Week 3 Lecture 2

NWEN 241
Systems Programming

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Admin Stuff

- **Gentle reminder: Assignment #1 is due on 13 days from now (25 March 2024 23:59)**

- You should have completed the first task by now…

- If you don’t want to  don’t wait until next week to get started

Content

- Structures
- Pointers

Recap: 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.

Creating New User Defined Types

- Instead of writing `struct student_info` every time we declare a variable, we can **define** it as a new data type

```
typedef struct {
      char name [20];
      int student_id;
      int age;
} StudentInfo;
```

- This makes `StudentInfo` a new user-defined type, and you can declare a variable as follows:

```
StudentInfo current_student;
```

Initializing at Declaration (1)

- It is possible to initialize a `struct` at declaration

```
typedef struct {
      char name [20];
      int student_id;
      int age;
} StudentInfo;

StudentInfo current_student =
      { "John Doe", 12345, 18 };
```

- Order of initializer values should follow order of declaration

Initializing at Declaration (1)

- Partial initialization is also possible

```
typedef struct {
      char name [20];
      int student_id;
      int age;
} StudentInfo;

StudentInfo current_student =
      {"John Doe", 12345 };
```

- Remaining fields will be set to 0

Initializing at Declaration (2)

- It is possible to initialize certain fields of `struct` using **designated initialization**

```
typedef struct {
      char name [20];
      int student_id;
      int age;
} StudentInfo;

StudentInfo s1 = { .age = 18, .name = "John Doe" };
// or StudentInfo s1 = { age: 18, name: "John Doe" };
```

- Initialization can be in any order

New struct and Data Type

- If `struct student_info` has been previously defined, then we can create a new data type using `typedef` :

```
typedef struct student_info StudentInfo;
```

Accessing and Manipulating structs

- We can reference a component of a structure by the **direct component selection operator**, which is a **period**, e.g.

```
strcpy(student1.name, "John Smith");
student1.age = 18;
printf("%s is in age %d\n", student1.name, student1.age);
```

- The **direct component selection operator** has level 1 priority in the operator precedence
- Copying of an entire structure can be easily done by the assignment operator

```
student2 = student1;
```

Example – `struct` and `typedef` (1)

```
#include <stdio.h>
#include <string.h>

int main() {

   typedef struct student_info {
       char name[20];
       int student_id;
       int age;
   } StudentInfo;

   StudentInfo current_student;     // declare new variable using
                                    // new type StudentInfo
   struct student_info new_student; // declare using struct format

   // do stuff – see next slide
```

Example – `struct` and `typedef` (2)

```
    // declarations in previous slide

    // initialize new student record
    strcpy(new_student.name , "John Smith");
    new_student.student_id = 300300300;
    new_student.age = 22;

    // copy new_student to current_student
    current_student = new_student;

    printf("Student name : %s\n", current_student.name);
    printf("Student ID   : %.9d\n", current_student.student_id);
    printf("Student Age  : %d\n", current_student.age);

}
```

Passing `struct` to Functions (1)

- Suppose there is a structure defined as follows

```
typedef struct {
      char name[20];
      double diameter;
      int moons;
      double orbit_time, rotation_time;
} planet_t;
```

Passing `struct` to Functions (2)

- When a structure variable is passed as an input argument to a function, all its component values are **copied** into the local structure variable

```
1.  /*
2.   * Displays with labels all components of a planet_t structure
3.   */
4.  void
5.  print_planet(planet_t pl) /* input - one planet structure */
6.  {
7.        printf("%s\n", pl.name);
8.        printf("  Equatorial diameter: %.0f km\n", pl.diameter);
9.        printf("  Number of moons: %d\n", pl.moons);
10.       printf("  Time to complete one orbit of the sun: %.2f years\n",
11.              pl.orbit_time);
12.       printf("  Time to complete one rotation on axis: %.4f hours\n",
13.              pl.rotation_time);
14. }
```

Passing `struct` to Functions (3)

- Passing entire copy of a structure can be inefficient, especially for large structs

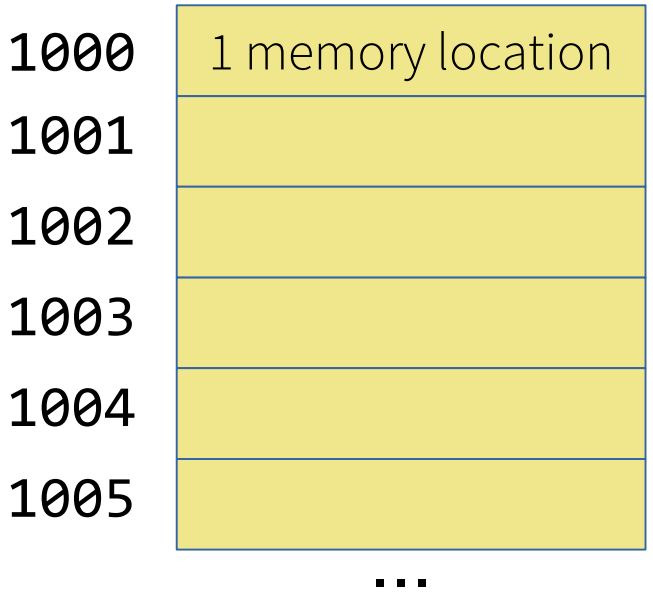
- There is a better way to pass structs to functions using pointers
  - To be discussed later

Pointers

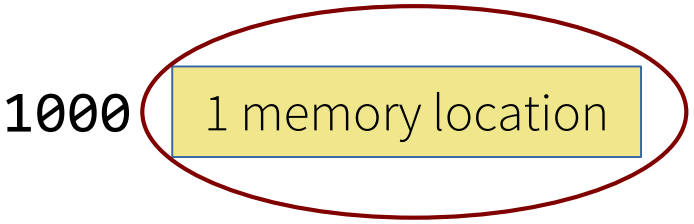
Memory Location

- All information accessible to a running computer program are stored somewhere in the computer's memory

Every *memory location* is identified by an **address**



Memory Location



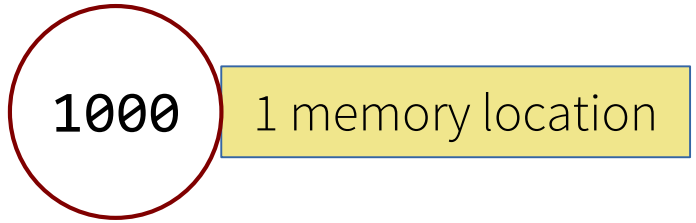
- How big is 1 memory location?
  - It depends on the computer memory architecture

Word-addressable architecture:
- Every memory location corresponds to one *word*

Byte-addressable architecture:
- Every memory location corresponds to one *byte*

Most computers today have byte-addressable memory

Memory Location



- How big is the address?
  - It depends on the number of bits used by CPU for addressing
- Example:
  - In a computer that uses 32 bits for addressing, an address has 32 bits
  - If the computer has byte-addressable memory, then the memory space is 2^{32} bytes = 4 gigabytes

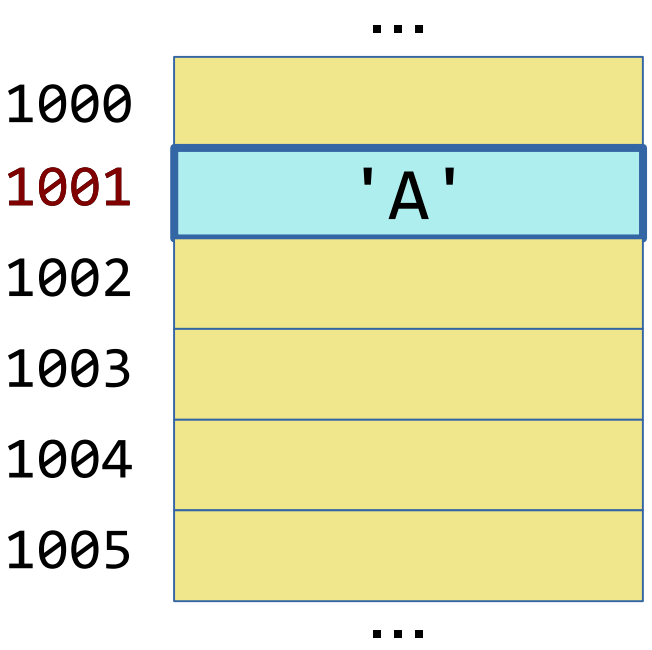
Memory Location and Variables

- A variable declaration allocates memory to store the value of the variable

```
char c = 'A';
```

Memory location 1001 contains value of variable c

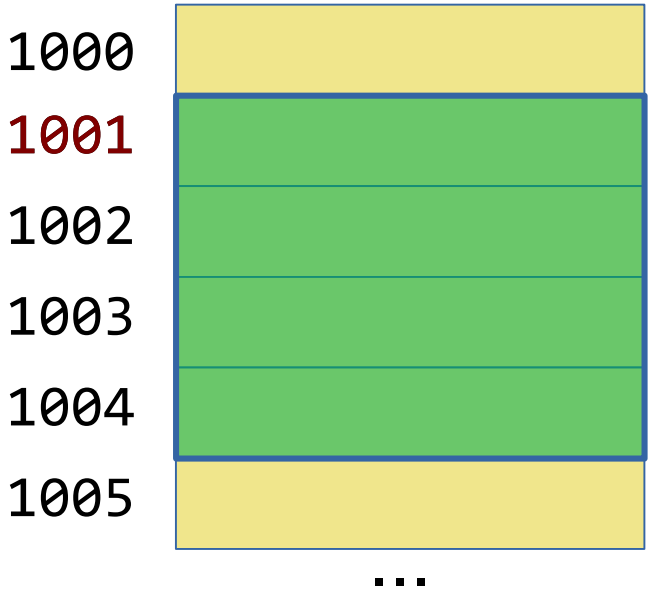
A variable directly references a value



Memory Location and Variables

- In a byte-addressable computer, how do we address a data that occupies more than 1 byte, *e.g.*, int, float or double?

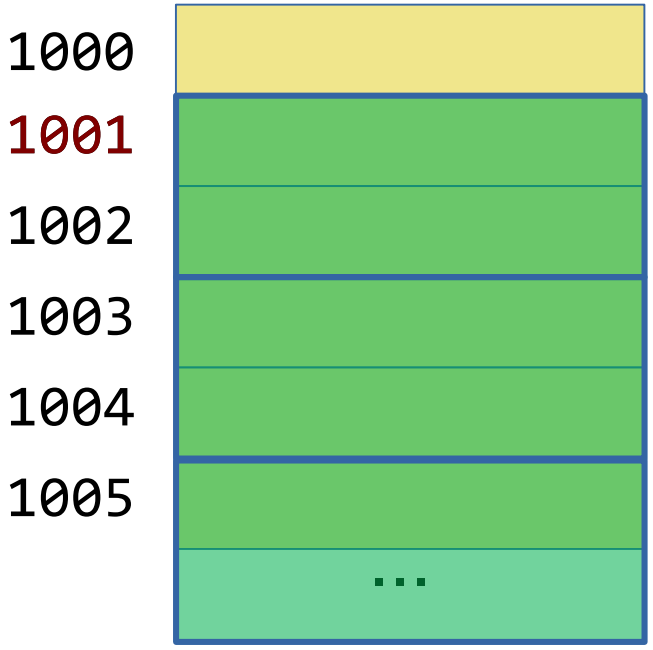
The address of a multi-byte data is the **starting address**



Memory Location and Variables

- In a byte-addressable computer, how do we address arrays?

The address of an array is the **starting address of the first element**



Memory Location and C

- C provides the ability to access specific memory locations, using **pointers**

Pointers are variables that contain memory addresses as their values

Variable vs Pointer

A variable directly references a value

A pointer indirectly references a value

Next Lecture

- More Pointers