantifier will match as much as it can, and back off if it needs to
  - We'll do examples in a moment
- A reluctant quantifier will match as little as possible, then take more if it needs to
  - You make a quantifier reluctant by appending a ?:
    X??   *X**?   *X*+?   *X*{*n*}?   *X*{*n*,}?   *X*{*n*,*m*}?
- A possessive quantifier will match as much as it can, and never let go
  - You make a quantifier possessive by appending a +:
    X?+   *X**+   *X*++   *X*{*n*}+   *X*{*n*,}+   *X*{*n*,*m*}+

Quantifier examples

- Suppose your text is aardvark
  - Using the pattern a*ardvark (a* is greedy):
    - The a* will first match aa, but then ardvark won't match
    - The a* then "backs off" and matches only a single a, allowing the rest of the pattern (ardvark) to succeed
  - Using the pattern a*?ardvark (a*? is reluctant):
    - The a*? will first match zero characters (the null string), but then ardvark won't match
    - The a*? then extends and matches the first a, allowing the rest of the pattern (ardvark) to succeed
  - Using the pattern a*+ardvark (a*+ is possessive):
    - The a*+ will match the aa, and will not back off, so ardvark never matches and the pattern match fails

Capturing groups

- In regular expressions, parentheses are used for grouping, but they also capture (keep for later use) anything matched by that part of the pattern
  - Example: `([a-zA-Z]*)([0-9]*)` matches any number of letters followed by any number of digits
  - If the match succeeds, `\1` holds the matched letters and `\2` holds the matched digits
  - In addition, `\0` holds everything matched by the entire pattern
- Capturing groups are numbered by counting their *opening parentheses* from left to right:
  - `( ( A ) ( B ( C ) ) )`
    `1 2     3   4`
    `\0 = \1 = ((A)(B(C))),    \2 = (A),    \3 = (B(C)),    \4 = (C)`
- Example: `([a-zA-Z])\1` will match a double letter, such as `letter`

Capturing groups in Java

- If `m` is a matcher that has just performed a successful match, then
  - `m.group(`***n***`)` returns the String matched by capturing group ***n***
    - This could be an empty string
    - This will be `null` if the pattern as a whole matched but this particular group didn't match anything
  - `m.group()` returns the String matched by the entire pattern (same as `m.group(0)`)
    - This could be an empty string
- If `m` didn't match (or wasn't tried), then these methods will throw an `IllegalStateException`

Example use of capturing groups

- Suppose word holds a word in English
- Also suppose we want to move all the consonants at the beginning of word (if any) to the end of the word (so string becomes ingstr)
  - ```
    Pattern p = Pattern.compile("([^aeiou]*)(.*)");
    Matcher m = p.matcher(word);
    if (m.matches()) {
      System.out.println(m.group(2) + m.group(1));
    }
    ```
- Note the use of (.*) to indicate "all the rest of the characters"
    ```

Double backslashes

- Backslashes have a special meaning in regular expressions; for example, `\b` means a word boundary
- Backslashes have a special meaning in Java; for example, `\b` means the backspace character
- Java syntax rules apply first!
  - If you write `"\b[a-z]+\b"` you get a string with backspace characters in it--this is *not* what you want!
  - Remember, you can quote a backslash with another backslash, so `"\\b[a-z]+\\b"` gives the correct string
- Note: if you *read in* a String from somewhere, this does not apply--you get whatever characters are actually there

Escaping metacharacters

- A lot of special characters--parentheses, brackets, braces, stars, plus signs, etc.--are used in defining regular expressions; these are called metacharacters
- Suppose you want to search for the character sequence `a*` (an `a` followed by a star)
  - `"a*"`; doesn't work; that means "zero or more `a`s"
  - `"a\*"`; doesn't work; since a star doesn't *need* to be escaped (in Java String constants), Java just ignores the `\`
  - `"a\\*"` *does* work; it's the three-character string `a`, `\`, `*`
- Just to make things even more difficult, it's *illegal* to escape a *non*-metacharacter in a regular expression

Spaces

- There is only one thing to be said about spaces (blanks) in regular expressions, but it's important:
  - *Spaces are significant!*
- A space stands for a *space*--when you put a space in a pattern, that means to match a space in the text string
- It's a *really bad idea* to put spaces in a regular expression just to make it look better

Additions to the String class

- All of the following are public:
  - public boolean matches(String *regex*)
  - public String replaceFirst(String *regex*, String *replacement*)
  - public String replaceAll(String *regex*, String *replacement*)
  - public String[ ] split(String *regex*)
  - public String[ ] split(String *regex*, int *limit*)
    - If the limit n is greater than zero then the pattern will be applied at most n - 1 times, the array's length will be no greater than n, and the array's last entry will contain all input beyond the last matched delimiter.
    - If n is non-positive then the pattern will be applied as many times as possible

Thinking in regular expressions

- Regular expressions are *not* easy to use at first
  - It's a bunch of punctuation, not words
  - The individual pieces are not hard, but it takes practice to learn to put them together correctly
  - Regular expressions form a miniature programming language
    - It's a different kind of programming language than Java, and requires you to learn new thought patterns
  - In Java you can't just *use* a regular expression; you have to first create Patterns and Matchers
  - Java's syntax for String constants doesn't help, either
- Despite all this, regular expressions bring so much power and convenience to String manipulation that they are well worth the effort of learning

The End

"A little learning is a dangerous thing;
drink deep, or taste not the Pierian spring:
there shallow draughts intoxicate the brain,
and drinking largely sobers us again."

--Alexander Pope