L17. Structures

Simple Structures
Structure Arrays
Structures with Array Fields
Other Possibilities

Data is Often Related

A point in the plane has an x coordinate and y coordinate.

If a program manipulates lots of points, there will be lots of x's and y's.

Anticipate clutter. Is there a way to "package" the two coordinate values?

Packaging Affects Thinking

Our Reasoning Level:

P and Q are points. Compute the midpoint M of the connecting line segment.

Behind the scenes we do this:

$M_x = (P_x + Q_x)/2$ $M_y = (P_y + Q_y)/2$

Seen This Before

Functions are used to ``package'' calculations.

Elevates the level of our reasoning.

Critical for problem solving.

Packaging

Functions ``package'' calculations.

Structures ``package'' data.

Simple Example

```
P1 = struct('x',3,'y',4);

P2 = struct('x',-1,'y',7);

D = sqrt((P1.x-P2.x)^2 + (P1.y-P2.y)^2);
```

Distance between two points.

P1.x, P1.y, P2.x,P2.y participating as variables—because they are.

Initialization

```
P1 = struct('x',3,'y',4);
```

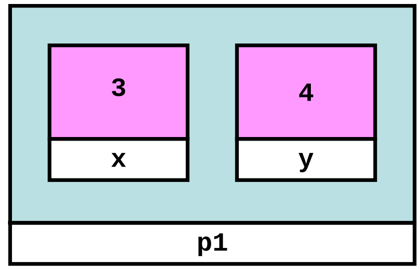
P1 is a structure.

The structure has two fields.

Their names are x and y.

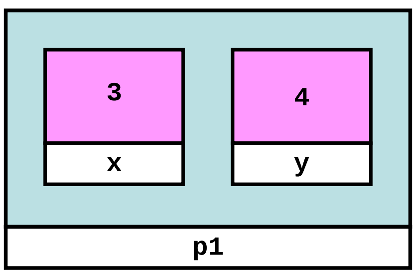
They are assigned the values 3 and 4.

How to Visualize p1




```
P1 = struct('x',3,'y',4);
```

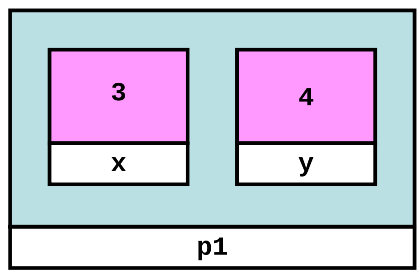
Accessing a Field




```
A = p1.x + p1.y
```

Assigns the value 7 to A.

Assigning to a Field




```
p1.x = p.y^2
```

Will assign the value 16 to p1.x

Another Example

```
A = struct('name','New York',…
           'capital', 'Albany',…
           'Pop',15.5)
```

Can have combinations of string fields and numeric fields.

Legal/Illegal Maneuvers

```
P = struct('x',3,'y',4)
Q = struct('x',5,'y',6)

R = Q    % Legal. R is copy of Q

S = (P+Q)/2  % Illegal.
```

Legal/Illegal Maneuvers

```
% Illegal…
P = struct('x',3,'y')
P.y = 4

% Legal
P = struct('x',3,'y',[])
P.y = 4
```

Using the Empty array as a place holder

A Function Can Have Inputs that are Structures

```
  function d = dist(P,Q)
% P and Q are points.
% d is the distance between them

  D = sqrt((P.x-Q.x)^2 + …
           (P.y-Q.y)^2);
```

A Function Can Return a Structure

```
  function P = MakePoint(x,y)
% P is a point with P.x and P.y
% assigned the values x and y.

  P = struct('x',x,'y',y);
```

Good Style.
Highlights the structure's definition.

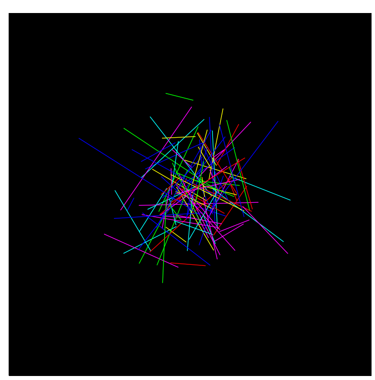
Functions and Structures

```
  function DrawLS(P,Q,c)
% P and Q are points.
% Draws a line segment connecting
% P and Q. Color specified by c

  plot([P.x Q.x],[P.y Q.y],c)
```

Pick Up Sticks Script

```
s = 'rgbmcy';
for k=1:100
   P = MakePoint(randn(1),randn(1));
   Q = MakePoint(randn(1),randn(1));
   c = s(ceil(6*rand(1)));
   DrawLS(P,Q,c)
end
```

Generates two random points
and chooses one of six colors randomly.



Structure Arrays

An array whose components are structures.

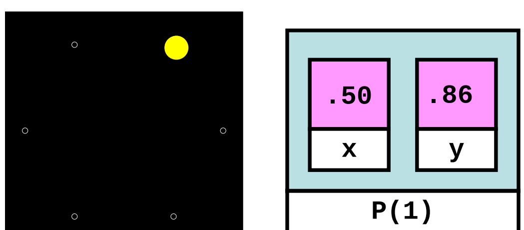
And all the structures are the same.

Example: An array of points…

Use this "Make" Function

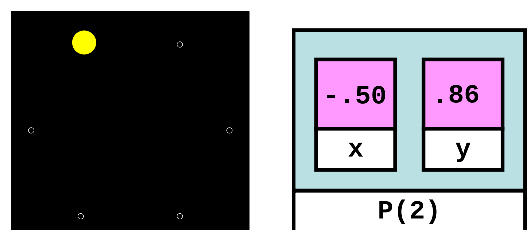
```
  function P = MakePoint(x,y)
% P is a point with P.x and P.y
% assigned the values x and y.

  P = struct('x',x,'y',y);
```

An Array of Points



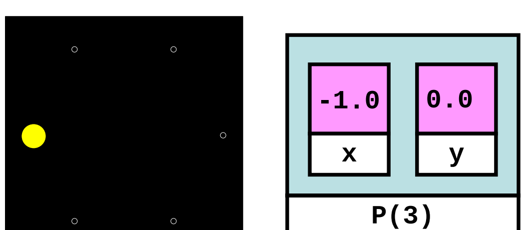
`P(1) = MakePoint(.50,.86)`

An Array of Points



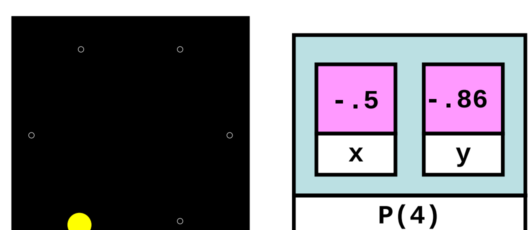
`P(2) = MakePoint(-.50,.86)`

An Array of Points



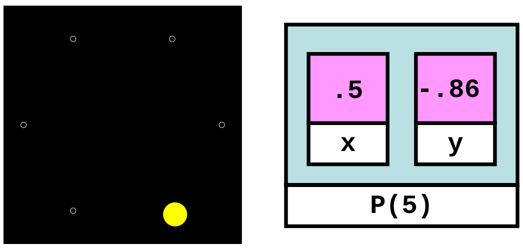
`P(3) = MakePoint(-1.0,0.0)`

An Array of Points



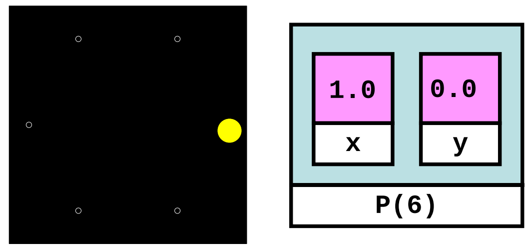
`P(4) = MakePoint(-.50,-.86)`

An Array of Points




```
P(5) = MakePoint(.50,-.86)
```

An Array of Points




```
P(6) = MakePoint(1.0,0.0)
```

A Function that Returns an Array of Points

```
function P = CirclePoints(n)

theta = 2*pi/n;
for k=1:n
   c = cos(theta*k);
   s = sin(theta*k);
   P(k) = MakePoint(c,s);
end
```

Structures with Array Fields

Let's develop a structure that can be used to represent a colored disk.

Four fields:

```
xc:   x-coordinate of center
yc:   y-coordinate  of center
r:    radius
c:    rgb color vector
```

Examples

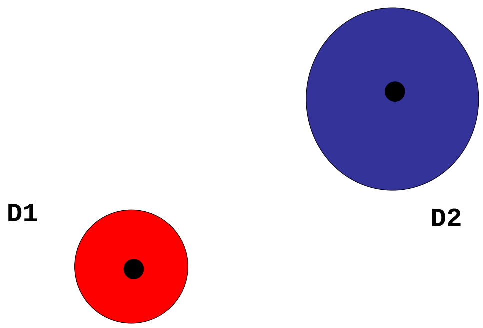
```
D1 = struct('xc',1,'yc',2,'r',3,…
            'c',[1 0 1])

D2 = struct('xc',4,'yc',0,'r',1,…
            'c',[.2 .5 .3])
```

Problem

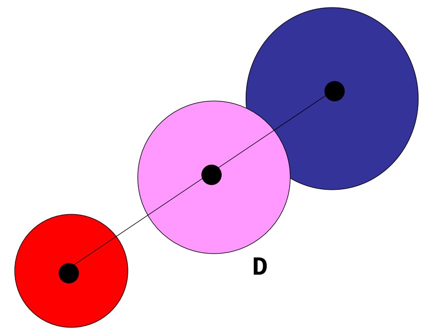
Assume D1 and D2 are colored disks.
Let's compute their "average".

```
r  = (D1.r  + D2.r) /2;
xc = (D1.xc + D2.xc)/2
yc = (D1.yc + D2.yc)/2
c  = (D1.c  + D2.c) /2;

D = struct('xc',xc,'yc'yc,'r',r,'c',c)
```

Example



Example



A Structure Can Have a Field That is a Structure

```
A = MakePoint(2,3)
B = MakePoint(4,5)
L = struct(‘P’,A,’Q’,B)
```

(One way to represent a line
Segment with endpoints P and Q.)

S = L.P.y assigns 3 to S.

More on Structures and Arrays

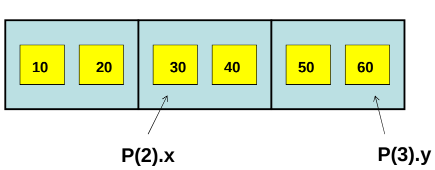
Let’s encode a collection of n random points.

Method 1. An array of points.

Method 2. A structure with array fields

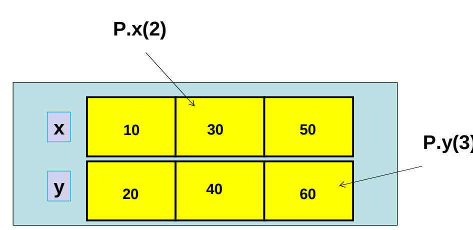
Method 1. An array of points.

```
for k=1:n
   u = randn(); v = randn();
   P(k) = MakePoint(u,v).
end
```



Method 2. A structure with array fields

```
x = randn(n,1); y = randn(n,1);
P = struct(‘x’,u,’y’,v)
```



More on Structures and Arrays

Let's encode a collection of n random points.

Method 1. An array of points.

Method 2. A structure with array fields

Choice sets a "computational stage."

Illustrate Ramifications

```
% Method 1 Centroid Computation
sx = 0; sy = 0;
for k=1:n
   sx = sx + P(k).x;
   sy = sy + P(k).y;
end
xBar = sx/n; yBar = sy/n;
```

Illustrate Ramifications

```
% Method 2 Centroid Computation
sx = 0; sy = 0;
for k=1:n
   sx = sx + P.x(k);
   sy = sy + P.y(k);
end
xBar = sx/n; yBar = sy/n;
```

Illustrate Ramifications

```
% Method 2 Centroid Computation
% Vectorized version…

xBar = sum(P.x)/n;
yBar = sum(P.y)/n;
```

A Structure Array with Components Whose Fields Are Arrays

```
  function P = MakeOutcome(s,n)
% s a string that names the player.
% n the number of dice rolls.
T = ceil(6*rand(1,n));
P = struct('name',s,'throws',T);
% P is an outcome
```

```
% Generate two outcomes…
G(1) = MakeOutcome('Me',10)
G(2) = MakeOutcome('You',10)
% Display the results…
for k=1:10
   if G(1).throws(k) > G(2).throws(k)
         disp(G(1).name)
   elseif G(1).throws(k) < G(2).throws(k)
         disp(G(2).name)
   elselse
         disp('Tie')
   end
end
```

Appreciate the Hierarchy

`G`	a structure array
`G(2)`	component in the structure array
`G(2).throws`	a field in the component
`G(2).throws(3)`	a component of the field

What did the 2nd player throw on the 3rd dice roll?

Designing Structures

```
function P = MakeOrbit(Name,P,A,phi,psi,rho,N)
% Name = planet/asteroid name (string)
% P = perihelion
% A = aphelion
% phi rotation in the plane of ecliptic
% psi tilt from the plane of the ecliptic
    :
    :
P = struct('x',x,'y',y,'z','z','t',t,…
            'name',Name,'P',P,'A',A,…
```