Structs, Unions, and Enums

CS449 Spring 2016

Data Type Review

- We already learned…
  - Primitive data types:
    - char, int, long, float, double…
  - Derived data types:
    - pointers, arrays, functions…
- Today we will learn two new derived types
  - Structs
  - Unions
- And one "syntactic sugar" data type
  - Enums

Structs

- **Struct**: A derived type for a collection of related variables under one name
  - Much like classes in Java with no methods
  - Members can be primitives or derived types
- Useful for…
  - Readability of code through conceptual grouping
  - File I/O of fixed length records into structs
  - Designing recursive data structures (e.g. linked lists, trees, graphs) using pointers

Struct Example

```
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point *ppnt) {
  printf("pnt=(%d, %d)\n", ppnt->x, ppnt->y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(&pnt);
  return 0;
}
```

```
>> ./a.out
pnt=(10, 20)
```

Struct Type Declaration

```
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point *ppnt) {
  printf("pnt=(%d, %d)\n", ppnt->x, ppnt->y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(&pnt);
  return 0;
}
```

- This declares a type “struct Point”
  - Similar to a class declaration in Java
- The struct has two *members* “x” and “y”
- Note: no new variables (storage locations) have been declared yet
  - “x” and “y” are not storage locations

Struct Variable Declaration

```
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point *ppnt) {
  printf("pnt=(%d, %d)\n", ppnt->x, ppnt->y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(&pnt);
  return 0;
}
```

- This declares a variable "pnt" of type "struct Point"

We can also combine type declaration with variable declaration, but in this case the type declaration and variable declaration will be in the same scope:

Example:

```
struct Point {
    int x;
    int y;
} pnt, pnt2, *ppnt;
```

Operations on Structs

```
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point *ppnt) {
  printf("pnt=(%d, %d)\n", ppnt->x, ppnt->y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(&pnt);
  return 0;
}
```

- Four valid operations on structs
  - The sizeof operator
  - The reference (&) operator
  - Accessing member variables
    - “.” (dot) operator (When accessed through struct var)
    - “->” (arrow) operator (When accessed through pointer to struct var)
  - The assignment (=) operator (e.g. struct Point x, y; x = y;)
- Recall: arrays were allowed sizeof, &, and [] operators but did not allow assign
- Passing structs to functions
  - By pointer (copy just the pointer)
  - By value (copy the entire struct)

Struct Initialization

```
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point *ppnt) {
  printf("pnt=(%d, %d)\n", ppnt->x, ppnt->y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(&pnt);
  return 0;
}
```

- Good habit to initialize all structs just like any variable
- Three ways to initialize
  - Initialize members one by one
  - Through assigning to another struct
  - Through struct initializer (e.g. struct Point pnt = {10, 20};)
- Struct initializers can only be used at variable declaration time, just like array initializers

Recursive Member Definitions

- Can structs have members of their own type?

```
struct A {
  int x;
  struct A y;
};
```

It is Illegal! (Think of what the size of struct A would be.)

- Can structs have members of *pointers* to own type?

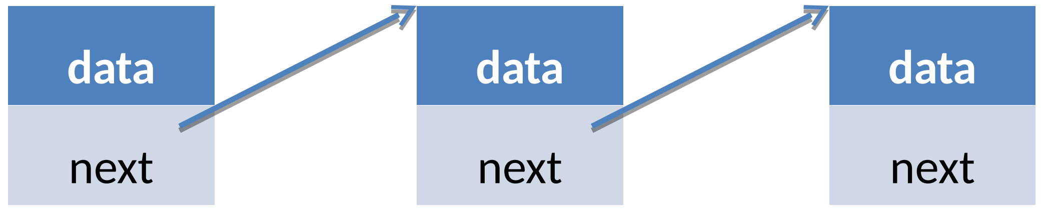
```
struct A {
  int x;
  struct A* y;
};
```

It is legal! (Now think of what the size of struct A would be.)

Recursive Data Structures

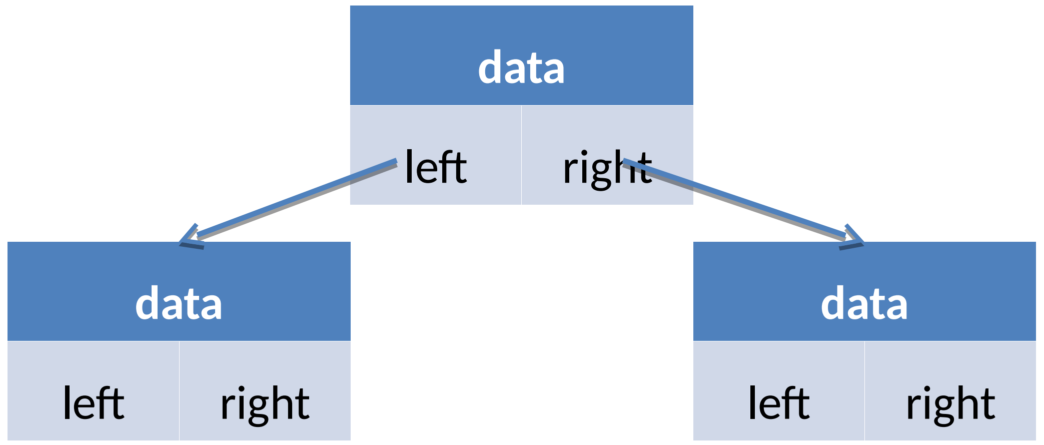
- **Linked List:**

```
struct Node {
  int data;
  struct Node *next;
};
```



- **Binary Tree:**

```
struct Node {
  int data;
  struct Node *left;
  struct Node *right;
};
```



Mysterious Sizeof Struct Example

```
#include <stdio.h>
int main (int argc, char *argv[])
{
  struct {
    char x;
    long long y;
  } A;
  printf("sizeof(A)=%d\n", sizeof(A));
  return 0;
}
```

```
>> ./a.out
sizeof(A)=16
```

- Why 16? Why not 9 (1 + 8)?
- Because the address of “y” needs to be *aligned*

Inefficiency of Word-Spanning Accesses

- Word: (largest) unit of data that can be accessed in a single memory operation
  - What it means to be a “32-bit” or “64-bit” system
  - Usually, size of word == register size
    - Efficient to load/store register in a single operation
- Problem: what if an access spans multiple words (lands on the boundary between two words)?
  - Would result in two memory accesses
    - Imagine patching together a value from two accesses
    - Imagine accesses to two different cache lines, pages etc

Alignment and Word Accesses

- n-byte aligned: address is n-byte aligned
  - if it is a multiple of n
- aligned (access): access is aligned
  - if address is n-byte aligned
  - if datum is n bytes long (where n is a power of 2)
  - then, aligned accesses never span words,
    if n <= word size

Alignment and Word Accesses

- aligned (primitive pointer): pointer *p* is aligned
  - if *p* points to a base type of n bytes
  - if *p* always points to an n-byte aligned address
  - then, accesses to *p* must be all aligned accesses

- aligned (aggregate pointer): pointer *p* is aligned
  - if pointer to each primitive member is aligned (even after performing pointer arithmetic on *p*)
  - For array: only requires first element to be aligned
  - For struct: more complicated (members differ in size)

Padding to Enforce Struct Alignment

```
struct {
  char x;
  long long y;
} A;
```

➔

```
struct {
  char x;
  char padding[7];
  long long y;
} A;
```

```
struct {
  long long y;
  char x;
} A;
```

➔

```
struct {
  long long y;
  char x;
  char padding[7];
} A;
```

- Compiler inserts padding to prevent misaligned accesses (Even when A is used in an array, hence 2nd case)
- Different compilers may produce different padding
  - ➔ Must be careful when writing/reading file using struct

Unions

- Union: A derived type for a variable that can store values of different data types
  - Syntax is exactly the same as structs
  - Members can be primitive or derived types
  - Each member begins at the same memory location (Members share space)
  - Update of member overwrites shared space
  - Only members last written to can be read
- Useful for…
  - Declaring storage space used for multiple purposes (e.g. storing a string, int, and float at different times)
  - Saves storage space

Union Example

```
#include <stdio.h>
#include <string.h>
union Number {
  int num;
  char str[100];
};
int main (int argc, char *argv[])
{
  union Number number;
  number.num = 5;
  printf("%d\n", number.num);
  strcpy(number.str, "Five");
  printf("%s\n", number.str);
  printf("%d\n", number.num);
  return 0;
}
```

```
>> ./a.out
5
Five
1702259014
```

Sizeof Union

```
#include <stdio.h>
union Number {
  int num;
  char str[100];
};
int main (int argc, char *argv[])
{
  printf("sizeof(union Number)=%d\n", sizeof(union Number));
  return 0;
}
```

```
>> ./a.out
sizeof(union Number)=100
```

- Size of union is at least as large as the largest member.

Enums

- Enumeration: data type consisting of a set of named values called enumerators. E.g.:
  - enum Suit {Spades, Diamonds, Clubs, Hearts} suit;
- In C, an enum is an alias for an integer type (size depends on compiler)
- Enumerators are aliases for integer constants
- Above variable declaration equivalent to:

int suit;

const int Spades = 0;

const int Diamonds = 1;

const int Clubs = 2;

const int Hearts =3;

- Can assign integer values to enumerators
  - enum Suit {Spades = 1, Diamonds, Clubs, Hearts}
  - enum Suit {Spades = 1, Diamonds = 2, Clubs = 4, Hearts = 8}

Enum Example

```
#include <stdio.h>
int main (int argc, char *argv[])
{
  enum Suit {Spades=1, Diamonds, Clubs, Hearts};
  enum Suit suit;
  for(suit = Spades; suit <= Hearts; ++suit) {
    printf("suit=%d\n", suit);
  }
  printf("Hearts=%d\n", Hearts);
  return 0;
}
```

```
>> ./a.out
suit=1
suit=2
suit=3
suit=4
Hearts=4
```

Operations on Enums

```
#include <stdio.h>
int main (int argc, char *argv[])
{
  enum Suit {Spades=1, Diamonds, Clubs, Hearts};
  enum Suit suit;
  for(suit = Spades; suit <= Hearts; ++suit) {
    printf("suit=%d\n", suit);
  }
  printf("Hearts=%d\n", Hearts);
  return 0;
}
```

- Since enum is really an integer, any arithmetic operation is permitted
- However, only comparison and increment/decrement operators make sense semantically

Operations on Enumerators

```
#include <stdio.h>
int main (int argc, char *argv[])
{
  enum Suit {Spades=1, Diamonds, Clubs, Hearts};
  enum Suit suit;
  for(suit = Spades; suit <= Hearts; ++suit) {
    printf("suit=%d\n", suit);
  }
  printf("Hearts=%d\n", Hearts);
  return 0;
}
```

- Since an enumerator is really a integer constant, any arithmetic operation or assignment to integer variables
- However, only meant to be used in relation to the original enum type

Operations on Enums

```
#include <stdio.h>
int main (int argc, char *argv[])
{
  enum Suit {Spades=1, Diamonds, Clubs, Hearts};
  enum Suit suit;
  for(suit = Spades; suit <= Hearts; ++suit) {
    printf("suit=%d\n", suit);
  }
  printf("Hearts=%d\n", Hearts);
  return 0;
}
```

- Since enum is really an integer, any arithmetic operation is permitted
- However, only comparison and increment/decrement operators make sense semantically

Review Question 1

What is wrong with the following code?

```
#include<stdio.h>
#include<string.h>
void modify(struct emp*);
struct emp
{
    char name[20];
    int age;
};
int main()
{
    struct emp e = {"John", 35};
    modify(&e);
    printf("%s %d", e.name, e.age);
    return 0;
}
void modify(struct emp *p)
{
     p ->age=p->age+2;
}
```

The struct emp is mentioned in the prototype of the function modify() before declaring the structure.To solve this problem declare struct emp before the modify() prototype.

Review Question 2

What is wrong with the following code?

```
#include<stdio.h>

int main()
{
    struct emp
    {
        char n[20];
        int age;
    };
    struct emp e1 = {"Dravid",
23};
    struct emp e2 = e1;
    if(e1 == e2)
        printf("The structure
are equal");
    return 0;
}
```

Structure cannot be compared using '=='

Review Question 3

What is wrong with the following code?

```
#include<stdio.h>

int main()
{
    struct emp
    {
        char name[25];
        int age;
        float bs;
    };
    struct emp e;
    e.name = "Suresh";
    e.age = 25;
    printf("%s %d\n", e.name,
e.age);
    return 0;
}
```

Incompatible types in assignment. We cannot assign a string to a struct variable like e.name = "Suresh"; in C.

We have to use strcpy(e.name, "Suresh"); to assign a string.

Review Question 4

Was array “**a**” copied to function “**fun**”
or was it passed by its address?

```
#include<stdio.h>
void  fun(int a[],int n);
int main()
{
    int a[5]={1,2,3,4,5};
    fun(a,5);
}
void  fun(int a[],int n)
{
    int i;
    for(i=0;i<=n-1;i++)
        printf("value=%d\n",a[i]);
}
```

It was passed by its address.
Arrays cannot be passed by copy in C (directly).

Review Question 5

Was structure “**pnt**” copied to function “**print_point**” (including its fields) or was it passed by its address?

```c
#include <stdio.h>
struct Point{
  int x;
  int y;
};
void print_point(const struct Point ppnt) {
  printf("pnt=(%d, %d)\n", ppnt.x, ppnt.y);
}
int main (int argc, char *argv[])
{
  struct Point pnt;
  pnt.x = 10;
  pnt.y = 20;
  print_point(pnt);
  return 0;
}
```

It was copied.

Review Question 6

Was array “`my_array`” copied to function “**print_point**” or was it passed by its address?

```
#include <stdio.h>
struct Point{
  int stuff;
  int my_array[4];
};
void print_point(const struct Point ppnt) {
  //...
}
int main (int argc, char *argv[])
{
  struct x Point = { 8, { 1, 2, 3, 4 } };
  print_point(pnt);
  return 0;
}
```

It was copied.