CSE 230
Intermediate Programming in C and C++
Structures
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Stony Brook University
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Introduction

- In C, you can define data types that are constructed from the fundamental types.
  - For example, an array type is an example of this; it is a derived type that is used to represent homogeneous data.

- In contrast, the structure type is used to represent heterogeneous data.
  - A structure has components, called members, that are individually named. Because the members of a structure can be of various types, the programmer can create aggregates of data that are suitable for a particular application.
Structures

■ Provides a means to aggregate variables of different types

■ Example: A structure to define a playing card
  – The spots on a card that represent its numeric value are called "pips." A playing card such as the three of spades has a pip value, 3, and a suit value, spades.

  ```c
  struct card {
    int pips;
    char suit;
  };
  ```

  (i) **struct is a keyword**, (ii) **card is the structure tag name**, and (iii) the variables **pips and suit** are members of the structure.

■ The variable **pips** will take values from 1 to 13, representing ace to king; the variable **suit** will take values from ‘c’, ‘d’, ‘h’, and ‘s’, representing the suits clubs, diamonds, hearts, and spades, respectively.
The declaration can be thought of as a template; it creates the `struct card`, but no storage is allocated.

The tag name, along with the keyword `struct`, can now be used to declare variables of this type.

```c
struct card c1, c2;
```

This declaration allocates storage for the identifiers `c1` and `c2`, which are of `struct card`.

To access the members of a structure, member access operator “.” is used.

```c
c1.pips = 3;
c1.suit = 's';
```

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Structure (cont.)

■ If we want \( c_2 \) to represent the same playing card as \( c_1 \), \( c_2 = c_1; \)
  - This causes each member of \( c_2 \) to be assigned the value of the corresponding member of \( c_1 \).

■ Programmers commonly use the `typedef` mechanism when using structure types.

```
typedef struct card card;
```

■ Now, if we want more variables to represent playing cards,

```
card c3, c4, c5;
```
Structure Member Naming

- Within a given structure, the member names must be unique.
  - However, members in different structures are allowed to have the same name. This does not create confusion because a member is always accessed through a structure identifier.

```c
struct fruit {
    char *name;
    int calories;
};

struct vegetable {
    char *name;
    int calories;
};

struct fruit a;
struct vegetable b;
```

- You can access `a.calories` and `b.calories` without ambiguity
Structure Declaration

- Structure declaration ::= struct_specifier declarator_list;
- Struct_specifier ::= struct tag_name
  I struct tag_name opt { { member_declaration} 1+ }
- tag_name ::= identifier
- member_declaratiion ::= type_specifier declarator_list
- declarator_list ::= declarator { , declarator } 0+
Structures (cont.)

- Structures can be complicated.
  - They can contain members that are themselves arrays or structures
  - we can have arrays of structures

```c
struct card {
    int pips;
    char suit;
} deck[52];
```

- the identifier deck is declared to be an array of struct card

- If a tag name is not supplied, then the structure type cannot be used in later declarations.

- It is usually good programming practice to associate a tag name with a structure type.
Example

```c
struct {
    int day, month, year;
    char day_name[4]; /* Mon, Tue, Wed, etc. */
    char month_name[4]; /* Jan, Feb, Mar, etc. */
} yesterday, today, tomorrow;

*more variables of this type cannot be declared later.

struct date{
    int day, month, year;
    char day_name[4]; /* Mon, Tue, Wed, etc. */
    char month_name[4]; /* Jan, Feb, Mar, etc. */
} yesterday, today, tomorrow;

struct date yesterday, today, tomorrow;
```
Structures (cont.)

- When using `typedef` to name a structure type, the tag name may be unimportant.

```c
typedef struct{
    float re;
    float im;
} complex;
complex a, b, c[100];
```

- The type `complex` now serves in place of the structure type. The programmer achieves a high degree of modularity and portability by using `typedef` to name such derived types and by storing them in header files.
Accessing Members of a Structure

■ Member access operators: “.” and “->”

In file class_info.h
#define CLASS_SIZE 100
struct student {
    char *last_name;
    int student_id;
    char grade;
} ;

#include "class_info.h"
int main(void) {
    struct student tmp, class[CLASS_SIZE];
    ... ...
    tmp.grade = 'A'; tmp.lastname = "john";
    tmp.student_id = 910017;

Suppose we are writing a program called class_info, which generates information about a class of 100 students.
Accessing Members of a Structure

- Now suppose we want to count the number of failing students in a given class.
  - To do this, we write a function named `fail()` that counts the number of F grades in the array `class[]`.
- The grade member of each element in the array of structures must be accessed.

```c
/* Count the failing grades. */
#include "class_info.h"
int fail(struct student class[])
{
    int i, cnt = 0;
    for (i = 0; i < CLASS_SIZE; ++i)
    {
        cnt += class[i].grade == 'F';
    }
    return cnt;
}
```
Accessing Members of a Structure

- C provides the member access operator \( \text{->} \) to access the members of a structure via a pointer.
  - This operator is typed on the keyboard as a minus sign followed by a greater than sign.
  - If a pointer variable is assigned the address of a structure, then a member of the structure can be accessed by a construct of the form \( \text{pointer_to_structure} \text{-> member_name} \)

- A construct that is equivalent to the above is \( (*\text{pointer_to_structure})\text{.member_name} \)

- The parentheses are necessary. Along with ( ) and [ ], the operators “.” and -> have the highest precedence and associate from left to right.
  - Thus, the preceding construct without parentheses would be equivalent to \( *(\text{pointer_to_structure. member_name}) \)
  - This is an error because only a structure can be used with the "." operator, not a pointer to a structure.
Example: add complex numbers

In file complex.h

```c
struct complex {
    double re; /* real part */
    double im; /* imag part */
};
typedef struct complex complex;
```

In file 2_add.c

```c
#include <complex.h>
/* a = b + c */
void add(complex *a, complex *b, complex *c) {
    a->re = b->re + c->re;
    a->im = b->im + c->im;
}
```
### Example: Member Access

#### Declaration and Assignment

```c
struct student tmp, *p = &tmp;
tmp.grade = 'A';
tmp.last_name = "Casanova";
tmp.student_id = 910017;
```

<table>
<thead>
<tr>
<th>Expression</th>
<th>Equivalent Expression</th>
<th>Conceptual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>tmp.grade</td>
<td>p-&gt;grade</td>
<td>A</td>
</tr>
<tr>
<td>tmp.last_name</td>
<td>p-&gt;last_name</td>
<td>Casanova</td>
</tr>
<tr>
<td>(*p).student_id</td>
<td>p-&gt;student_id</td>
<td>910017</td>
</tr>
<tr>
<td>*p-&gt;last_name+1</td>
<td>(*p-&gt;last_name)+1</td>
<td>D</td>
</tr>
<tr>
<td>*(p-&gt;last_name + 2)</td>
<td>(p-&gt;last_name)[2]</td>
<td>s</td>
</tr>
</tbody>
</table>
Using Structures with Functions

- Structures can be passed as **arguments** to a function and can be **returned** from them.

- When a structure is passed as an argument to a function, it is passed by value, meaning that a local copy is made for use in the body.
  - If a member of the structure is an array, then the array gets copied as well.
  - If the structure has many members, or members that are large arrays, then passing the structure as an argument can be relatively inefficient.

- An alternate scheme is to write functions that take an address of the structure as an argument instead.
Example: Business Application

define struct {
    char name[25];
    int employee_id;
    struct dept department;
    struct home_address *a_ptr;
    double salary;
} employee_data;

struct dept {
    char dept_name[25];
    int dep_no;
};

the compiler has to know the size of each member

Structure type member

the compiler already knows the size of a pointer, this structure need not be defined first.

Pointer to a Structure
Example: Business Application

- Function to update employee information

```c
employee_data update(employee_data e)
{
    printf("Input the department number: ");
    scanf("%d", &n);
    e.department.dept_no = n;
    return e;
}
```

- we are accessing a member of a structure within a structure
  
  `e.department.dept_no` is equivalent to
  
  `(e.department).dept_no`

- To use the function `update()`, we could write in `main()` or in some other function

```c
employee_data e;
```

```c
e = update(e);
```
Copy Problem

```c
employee_data update(employee_data e)
{
    printf(“Input the department number: “);
    scanf(“%d”, &n);
    e.department.dept_no = n;
    return e;
}

employee_data e;

e = update(e);
```

- `e` is being passed by value, causing a local copy of `e` to be used in the body of the function; when a structure is returned from `update()`, it is assigned to `e`, causing a member-by-member copy to be performed. Because the structure is large, the compiler must do a lot of copy work.
Alternate: Update Function

```c
void update(employee_data *p)
{
    printf("Input the department number: ");
    scanf("%d", &n);
    p->department.dept_no = n;
}
```

`p->department.dept_no` is equivalent to `(p->department).dept_no`

This version of `update()` can be used in `main()` as follows:

```c
employee_data e;
update(&e);
```

- Here, the address of `e` is being passed, so no local copy of the structure is needed within the `update()` function. For most applications this is the more efficient of the two methods.

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Initialization of Structures

If not explicitly initialized by the programmer structures are automatically initialized by the system to zero. Structure initialization is similar to array.

card c = {13, 'h'}; /* the king of hearts */
complex a[3][3] = {
  {{1.0, -0.1}, {2.0, 0.2}, {3.0, 0.3}},
  {{4.0, -0.4}, {5.0, 0.5}, {6.0, 0.6}},
}; /* a[2][] is assigned zeroes */
struct fruit frt = {"plum", 150};
struct home_address {
  char *street;
  char *city_and_state;
  long zip_code;
} address = {"87 West Street", "Aspen, Colorado", 80526};
struct home_address previous_address = {0};

The last example illustrates a convenient way to initialize all members of a structure to have value zero. It causes pointer members to be initialized with the pointer value NULL and array members to have their elements initialized to zero.
An Example: Playing Poker

- The program will compute the probability that a flush is dealt, meaning that all five cards in a hand are of the same suit.

In file poker.c

```c
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

#define NDEALS 3000 /* number of deals */
#define NPLAYERS 6   /* number of players */

typedef enum {clubs, diamonds, hearts, spades} cdhs;

struct card {
    int pips;
    cdhs suit;
};

typedef struct card card;
```
An Example: Playing Poker

card assign_values(int pips, cdhs suit);
void prn_card_values(card *c_ptr);
void play_poker(card deck[52]);
void shuffle(card deck[52]);
void swap(card *p, card *q);
void deal_the_cards(card deck[52], card hand[NPLAYERS][5]);
int is_flush(card h[5]);
An Example: Playing Poker

```c
int main(void)
{
    cdhs suit;
    int i, pips;
    card deck[52];

    for (i = 0; i < 52; ++i) {
        pips = i % 13 + 1;
        if (i < 13)
            suit = clubs;
        else if (i < 26)
            suit = diamonds;
        else if (i < 39)
            suit = hearts;
        else
            suit = spades;
        deck[i] = assign_values(pips, suit);
    }
    for (i = 26; i < 39; ++i) /* print out the hearts */
        prn_card_values(&deck[i]);
    play_poker(deck);
    return 0;
}
```
An Example: Playing Poker

card assign_values(int pips, cdhs suit)
{
    card c;
    c.pips = pips;
    c.suit = suit;
    return c;
}

void prn_card_values(card *c_ptr)
{
    int pips = c_ptr -> pips;
    cdhs suit = c_ptr -> suit;
    char *suit_name;

    if (suit == clubs)
        suit_name = "clubs";
    else if (suit == diamonds)
        suit_name = "diamonds";
    else if (suit == hearts)
        suit_name = "hearts";
    else if (suit == spades)
        suit_name = "spades";
    printf("card: %2d of %s\n", pips, suit_name);
}
void play_poker(card deck[52])
{
    int    flush_cnt = 0, hand_cnt = 0;
    int    i, j;
    card   hand[NPLAYERS][5];  /* each player dealt 5 cards */

    srand(time(NULL));  /* seed random-number generator */
    for (i = 0; i < NDEALS; ++i) {
        shuffle(deck);
        deal_the_cards(deck, hand);
        for (j = 0; j < NPLAYERS; ++j) {
            ++hand_cnt;
            if (is_flush(hand[j])) {
                ++flush_cnt;
                printf("%s%d\n%s%d\n%s%f\n\n",
                        "Hand number: ", hand_cnt,
                        "Flush number: ", flush_cnt,
                        "Flush probability: ",
                        (double) flush_cnt / hand_cnt);
            }
        }
    }
}
An Example: Playing Poker

```c
void shuffle(card deck[52])
{
    int i, j;

    for (i = 0; i < 52; ++i)
        j = rand() % 52;
    swap(&deck[i], &deck[j]);
}

void swap(card *p, card *q)
{
    card tmp;

    tmp = *p;
    *p = *q;
    *q = tmp;
}

void deal_the_cards(card deck[52], card hand[NPLAYERS][5])
{
    int card_cnt = 0, i, j;

    for (j = 0; j < 5; ++j)
        for (i = 0; i < NPLAYERS; ++i)
            hand[i][j] = deck[card_cnt++];
}

int is_flush(card h[5])
{
    int i;

    for (i = 1; i < 5; ++i)
        if (h[i].suit != h[0].suit)
            return 0;
    return 1;
}
```