Complex Data Types

IC-100

2 January 2023

Today's Topics

- Enumerations
- Composite data types
  - Structure
  - Union

Why Enumerated Type?

- Collecting data about bank accounts
  - Need a variable for account type: Checking, Saving, …
- Dealing with the color of a traffic light
  - A variable that can hold only three values: red, yellow, green
- Enumerated type comes to the rescue

Enumerated Types

- Enumerated type allows us to create our own symbolic name for a list of related ideas.
  - The key word for an enumerated type is **enum**.

- C statement to create an enumerated type to represent various “account types”

```
enum act_Type { savings, current, fixDeposit, minor };
```

Example: Enumerated Types

- Account type via Enumerated Types.

```
enum act_Type { savings, current, fixDeposit, minor };

enum act_Type a;
a = current;

if (a==savings)
        printf("Savings account\n");

if (a==current)
        printf("Current account\n");
```

Enumerated types provide a symbol to represent one state out of several constant states.

Structures: Motivation

- A geometry package – we want to define a point as having an x coordinate, and a y coordinate.
- Student data – Name and Roll Number
- First strategy: Array of size 2?
  - Can not mix TYPES
- Two variables,

  int point_x , point_y ; char *name; int roll_num;
  - No way to indicate that they are part of the same name
  - We need to be very careful about variable names.
- Is there any better way ?

Structures

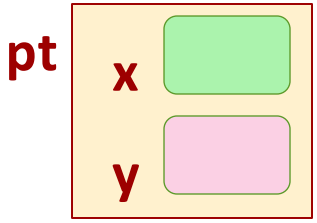
- A structure is a collection, of variables, under a common name.
- The variables can be of different types (including arrays, pointers or structures themselves!).
- Structure variables are called fields.

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

```
struct point pt;
```

Defines a structure called point containing two integer variables (fields), called x and y.

struct point pt defines a variable pt to be of type struct point.



memory depiction of pt

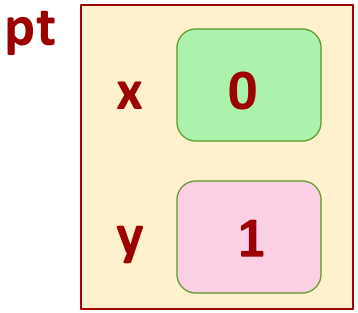
Structures

- The x field of pt is accessed as pt.x.
- Field pt.x is an int and can be used as any other int.
- Similarly the y field of pt is accessed as pt.y

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

```
struct point pt;
```

```
pt.x = 0;
pt.y = 1;
```



memory depiction of pt

Structures

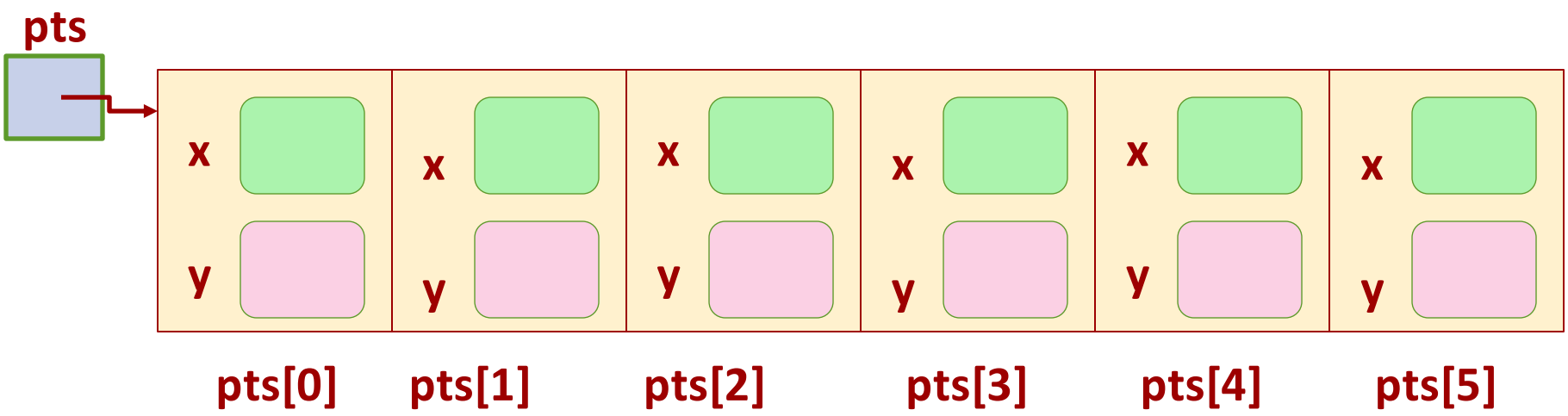
```
struct point {
        int x; int y;
}
```

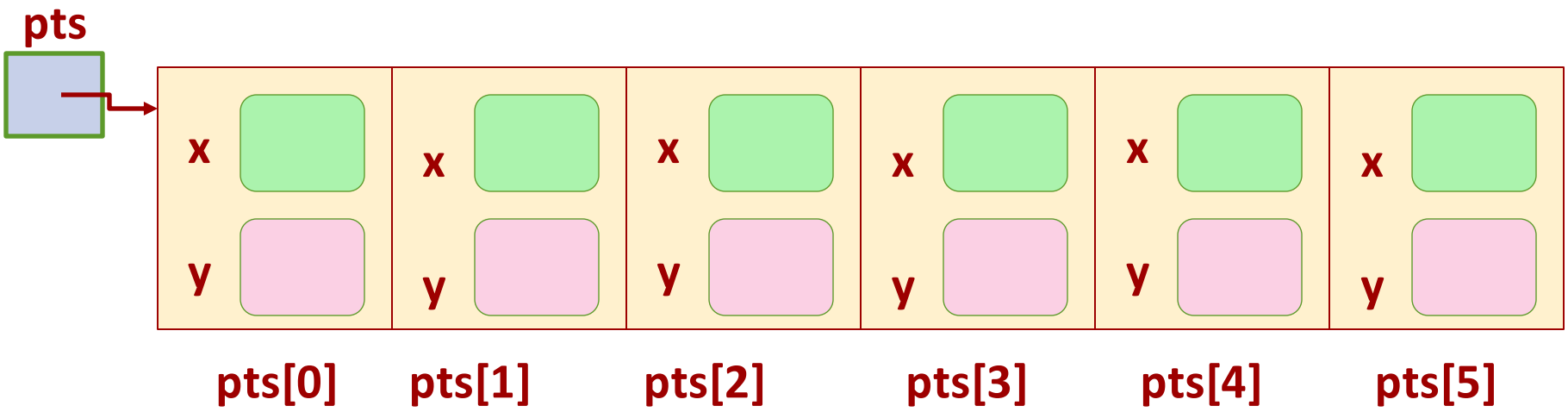
struct point is a type.
It can be used just like int, char etc..

For now, define structs in the beginning of the file, after #include.

We can define array of struct point also.

```
struct point pt1,pt2;
struct point pts[6];
```





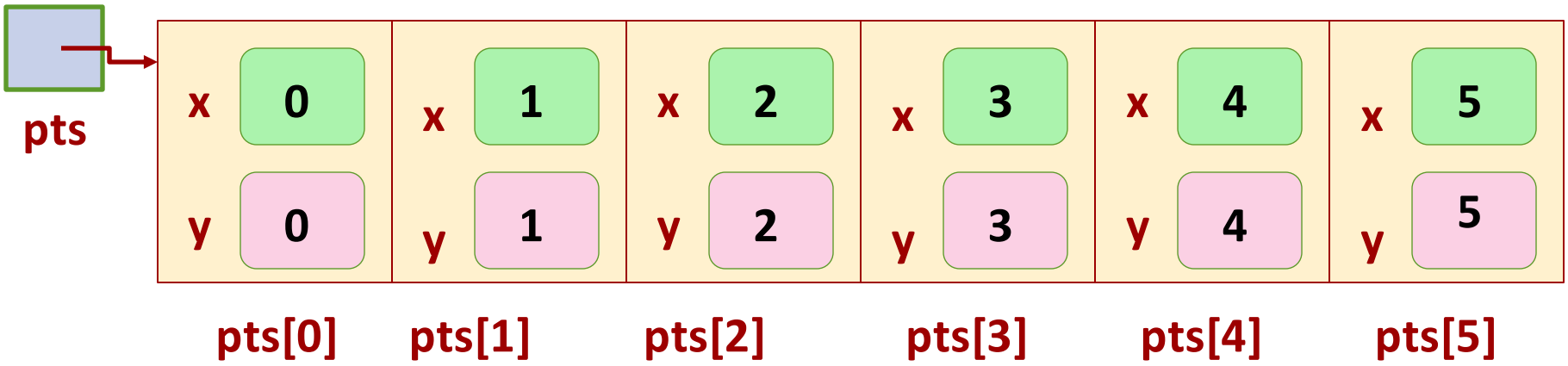

```
int i;
for (i=0; i < 6; i=i+1) {
        pts[i].x = i;
        pts[i].y = i;
}
```

Read pts[i].x as (pts[i]).x.
The . and [] operators have same precedence.
Associativity: left-right.

Structures

```
struct point {
        int x; int y;
};
struct point pts[6];
int i;
for (i=0; i < 6; i=i+1) {
        pts[i].x = i;
        pts[i].y = i;
}
```

State of memory after the code executes.



Reading Structures (scanf ?)

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

```
int main() {
    int x, y;
    struct point pt;
    scanf("%d%d", &(pt.x),&(pt.y));
    return 0;
}
```

1. You **can not** read a structure directly using scanf!
2. **Read individual fields** using scanf (note the &).
3. A better way is to define our own functions to read structures
   - to avoid cluttering the code!

Functions Returning Structures

```
struct point make_pt(int x, int y) {
        struct point temp;
        temp.x = x;
        temp.y = y;
        return temp;    }

int main() {
        int x, y;
        struct point pt;
        scanf("%d%d", &x,&y);
        pt = make_pt(x,y);
    return 0;
}
```

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

1. **make_pt(x,y):**
   creates a struct point with coordinates (x,y), and returns a struct point.
1. Functions can return structures just like int, char, int *, etc..
2. struct can be passed as arguments (pass by value).

Given int coordinates x,y, make_pt(x,y) creates and returns a struct point with these coordinates.

Functions with Structures as Parameters

```
# include <stdio.h>
# include <math.h>
struct point {
        int x; int y;
};
double norm2( struct point p)  {
   return sqrt ( p.x*p.x + p.y*p.y);
}
int main() {
        int x, y;
        struct point pt;
        scanf("%d%d", &x,&y);
        pt = make_point(x,y);
        printf("distance from origin
            is %f ", norm2(pt) );
     return 0;
}
```

The norm2 or Euclidean norm of point (x,y) is

$$\sqrt{x^2 + y^2}$$

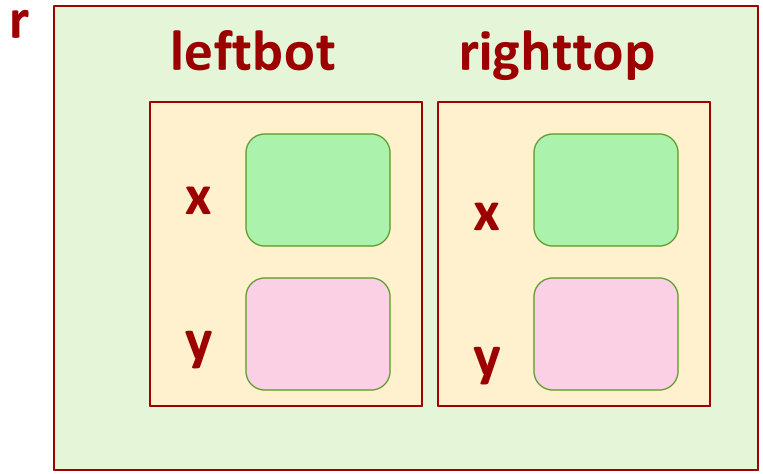
norm2(struct point p) returns Euclidean norm of point p.

Structures inside Structures

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

```
struct rect {
  struct point leftbot;
  struct point righttop;
};
struct rect r;
```

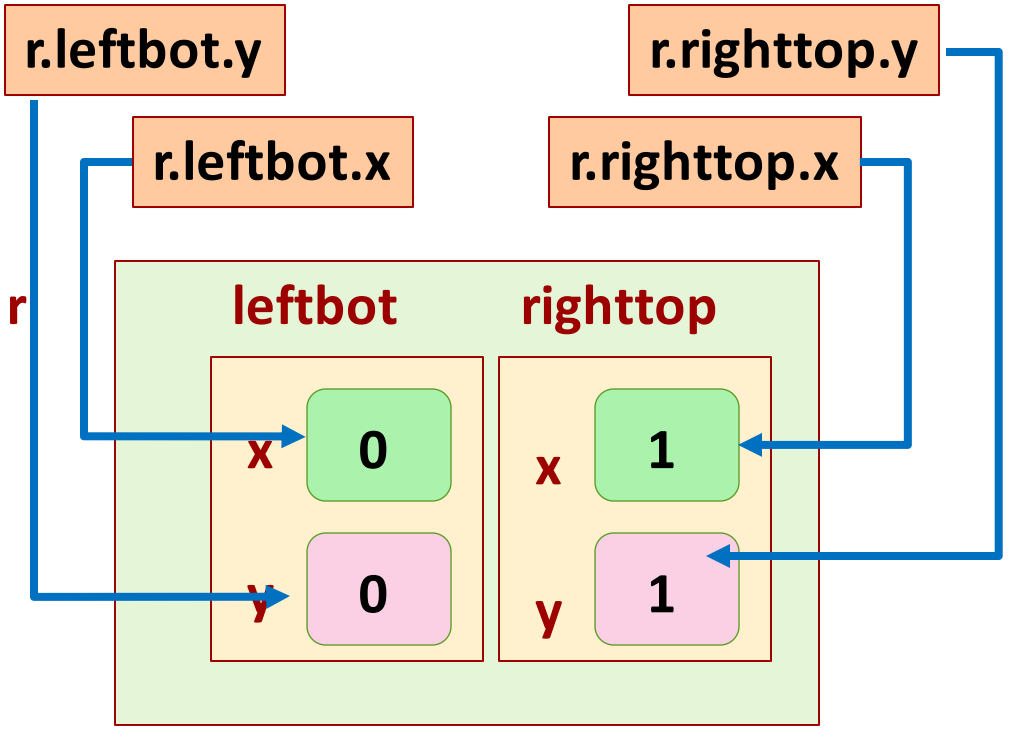
1. Recall, a structure definition defines a type.
2. Once a type is defined, it can be used in the definition of new types.
3. struct point is used to define struct rect. Each struct rect has two instances of struct point.



r is a variable of type struct rect. It has two struct point structures as fields.

So how do we refer to the x of leftbot point structure of r?

```
struct point {
        int x;
        int y;
};
struct rect {
  struct point leftbot;
  struct point righttop;
};
int main() {
        struct rect r;
        r.leftbot.x = 0;
        r.leftbot.y = 0;
        r.righttop.x = 1;
        r.righttop.y = 1;
    return 0;
}
```



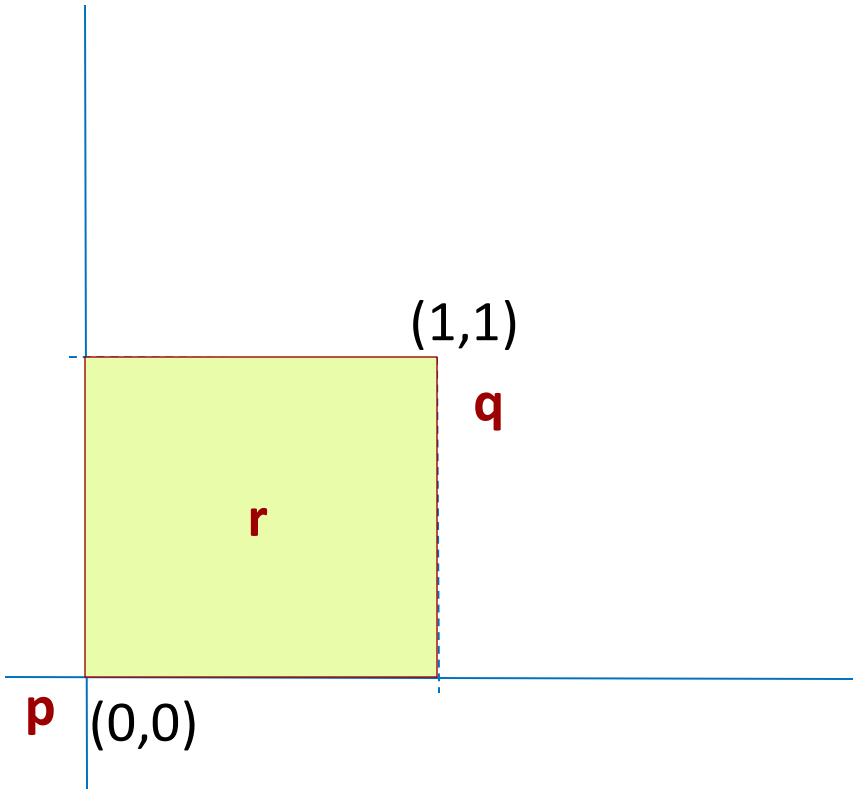
Addressing nested fields unambiguously

Initializing Structures

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

1. Initializing structures is very similar to initializing arrays.
2. Enclose the values of all the fields in braces.
3. Values of different fields are separated by commas.

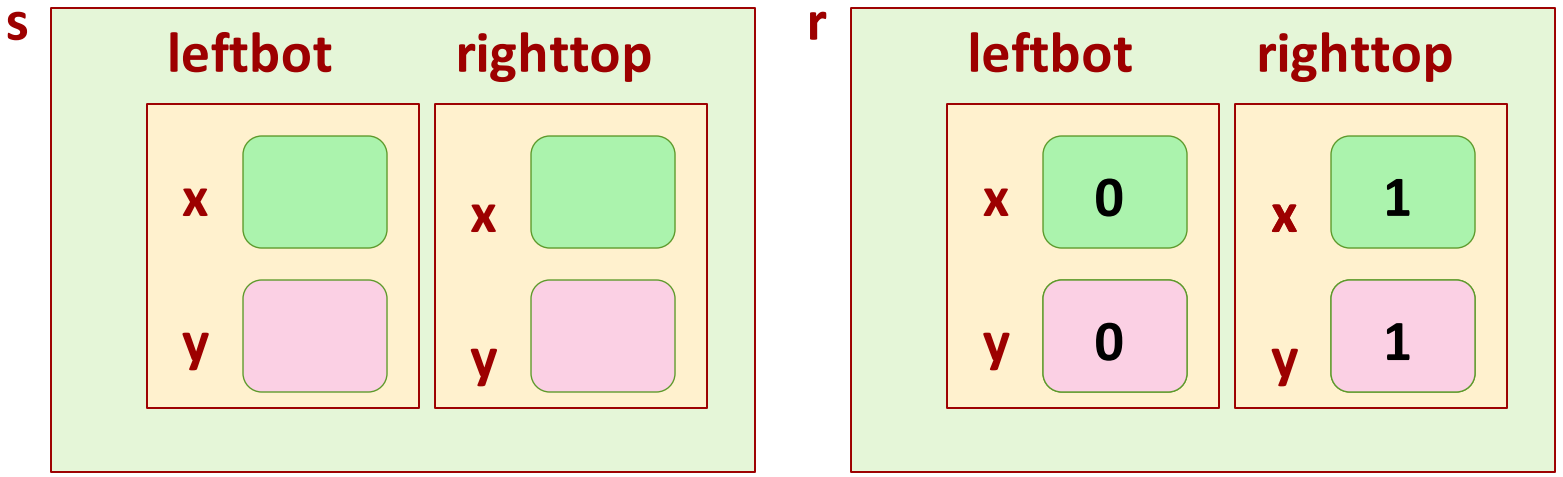
```
struct rect {
   struct point leftbot;
   struct point righttop;
};
struct point p = {0,0};
struct point q = {1,1};
struct rect r = {{0,0}, {1,1}};
```



Assigning Structure Variables

```
struct rect r,s;
r.leftbot.x = 0;
r.leftbot.y = 0;
r.righttop.x = 1;
r.righttop.y = 1;
s=r;
```

1. We can assign a structure variable to another structure variable
2. The statement s=r; does this
3. Structures are *assignable* variables, unlike arrays!

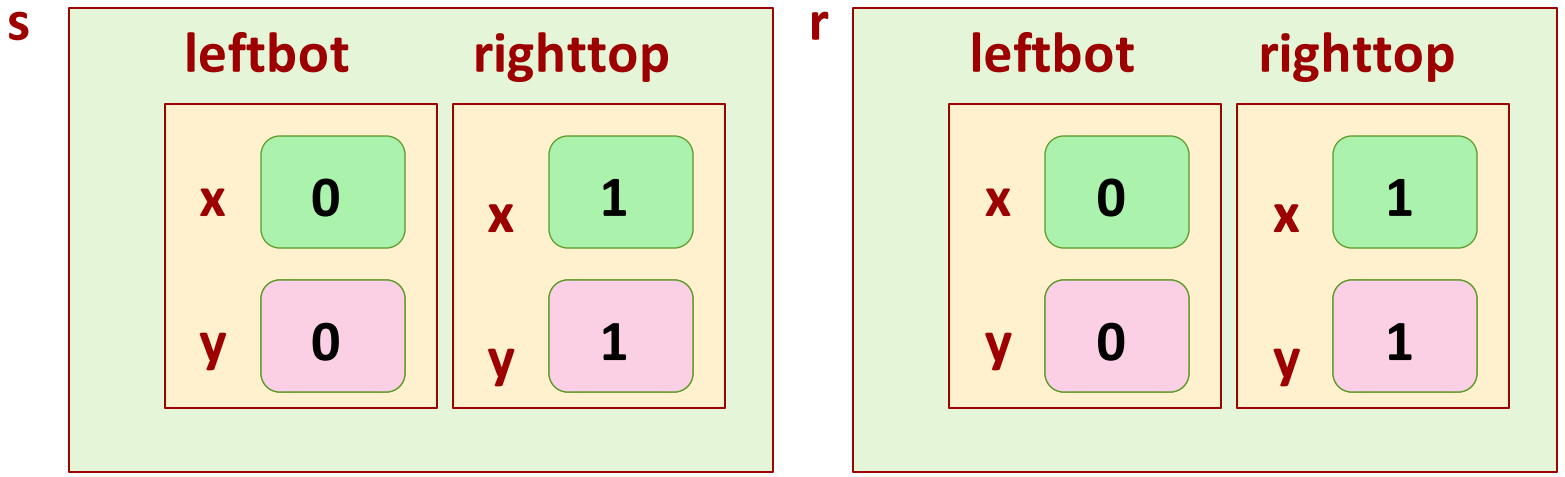


Before the assignment

Assigning Structure Variables

```
struct rect r,s;
r.leftbot.x = 0;
r.leftbot.y = 0;
r.righttop.x = 1;
r.righttop.y = 1;
s=r;
```

1. We can assign a structure variable to another structure variable
2. The statement s=r; does this.
3. Structures are *assignable* variables, unlike arrays!

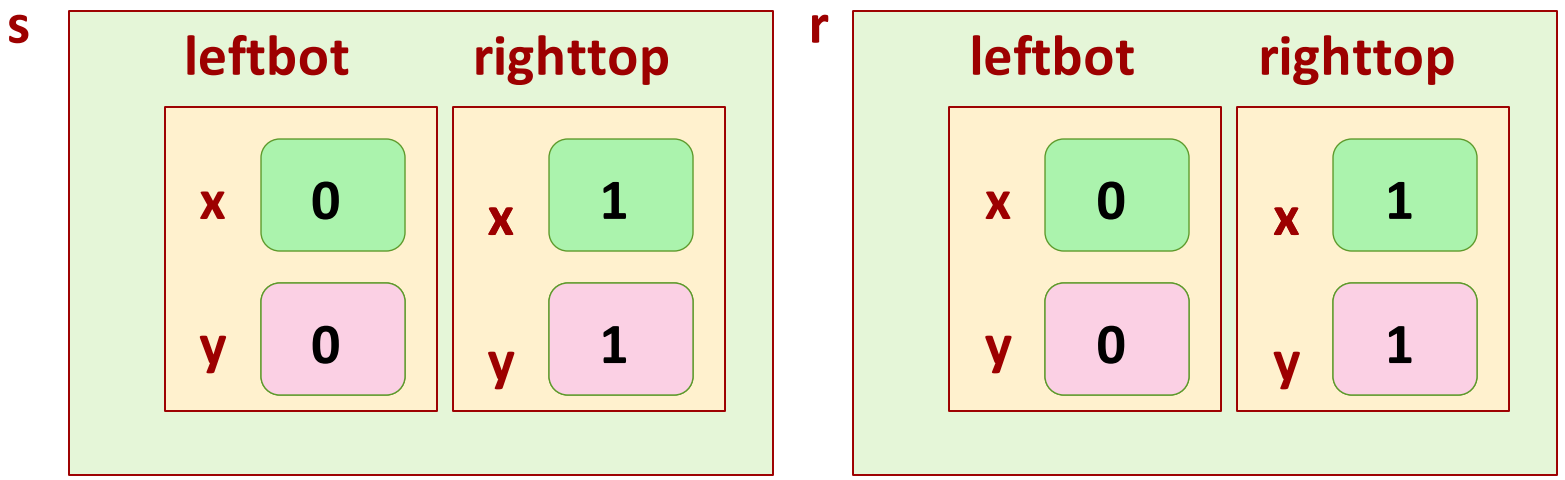


After the assignment

Assigning Structure Variables

```
struct rect r,s;
r.leftbot.x = 0;
r.leftbot.y = 0;
r.righttop.x = 1;
r.righttop.y = 1;
s=r;
```

1. We can assign a structure variable to another structure variable
2. The statement s=r; does this.
3. Structures are *assignable* variables, unlike arrays!
4. Structure name is *not* a pointer, unlike arrays.



After the assignment

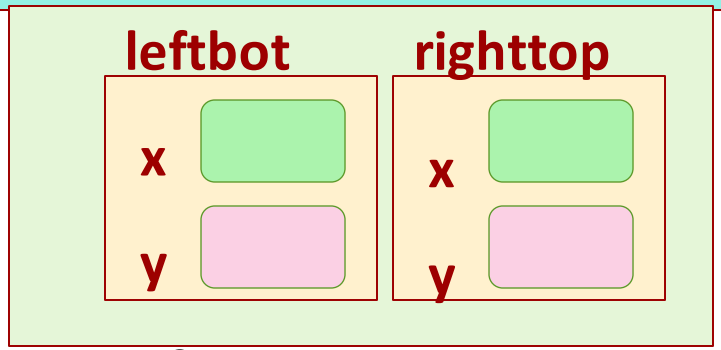
Passing Structures?

```
struct rect { struct point leftbot;
              struct point righttop; };
int area(struct rect r) {
  return
     (r.righttop.x – r.leftbot.x) *
     (r.righttop.y – r.leftbot.y);
}
void fun() {
  struct rect r1 ={{0,0}, {1,1}};
  area(r1);
}
```

We can pass structures as parameters, and return structures from functions, like the basic types int, char, double etc..

But is it efficient to pass structures or to return structures?

Usually NO. E.g., to pass struct rect as parameter, 4 integers are copied. This is expensive.



Same for returning structures

So what should be done to pass structures to functions?

Passing Structures?

```
struct rect { struct point leftbot;
              struct point righttop;};
int area(struct rect *pr) {
  return
 ((*pr).righttop.x – (*pr).leftbot.x) *
 ((*pr).righttop.y – (*pr).leftbot.y);
}
void fun() {
   struct rect r ={{0,0}, {1,1}};
   area (&r);
 }
```

Instead of passing structures, pass pointers to structures.

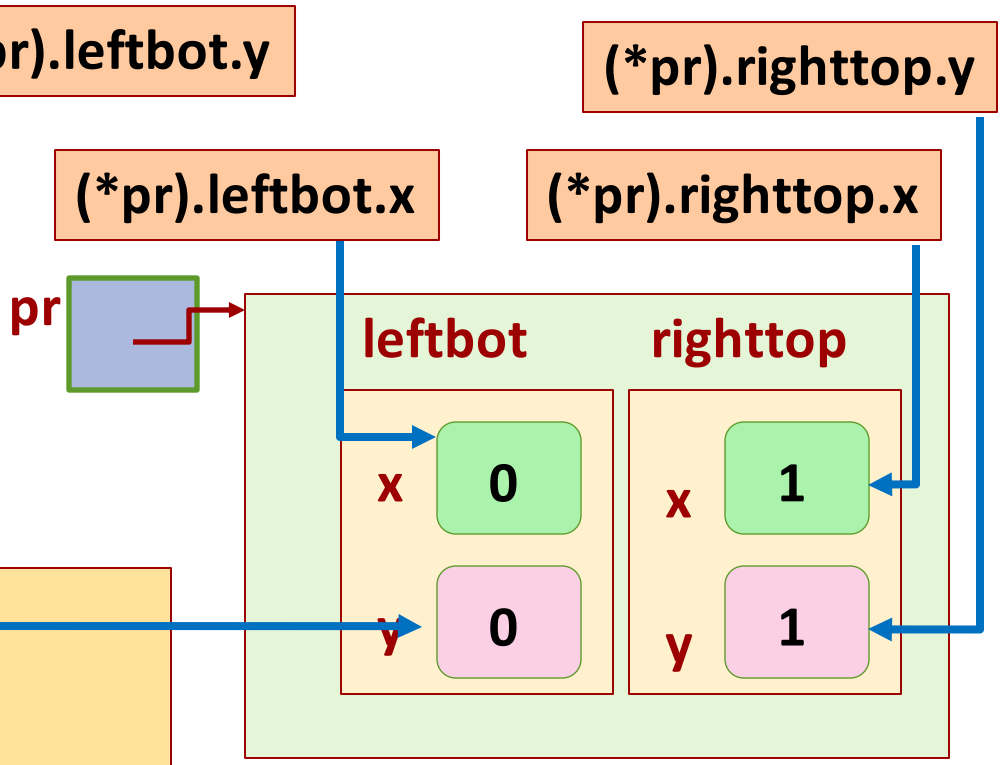
area() uses a pointer to struct as a parameter, instead of struct rect itself.

Only one pointer instead of large struct.

Same for returning structures

Structure Pointers

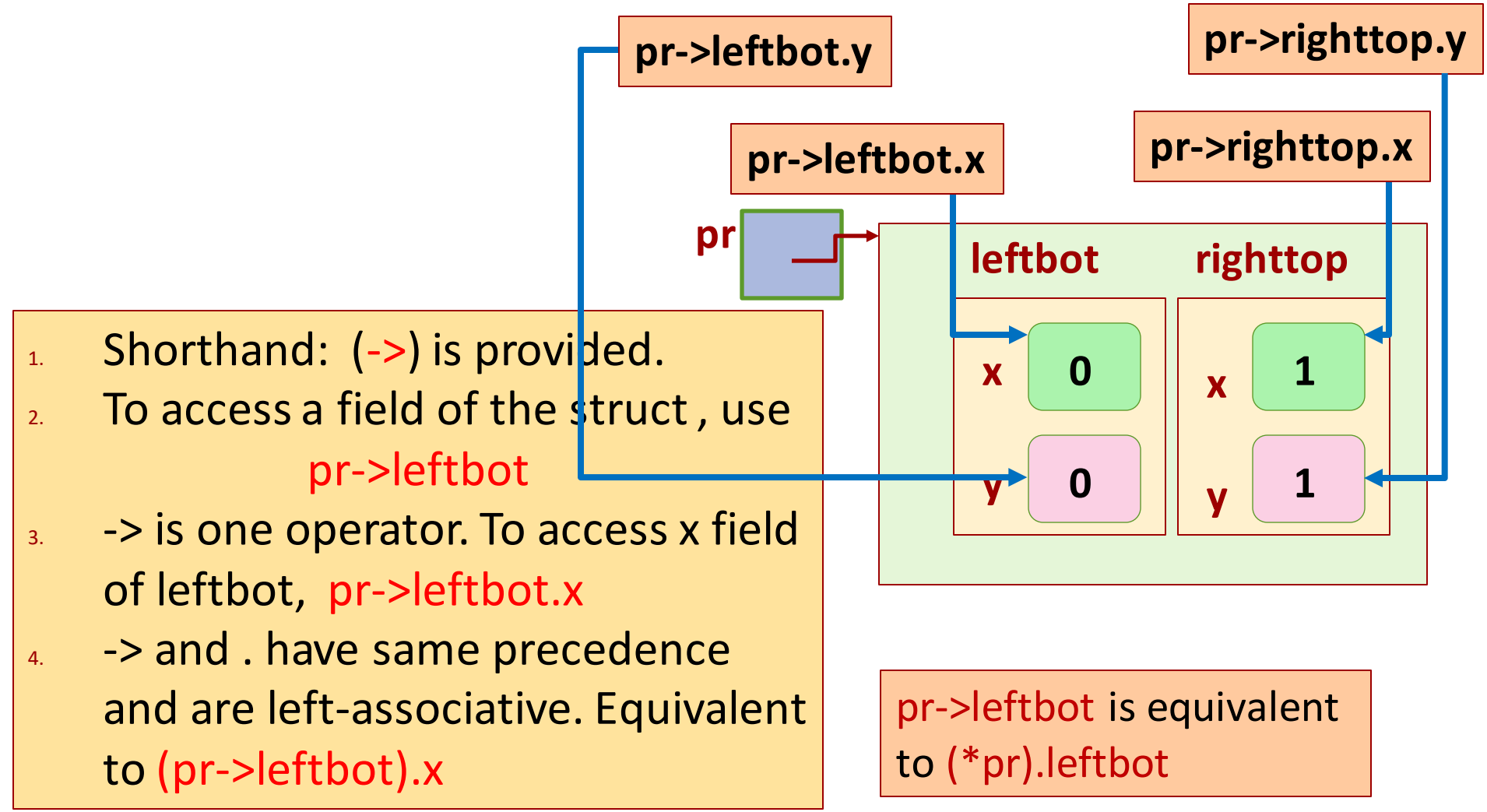
```
struct point {
        int x; int y;};
struct rect {
  struct point leftbot;
  struct point righttop;
};
struct rect *pr;
```



1. pr is pointer to struct rect.
2. To access a field of the struct pointed to by struct rect, use
   (*pr).leftbot
   (*pr).righttop
3. Bracketing (*pr) is essential here. * has lower precedence than .
4. To access the x field of leftbot, use
   (*pr).leftbot.x

Addressing fields
via the structure's pointer

Addressing Fields via the Pointer (Shorthand)



1. Shorthand: (->) is provided.
2. To access a field of the struct , use
   pr->leftbot
3. -> is one operator. To access x field of leftbot, pr->leftbot.x
4. -> and . have same precedence and are left-associative. Equivalent to (pr->leftbot).x

pr->leftbot is equivalent to (*pr).leftbot

Union

- Like structure. Contains members of different datatypes
- The members within a **union** shares the same storage area
- Useful for applications involving multiple members whose values are not required simultaneously
- Useful to conserve memory

Union Example

```
union Data {
   int i;
   float f;
   char str[20];
} data;
```

Sizeof a union Variable

Size of the largest member of the union

```
union Data {
  int i;
  float f;
  char str[20];
};

int main( ) {
  union Data data;
  printf( "Memory size occupied by data : %d\n", sizeof(data));
  return 0;
}
```

Memory size occupied by data : 20

Accessing Union Members

```
int main( ) {
   union Data data;

   data.i = 10;
   data.f = 220.5;
   strcpy( data.str, “ESC101”);
   printf( "data.i : %d\n", data.i);
   printf( "data.f : %f\n", data.f);
   printf( "data.str : %s\n", data.str);
   return 0;
}
```

```
data.i : Garbage
data.f : Garbage
data.str : ESC101
```

Accessing Union Members

```
int main( ) {
   union Data data;

   data.i = 10;
   printf( "data.i : %d\n", data.i);
   data.f = 220.5;
   printf( "data.f : %f\n", data.f);
   strcpy( data.str, ”ESC101");
   printf( "data.str : %s\n", data.str);
   return 0;
}
```

```
data.i : 10
data.f : 220.500000
data.str : ESC101
```

Next Class

- Data structures using structure and pointers