Week 3 Lecture 1

NWEN 241
Systems Programming

Jyoti Sahni

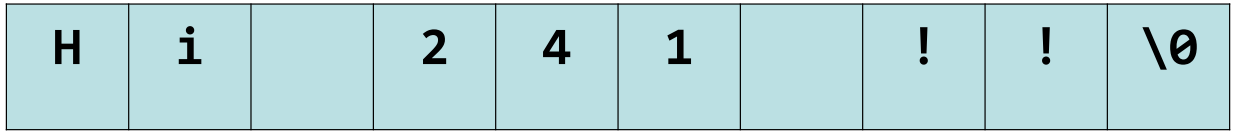
Jyoti.sahni@ecs.vuw.ac.nz

Content

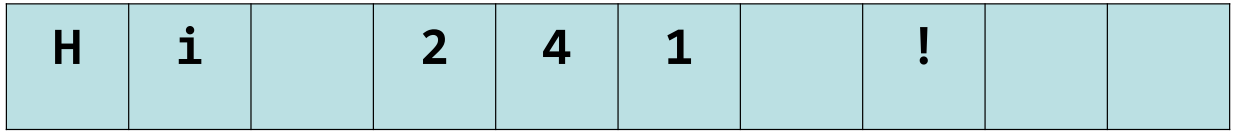
- Strings (cont.)
- Structures

Recap: What is String in C?

- C language **does not support strings** as a basic data type
- A C string is just an array that contains ASCII characters terminated by the **null character `'\0'`**
- A C string is stored in an array of chars




```
"Hi 241 !!"
```

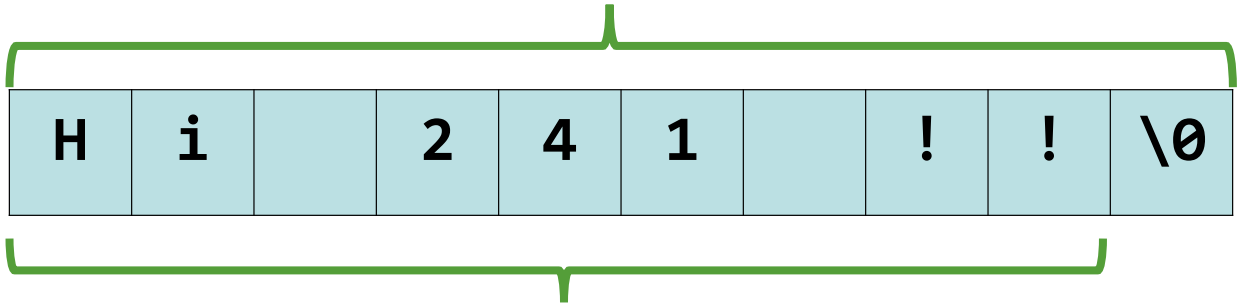


Not a valid string

Recap: String Length

- Number of bytes/characters **excluding** the null character

Entire string occupies 10 bytes



String length = 9 bytes

- `strlen()` function in `<string.h>` returns the string length

String Literal vs String Variable

- In C, we distinguish between **string literals** and **string variables**
- A **string literal** refers to the string constant value which is stored in the read-only memory area of the program
- A **string variable** refers to a string that is stored in an array which can be modified

String Literal (1)

- Enclosed in double quotes (") and can contain character literals (plain and escape characters)
- Can be broken up into multiple lines (each line ends with \) or separated by whitespaces

```
"Hello, world"
```

```
"Hello" ", " "world"
```

```
"Hello, \
world"
```

String Literal (2)

- String literals may contain as few as **one** or **even zero** characters

- Do not confuse a single-character string literal, e.g. `"A"` with a character constant, `'A'`
  - The former is actually two characters, because of the null-terminator stored at the end

- An **empty string**, `""`, consists of only the null-terminator, and is considered to have a string length of zero, because the null-terminator does not count when determining string lengths

String Literal (3)

- String literals are passed to functions as *pointers* to a stored string. For example, given the statement:

```
printf("Hello world!\n");
```

  - The string literal **`"Hello world!\n"`** will be stored somewhere in memory, and the address will be passed to **`printf()`**
  - The first argument to **`printf()`** is actually defined as a **`char *`**

- We will revisit this when we talk about pointers

Operations on String Literals

- String literals may be subscripted

```
printf("%c\n", "Hello"[2]);    /* will print 'l' */
```

- Attempting to modify a string literal results in undefined behaviour, and may cause problems in different ways depending on the compiler, *e.g.*

```
"Hello"[2] = 'e';
```

Symbolic String Constants

- Similar to integer and float symbolic constants, symbolic string constants can be declared using `const` qualifier or `#define` pre-processor

```
const char *MSG = "Hello, world";
const char *MSG_A = "Hello, \
world";
const char *MSG_B = "Hello" ", " "world";
```

```
#define MSG   "Hello, world";
#define MSG_A "Hello, \
world"
#define MSG_B "Hello" ", " "world"
```

String Variables

- **String variables** are stored as arrays of chars, terminated by the **null character**
- A string variable can be initialized in 2 ways using the methods discussed in previous lecture:

```
char str[10];
str[0] = 'H';
str[1] = 'e';
str[2] = 'l';
str[3] = 'l';
str[4] = 'o';
str[5] = ' ';
str[6] = '!';
str[7] = '\0';
```

```
char str[10] = {'H', 'e', 'l',
    'l', 'o', ' ', '!', '\0' };
```

Efficient String Variable Initialization

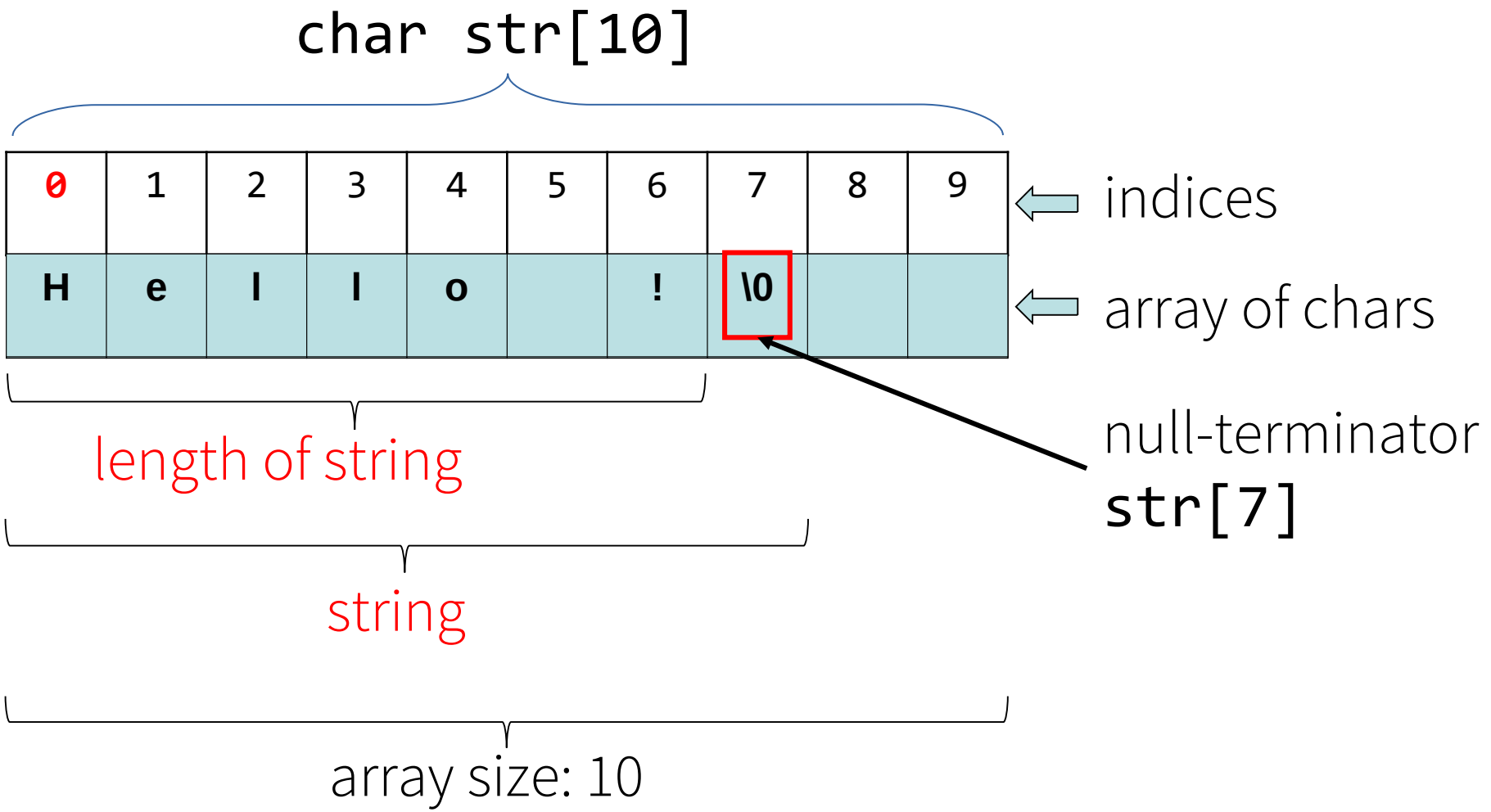
- Another way to initialize a char array to hold a string variable: **assign a string literal to the array during declaration**

```
char str[10] = "Hello !";
```

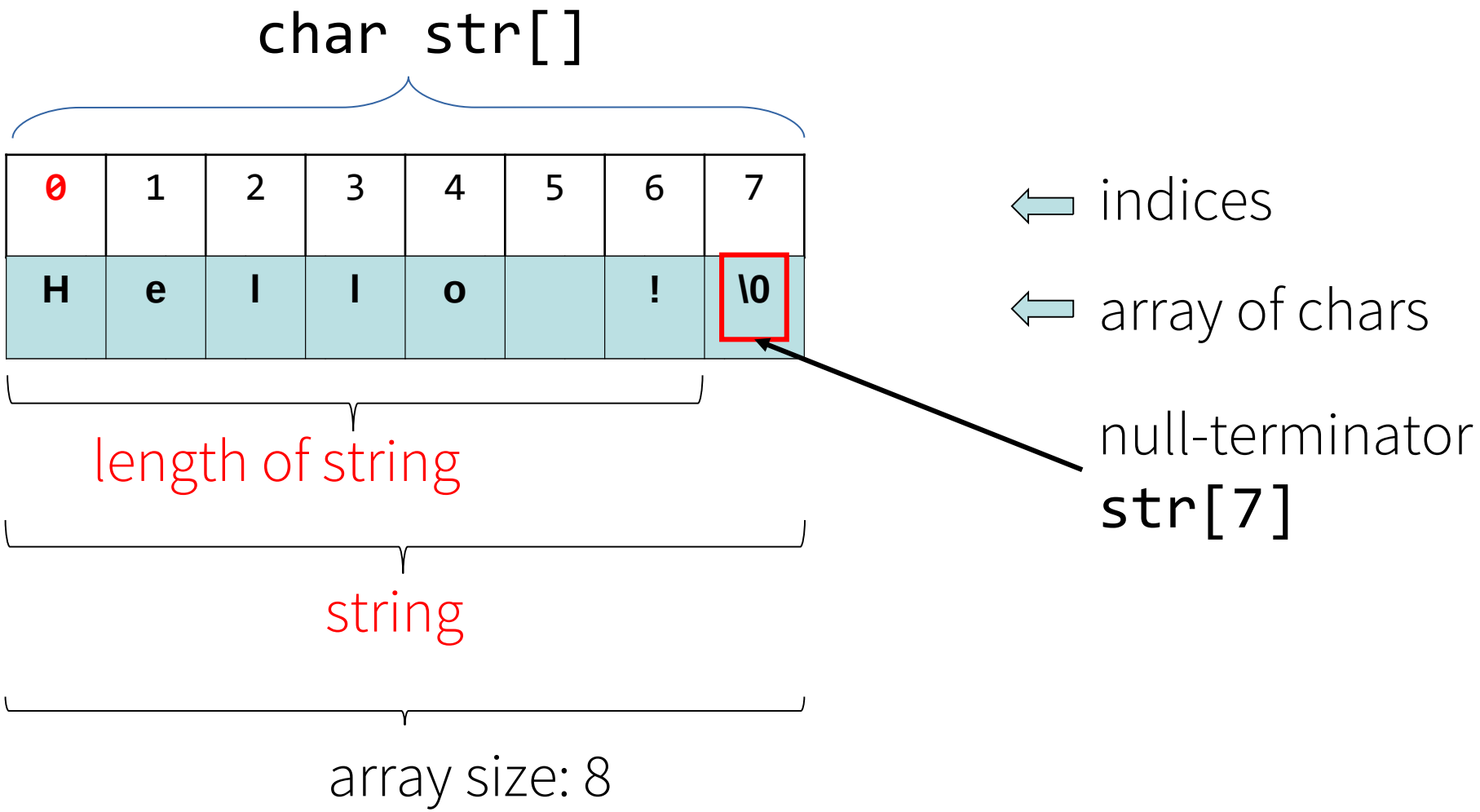
```
char str[] = "Hello !";
```

What's the difference between the two?

```
char str[10] = "Hello !";
```



```
char str[] = "Hello !";
```



Assigning a string after array declaration

```
char str[10];
…
str = "Hello !";
```

Illegal! Use `strcpy()` function

```
char str[10];
…
strcpy(str, "Hello !");
```

Null Terminator

- A string is an array of characters that ends with the first occurrence of `'\0'`
- What comes **after** the end of the string **doesn't matter**, since the string has ended

```
char str[] = "One\0Two";
printf("%s\n", str);
```

- The program will print only the string “One”
  - The `'\0'` character terminates the string
  - What comes after, does not matter
- The array will contain 8 elements

Displaying Strings: `printf()`

- Strings can be displayed on the screen using `printf()`

```
printf("%s\n", str);
```

- The **precision** (`'%.N'`) parameter limits the length of longer strings to at most `N`

```
printf("%.5s\n", "abcdefg");
   // only "abcde" will be displayed
```

- The **width** (`'%N'`) parameter can be used to print a short string in a long space, at least `N` characters

```
printf( "%5s\n", "abc" );
   // prints "  abc". Note the leading
   // two spaced at the beginning.
```

Displaying Strings: `puts()`

- The `puts()` function writes the string out to standard output and automatically appends a newline character at the end

```
char str[] = "This is an ";
printf("%s", str);
puts("example string.");
printf("See??\n");
```

- The output will be:

```
This is an example string.
See??
```

Reading in strings – `scanf()`

- The standard format specifier for reading strings with `scanf()` is `%s` that the `'&'` is not required in the case of strings, since the string is a memory address itself

- `scanf()` appends a `'\0'` to the end of the character string stored

- `scanf()` does skip over any leading whitespace characters in order to find the first non-whitespace character

Reading in strings – `scanf()`

- The **width field** can be used to limit the maximum number of characters to read from the input
- You should use one character less as input than the size of the array used for holding the result

```
char str[6];
printf("Hi\n");
scanf("%5s", str);
   // If you enter "HelloBello123xyz", only the
   // first 5 characters will be read and a
   // concluding '\0' will be put at the end

printf("%s\n", str);
```

Reading in strings – `scanf()`

- `scanf()` reads in a string of characters, only up to the first whitespace character
  - it stops reading when it encounters a space, tab, or newline character
- C supports a format specification known as the edit set conversion code `%[...]`
  - it can be used to read a line containing a variety of characters, including white spaces

```
char str[20];
printf("Enter a string:\n");
scanf("%[^\n]", str);
printf("%s\n",str);
```

Reading in strings – `scanf()`

- Always use the width field to limit the maximum number of characters to read with `"%s"` and `"%[...]"` in all production quality code!
  - No exceptions!

Reading in strings – `gets()`

- `gets()` is used to scan a line of text from a standard input device, until a newline character input
- **The string may include white space characters**
- The newline character won't be included as part of the string
- `'\0'` is always appended to the end of the string of stored characters

Reading in strings – `gets()`

```
char str[15];
printf("Enter your name: \n");
gets(str);
printf("%s\n", str);
```

- `gets()` has no provision for limiting the number of characters to read
  - This can lead to overflow problems!

Reading strings character by character

- Read in character by character is useful when
  - you don't know how long the string might be,
  - or if you want to consider other stopping conditions besides spaces and newlines
    - e.g. stop on periods, or when two successive slashes, //, are encountered.

- The `scanf()` format specifier for reading individual characters is %c

- If a width greater than 1 is given (%2c), then multiple characters are read, and stored in successive positions in a char array

`sscanf()` and `sprintf()` functions

- `scanf()` and `printf()` functions are used to read from and write to the standard input/output
- `sscanf()` and `sprintf()` are used for the same goal but instead of the standard input/output, **they use strings**
- One of their main advantage is when you need to prepare a string for later use

The <ctype.h> header

- `<ctype.h>` declares a set of functions to classify and transform individual chars
  - **`#include <ctype.h>`** is required to use any of these functions
  - https://www.tutorialspoint.com/c_standard_library/ctype_h.htm documents the library

The <ctype.h> header

- Some of the more commonly used functions:
  - `isupper()` – checks if a character is an uppercase letter
    - A value different from zero is returned if the character is an uppercase alphabetic letter, zero otherwise
  - `islower()` – checks if a character is a lowercase letter
    - A value different from zero is returned if the character is a lowercase alphabetic letter, zero otherwise
  - `toupper()` – converts a character to its uppercase equivalent if the character is an lowercase letter and has an uppercase equivalent
    - If no such conversion is possible, the returned value is unchanged
  - `tolower()` – converts a character to its lowercase equivalent if the character is an uppercase letter and has a lowercase equivalent
    - If no such conversion is possible, the returned value is unchanged

The <string.h> header

- `<string.h>` defines several functions to manipulate null-byte terminated arrays of chars
  - `#include <string.h>` is required to use any of these functions
  - https://www.tutorialspoint.com/c_standard_library/string_h.htm documents the library

The <string.h> header

- Some of the more commonly used functions:
  - `strcpy()` – copies a string from source to destination
  - `strcat()` – concatenates (appends) source to the end of destination
  - `strlen()` – returns length of the string, not counting the '\0'
  - `strcmp()` – compares strings str1 and str2, up until the first encountered null-term
    - Returns zero if the two strings are equal
    - Returns a positive value (1?) if the first encountered difference has a larger value in str1 than str2
    - Returns a negative value (-1?) if the first encountered difference has a smaller value in str1 than str2

The <stdlib.h> header

- `stdlib.h` defines several functions, including searching, sorting and converting
  - `#include <stdlib.h>` is required to use any of these functions
  - https://www.tutorialspoint.com/c_standard_library/stdlib_h.htm documents the library

- Some of the more commonly used functions:
  - `atoi()`, `atof()`, `atol()`, `atoll()` – parses a string of numeric characters into a number of type **int**, **double**, **long int**, or **long long int**, respectively

Structures

Background

- Basic data types
  - **int** : integer ✓
  - **char** : character ✓
  - **float** : floating point number ✓
  - **double** : double-precision floating point number ✓

- Derived data types
  - Arrays ✓
  - Strings ✓
  - **Structures**

Structures

- A `struct` is a derived data type composed of members that are each basic or derived data types

- A single `struct` would store the data for one object. An array of `struct`s would store the data for several objects

- A `struct` can be defined in several ways as illustrated in the following examples

Declaring a Structure

- Syntax of the structure type declaration:

```
struct structure_tag {
      type1 member1;
      type2 member2;
      ...
} variable_list;
```

  - ***structure_tag*** specifies the name of the structure
  - ***structure_tag*** and ***variable_list*** are optional
  - If ***structure_tag*** is not specified, ***variable_list*** should be specified; otherwise, there is no way to declare variables using the unnamed structure type

Declaring a Structure

- Syntax of the structure type declaration:

```
struct structure_tag {
      type1 member1;
      type2 member2;
      ...
} variable_list;
```

- Structure members can be
  - Basic data types
  - Derived and user-defined types
  - *Pointers to basic, derived and user-defined data types*
  - *Function pointers*

Examples

- struct declaration that only defines a type:

```
struct student_info { // named struct
      char name [20];
      int student_id;
      int age;
}; // does not reserve any space
```

- struct declaration that defines a type **and** reserves storage for variables:

```
struct student_info { // named struct
      char name [20];
      int student_id;
      int age;
} s, t; // reserves space for s and t
```

Examples

- Declaring a variable `struct current_student`

```
struct student_info current_student;
```

- Above statement reserves space for:
  - 20 character array,
  - integer to store student ID, and
  - integer to store age

Examples

- Declaring array of structures to store information of enrolled students in a class

```
struct student_info nwen241class[250];
```

- Reserves space for 250 element array of records (structs) for students enrolled in NWEN241.

Next Lecture

- Structures
- Pointers