- Previous lecture:
  - Structure & structure array
- Today's lecture:
  - More on structs
  - Introduction to objects and classes
- Announcements:
  - Project 5 due tonight at 11pm
  - Do Exercise 11 question 3.1 and 3.2. Submit on paper at beginning of your next discussion
  - Prelim 2 on Thurs, Nov 13 at 7:30pm
  - Prelim 2 topics: end with Project 5 and Lecture 19, i.e., will NOT include structs

Different kinds of abstraction

- Packaging procedures (program instructions) into a function
  - A program is a set of functions executed in the specified order
  - Data is passed to (and from) each function
- Packaging data into a structure
  - Elevates thinking
  - Reduces the number of variables being passed to and from functions

All possible (i,j,k) combinations but avoid duplicates.
Loop index values have this relationship i < j < k

i j k			
1 2 3	2 3 4	3 4 5	4 5 6
1 2 4	2 3 5	3 4 6	
1 2 5	2 3 6	3 5 6	
1 2 6	2 4 5		
1 3 4	2 4 6		
1 3 5	2 5 6		
1 3 6			
1 4 5			
1 4 6			
1 5 6			
i = 1	**i = 2**	**i = 3**	**i = 4**

```
for i=1:n-2
  for j=i+1:n-1
    for k=j+1:n
      disp([i j k])
    end
  end
end
```

Still get the same result if all three loop indices end with n?

A: Yes

B: No

i j k

1 2 3
1 2 4
1 2 5
1 2 6
1 3 4
1 3 5
1 3 6
1 4 5
1 4 6
1 5 6

i = 1

2 3 4
2 3 5
2 3 6
2 4 5
2 4 6
2 5 6

i = 2

3 4 5
3 4 6
3 5 6

i = 3

4 5 6

i = 4

```
for i=1:n
  for j=i+1:n
    for k=j+1:n
      disp([i j k])
    end
  end
end
```

Structures with array fields

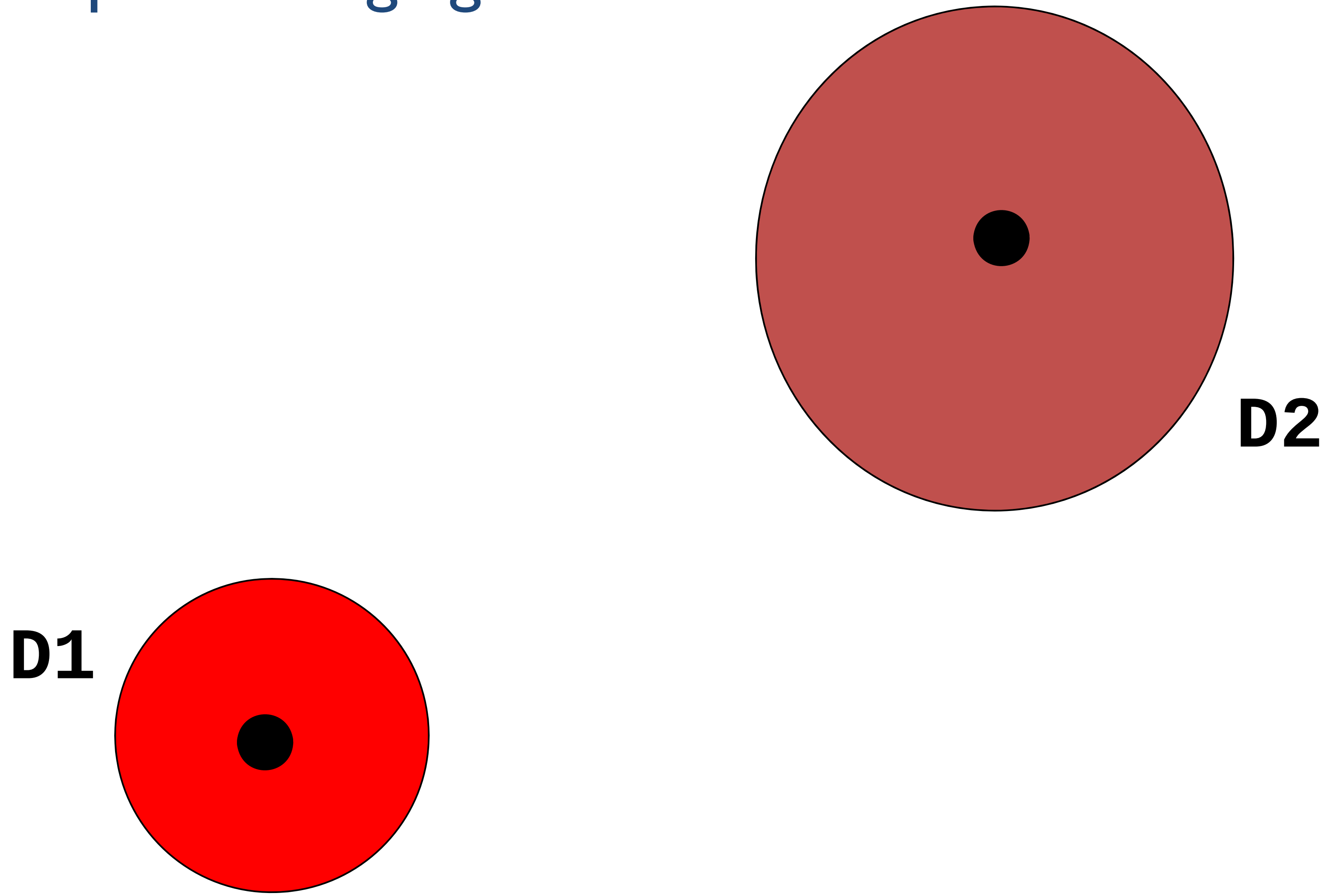
Let’s develop a structure that can be used to represent a colored disk. It has four fields:

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

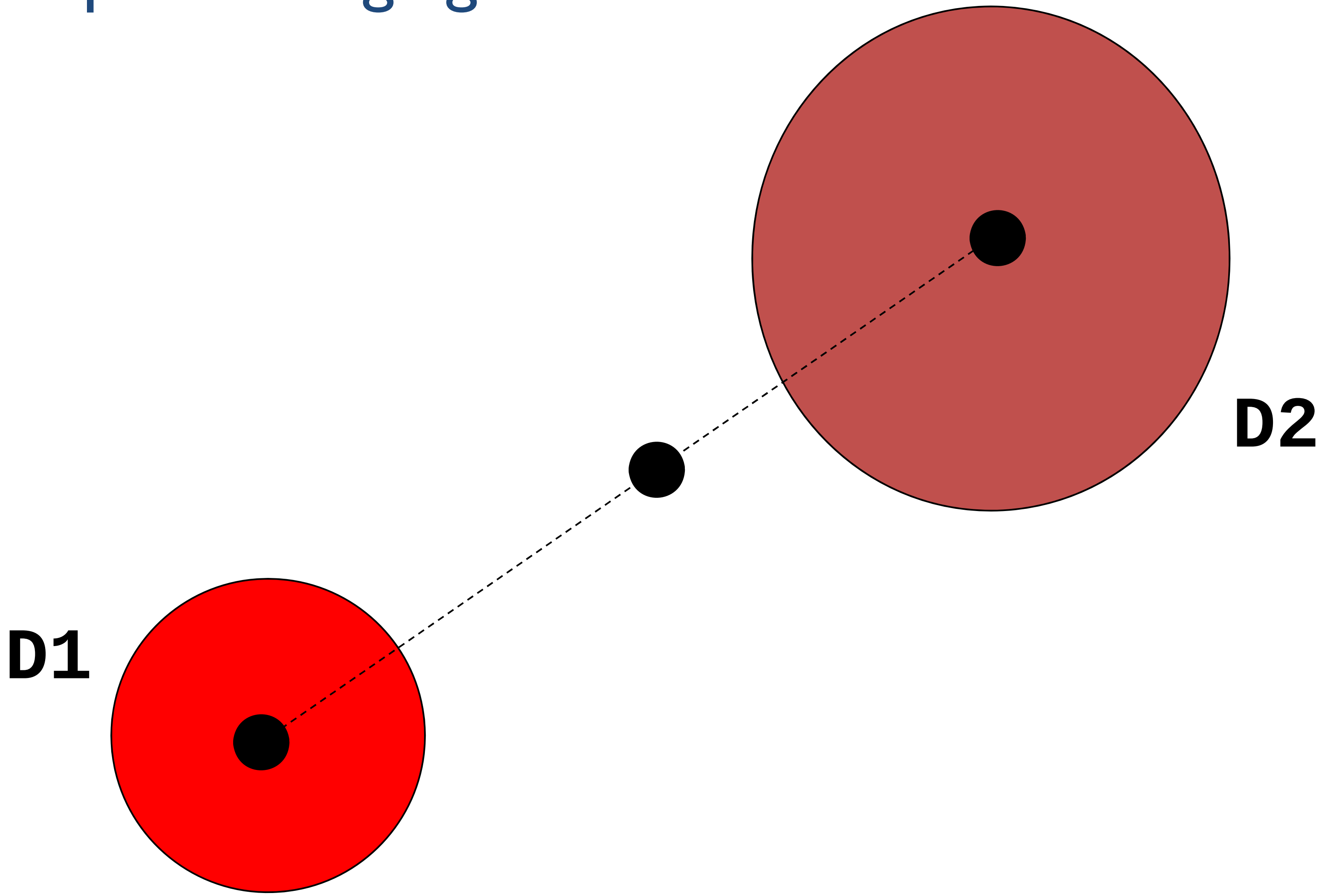
Examples:

```
D1 = struct(‘xc’,1,’yc’,2,’r’,3,…
            ’c’,[1 0 1]);
D2 = struct(‘xc’,4,’yc’,0,’r’,1,…
            ’c’,[.2 .5 .3]);
```

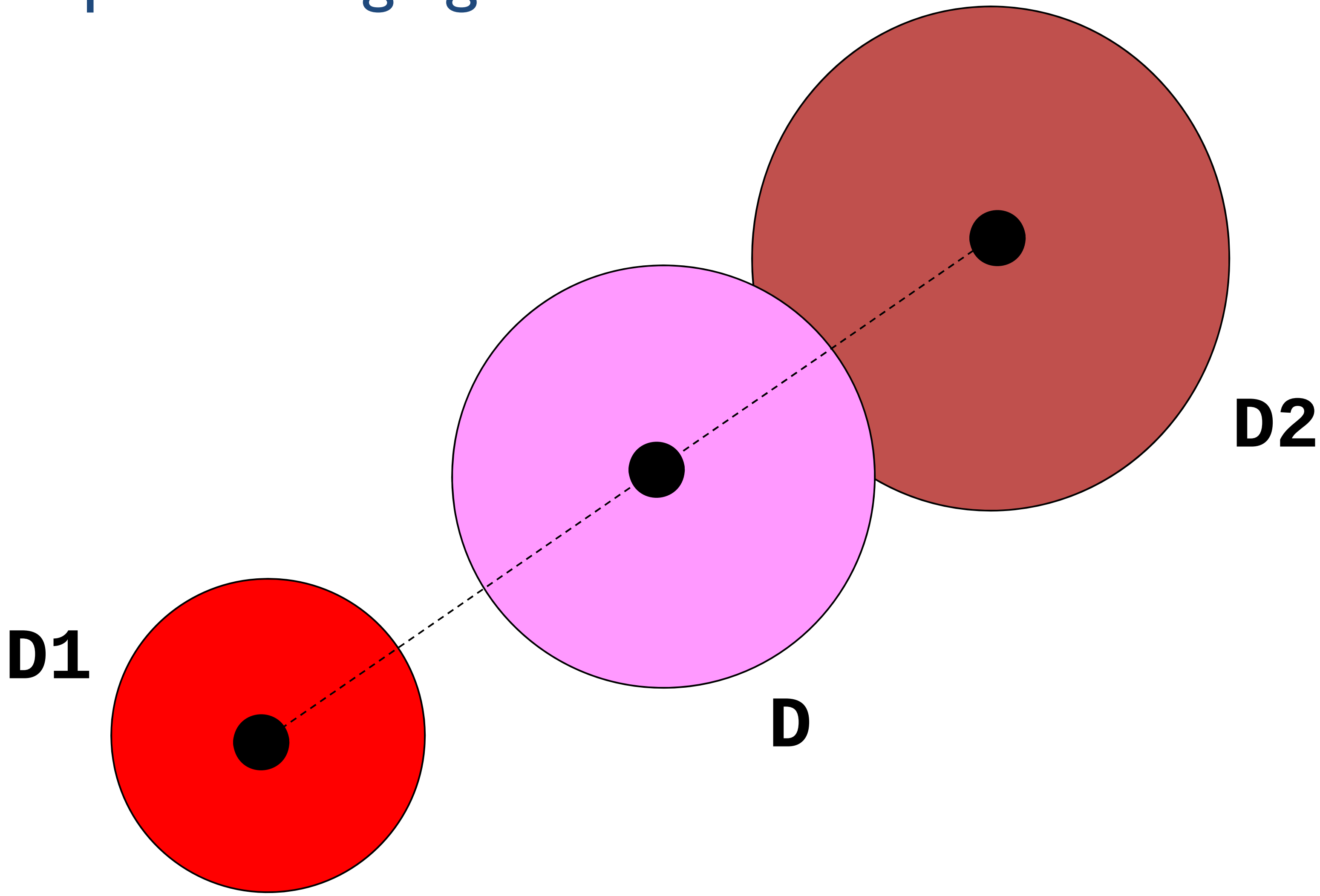
Example: Averaging two disks



Example: Averaging two disks



Example: Averaging two disks



Example: compute “average” of two disks

```
% D1 and D2 are disk structures.
% Average is:
r  = (D1.r  + D2.r) /2;
xc = (D1.xc + D2.xc)/2;
yc = (D1.yc + D2.yc)/2;
c  = (D1.c  + D2.c) /2;

% The average is also a disk
D = struct(‘xc’,xc,’yc’yc,’r’,r,’c’,c)
```

How do you assign to **`g`** the green-color component of disk **`D`**?

```
D= struct('xc',3.5, 'yc',2, ...
              'r',1.0, 'c',[.4 .1 .5])
```

A: `g = D.g;`

B: `g = D.c.g;`

C: `g = D.c.2;`

D: `g = D.c(2);`

E: *other*

A structure's field can hold a structure

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

Recall that a Point has the fields x, y

- This could be used to represent a line segment with endpoints P and Q, for instance
- Given the MakePoint function to create a point structure, what is x below?

```
x = L.P.y;
```

A: 2 B: 3 C: 4 D: 5 E: *error*

Different kinds of abstraction

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  - A program is a set of functions executed in the specified order
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- Packaging data into a structure
  - Elevates thinking
  - Reduces the number of variables being passed to and from functions
- Packaging data, and the instructions that work on those data, into an object
  - A program is the interaction among objects
  - Object-oriented programming (OOP) focuses on the design of data-instructions groupings

A card game, developed in two ways

- Develop the algorithm—the logic—of the card game:
  - Set up a deck as an array of cards. (First, choose representation of cards.)
  - Shuffle the cards
  - Deal cards to players
  - Evaluate each player's hand to determine winner

<u>Procedural programming</u>: focus on the algorithm, i.e., the procedures, necessary for solving a problem

- Identify "objects" in the game and define each:
  - Card
    - Properties: suit, rank
    - Actions: compare, show
  - Deck
    - Property: array of Cards
    - Actions: shuffle, deal, get #cards left
  - Hand …
  - Player …
- Then write the game—the algorithm—using objects of the above "classes"

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  - Player …
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Object-oriented programming: focus on the design of the objects (data + actions) necessary for solving a problem

Notice the two steps involved in OOP?

- Define the classes (of the objects)
  - Identify the properties (data) and actions (methods, i.e., functions) of each class

- Create the objects (from the classes) that are then used—that interact with one another

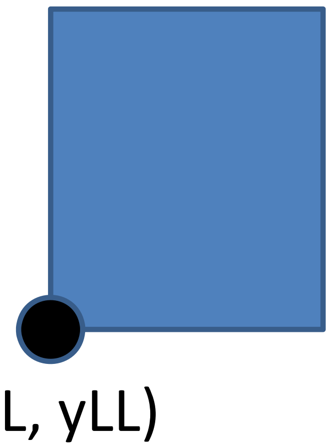
Defining a class ≠ creating an object

- A class is a specification
  - E.g., a cookie cutter specifies the shape of a cookie

- An object is a concrete instance of the class
  - Need to apply the cookie cutter to get a cookie (an instance, the object)
  - Many instances (cookies) can be made using the class (cookie cutter)
  - Instances do not interfere with one another. E.g., biting the head off one cookie doesn't remove the heads of the other cookies

Example class: Rectangle

- Properties:
  - xLL, yLL, width, height
- Methods (actions):
  - Calculate area
  - Calculate perimeter
  - Draw
  - Intersect (the intersection between two rectangles is a rectangle!)

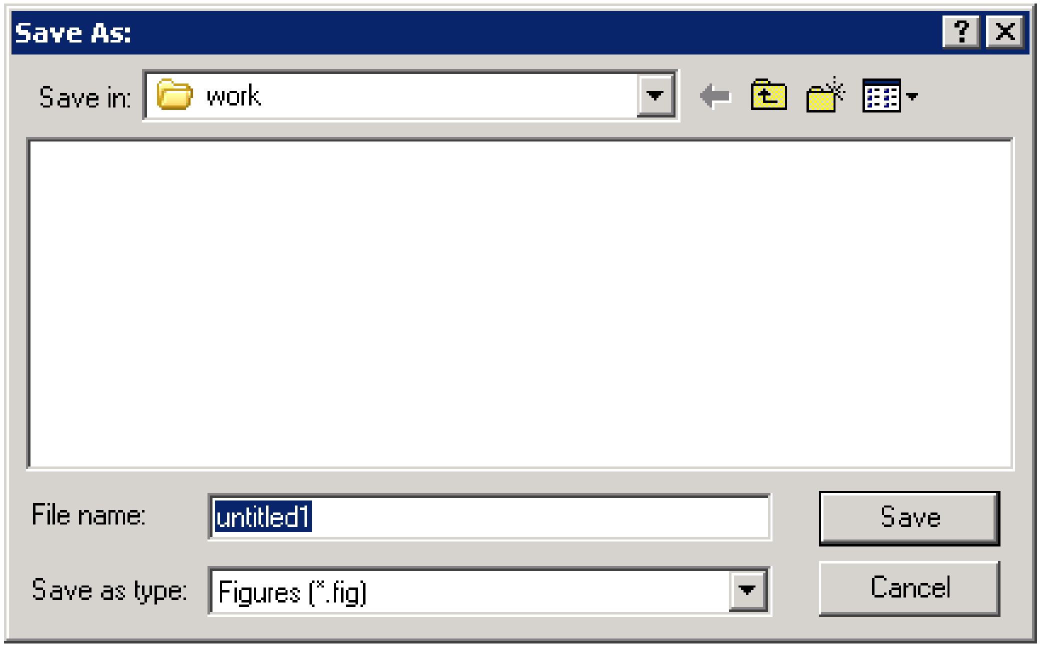


Example class: Time

- Properties:
  - Hour, minute, second
- Methods (actions):
  - Show (e.g., display in hh:mm:ss format)
  - Advance (e.g., advance current time by some amount)

Example class: Window (e.g., dialog box)

- Properties:
  - Title, option buttons, input dialog …
- Methods (actions):
  - Show
  - Resize
  - …



Many such useful classes have been predefined!

Matlab supports procedural and object-oriented programming

- We have been writing procedural programs—focusing on the algorithm, implemented as a set of functions
- We have used objects in Matlab as well, e.g., graphics
- A plot is a "*handle graphics*" object
  - Can produce plots without knowing about objects
  - Knowing about objects gives more possibilities

The `plot` handle graphics object in Matlab

```
x=…; y=…;
plot(x,y)
```
creates a graphics object

- In the past we focused on the visual produced by that command. If we want the visual to look different we make *another* plot.
- We can actually "hold on" to the graphics object—store its "*handle*"—so that we can later make changes to *that* object.

Objects of the same class have the same properties

```
x= 1:10;
% Two separate graphics objects:
plot(x, sin(x), 'k-')
plot(x(1:5), 2.^x, 'm-*')
```

- Both objects have some x-data, some y-data, some line style, and some marker style. These are the properties of one kind, or class, of the objects (plots)
- The values of the properties are different for the individual objects

See **demoPlotObj.m**

Object-Oriented Programming

- First design and define the classes (of the objects)
  - Identify the properties (data) and actions (methods, i.e., functions) of each class

- Then create the objects (from the classes) that are then used, that interact with one another