CSE 142 Programming I

Structures

Chapter 11

Read 11.1-11.3, 11.5, & 11.7

- 11.1: Structure types
- 11.2: Structures as parameters
- 11.3: Structures as return values
- 11.5: Arrays of structures

Optional examples; skim or read:

- 11.4: Complex numbers

Review: Data Structures

- Functions give us a way to organize programs.
- Data structures are needed to organize data, especially:
  1. large amounts of data
  2. variable amounts of data
  3. sets of data where the individual pieces are related to one another
- Arrays helped with points 1 and 2, but not with point 3
  - Example: the data describing *one* sprite: type, x, y, color
  - Example: information about one student: name, ID, GPA, etc. etc.

Structs: Heterogeneous Structures

- Collection of values of possibly differing types.
- Name the collection; name the components.
- Example: a student record collects under one name various pieces of information about a student

"harvey" -- informally, harvey consists of:

name	"Harvey S."
id	9501234
hw	87
exams	74
grade	3.1

C expressions:

- *harvey.hw* is 87
- *harvey.name* is "Harvey S."
- *2*harvey.exams* is 148

Defining *structs*

```
#define MAX_NAME  40
typedef struct {   /* typedefs go at the top of the program */
    char   name [MAX_NAME + 1] ;
    int    id ;
    int    hw, exams ;
    double  grade ;
} student_record ;
```

Defines a new data type called student_record. Does not declare (create) a variable. No storage is allocated.

Terminology

- A "*struct*" is sometimes called a "record" or "structure".
- Its "components" are often called "fields" or "members".

Structs are the basis of classes in C++ and Java. Classes are the fundamental building-blocks for object-oriented programming.

User-Defined Types

- C provides a limited set of built-in types: int, char, double (and variants of these not discussed in 142)
- Pointers introduced some new types
- Arrays further enrich the possible types available
- But... the objects in the real world and in computer applications are often more complex than these types allow
- With *structs*, we're moving toward a way for programmers to define their own types.
  - More about this in 143 and beyond

Declaring *struct* Variables

```
… /*typedef students_record goes at top of program */
…
int     i1 ;          /* int decls. and initializers */
int     count = 0 ; /*nothing new */
char    c1[5] ;       /*array decls.  */

student_record   s1 ;
student_record   harvey ;

/*student_record is a type; s1 and harvey are variables. */
```


Things You Can and Can't Do

- You can
  use = to assign whole *struct* variables
- You can
  have a *struct* as a function return type
- You can't
  use == to directly compare *struct* variables; can compare fields directly
- You can't
  directly *scanf* or *printf* structs; can read the individual fields

struct initializers

```
… /*typedef structs go at top*/

int     i1 ;          /* int decls. and initializers */
int     count = 0 ; /*nothing new */
char    c1[5] ;       /*array decls. and initializers */
char    pet[5] = "lamb" ;      /*string initializer*/

student_record   harvey = {"Harvey S.", 9501234,
                           87, 74, 3.1} ;
```


Using Components of *struct* Variables

```
student_record s1;
...
scanStatus = scanf("%d", &s1.id) ;
s1.hw     = 90 ;
s1.exams= 80 ;
s1.grade = (double)(s1.hw + s1.exams) / 50.0 ;
printf("%d: %f", s1.id, s1.grade) ;
```


Assigning Whole *structs*

```
s1 = harvey ;
   equivalent to

s1.id      = harvey.id ;
s1.hw      = harvey.hw ;
s1.exams     = harvey.exams ;
s1.grade= harvey.grade ;
strcpy(s1.name, harvey.name) ;
   /* string copy – covered in slides on strings */
```

Why use *structs*?

- Collect together values that are treated as a unit (for compactness, readability, maintainability).

```
typedef struct {
    int  dollars, cents ;
} money ;
```

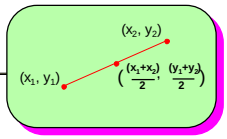
```
typedef struct {
    int hours, minutes ;
    double  seconds ;
} time ;
```

- Functions can return *structs*
  - another way to have "multiple" return values.
- Files and databases: collections of *structs*
  e.g., 300 (or 30,000) student records.

Recall Midpoint Example

```
/* Given 2 endpoints of a line, "return" coordinates of midpoint */

void  midpoint(
    double x1, double y1,          /* 1st endpoint      */
    double x2, double y2,          /* 2nd endpoint      */
    double *midxp, double *midyp ) /* Pointers to midpoint */
{
    *midxp = (x1 + x2) / 2.0;
    *midyp = (y1 + y2) / 2.0;
}
```




```
double ax, ay, bx, by, mx, my;
...
midpoint(ax, ay, bx, by, &mx, &my);
```


Points as *structs*

```
typedef struct {
    double  x, y ;
} point ;
...
point  a = {0.0, 0.0},  b = {5.0, 10.0} ;
point  m ;
m.x = (a.x + b.x) / 2.0 ;
m.y = (a.y + b.y) / 2.0 ;
```


Midpoint Function via *structs*

```
point midpoint (point  pt1,  point  pt2)
{
    point  mid;          structs passed by value (copied)
    mid.x = ( pt1.x + pt2.x ) / 2.0 ;
    mid.y = ( pt1.y + pt2.y ) / 2.0 ;
    return (mid);
}
...
point  a = {0.0, 0.0}, b = {5.0, 10.0}, m;
                /* struct declaration and initialization */
...
m = midpoint (a, b) ;          /* struct assignment */
```


Midpoint with Pointers

```
void set_midpoint (point  pt1,  point  pt2, point  *mid)
{
    (*mid).x = ( pt1.x + pt2.x ) / 2.0 ;
    (*mid).y = ( pt1.y + pt2.y ) / 2.0 ;
}                          /* . has high precedence than * */

point  a = {0.0, 0.0}, b = {5.0, 10.0}, m;
set_midpoint (a, b, &m) ;
```

- Structs behave like all non-array types when used as parameters.

Pointer Shorthand: ->

```
void set_midpoint (point  pt1,  point  pt2, point  *mid)
{
    mid->x = ( pt1.x + pt2.x ) / 2.0 ;
    mid->y = ( pt1.y + pt2.y ) / 2.0 ;
}
```

structp - > component means (*structp).component

-> is called the "indirect component selection operator"

Testing Equality of *structs*

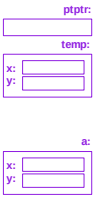
```
if (pt1 = = pt2) { ... }     /* Doesn't work */
```

```
int points_equal(point pt1, point pt2)
{
    return (pt1.x = = pt2.x   &&
            pt1.y = = pt2.y ) ;
}
```

```
if (points_equal(pt1, pt2)) { ... }   /* OK */
```

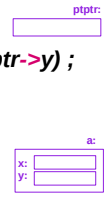

Do-it-yourself *struct* I/O

```
void print_point (point p)  {
    printf ("(%f,%f)", p.x, p.y) ;
}
void scan_point (point *ptptr)  {
    point temp ;
    scanf ("%lf %lf", &temp.x, &temp.y) ;
    *ptptr = temp ;
}
point a ;
scan_point (&a) ;
print_point (a) ;
```



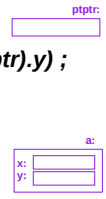
Alternative *scan_point*

```
void scan_point (point *ptptr)  {
    scanf ("%lf %lf",  & ptptr->x,  & ptptr->y) ;
}
point a ;
scan_point (&a) ;
print_point (a) ;
```

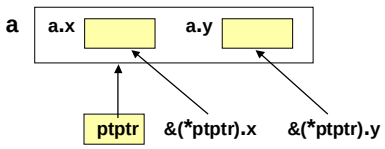


scan_point without ->

```
void scan_point (point *ptptr)  {
    scanf ("%lf %lf", &(*ptptr).x, &(*ptptr).y) ;
}
point a ;
scan_point (&a) ;
print_point (a) ;
```



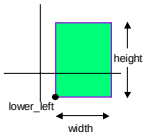
Pointers and *structs*



expression	type
ptptr	point *
*ptptr	point
(*ptptr).x	double
&(*ptptr).x	double *

Hierarchical *structs*

```
typedef struct {
    double  x, y ;
} point ;
typedef struct {
    double  width, height ;
} dimension ;
typedef struct {
    dimension  size ;
    point      lower_left ;
    int        line_color, fill_color ;
} rectangle ;
```



Using *structs* within *structs*

```
point origin = { 0.0, 0.0 } ;
rectangle  a = { {5.0, 10.0}, {1.0, -2.0}, BLUE, CYAN } ;
rectangle  b ;

b.fill_color     = BLUE ;
b.lower_left     = origin ;              /* place at origin */
b.lower_left.y = 15.0 ;                  /* move up 15      */
...
b.size.width  = 2.0 * b.size.width ;     /* stretch in x    */
b.size.height = 4.0 * b.size.height ;    /* stretch in y    */
```


QUIZ: Calculating Types

```
rectangle R;
rectangle * rp;
```

```
R.size
R.lower_left
R.fill_color
R.lower_left.x
&R.lower_left.y
rp -> size
&rp -> lower_left
*rp.line_color
R  -> size
rp -> size -> width
```