תכנות מתקדם ושפת C++
מצגת 7

מחרוזות וביטויים רגולריים

מחרוזת

- בשפת C מחרוזת היא מערך של תווים שמסתיים בתוו שערכו 0
- בשפת C אין מחלקות אין פונקציות חברות ואין העמסת אופרטורים, וכדי לעבד מחרוזות משתמשים בפונקציות שמקבלות מחרוזת כפרמטר:

```
strcpy(), strcat(), strcmp(),  strlen()
```

- בשפת C++ נשתמש במחלקה string שמאפשרת לעבד מחרוזות בצורה נוחה:

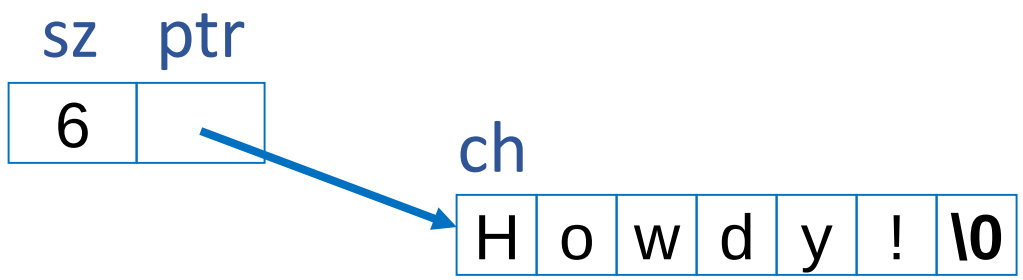
```
s1 = s2        // Assign s2 to s1
s1 += x        // Add a character or a string at end
s1 + s2        // Concatenation
s1 == s2       // Comparison
s1 < s2        // Lexicographical comparison
s.size()       // Number of characters
s.c_str()      // C-style version of string
```

מימוש המחלקה מחרוזת

- נשתמש במערך של תווים שמסתיים ב- 0 לייצוג המחרוזת בתוך המחלקה, זה מפשט העתקה ממחרוזת שמיוצגת בסגנון C
- כדי ליעל, מחרוזות קצרות יישמרו בתוך האובייקט, מחרוזות ארוכות יישמרו בזיכרון הדינמי
- מחרוזת קצרה בתוך האובייקט תשמר במערך ch
- המשתנה short_max מכיל את הגודל המירבי (15) לשמירת המחרוזת בתוך האובייקט
- בשני המקרים, המשתנה ptr יצביע על התוו הראשון במחרוזת
- כפי שעשינו במימוש וקטור, גם כאן נקצה זיכרון עודף כדי ליעל הוספה של תווים

ייצוג המחרוזת

```
class String {
private:
    static const int short_max = 15;
    int sz; // number of characters
    char* ptr;
    int space; // unused space on free store
    char ch[short_max+1]; // leave space for 0 (16)
};
```



מימוש בסיסי של מחרוזת

```
class String {
public:
    String(); //default constructor: x{""}
    String(const char* p); // C-style: x{"Euler"}
    String(const String&); // copy constructor
    String& operator=(const String&); // copy assignment
    String(String&& x); // move constructor
    String& operator=(String&& x); // move assignment
    ~String() { if (sz > short_max) delete[] ptr; }
    const char* c_str() { return ptr; } // C-style access
    int size() const { return sz; } // number of elements
};
```

מימוש הבנאים

- The default constructor defines a String to be **empty**:

```
String::String() : sz{0}, ptr{ch}
{
    ch[0] = 0; // terminating 0
}
```

- The constructor that takes a **C-style** string argument:

```
String::String(const char* p) : sz{strlen(p)},
    ptr{(sz<=short_max) ? ch : new char[sz+1]},
    space{0}
{
    strcpy(ptr,p); // copy characters into ptr from p
}
```

ביטוים רגולריים

- ביטוי רגולרי הוא מחרוזת המתארת תבנית של טכסט.
- ביטוי רגולרי משמש לחיפוש והחלפה של טכסט וכדי לבדוק תקינות של קלט.
- הפונקציות הבאות ב- C++ מאפשרות שימוש בביטויים רגולריים:
- **regex_match** פונקציה המנסה להתאים את הביטוי הרגולרי **לכל** המחרוזת
- **regex_search** פונקציה המנסה להתאים את הביטוי הרגולרי **לחלק** מהמחרוזת
- **regex_replace** פונקציה המחליפה מופעים של הביטוי הרגולרי בטכסט אחר
- **sregex_iterator** יוצר איטרטור שמאפשר מעבר על כל ההתאמות בטכסט

regex_match()

```
string input;
regex pat("abc");
regex pat("[abc]");
regex pat("\\d"); // String literals: "a\\n"
regex pat(R"(\d)"); // Raw string literals: R"(a\n)"
regex pat("C\\+\\+");
regex pat(R"(C\+\+)");
while (true){
    cout << "Enter text:" << endl;
    if(!(cin >> input)) break;
    if(regex_match(input, pat)) cout << "Match" << endl;
        else cout << "No Match" << endl;
}
```

Match any one of several characters

- The notation using square brackets is called a **character class**
- A character class matches a **single character** out of a list of possible characters
  - Match english vowels: **[aeiouy]** (y in sky)
  - Match all common misspellings of calendar: **c[ae]l[ae]nd[ae]r**
- A hyphen **(-)** creates a range when it is placed between two characters
  - Match hexadecimal character: **[a-fA-F0-9]**
- A caret **(^)** negates the character class if you place it immediately after the opening bracket
  - **[^aeiouy]** not an English vowel
  - **[a^eiouy]** an English vowel or **^**
  - Match non-hexadecimal character: **[^a-fA-F0-9]**

One of several characters **shorthand**

- Six regex tokens that consist of a backslash and a letter form **shorthand character classes**: **\d, \D, \w, \W, \s** and **\S:**
  - **\d** matches a single digit
  - **\D** matches any character that is not a digit, and is equivalent to **[^\d]**
  - **\w** matches a single word character, usually it is identical to **[a-zA-Z0-9_]**
  - **\s** matches any whitespace character - spaces, tabs, and line breaks
  - **\S** matches any character not matched by **\s**

Examples:

\d–\d	matches **1-2, 3-4**
\w\w-\d\d	matches **Ab-12, 12-34** - digits are in **\w**
q[^u]	does **not** match Iraq

Regex meta-characters

- There are 12 punctuation characters that make regular expressions work their magic, they are called **meta-characters**
- Any regular expression that **does not** include any of the 12 meta-characters **$()*+.?[\^{|** simply **matches itself**
- If you want your regex to match them literally, you need to escape them by placing a backslash in front of them

  Thus, the regex: ***\+\.\?** matches the text ***+.?**
- Those backslashes may need to be **doubled** up to quote the regex as a literal string in source code (unless you use **raw** string):

  "*"

Regex meta-characters

- Absent from the list are the closing square bracket **]**, the hyphen **-**, and the closing curly bracket **}**
- The first two become metacharacters only after an unescaped **[**, and the **}** only after an unescaped **{**
- The rules about which characters are different inside a character class:
  - dot is a meta character outside of a class, but not within one
  - dash is a meta character within a class (between two characters), but not outside
  - caret has one meaning outside, and another meaning if specified inside a class immediately after the opening **[**

Match any character

- **dot .** matches any character **except** line breaks
- **[\s\S]** matches any character **including** line breaks
- **[\d\D]** and **[\w\W]** have the **same** effect
- Dot abuse:

  \d\d.\d\d.\d\d is **not a good** way to match a date

  It does match 05/16/08,

  but it also matches 12345678

  Replacing the dot with a more appropriate character class

  \d\d[-/.]\d\d[-/.]\d\d

  allows a **hyphen, forward slash or dot**, to be used as the date separator.

Repeat part of the regex

- *** (star)** after a regex token means **zero or more**, example **\d***
- **+ (plus)** after a regex token means **one or more**, example **\d+**
- The quantifier **{n}**, repeats the preceding regex token **n** number of times
- The quantifier **{n,m}**, repeats the preceding regex token n to m times
- A **question mark ?** after a regex token means **zero or once**
- **Examples:**

  [A-Za-z_][A-Za-z_0-9]* an identifier in a programming language

  0[xX][A-Fa-f0-9]+ C-style hexadecimal number

  10{100} a googol (10^{100})

  [A-Fa-f0-9]{1,8}h? 1-8 digit hexadecimal number with an **optional h** suffix

  colou?r matches both colour and color

  A*B+C? **matches** AAABBB, BC, B **does not match** AAA, AABBCC

  ^\d{1,3}\.\d{1,3}\.\d{1,3}\.\d{1,3}$ **matches** an IP Address

greedy and **lazy** matches

- To match an HTML tag:

  This is a <EM>first</EM> test

  you may attempt to use

  <.+>

  but this matches **<EM>first</EM>**, not **<EM>**
- The reason is that *** , +** and **{n,m}** are **greedy**, they repeat the preceding token as many times as possible (longest match)
- **.*[0-9]+ applied to "Copyright 2003", [0-9]+ matches only "3"**
- You can make them **lazy** instead of **greedy** by putting a **?** after them

  <.+?>

  or use the pattern: **<[^>]+>**
- **(ab)+** matches all of ababab, however **(ab)+?** matches only the first ab

Match at start and end of a line

- The regular expression tokens **^, $** are called **anchors**
- They do not match any characters, instead they match at certain positions, effectively anchoring the regular expression match
- **^ (caret)** matches only if it occurs at the beginning of a string
- **$ (dollar)** matches only if it occurs at the end of a string
- **Examples:**

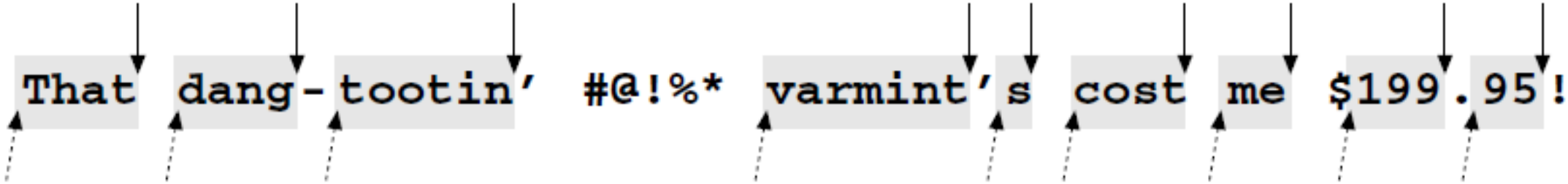
^cat	a line that begins with cat, matches **catxxx**
cat$	a line that ends with cat, matches **xxzxcat**
^cat$	a line that consists of only cat, matches **cat**
^$	matches an empty line

Match whole words

- Create a regex that matches the word **cat** in "**A cat and a mouse**", but not in **cat**egory or **bob**cat

  Place the word **cat** between two word boundaries **\bcat\b**

- The regular expression token **\b** is called a word boundary, it matches at the start or the end of a word
- The first **\b** requires the **c** to occur at the very start of the string, or after a non-word character.
- The second **\b** requires the **t** to occur at the very end of the string, or before a non-word character



Match one of several alternatives

- The **vertical bar or pipe symbol |**, splits the regular expression into multiple alternatives
- **Mary|Jane|Sue** matches Mary, or Jane, or Sue with each match attempt
- The regular expression finds the **leftmost match**:

  When you apply **Mary|Jane|Sue** to

  Jane, Mary and Sue went to Mary's house

  the match Jane is found first

  The match that begins earliest (leftmost) wins
- Each alternative is checked in a left-to-right order:

  Jane|Janet matches **Jane** in **Her name is Janet**

Group parts of the match

- Improve the regular expression for matching Mary, Jane, or Sue by forcing the match to be a whole word
- Use grouping to achieve this with one pair of word boundaries for the whole regex, instead of one pair for each alternative
- **\b(Mary|Jane|Sue)\b** has three alternatives: Mary, Jane, and Sue, all three between two word boundaries
  - This regex **does not match** anything in **Her name is Janet**
- The alternation operator, has the **lowest** precedence of all regex operators
  - If you try **\bMary|Jane|Sue\b**, the three alternatives are \bMary, Jane, and Sue\b
  - This regex matches **Jane** in **Her name is Janet**

Group Parts of the Match

- Examples
- **Nov(ember)?** matches November and Nov (**greedy**)
- **Feb(ruary)? 23(rd)?** matches many alternatives
- **\b(one|two|three)\b** Find a line containing certain words:
- **(\s|:|,)*(\d+)** spaces, colons, commas followed by a number
- **(?\s|:|,)*(\d*)** parentheses that dont define a subpattern
- **<HR(+SIZE *= *[0-9]+)? *>** <HR SIZE=30>
- **\$[0-9]+(\.[0-9][0-9])?** Dollar amount with optional cents
- We have seen two uses for grouping parentheses:
  - to limit the scope of alternation
  - to group multiple characters into larger units to which you can apply quantifiers like question mark and star

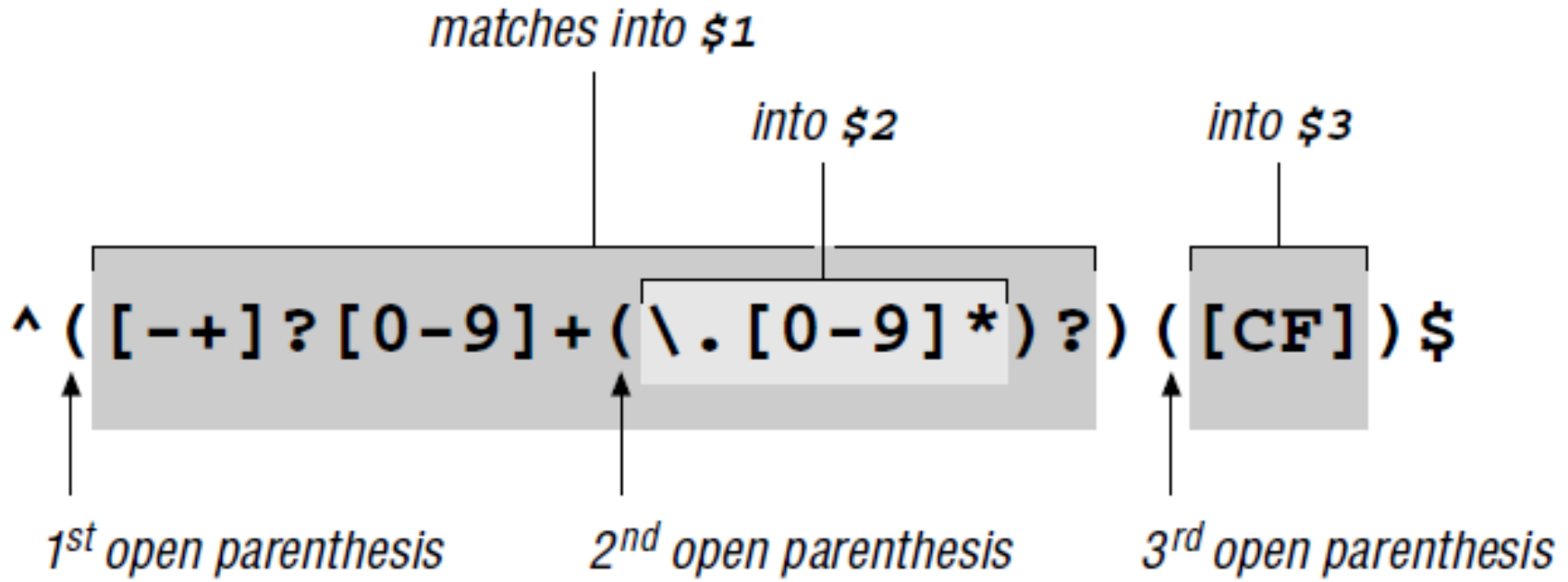
Capture parts of the match

- Create a regular expression that matches any date in **yyyy-mm-dd** format, and separately **captures** the **year**, **month**, and **day**
- A pair of **parentheses** isn't just a group, it's a **capturing** group
- Captures become useful when they cover only part of the regular expression, as in **\b(\d\d\d\d)-(\d\d)-(\d\d)\b**
- The regex **\b\d\d\d\d-\d\d-\d\d\b** does exactly the same, but does not capture
- Captures are numbered by counting opening parentheses from left to right
- There are three ways you can use the captured text:
  - match the captured text again within the same regex match
  - insert the captured text into the replacement text
  - The program can use the parts of the regex match

Capture parts of the match

- Example, convert temperatures:

  ^([-+]?[0-9]+(\.[0-9]+)?)([CF])$



- or group but do not capture:

  ^([-+]?[0-9]+(?\.[0-9]+)?)([CF])$

- Now, the text that the parentheses surrounding [CF] match, goes to $2

Match previously matched text again

- Create a regular expression that matches “magical” dates
- A date is magical if the year minus the century, the month, and the day of the month are all the same numbers
- For example, 2010-10-10 is a magical date:

  we first have to capture the previous text, then we match the same text using a **back-reference**

  \b\d\d(\d\d)-\1-\1\b

  The **(\d\d)** matches 10, and is stored in capturing group 1

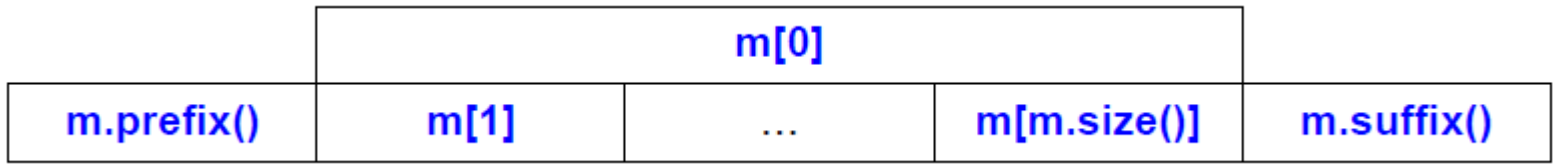
  The **back-reference \1** matches the **10** of the **month** and **day**
- Match a pair of opening and closing HTML tags:

  <([A-Z][A-Z0-9]*)[^>]*>.*?</\1>
- Checking for Doubled Words (the the):

  \b(\w+)\s+\1\b

regex_search(), smatch

```
string input;
regex pattern(R"(\d+)");
smatch result;
while (true) {
      cout<<"Enter:"<<endl;
      if(!(cin >> input)) break;
      if(regex_search(input, result, pattern)) {
            cout<<"Match prefix: "<<result.prefix()<<endl;
            cout<<"Match string: "<<result[0]<<endl;
            cout<<"Match suffix: "<<result.suffix()<<endl;
      }
      else cout<<"No Match"<<endl;
}
```



regex_search(), smatch

```
void use() {
    ifstream in("file.txt"); if (!in) cerr << "no file\n";
    regex pat {R"(\w{2}\s*\d{5}(-\d{4})?)"}; //postal code
    int lineno = 0;
    smatch matches; // matched strings go here
    for (string line; getline(in,line);) {
        ++lineno;
        if (regex_search(line , matches, pat)) {
            cout << lineno << ": " << matches[0] << '\n';
        if (1 < matches.size() && matches[1].matched)
        cout << "\t: " << matches[1] << '\n'; // sub-match
        }
    } } // TX77845 and DC 20500-0001 match
```

regex_replace()

Replace all matchings of pattern:

```
string input {"x 1 y2 22 zaq 34567"};
regex pat {"(\w+)\s(\d+)"}; // word space number
string format {"{$1,$2}\n"};
cout << regex_replace(input,pat,format);
```

- The output is:

```
{x,1}
{y2,22}
{zaq,34567}
```

sregex_iterator

Replace all matchings of pattern:

```
regex reg("([A-Za-z]+) \\1");
string target = "the the cow jumped over over the fence";
sregex_iterator reg_begin =
   sregex_iterator(target.begin(), target.end(), reg);
sregex_iterator reg_end = sregex_iterator();
for (sregex_iterator it = reg_begin; it != reg_end; ++it) {
   cout << "Substring: " << it->str() << ", ";
   cout << "Position: " << it->position() << endl;
}
cout << "Found: " << distance(reg_begin, reg_end) << endl;
```

The output is:

```
Substring: the the, Position: 0
Substring: over over, Position: 19
Found: 2
```

Special Characters

Regular Expression Special Characters

.	Any single character (a "wildcard")
[	Begin character class
]	End character class
{	Begin count
}	End count
(	Begin grouping
)	End grouping
\	Next character has a special meaning
*	Zero or more (suffix operation)
+	One or more (suffix operation)
?	Optional (zero or one) (suffix operation)
|	Alternative (or)
^	Start of line; negation
$	End of line

Repetition

{ n }	Exactly n times
{ n, }	n or more times
{n,m}	At least n and at most m times
*	Zero or more, that is, {0,}
+	One or more, that is, {1,}
?	Optional (zero or one), that is {0,1}

Character Class

\d	A decimal digit
\s	A space (space, tab, etc.)
\w	A letter (a-z) or digit (0-9) or underscore (_)
\D	Not \d
\S	Not \s
\W	Not \w