- Previous lecture:
  - File I/O, sort
- Today's lecture:
  - Introduction to objects and classes
- Announcements:
  - Try to finish Exercise 11 during DIS section ahead of Thursday's lecture.
  - Test 2A will be released on Canvas at 4:30pm EDT
    - No Piazza, Consulting Tue/Wed. OH available for projects
  - Project 5 will be released tonight, due next Thurs
  - Reminder: academic integrity

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 an array or 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

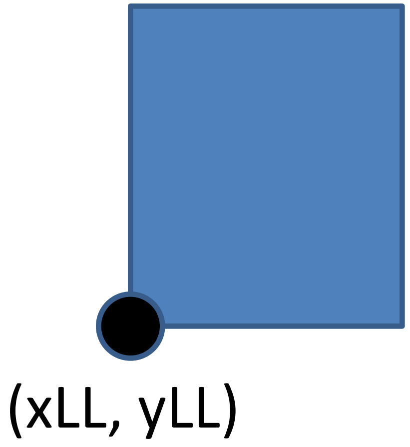
- Create the objects (from the classes) that are then used—that interact with one another

Defining a class ≠ creating an object

- A class is a specification/template
  - 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

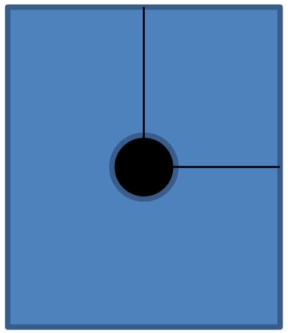
- Properties:
  - xLL, yLL, width, height
- Methods (actions):
  - Calculate area
  - Calculate perimeter
  - Draw
  - Intersect (the intersection between two rectangles is a rectangle!)



Poll: properties & methods

What if rectangles stored the following properties instead:

- xCenter, yCenter, halfWidth, halfHeight



Can they still provide these methods?

- Calculate area
- Calculate perimeter
- Draw
- Intersect

A: yes

B: no

Example class: TimeOfDay

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

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

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(1:5), '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

Optional reading: Script **demoPlotObj.m** shows some properties of graphics objects. Can also see MATLAB documentation for further detail.

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

Class Interval

- An interval has two properties:
  - left, right
- Actions—methods—of an interval include
  - Scale, i.e., expand
  - Shift
  - Check if one interval is in another
  - Check if one interval overlaps with another

See **`demoInterval0.m`**

Class Interval

- An interval has two properties:
  - left, right
- Actions—methods—of an interval include
  - Scale, i.e., expand
  - Shift
  - Check if one interval is in another
  - Check if one interval overlaps with another

```
classdef  Interval < handle

  properties
    left
    right
  end

  methods
     function  scaleRIght(self,  f)
        . . .
     end

     function  shift(self,  s)
        . . .
     end

     function  Inter = overlap(self,  other)
        . . .
     end

     . . .

  end

end
```

To specify the properties and actions of an object is to define its class. This files is Interval.m

These methods (functions) are **inside** the classdef

Given class Interval (file Interval.m) …

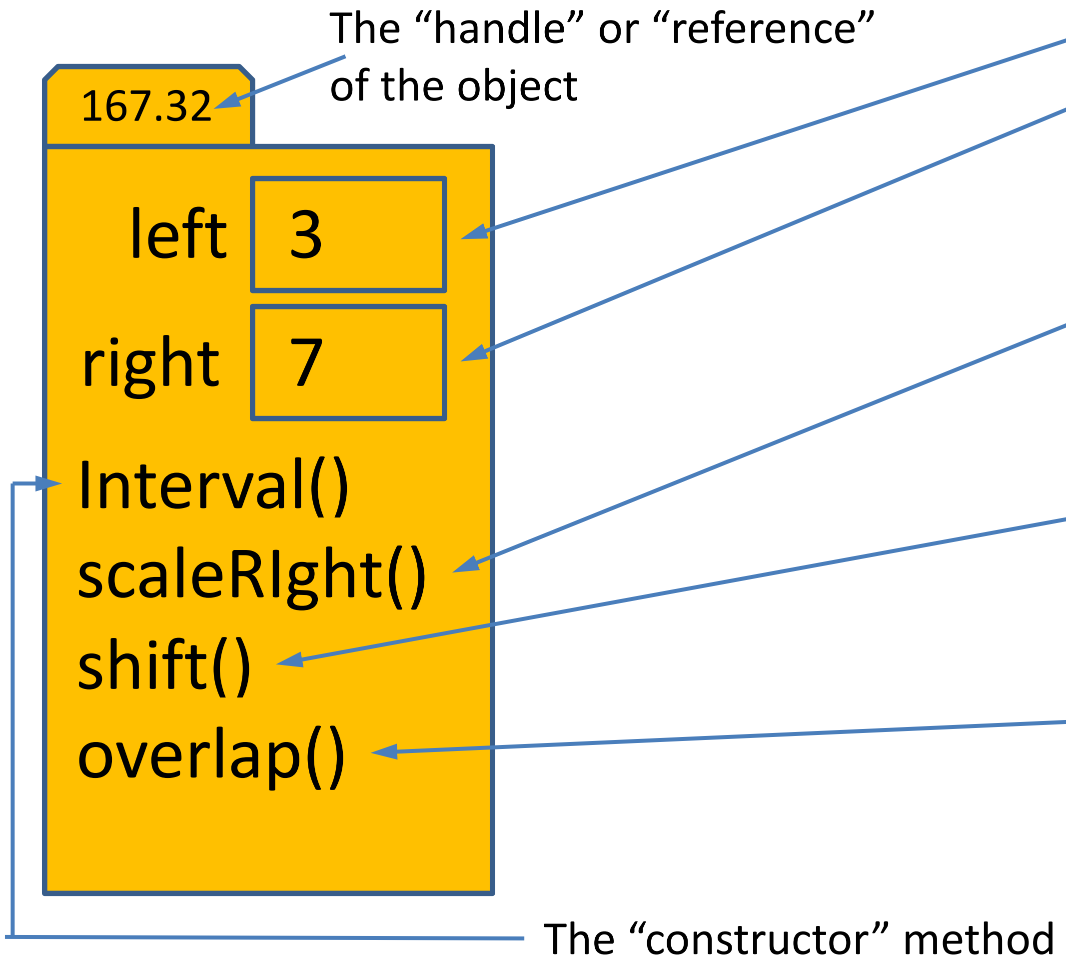
```
% Create 2 Intervals, call them A, B
A= Interval(2,4.5)
B= Interval(-3,1)

% Assignment another right end point
A.right= 14

% Half the width of A (scale by 0.5)
A.scaleRight(.5)

% See the result
disp(A.right)  % show value in right property in A
disp(A)        % show all property values in A
disp(B)
```

Observations:

- Each object is referenced by a name.
- Two objects of same class has the same properties (and methods).
- To access a property value, you have to specify whose property (which object's property) using the dot notation.
- Changing the property values of one object doesn't affect the property values of another object.

See `demoInterval0.m`

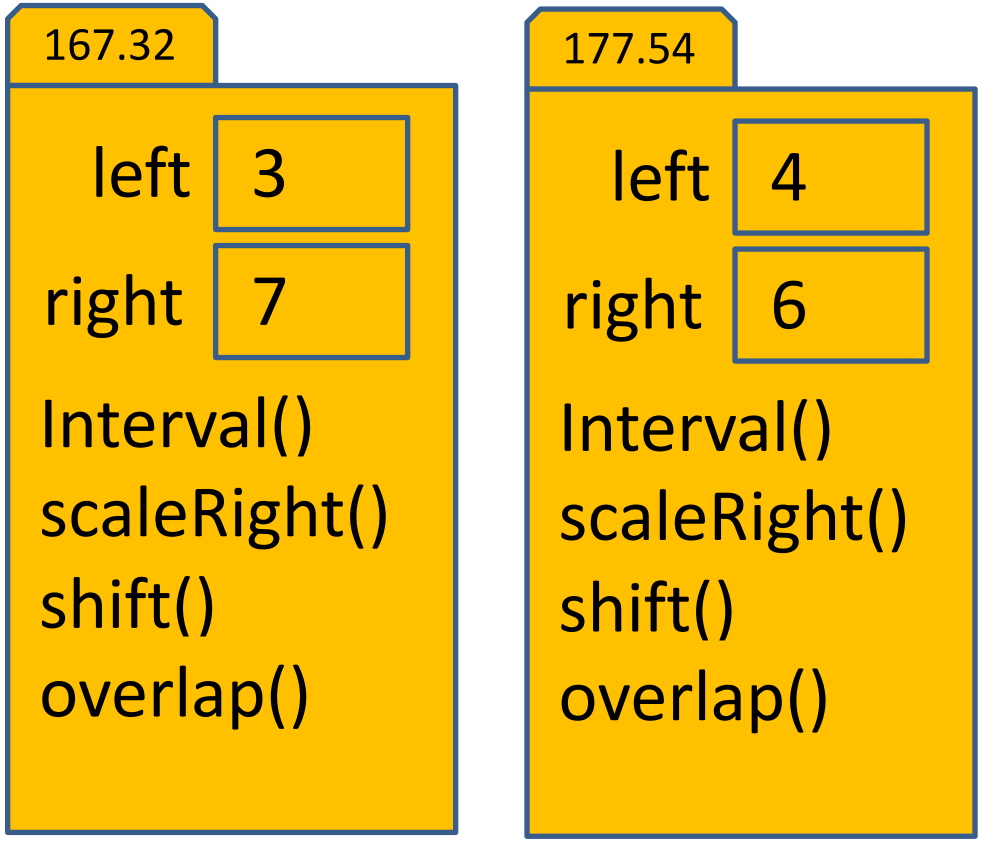
An Interval object




```
classdef  Interval < handle

  properties
    left
    right
  end

  methods
     function  scaleRIght(self,  f)
        ...
     end

     function  shift(self,  s)
        ...
     end

     function  Inter = overlap(self,  other)
        ...
     end

      ...

  end

end
```

An object is also called an “instance” of a class. It contains every property, “instance variable,” and every “instance method” defined in the class.

Multiple Interval objects

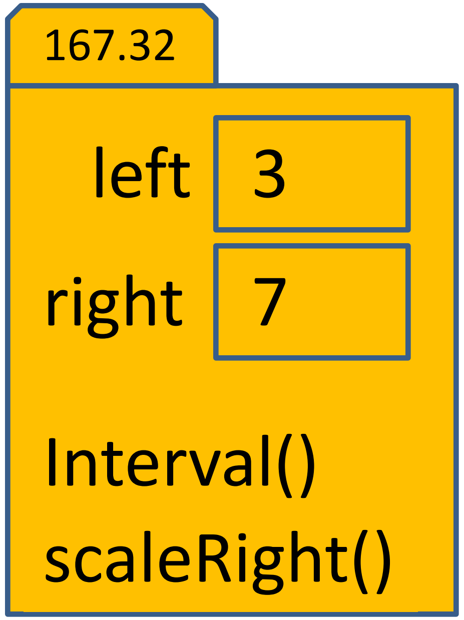


Every object (instance) contains every “instance variable” and every “instance method” defined in the class. Every object has a unique handle.

```
classdef  Interval < handle

  properties
    left
    right
  end

  methods
     function  scaleRight(self,  f)
       . . .
     end

     function  shift(self,  s)
       . . .
     end

     function  Inter = overlap(self,  other)
       . . .
     end

     . . .

  end

end
```

Simplified Interval class

To create an Interval object, use its class name as a function call: p = Interval(3,7)



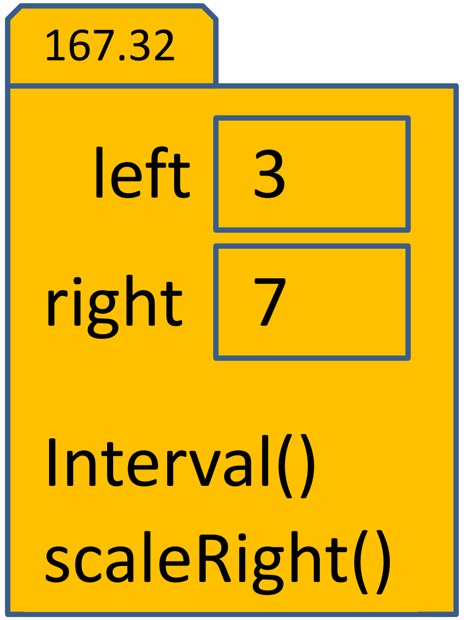

```
classdef Interval < handle
% An Interval has a left end and a right end

  properties
    left
    right
  end

  methods
    function Inter = Interval(lt, rt)
    % Constructor: construct an Interval obj
      Inter.left= lt;
      Inter.right= rt;
    end

    function scaleRight(self, f)
    % Scale the interval by a factor f
      w= self.right - self.left;
      self.right= self.left + w*f;
    end
  end
end
```

The *constructor* method

To create an Interval object, use its class name as a function call: p = Interval(3,7)

```
classdef  Interval < handle
% An Interval has a left end and a right end

  properties
    left
    right
  end

  methods
    function Inter = Interval(lt, rt)
    % Constructor:  construct an Interval obj
      Inter.left= lt;
      Inter.right= rt;
    end
```

> Stores the handle of the object being created



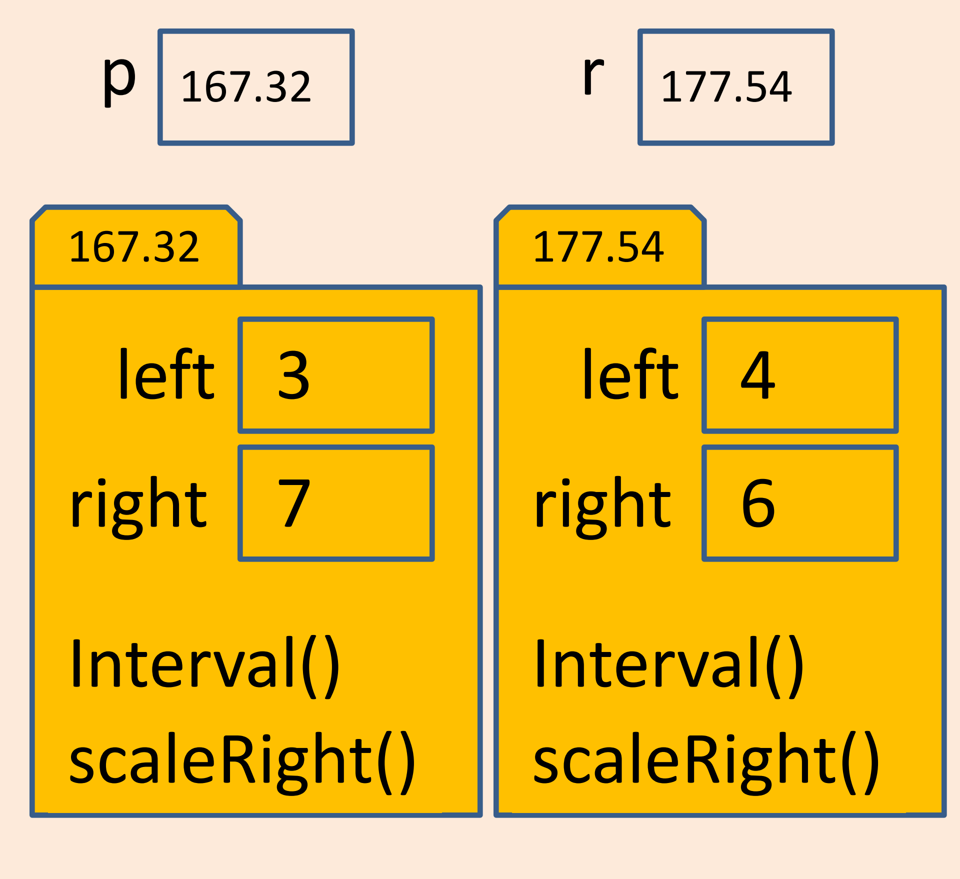
Constructor, a special method with these jobs:

- Automatically compute the handle of the new object; the handle must be returned.
- Execute the function code (to assign values to properties)

Constructor is the only method that has the name of the class.

A handle object is referenced by its handle

```
p = Interval(3,7);
r = Interval(4,6);
```

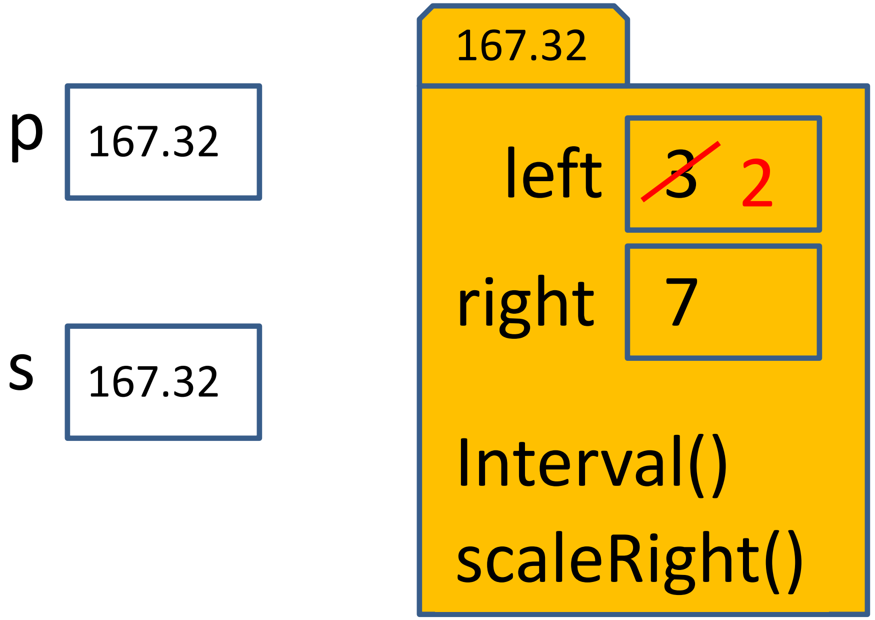


A handle, also called a reference, is like an address; it indicates the memory location where the object is stored.

What's the effect of storing data "by reference"?

What is the effect of referencing?

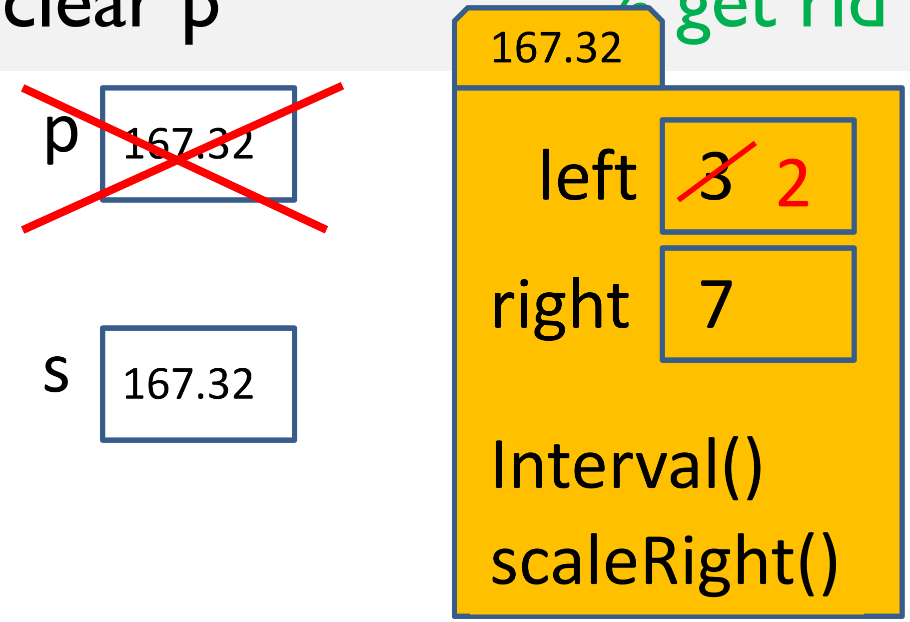
```
p = Interval(3,7);   % p references an Interval object
s = p;               % s stores the same reference as p
s.left = 2;          % change value inside object
disp(p.left)         % 2 is displayed
```



The object is not copied—no new object is created! s and p both reference the same object; s is an **alias** of p.

What is the effect of referencing?

```
p = Interval(3,7);   % p references an Interval object
s = p;               % s stores the same reference as p
s.left = 2;          % change value inside object
disp(p.left)         % 2 is displayed
clear p              % get rid of p from memory
```



The object still can be accessed through s.

In contrast, arrays are stored by value …

```
p= [3, 7];   % A vector with two elements
s= p;        % s gets a copy of p--s is ANOTHER
             %   vector with same element values
s(1)= 2;     % Changes s’s copy only, not p’s
disp(p(1))   % What is displayed?
```

A: 2 | B: 3 | B: Something else

Draw the memory!

p: [3 7]

s: