CPE 101 slides based on UW slides

Lecture 18:
Structures

Concepts this lecture

Review: Data structures
Heterogenous structures (structs, records)
struct type definitions (typedef)
Field selection (. operator)
Structs as parameters
- Call by value
- Pointer parameters and -> operator

Chapter 11

Read 11.1-11.3, & 11.7
- 11.1: Structure types
- 11.2: Structures as parameters
- 11.3: Structures as return values
- Optional examples; skim or read:
  - 11.4: Complex numbers

Review: Data Structures

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* house in a neighborhood: x, y, color, # windows, etc.
- Example: information about one student: name, ID, GPA, etc. etc.

Problem: Account Records

The Engulf & Devour Credit Co. Inc., Ltd. needs to keep track of insurance policies it has issued.
Information recorded for each policy
- Account number (integer)
- Policy holder's age (integer) and sex ('m' or 'f')
- Monthly premium (double)

At E&G, customers are only known by their account #, so there is no need to store their names.

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Collection of values of possibly <u>differing types</u>.

Name the collection; name the components (fields).

Example: Insurance policy information for Alice (informally)

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"alice"
- account 9501234
- age 23
- sex 'f'
- premium 42.17

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Example: Insurance policy information for Alice (informally)

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Structs: Heterogeneous Structures

Collection of values of possibly <u>differing types</u>.

Name the collection; name the components (fields).

Example: Insurance policy information for Alice (informally)

"alice"
- account 9501234
- age 23
- sex 'f'
- premium 42.17

C expressions:
- *alice.age* is 23
- *alice.sex* is 'f'
- *2*alice.premium* is 84.34

S-11

Defining *structs*

S-12

Defining *structs*

There are several ways to define a struct in a C program. For this course:
- Define a new *type* specifying the fields in the struct
- Declare variables as needed using that new type

The type is defined only once at the beginning of the program

Variables with this new type can be declared as needed.

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Defining *struct* types

```
typedef struct {             /* record for one policy:*/
    int     account ;        /* account number */
    int     age ;            /* policy holder's age */
    char    sex;             /* policy holder's sex */
    double  premium;         /* monthly premium */
} account_record ;
```

Defines a new data type called account_record.

Does not declare (create) any variables. No storage is allocated.

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Style Points in *struct* types

In a type definition, use comments to describe the fields,
- not the contents of the fields for any particular variable
- I.e.. describe the layout of an *account_record*, not information about Alice's account.

typedefs normally are placed at the top of the program file

S-15

Declaring *struct* Variables

Follow the usual rules:
- write the type name followed by one or more variable identifiers
- Only difference: this time the type is defined by the programmer, not built in

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Declaring *struct* Variables

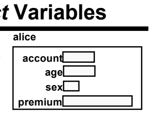
```
/*typedef students_record
  goes at top of program */
...

account_record alice ;
account_record bob;
```

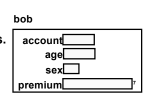
account_record is a type; alice and bob are variables.

Both variables have the same internal layout

alice



bob



S-17

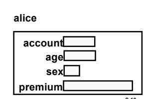
Field access

A fundamental operation on struct variables is field access:
- struct_name.field_name

selects the given field (variable) from the struct

```
alice.age = 23;
alice.premium = 12.20;
alice.premium = 2 *
        alice.premium;
```

alice



S-18

Field access

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```
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alice.premium = 2 *
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```

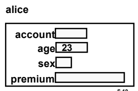

S-19

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alice.premium = 2 *
        alice.premium;
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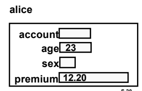

S-20

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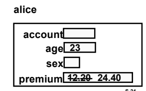

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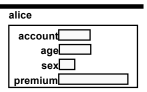
Field access

A selected field is an ordinary variable - it can be used in all the usual ways




```
alice.age++;
printf("Alice is %d years old\n",
        alice.age);
scanf("%lf", &alice.premium);
```

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Terminology

The terms "*struct*", "record" and "structure" mean the same thing

"fields" are often called "components" or "members".

S-23

Why use *structs*?

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

S-24

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

S-25

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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 ;
```

S-26

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 ;
```

This is an example of "abstraction"

S-27

Structs as User-Defined Types

C provides a limited set of built-in types: int, char, double (and variants of these not discussed in these lectures)

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.

S-28

Some Limitations

Like arrays, there are some restrictions on how a struct can be used compared to a simple variable (int, double, etc.)

- Can't compare (==, !=) two structs directly
- Can't read or write an entire struct with scanf/printf

But you can do these things on individual fields

S-29

struct Assignment

Unlike arrays, entire structs can be copied in a single operation. Don't need to copy field-by-field.

- Can assign struct values with =
- Can have functions with struct result types, and can use struct values in a return statement

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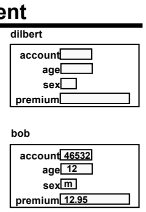
struct Assignment

A struct assignment copies all of the fields. If dilbert is another account_record, then

```
   dilbert = bob;
is equivalent to
   dilbert.account =
          bob.account;
   dilbert.age = bob.age;
   dilbert.sex = bob.sex;
   dilbert.premium =
          bob.premium;
```



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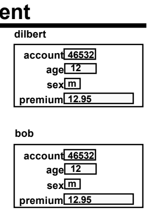


structs as Parameters

structs behave like all other non-array values when used as function parameters

- Can be call-by-value (copied)
- Can use as pointer parameters

S-33

struct initializers

A struct can be given an initial value when it is declared. List initial values for the fields in the same order they appear in the struct typedef.

```
account_record
        ratbert = {  970142, 6, '?', 99.95 } ;
```

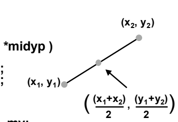
S-34

Midpoint Example Revisited

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

void  midpoint(
    double x1, double y1,
    double x2, double y2,
    double *midxp, double *midyp )
{
    *midxp = (x1 + x2) / 2.0;
    *midyp = (y1 + y2) / 2.0;
}

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



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Points as *structs*

Better: use a struct to make the concept of a "point" explicit in the code

```
typedef struct {        /* representation of a point */
    double    x, y ;    /* x and y coordinates        */
} 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 ;
```

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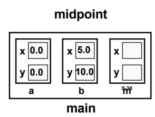
Midpoint with *point*s

```
/* return point whose coordinates are the
   center of the  line segment with endpoints
   pt1 and pt2.                   */
point midpoint (point  pt1,  point  pt2) {
     point  mid;
     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 */
```

Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   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;
...
m = midpoint (a, b) ;
```



Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   mid.x = ( pt1.x + pt2.x ) / 2.0 ;
   mid.y = ( pt1.y + pt2.y ) / 2.0 ;
   return mid;
}
...
point  a = {0.0, 0.0},
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...
m = midpoint (a, b) ;
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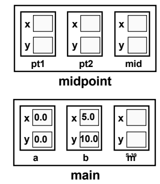

Execution

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point midpoint (
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   point  mid;
   mid.x = ( pt1.x + pt2.x ) / 2.0 ;
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   return mid;
}
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point  a = {0.0, 0.0},
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m = midpoint (a, b) ;
```
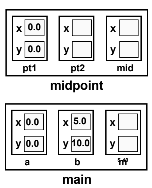
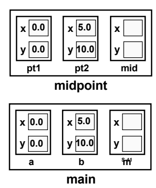



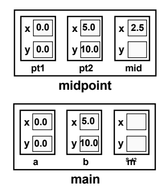
Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   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;
...
m = midpoint (a, b) ;
```



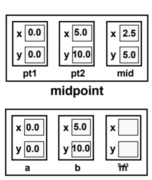
Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   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;
...
m = midpoint (a, b) ;
```



Execution

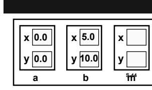
```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   mid.x = ( pt1.x + pt2.x ) / 2.0 ;
   mid.y = ( pt1.y + pt2.y ) / 2.0 ;
   return mid;
}
...
point  a = {0.0, 0.0},
        b = {5.0, 10.0}, m;
...
m = midpoint (a, b) ;
```



Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   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;
...
m = midpoint (a, b) ;
```

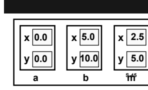
[redacted]



Execution

```
point midpoint (
        point  pt1,  point  pt2) {
   point  mid;
   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;
...
m = midpoint (a, b) ;
```

[redacted]



Midpoint with Pointers

Instead of creating a temporary variable and returning a copy of it, we could write the function so it stores the midpoint coordinates directly in the destination variable.
How? Use a pointer parameter:

void set_midpoint (point pt1, point pt2, point *mid)

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.

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Field Access via Pointers

Function set_midpoint needs to access the x and y fields of its third parameter. How?

void set_midpoint (point pt1, point pt2, point *mid)
…

Field access requires two steps:
1) Dereference the pointer with *
2) Select the desired field with .
Technicality: field selection has higher precedence than pointer dereference, so parentheses are needed: (*mid).x

S-47

Midpoint with Pointers

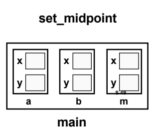
```
/* Store in *mid the coordinates of the midpoint */
/* of the line segment with endpoints pt1 and pt2 */
void set_midpoint (point pt1, point pt2, point *mid)
{
    (*mid).x = ( pt1.x + pt2.x ) / 2.0 ;
    (*mid).y = ( pt1.y + pt2.y ) / 2.0 ;
}

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

S-48

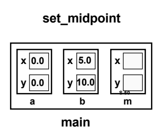
Execution

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



Execution

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



Execution

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

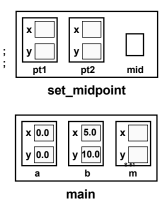

Execution

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        point pt2, point *mid) {
    (*mid).x = ( pt1.x + pt2.x ) / 2.0 ;
    (*mid).y = ( pt1.y + pt2.y ) / 2.0 ;
}
...
point a = {0.0, 0.0},
      b = {5.0, 10.0}, m;
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set_midpoint (a, b, &m) ;
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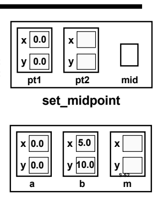

Execution

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void set_midpoint (point pt1,
        point pt2, point *mid) {
    (*mid).x = ( pt1.x + pt2.x ) / 2.0 ;
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}
...
point a = {0.0, 0.0},
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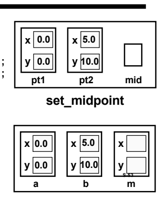

Execution

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}
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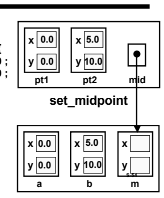

Execution

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void set_midpoint (point  pt1,
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      (*mid).x = ( pt1.x + pt2.x ) / 2.0 ;
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}
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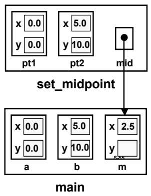
         b = {5.0, 10.0}, m;
...
set_midpoint (a, b, &m) ;
```



Execution

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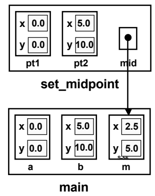
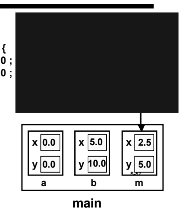



Execution

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



Pointer Shorthand: ->

"Follow the pointer and select a field" is a very common operation. C provides a shorthand operator to make this more convenient.

    structp - > component

means exactly the same thing as

    (*structp).component

-> is (sometimes) called the "indirect component selection operator"

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Pointer Shorthand: ->

Function set_midpoint would normally be written like this:

```
/* Store in *mid the coordinates of the midpoint */
/* of the line segment with endpoints pt1 and pt2 */
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 ;
}
```

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Summary

Structs collect variables ("fields")
- possibly of differing types
- each field has a name
- . operator used to access

Struct fields follow the rules for their types

Whole structs can be assigned
An important tool for organizing data

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