- Previous lecture:
  - Structure & structure array
- Today's lecture:
  - Introduction to objects and classes
  - Value vs. reference
  - Instantiating an object; accessing its properties and methods
- Announcements:
  - Discussion this week in classrooms, not UP B7
  - Prelim 2 at 7:30pm tonight
    - Lastnames A-H Kimball B11
    - Lastnames I-Q Upson B17
    - Lastnames R-Z Hollister B14

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
- 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

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.

See `demoPlotObj.m`

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 objects (plots)
- The values of the properties are different for the individual objects

To specify the properties & methods of an object is to define its class

- An interval has two endpoints
- We may want to perform these actions:
  - scale and shift individual intervals
  - Determine whether two intervals overlap
  - Add and subtract two intervals

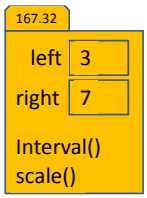
```
classdef Interval < handle

  properties
    left
    right
  end

  methods
    function scale(self, f)
      …
    end

    function Inter = overlap(self, other)
      …
    end

    function Inter = add(self, other)
      …
    end

    …

  end

end
```

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

Simplified Interval class

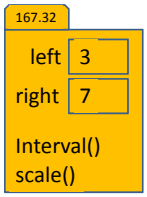
To create an Interval object, use its class name as a function call: p = Interval(3,7)




```
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 scale(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)



The *constructor*, a specialized method whose main jobs are to
- compute the handle of the new object
- execute the function code (to assign values to properties)
- return the handle of the object

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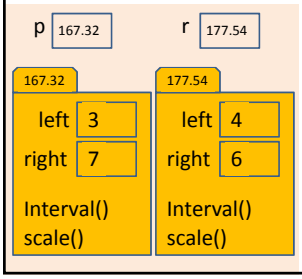
    function scale(self, f)
    % Scale the interval by a factor f
      w= self.right - self.left;
      self.right= self.left + w*f;
    end
  end
end
```

A handle object is referenced by its handle

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

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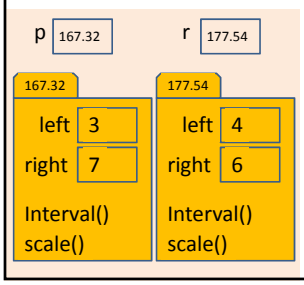
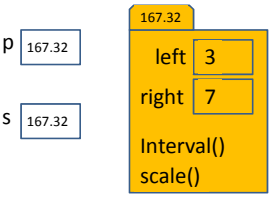


A handle, also called a reference, is like an address; it indicates the memory location where the object is stored.

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.

By contrast, structs are stored by value …

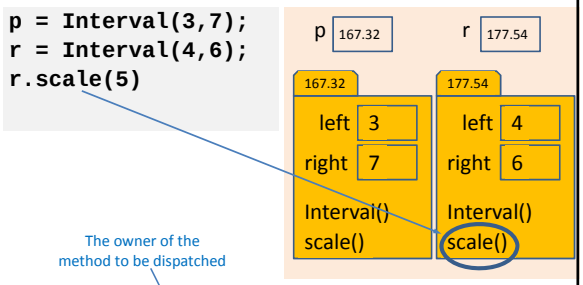
```
P.x=5; P.y=0;   % A point struct P
Q=P;            % Q gets a copy of P--copy
                %   all the values in the fields
Q.y=9;          % Changes Q's copy only, not P's
disp(P.y)       % 0 is display
```

In fact, storing-by-value is true of all non-handle-object variables. You already know this from before …

```
a=5;
b=a+1;   % b stores the value 6, not
         %   the "definition" a+1
a=8;     % Changing a does not change b
disp(b)  % 6 is displayed
```

Calling an object's method (instance method)

```
p = Interval(3,7);
r = Interval(4,6);
r.scale(5)
```



The owner of the method to be dispatched

Syntax: *<referencename>.<methodname>(<arguments >)*

Syntax for calling an instance method

```
r = Interval(4,6);
r.scale(5)
```

Method name

Reference of the object whose method is to be dispatched

Argument for the second parameter specified in function header (f). Argument for first parameter (self) is absent because it is the same as r, the owner of the method

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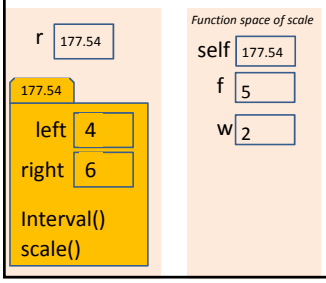

Executing an instance method

```
r = Interval(4,6);
r.scale(5)
```

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```

Executing an instance method

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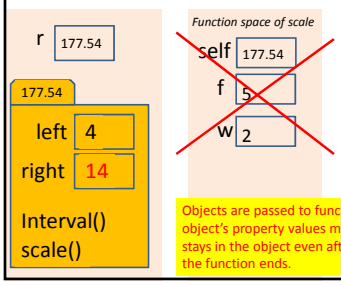

Objects are passed to functions by reference. Changes to an object's property values made through the local reference (self) stays in the object even after the local reference disappears when the function ends.

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```

classdef syntax summary

A class file begins with keyword classdef:

classdef *classname* < handle

The class specifies handle objects

Constructor returns a reference to the class object

Each instance method's first parameter must be a reference to the instance (object) itself

Use keyword end for keywords classdef, properties, methods, function.

Properties

Constructor

Instance methods (functions)

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