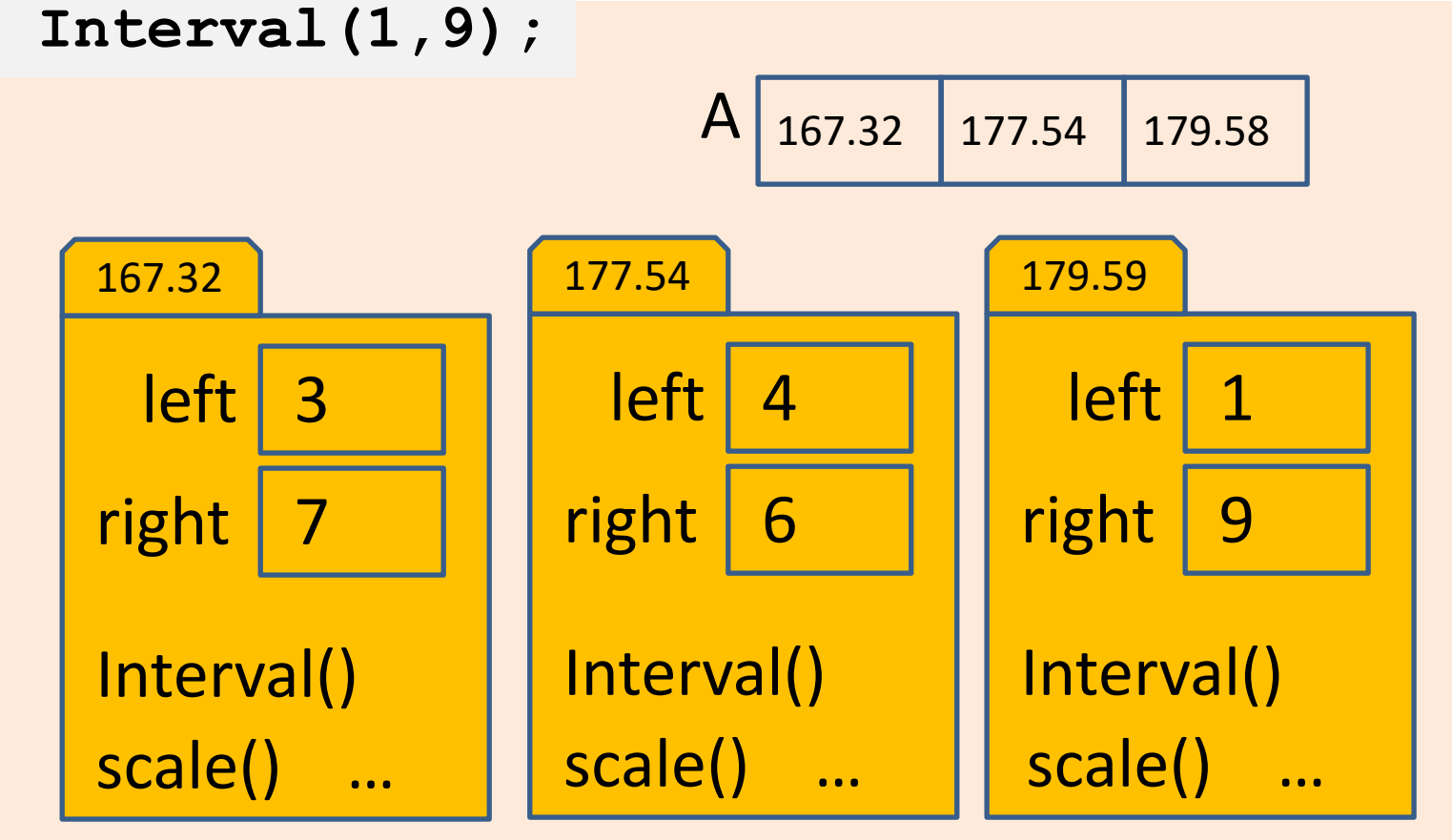
- Previous lecture:
  - Objects are passed by reference to functions
  - Details on class definition (constructor, instance method)
- Today's lecture:
  - Overloading methods
  - Array of objects
  - Class reuse
- Announcements:
  - Discussion via Zoom – please attend
  - Test 2A feedback on Gradescope. Learn from the exam by re-doing the problems—don't just read the solutions (to be posted later)
  - Showcase on Piazza – vote for your favorites!

An "array of objects" is really an …

array of references to objects

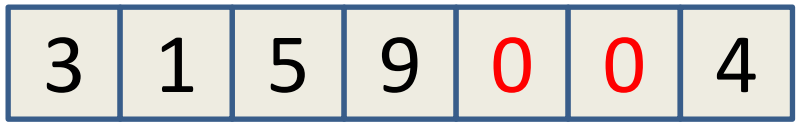
```
>> A= Interval(3,7);
>> A(2)= Interval(4,6);
>> A(3)= Interval(1,9);
```



MATLAB allows an array to be appended

```
v= [3 1 5 9]
v(7)= 4
```

- What happens to `v(5)` and `v(6)`?



- MATLAB assigns some "default value" to the skipped over components for arrays
- For arrays of objects, you must implement the constructor to handle such a situation

Constructor needs to be able to handle a call with no arguments

```
>> A= Interval(3,7);     % Array of length 1
>> A(2)= Interval(4,6); % Array of length 2
>> A(3)= Interval(1,9); % Array of length 3
>> A(5)= Interval(2,5); % Array of length 5
```

Error!

- Interval constructor we have so far requires two parameters:

```
function Inter = Interval(lt, rt)
```

- User specified two arguments as required for A(5), but…
- Matlab has to assign A(4) "on its own" by calling the constructor, but no arguments get passed → Error!

Function overloading I

Problem: "default construction" passes 0 args, but our constructor has 2 input params

Want a function that performs the same task for different numbers of inputs

- MATLAB's solution: accept all possible arguments, then ask how many we got

Examples

- `rand(), rand(2), rand(1, 3)`
- `max(4, 3), max([6 7 5])`
- `plot(x, y), plot(x, y, 'm-*'), plot(x, y, v, w)`
- `Interval(4, 6), Interval()`

Constructor that handles variable number of args

- When used inside a function, `nargin` evaluates to the number of arguments that were passed

```
classdef  Interval < handle

 properties
   left
   right
 end

 methods
   function  Inter = Interval(lt, rt)

         Inter.left= lt;
         Inter.right= rt;

   end

   . . .

 end

end
```

Constructor that handles variable number of args

- When used inside a function, `nargin` evaluates to the number of arguments that were passed
- If `nargin`≠2, constructor ends without executing the assignment statements. Then `Inter.left` and `Inter.right` get any default values defined under properties. In this case the default property values are `[]` (type `double`)

```
classdef  Interval < handle

 properties
   left
   right
 end

 methods
   function  Inter = Interval(lt, rt)
     if  nargin==2
         Inter.left= lt;
         Inter.right= rt;
     end
   end

   …

 end

end
```

Default values

- Default property value: empty double array `[ ]`
- Within an array:
  - Default double: `0`
  - Default char: null (char(0), but looks like a space in MATLAB)
  - Default cell: empty cell `{ }`
  - Default object: call constructor with no arguments
    - Advantage of bundling behavior with data

Later: customizing default property values in objects

Function overloading II (arguably "overriding")

Want to customize an existing function for new classes

- MATLAB's solution: define a method in the class with the same function name

Examples

- `disp`
- `plot`
- Operators!

DEMO

Overload `disp` in Interval.m

If a class defines an object that may be used in an array…

- Constructor must be able handle a call that does not specify any arguments
  - Use built-in command **`nargin`**, which returns the number of function input arguments passed

- The overridden **`disp`** method, if implemented, should check for an input argument that is an array and handle that case explicitly.
  - Caution: accessing properties of an entire array produces "comma-separated lists" – an advanced topic

Write a function to create an array of random intervals

EXERCISE

A function to create an array of `Intervals`

```
function inters = intervalArray(n)
% Generate n random Intervals.  The left and
% right ends of each interval is in (0,1)
```

A function to create an array of **Intervals**

```
function inters = intervalArray(n)
% Generate n random Intervals.  The left and
% right ends of each interval is in (0,1)

for k = 1:n
  randVals= rand(1,2);
  if randVals(1) > randVals(2)
     tmp= randVals(1);
     randVals(1)= randVals(2);
     randVals(2)= tmp;
  end
  inters(k)= Interval(randVals(1),randVals(2));
end
```

An independent function, not an instance method. See **intervalArray.m**

Write a function to return the widest interval in an array

EXERCISE

A function to find the widest Interval in an array

```
function inter = widestInterval(A)
% inter is the widest Interval (by width) in
% A, an array of Intervals
```

An independent function, not an instance method. See **widestInterval.m**

A function to find the widest Interval in an array

```
function inter = widestInterval(A)
% inter is the widest Interval (by width) in
% A, an array of Intervals

inter= A(1);  % widest Interval so far
for k= 2:length(A)
   if A(k).right - A(k).left > ...
                        inter.right - inter.left
       inter= A(k);
   end
end
```

An independent function, not an instance method. See **widestInterval.m**

A function to find the widest Interval in an array

```
function inter = widestInterval(A)
% inter is the widest Interval (by width) in
% A, an array of Intervals

inter= A(1);  % widest Interval so far
for k= 2:length(A)
    if A(k).getWidth() > inter.getWidth()
        inter= A(k);
    end
end
```

An independent function, not an instance method. See **widestInterval.m**

Poll: Functions returning objects

```
v = [Interval(2, 4) Interval(3, 7)];
w = widestInterval(v);
w.scale(2);
disp(v(2).right)
```

What is displayed?

- A: 7 — Intervals were copied when passed into function, so original does not change
- B: 7 — New Interval was created when returned from function, so original does not change
- C: 11 — Original is modified through returned value

```
function inter = widestInterval(A)
% inter is the widest Interval (by width) in
% A, an array of Intervals

inter= A(1);  % widest Interval so far
for k= 2:length(A)
   if A(k).getWidth() > inter.getWidth()
       inter= A(k);
   end
end
```

A weather object can make use of Intervals …

- Define a class LocalWeather to store the weather data of a city, including monthly high and low temperatures and precipitation
  - Temperature: low and high → an Interval
    - For a year → length 12 array of Intervals
  - Precipitation: a scalar value
    - For a year → length 12 numeric vector
  - Include the city name: a string

```
classdef LocalWeather < handle

  properties
    city     % string
    temps    % array of Intervals
    precip   % numeric vector
  end

  methods
    …
  end

end
```

Weather data file

```
//Syracuse
//Monthly temperature and precipitation
//Lows (cols 4-8), Highs (col 12-16), precip (cols 20-24)
//Units:  English
      14       31     3.07
      16       33     2.96
      23       42     3.09
      34       55     3.91
      43       67     3.86
      52       76     4.27
      58       80     4.03
      56       79     3.95
      48       70     3.79
      42       58     3.44
      31       47     3.19
      21       36     2.82
```

Class **LocalWeather** should be able to construct an object from such data files, given the known file format.

Weather data file

```
//Ithaca
//Monthly temperature and precipitation
//Lows (cols 4-8), Highs (col 12-16), precip (cols 20-24)
//Units:  English
      15       31     2.08
      17       34     2.06
      23       42     2.64
      34       56     3.29
      44       67     3.19
      53       76     3.99
      58       80     3.83
      56       79     3.63
      49       71     3.69
     NaN       59      NaN
      32       48     3.16
      22       36     2.40
```

Class **LocalWeather** should be able to construct an object from such data files, given the known file format.

See **ithacaWeather.txt**, **LocalWeather.m**

```
classdef  LocalWeather < handle

  properties
    city= ”;
    temps= Interval.empty();
    precip
  end

  methods
    function lw = LocalWeather(fname)
      …
    end

    …
  end

end
```

Set property variable that will store an array of objects to the correct type, either under properties or in the constructor

```
classdef LocalWeather < handle
 properties
  city=''; temps=Interval.empty(); precip=0;
 end
 methods
  function lw = LocalWeather(fname)
   fid= fopen(fname,'r');
   s= fgetl(fid);
   lw.city= s(3:length(s));
   for k= 1:3
      s= fgetl(fid);
   end
   for k=1:12
      s= fgetl(fid);
      lw.temps(k)= Interval(str2double(s(4:8)), ...
                            str2double(s(12:16)));
      lw.precip(k)= str2double(s(20:24));
   end
   fclose(fid);
  end
  ...
 end  %methods
end  %classdef
```

```
//Ithaca
//Monthly temperature and precipitation
//Lows (cols 4-8), Highs (col 12-16), p
//Units:  English
      15       31    2.08
      17       34    2.06
      23       42    2.64
      34       56    3.29
      44       67    3.19
      53       76    3.99
      58       80    3.83
      56       79    3.63
      49       71    3.69
     NaN       59     NaN
      32       48    3.16
      22       36    2.40
```

See **`LocalWeather.m`** for complete code including use of **`nargin`**

Function to show data of a month of **LocalWeather**

```
function showMonthData(self, m)
% Show data for month m, 1<=m<=12.









end
```

Should display which month, the high and low temperatures, and precipitation

Function to show data of a month of **LocalWeather**

```
function showMonthData(self, m)
% Show data for month m, 1<=m<=12.

 mo= {'Jan','Feb','Mar','Apr','May','June',...
      'July','Aug','Sep','Oct','Nov','Dec'};
 fprintf('%s Data\n', mo{m})
 fprintf('Temperature range: ')
 disp(self.temps(m))
 fprintf('Average precipitation: %.2f\n', ...
         self.precip(m))
end
```

See **LocalWeather.m**

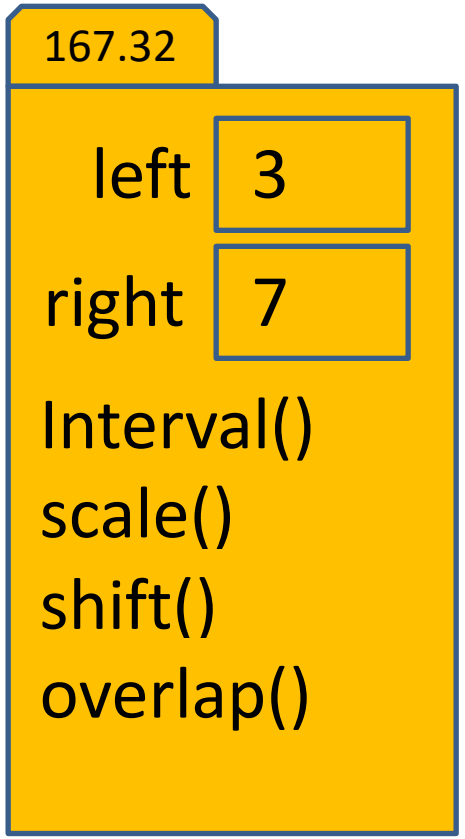
Observations about our class Interval

- We can use it (create Interval objects) anywhere
  - Within the Interval class, e.g., in method overlap
  - "on the fly" in the Command Window
  - In other function/script files – not class definition files
  - In another class definition
- Designing a class well means that it can be used in many different applications and situations

OOP ideas

- Aggregate variables/methods into an abstraction (a class) that makes their relationship to one another explicit
- Object properties (data) need not be passed to instance methods—only the object handle (reference) is passed. Useful for large data sets!

Pass reference, not properties



When an instance method executes, the properties—data—are accessible through the handle (reference). No local copy of the data is needed in the method's memory space.

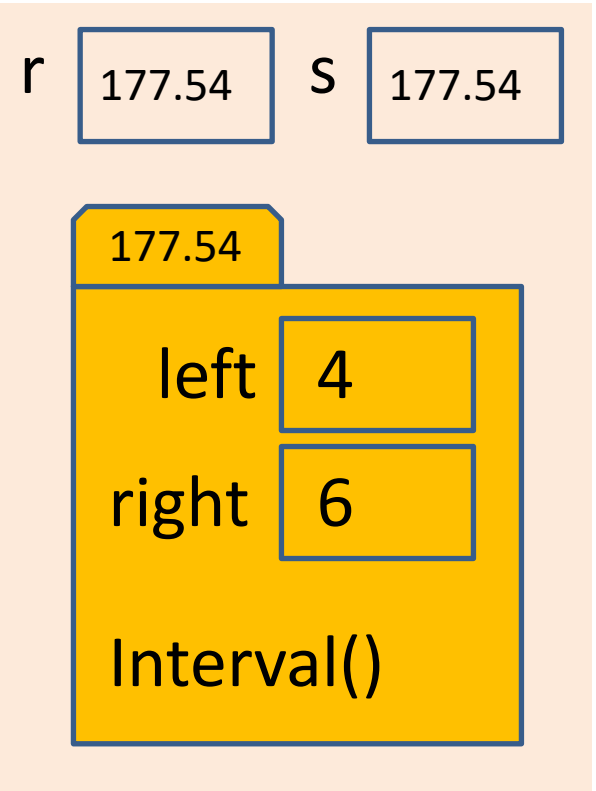
```
classdef Interval < handle

  properties
    left
    right
  end

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

    function shift(self, s)
      ...
    end

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

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

    ...

  end

end
```

Poll: Assigning handles

```
r = Interval(4, 6);
s = r;
s.left = 5;
s = Interval(3, 7);
disp(r.left)
```

What will be displayed?

- A: 3
- B: 4
- C: 5
- D: 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
  end
end
```

Interval.m