Structures, Unions, and Enumerations

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CS246 Programming Paradigm

Structure

- Structures group multiple (heterogeneous) variables
  - The elements of a structure (its members) aren't required to have the same type.
  - The members of a structure have names; to select a particular member, we specify its name, not its position.
- In some languages, structures are called records, and members are known as fields.

Structure Operations

- Structure type declaration
- Structure variable declaration
- Member assignment/reference
- Structure initialization
- Structure assignment

Structure Type (Structure Tag)

- Suppose that a program needs to declare several structure variables with identical members.
- A structure tag is a name used to identify a particular kind of structure.
- The declaration of a structure tag named `part`:

```
struct part {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
};
```

Structure tag

- Note that a semicolon must follow the right brace.

Structure Variables

- The `part` tag can be used to declare variables:

```
struct part part1, part2;
```

- We cannot drop the word `struct`:

```
part part1, part2;   /*** WRONG ***/
```

`part` isn't a type name; without the word `struct`, it is meaningless.

- Since structure tags aren't recognized unless preceded by the word `struct`, they don't conflict with other names used in a program.

Declaring a Structure Tag

- The declaration of a structure **tag** can be combined with the declaration of structure **variables**:

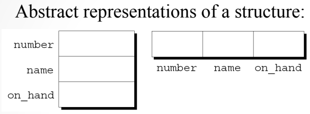
```
struct part {
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1, part2;
```

- All structures declared to have type `struct part` are compatible with one another:

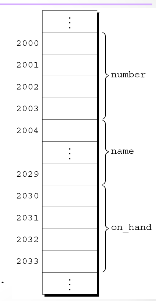
```
struct part part1 = {528, "Disk drive", 10};
struct part part2;

part2 = part1;
  /* legal; both parts have the same type */
```

Structure Representation

- Abstract representations of a structure:



- Appearance of `part1` →
- Assumptions:
  - `part1` is located at address 2000.
  - Integers occupy four bytes.
  - `NAME_LEN` has the value 25.
  - There are no gaps between the members.



Type Definition

- The `#define` directive can be used to create a "Boolean type" macro:

```
#define BOOL int
```

- A better way to define a synonym for existing (complicated) types is to use type definition:

```
typedef int Bool;
typedef int* Intptr;
```

- Array and pointer types cannot be defined as macros.
- `typedef` names are subject to the same scope rules as variables.

`typedef` and Structures

- Instead of

```
struct part part1;
```

use

```
typedef struct part Part;
```

then

```
Part part1;
```

- `Part` is a new user-defined type and can be used in the same way as the built-in types.
- **`typedef`**ed type names by convention have the first letter in uppercase.

Structure Variable Declaration

```
struct part {
    int number;
    char name[NAME_LEN+1];
    int on_hand;
} part1, part2;

int main() {
  struct part part3;
  /* skipped */
}
```

```
typedef struct part {
    int number;
    char name[NAME_LEN+1];
    int on_hand;
} Part;

int main() {
  Part part1, part2, part3;
  /* skipped */
}
```

- When it comes time to name a structure, we can usually choose either to declare a structure tag or to use `typedef`.

Scope of Structure Variables

- Each structure represents a new scope.
- Any names declared in that scope won't conflict with other names in a program.
- In C terminology, each structure has a separate name space for its members.

```
struct part{
   int number;
   char name[NAME_LEN+1];
   int on_hand;
 } part1, part2;

 struct employee{
   char name[NAME_LEN+1];
   int number;
   char sex;
 } employee1, employee2;
```

Initializing Structure Variables

- A structure declaration may include an initializer:

```
struct part{
  int number;
  char name[NAME_LEN+1];
  int on_hand;
} part1 = {528, "Disk drive", 10},
  part2 = {914, "Printer cable", 5};
```

- Appearance of `part1` after initialization:

number	528
name	Disk drive
on_hand	10

Initializing Structure Variables

- Structure initializers follow rules similar to those for array initializers.
- An initializer can have fewer members than the structure it's initializing.
- Any "leftover" members are given 0 as their initial value.
- Like array initializations, this only works at the time of declaration.
- Afterwards you must assign/initialize each member one by one.

Member Reference/Assignment

- To access a member within a structure, we write
  - structVar . memberName

```
printf("Part number: %d\n", part1.number);
printf("Part name: %s\n", part1.name);
printf("Quantity on hand: %d\n", part1.on_hand);
```

- The members of a structure are lvalues.
  - structVar . memberName = exp;

```
part1.number = 258;
  /* changes part1's part number */
part1.on_hand++;
  /* increments part1's quantity on hand */
```

. Operator

- The period used to access a structure member is actually a C operator.
- It takes precedence over nearly all other operators.
- Example:

```
scanf("%d", &part1.on_hand);
```

The `.` operator takes precedence over the `&` operator, so `&` computes the address of `part1.on_hand`.

Structure Assignment

- The other major structure operation is assignment:

```
part2 = part1;
```

- The effect of this statement is to copy `part1.number` into `part2.number`, `part1.name` into `part2.name`, and so on.
- Each member's value will be copied
- Arrays can't be copied using the = operator, but an array embedded within a structure is copied when the enclosing structure is copied.

```
struct { int a[10]; } a1, a2;
a1 = a2;
/* legal, since a1 and a2 are structures */
```

Structure Assignment

- The = operator can be used only with structures of compatible types.
  - Two structures declared at the same time (as part1 and part2 were) are compatible.
  - Structures declared using the same "structure tag" or the same type name are also compatible.
- Other than assignment, C provides no operations on entire structures.
- In particular, the == and != operators can't be used with structures.

Structures as Arguments

- A function with a structure argument:

```
void print_part(struct part p)
{
  printf("Part number: %d\n", p.number);
  printf("Part name: %s\n", p.name);
  printf("Quantity on hand: %d\n", p.on_hand);
}
```

- A call of `print_part`:

```
print_part(part1);
```

Structures as Return Values

- A function that returns a `part` structure:

```
struct part build_part(int number,
                       const char *name,
                       int on_hand)
{
  struct part p;
  p.number = number;
  strcpy(p.name, name);
  p.on_hand = on_hand;
  return p;
}
```

- A call of `build_part`:

```
part1 = build_part(528, "Disk drive", 10);
```

Pointer to Structure

- Passing a structure to a function and returning a structure from a function both require making a copy of all members in the structure.
- To modify the original value, pass the pointer to a structure

```
void updateNumOnHand(Part *b) {
  (*b).on_hand += 10;
}

int main() {
  Part a = initialization;
  updateNumOnHand (&a);
  return 0;
}
```

Pointer to Structure

- To deal with pointers to structure, the shorthand form is more commonly used.
- Pattern
  - StructPtrVar→member_of_structure;

```
void updateNumOnHand(Part *b) {
  b->on_hand += 10; /* same as (*b).on_hand */
}

int main() {
  Part a = initialization;
  updateNumOnHand (&a);
  return 0;
}
```

Nested Arrays and Structures

- Structures and arrays can be combined without restriction.
- Arrays may have structures as their elements, and structures may contain arrays and structures as members.

Nested Structures

- Nesting one structure inside another is often useful.

```
struct person_name {
  char first[FIRST_NAME_LEN+1];
  char middle_initial;
  char last[LAST_NAME_LEN+1];
};
struct student {
  struct person_name name;
  int id, age;
  char sex;
} student1, student2;
```

- Accessing `student1`'s first name:

```
strcpy(student1.name.first, "Fred");
```

Nested Structures

- Copying the information from a `person_name` structure to the `name` member of a student structure would take one assignment instead of three:

```
struct person_name new_name;
…
student1.name = new_name;
```

Arrays of Structures

- An array of structures can serve as a simple database.
- An array of `part` structures:

```
struct part inventory[100];
```

- Accessing a part in the array :

```
print_part(inventory[i]);
```

- Accessing a member within a `part` structure:

```
inventory[i].number = 883;
```

- Accessing a single character in a part name:

```
inventory[i].name[0] = '\0';
```

Initializing an Array of Structures

- Initializing an array of structures is done in much the same way as initializing a multidimensional array.
- Each structure has its own brace-enclosed initializer; the array initializer wraps another set of braces around the structure initializers.
- Example: an array that contains country codes used when making international telephone calls.

```
struct dialing_code {
  char *country;
  int code;
};
```

Initializing an Array of Structures

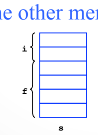
```
const struct dialing_code country_codes[] =
  {{"Argentina",            54}, {"Bangladesh",      880},
   {"Brazil",               55}, {"Burma (Myanmar)",  95},
   {"China",                86}, {"Colombia",         57},
   {"Congo, Dem. Rep. of", 243}, {"Egypt",            20},
   {"Ethiopia",            251}, {"France",           33},
   {"Germany",              49}, {"India",            91},
   {"Indonesia",            62}, {"Iran",             98},
   {"Italy",                39}, {"Japan",            81},
   {"Mexico",               52}, {"Nigeria",         234},
   {"Pakistan",             92}, {"Philippines",      63},
   {"Poland",               48}, {"Russia",            7},
   {"South Africa",         27}, {"South Korea",      82},
   {"Spain",                34}, {"Sudan",           249},
   {"Thailand",             66}, {"Turkey",           90},
   {"Ukraine",             380}, {"United Kingdom",   44},
   {"United States",         1}, {"Vietnam",          84}};
```

- The inner braces around each structure value are optional.

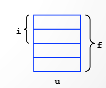
Unions

- A union, like a structure, consists of one or more members, possibly of different types.
- The compiler allocates only enough space for the largest of the members, which overlay each other within this space.
- Assigning a new value to one member alters the values of the other members as well.

```
struct {
  int i;
  float f;
} s;
```



```
union {
  int i;
  float f;
} u;
```



Unions – Member Access

- Members of a union are accessed in the same way as members of a structure:

```
u.i = 82;
u.d = 74.8;
```

- Changing one member of a union alters any value previously stored in any of the other members.
  - Storing a value in `u.d` causes any value previously stored in `u.i` to be lost.
  - Changing `u.i` corrupts `u.d`.

Unions

- The properties of unions are almost identical to the properties of structures.
- We can declare union tags and union types in the same way we declare structure tags and types.
- Like structures, unions can be copied using the = operator, passed to functions, and returned by functions.

Initializing Unions

- Only the first member of a union can be given an initial value.
- How to initialize the `i` member of `u` to 0:

```
union {
  int i;
  double d;
} u = {0};
```

Using Unions to Save Space

```
struct catalog_item {
  int stock_number;
  double price;
  int item_type;
  union {
    struct {
      char title[TITLE_LEN+1];
      char author[AUTHOR_LEN+1];
      int num_pages;
    } book;
    struct {
      char design[DESIGN_LEN+1];
    } mug;
    struct {
      char design[DESIGN_LEN+1];
      int colors;
      int sizes;
    } shirt;
  } item;
};
```

Using Unions to Save Space

- If `c` is a `catalog_item` structure that represents a book, we can print the book's title in the following way:

```
printf("%s", c.item.book.title);
```

- As this example shows, accessing a union that's nested inside a structure can be awkward.

Unions Usage

- Mixed types

```
typedef union{
  int i;
  float f;
} Number;
```

```
Number a[100];
a[0].i = 5;
a[1].f = 5.5;
```

- Tag field

```
typedef struct {
  int type;
  union{
    int i;
    float f;
  } u;
} Number;
```

```
void print(Number n){
  switch(n.type) {
    case(INTEGER):
      printf("%d", n.u.i);
    case(FLOAT):
      printf("%f", n.u.f);
  }
}
```

Enumerations

- A special type in C whose values are enumerated by the programmer
- A way to group a set of related **`#define`**s.

```
#define SUIT int
#define CLUB 0
#define DIAMOND 1
#define HEART 2
#define SPADE 3
```

```
enum {CLUB, DIAMOND, HEART, SPADE};
```

```
enum SUIT {CLUB, DIAMOND, HEART, SPADE};
SUIT s1 = HEART, s2;
```

```
typedef enum {CLUB,DIAMOND,HEART,SPADE} Suit;
```

```
typedef enum {FALSE, TRUE} Bool;
```

- If unspecified, **`enum`**s by default start from **`0`** and increment by **`1`**

Enumerations

- All **`enum`**s are integers.
- More flexible **`enum`**
  - Specify values: `enum REDSUIT {HEART=10, DIAMOND=1};`
  - If no value specified, value is **`1`** greater than the previous constant (first constant is by default **`0`**):

```
enum EGA {BLACK,LTGRAY=7,DKGRAY,WHITE=15};
```

- C allows mixing **`enum`** and **`int`**

```
enum {CLUB,DIAMOND,HEART,SPADE} s;
int i = DIAMOND; // i is 1
s = 2; // s is HEART
i++; // i is HEART
```

Enumerations

- The names of enumeration constants must be different from other identifiers declared in the enclosing scope.
- Enumeration constants are similar to constants created with the `#define` directive, but they're not equivalent.
- If an enumeration is declared inside a function, its constants won't be visible outside the function.

Enumeration Tags and Type Names

- As with structures and unions, to name an enumeration:
  - by declaring a tag
  - by using `typedef` to create a genuine type name.
- Enumeration tags :

```
enum suit {CLUBS, DIAMONDS, HEARTS, SPADES};
enum suit s1, s2;
```

- Use `typedef` to make Suit a type name:

```
typedef enum {CLUBS, DIAMONDS, HEARTS, SPADES} Suit;
Suit s1, s2;
typedef enum {FALSE, TRUE} Bool;
```

Enumerations as Integers

- Enumeration values can be mixed with ordinary integers:

```
int i;
enum {CLUBS, DIAMONDS, HEARTS, SPADES} s;

i = DIAMONDS;   /* i is now 1            */
s = 0;          /* s is now 0 (CLUBS)    */
s++;            /* s is now 1 (DIAMONDS) */
i = s + 2;      /* i is now 3            */
```

- `s` is treated as a variable of some integer type.
- `CLUBS`, `DIAMONDS`, `HEARTS`, and `SPADES` are names for the integers 0, 1, 2, and 3.

Enumerations as Integers

- It's dangerous to use an integer as an enumeration value.
- For example, we might accidentally store the number 4—which doesn't correspond to any suit—into `s`.

Using Enumerations to Declare "Tag Fields"

- Enumerations are perfect for determining which member of a union was the last to be assigned a value.
- In the `Number` structure, we can make the `kind` member an enumeration instead of an `int`:

```
typedef struct {
  enum {INT_KIND, DOUBLE_KIND} kind;
  union {
    int i;
    double d;
  } u;
} Number;
```

Using Enumerations to Declare "Tag Fields"

- The new structure is used in exactly the same way as the old one.
- Advantages of the new structure:
  - Does away with the `INT_KIND` and `DOUBLE_KIND` macros
  - Makes it obvious that `kind` has only two possible values: `INT_KIND` and `DOUBLE_KIND`