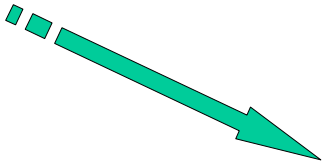
Lecture 15

Page 81 of notes

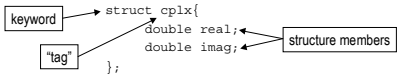


Data Structures

- One use of functions is that of procedural abstraction
  - Breaking a complicated program into smaller manageable pieces
  - This is knows as structured programming
- Programs consist of both algorithms and data and structures
- C provides a way of structuring complicated data into neat units too - the data structure

Data Structures

- A simple example is a complex number
- Complex numbers consist of
  - a real part
  - an imaginary part
- We could represent this using an array of size 2
  - double array[2]
- Or we can declare a data structure




```
struct cplx{
     double real;
     double imag;
};
```

Data Structures

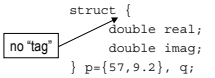
```
struct cplx{
     double real;
     double imag;
};
```

- This creates a new structured data type called `struct cplx` which we can use in a similar way to other data types (`int`, `char` etc)
- e.g. we can declare and initialise variables of this type:

```
struct cplx a, b={1.0, -5.3}, c;
```

Data Structures

- Actually the "tag" is optional (but useful) so if we want to declare a single structured variable we can omit it.
- We can also combine this with the initialisation




```
struct {
     double real;
     double imag;
} p={57,9.2}, q;
```

- However, we now cant use this structure to define further variables of the same type.

Structure Members

- The structure members can be a mixture of different data types, including simple types (`int`, `long`, `double`, etc) arrays, pointers, strings and other `structs`
- We can then refer to members using a dot notation e.g.

```
p.thing=17;     q.other=p.other/3.2;
```

(an `int`) (a `float`) (a `float`)

Structure Members

```
/* Example: using structures to represent complex numbers */

#include <stdio.h>


void main(void)
{
  struct cplx {
               double real;  /* real part */
               double imag;  /* imaginary part */
             };

  struct cplx x = {2.5, 5.0}, y = {3.2, -1.7}, z;

  z.real = x.real + y.real;  /* add real parts */
  z.imag = x.imag + y.imag;  /* add imaginary parts */

  printf("z = %4.2f + %4.2f j\n", z.real, z.imag);

  return;
}
```

complex1.c pg 81

```
z = 5.70 + 3.30 j
```

Operations on Structures

- The only legal operations on a structure are
  - accessing its members (see last slide)
  - copying or assigning to it
  - taking its address
- In the previous example we could have written `q=p`; then `q` is an individual copy of `p`
  - we don't have to copy the members of the structure individually the compiler will do this for us
- Remember that
  - calling a function by value includes copying its arguments
  - returning a value also includes a copy process
- Structures are therefore a very convenient way of passing information into and out of functions

```
/* Example: structures as function arguments and return values */

#include <stdio.h>

struct cplx {
              double real;  /* real part */
              double imag;  /* imaginary part */
            };

struct cplx add(struct cplx a, struct cplx b);  /* function prototype */


void main(void)
{
  struct cplx x = {2.5, 5.0}, y = {3.2, -1.7}, z;

  z = add(x, y);
  printf("z = %4.2f + %4.2f j\n", z.real, z.imag);
  return;
}


struct cplx add(struct cplx a, struct cplx b)
{
  struct cplx c = a;  /* can initialise an auto struct variable */

  c.real += b.real;
  c.imag += b.imag;
  return c;           /* can return a struct value */
}
```

complex2.c pg 82

```
z = 5.70 + 3.30 j
```

Scope of Structures

- The scope rules for `struct` are similar to those for variables
- A `struct` declared within a block (including function body) is visible only within that block
- A `struct` declared at the start of a program, outside any block is visible throughout the program i.e. it is global
  - This is useful where a `struct` is to be passed to functions

Pointers to Structures

- A pointer to a `struct` can be created and initialised with the & (address of operator) just as with any other type
- e.g. using the `struct cplx` previously declared

```
struct cplx x={1.0, -2.1}, y;
struct cplx* px;
px=&x;
y=*px;
(*px).real=33.5;
```

Pointers to Structures

```
(*px).real=33.5;
```

- Note that the parentheses () are necessary
- This is such a common operation that there is a special notation for it

```
(*px).real   =   px->real
```

- which means take the thing `px` points to and access its member
- Pointers allow us to use call-by-reference
  - useful because it can avoid a lot of copying if structures are large, this can slow down your program

complex3.c
pg 82

```
/* Example: pointers to structures */

#include <stdio.h>

struct cplx {
              double real;  /* real part */
              double imag;  /* imaginary part */
            };

void add(struct cplx *pa, struct cplx *pb, struct cplx *pc);


void main(void)
{
  struct cplx x = {2.5, 5.0}, y = {3.2, -1.7}, z;

  add(&x, &y, &z);  /* call by reference: pointers are passed */
  printf("z = %4.2f + %4.2f j\n", z.real, z.imag);
  return;
}


void add(struct cplx *pa, struct cplx *pb, struct cplx *pc)
{
  (*pc).real = (*pa).real + (*pb).real;  /* add real parts */
  (*pc).imag = (*pa).imag + (*pb).imag;  /* add imaginary parts */

  /* Or we could write  pc->real = pa->real + pb->real;
                        pc->imag = pa->imag + pb->imag;

  which is a shorthand notation meaning exactly the same thing. */

  return;
}
```

Arrays of Structures

- As with other data types we can have arrays which are very useful

  e.g. `struct cplx arr[35];`

stores.c
pg 83

```
/* Example: array of structures -- stores items */
#include <stdio.h>
#include <string.h>

void main(void)
{  struct {
            char part_no[7];  /* stores part number */
            char desc[40];    /* description */
            float price;      /* price each */
            int qty;          /* quantity in stock */
          } part[20];  /* array of structures */

   int total_stock;
   float total_value;

   /* assign values to structure members (in practice this would
   probably be done by reading the data from a file): */

   strcpy(part[0].part_no, "4Y4759");
   strcpy(part[0].desc, "741 OP AMP IC");
   part[0].price = 0.25;
   part[0].qty = 1738;

   strcpy(part[1].part_no, "2K6641");
   strcpy(part[1].desc, "10K OHM 5% 0.24W RESISTOR");
   part[1].price = 0.05;
   part[1].qty = 23438;

   /* access structure members: */

   total_stock = part[0].qty + part[1].qty;
   total_value = part[0].qty * part[0].price
               + part[1].qty * part[1].price;

   printf("Total stock level = %i items\n", total_stock);
   printf("Total stock value = %4.2f\n", total_value);
   return;
}
```

Structures containing Structures

- There is no reason why one structure cant contain another
- This allows us to build up complicated real-world data records step by step
- If structure1 contains structure2 which has a member x we can access it using

  `structure1.structure2.x`

students.c
pg 84

```
/* Example: building a complicated data structure, step by step */
#include <stdio.h>
/* declare structures: */
struct date {
              int d;  /* day of month, 1 to 31 */
              int m;  /* month, 1 to 12 */
              int y;  /* year, e.g. 1984 - avoids millenium bug! */
            };
struct module {
                unsigned int pc;  /* percentage mark, 0 to 100 */
                char gr;          /* letter grade, S to F */
                unsigned int cr;  /* credits awarded */
              };
struct student {
                 long urn;            /* University Reg. No. */
                 char surname[20];    /* surname */
                 char forename[30];   /* forename */
                 struct date born;    /* date of birth */
                 struct date enrol;   /* date of enrolment */
                 struct module liu10; /* programming module */
               };
void print_results(struct student a);  /* function prototype */

void main(void)
{
  /* declare and initialise structured variables: */
  struct student him = {1234567, "JEDEDIAH", "Jeremiah Methuselah",
                        {27, 3, 1974}, {3, 9, 1995}, {0, '\0', 0.}
                       };
  struct student her = {5342096, "ROBINSON", "Anne Louise",
                        {5, 11, 1978}, {1, 9, 1996}, {0, '\0', 0.}
                       };

  /* assign values to structure members: */

  him.liu10.pc = 23; him.liu10.gr = 'F'; him.liu10.cr = 0;
  her.liu10.pc = 89; her.liu10.gr = 'S'; her.liu10.cr = 10;

  /* call a function, passing structure as argument: */

  print_results(him);
  print_results(her);
  return;
}

void print_results(struct student a)
{
  printf("URN: %li -- ", a.urn);
  printf("%s %s\n", a.forename, a.surname);
  printf("  Born:     %i/%i/%i\n", a.born.d, a.born.m, a.born.y);
  printf("  Enrolled: %i/%i/%i\n", a.enrol.d, a.enrol.m, a.enrol.y);
  printf("Module LIU10: %i%%, ", a.liu10.pc);
  printf("grade %c, ", a.liu10.gr);
  printf("%i credits\n\n", a.liu10.cr);
  return;
}
```

Defining a Structural Data Type

- The `typedef` keyword allows us to use a name as a synonym for another type

  e.g.
  ```
  typedef long, urn;
  urn u, v=1234567;
  ```
  original type

  new type

- This is most useful when a structured data type is to be used widely e.g. for the complex number program

  ```
  typedef struct {
        double real;
        double imag;
  } Cplx;
  ```

```c
/* Example: using typedef to define a structure type */
/* This program is based closely on complex2.c; compare them */

#include <stdio.h>

typedef struct {
                double real;  /* real part */
                double imag;  /* imaginary part */
              }
                Cplx;

/* "Cplx" can now be used as a synonym for this struct. This neatens
things up somewhat. */

Cplx add(Cplx a, Cplx b);  /* function prototype */

void main(void)
{
  Cplx x = {2.5, 5.0}, y = {3.2, -1.7}, z;

  z = add(x, y);
  printf("z = %4.2f + %4.2f j\n", z.real, z.imag);
  return;
}


Cplx add(Cplx a, Cplx b)
{
  Cplx c = a;

  c.real += b.real;
  c.imag += b.imag;
  return c;
}
```

typedef.c
pg 85

What are the advantages of this approach ?

What are the advantages of this approach?

- Hides the complexity of the data structure
- Our user defined type can be used almost exactly the same way as any other data type
  - simpler to write
  - makes the program easier to understand
  - we can write more complex functions which perform higher level operations on structured data rather than just simple variables
- If you think of these structures as objects then you are well on the way of moving to Object Orientated Programming and C++

The FILE data type

- Remember last lecture we looked at files/streams and the use of the FILE data type
- Well FILE is actually a typedef in <stdio.h>

```c
/* Typical definition of type FILE in <stdio.h>*/

#define OPEN_MAX 32

typedef struct _iobuf {
          int cnt;          /* characters left  */
          char *ptr;        /* next character   */
          char *base;       /* start of buffer  */
          int bufsize;      /* size of buffer   */
          int flag;         /* file access mode */
          int fd;           /* file "handle"    */
} FILE;

FILE _iob[OPEN_MAX]; /* global array of FILE structs */

#define stdin (&_iob[0])      /* standard input stream */
#define stdout (&_iob[1])     /* standard output stream */
#define stderr (&_iob[2])     /* standard error stream */
```

pg 86

- Lectures 12 and 13 looked at how to use functions to structure your programs
- Today we looked at how to also structure your data
  - This was the last piece of the equation for programming C
- **You are now programmers!!!**
  - Well not really but you now know enough C to become programmers
  - The rest is up to you and it involves practice
- Next Lecture we will cover some of the revision topics you have requested, namely
  - Arrays
  - Pointers
  - Functions
- Is there anything else you would like to cover again