- Previous lecture:
  - Array of objects
  - Methods that handle a variable number of arguments
  - Using a class in another
- Today's lecture:
  - Why use OOP?
  - Attributes for properties and methods
  - Inheritance: extending a superclass
- Announcement:
  - Pick up prelim 2 at ACCEL Green Rm during consulting hrs

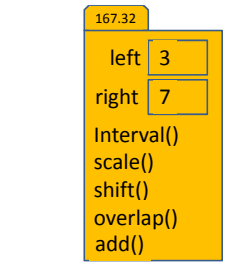
Observations about our class Interval

- 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. Important for large data sets!
- Objects (instances of a class) are self-governing (protect and manage themselves)
  - Hide details from client, and restrict client's use of the services
  - Provide clients with the services they need so that they can create/manipulate as many objects as they need

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
```

Restricting access to properties and methods

- Hide data from "outside parties" who do not need to access that data—need-to-know basis
- E.g., we decide that users of Interval class cannot directly change `left` and `right` once the object has been created. Force users to use the provided methods—scale, shift, etc.—to cause changes in the object data
- Protect data from unanticipated user action
- Information hiding is very important in large projects

Constructor can be written to do error checking!

```
classdef Interval < handle
  properties
    left
    right
  end

  methods
    function Inter = Interval(lt, rt)
      if nargin==2
        if lt <= rt
          Inter.left= lt;
          Inter.right= rt;
        else
          disp('Error at instantiation: left>right')
        end
      end
    end
    …
  end
end
```

Alternative: use built-in function error to halt program execution, e.g., error('Error at instantiation: left>right')

Should force users (clients) to use code provided in the class to create an Interval or to change its property values once the Interval has been created.

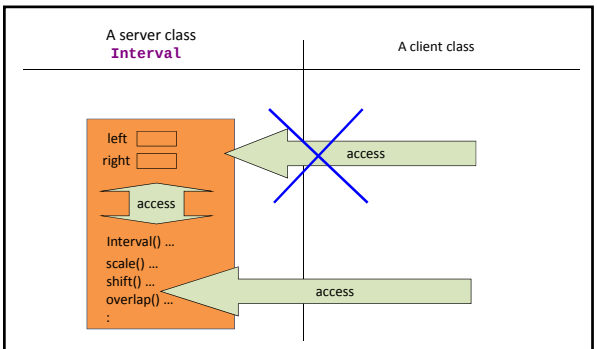
E.g., if users cannot directly set the properties left and right, then they cannot accidentally "mess up" an Interval.

```
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
```

Server

```
% Interval experiments
for k=1:5
   fprintf('Trial %d\n', k)
   a= Interval(3, 3+rand*5);
   b= Interval(6, 6+rand*3);
   disp(a)
   disp(b)
   c= a.overlap(b);
   if ~isempty(c)
      fprintf('Overlap is ')
      disp(c)
   else
      disp('No overlap')
   end
   pause
end
```

Example client code



Data that the client does not need to access should be protected: **`private`**
Provide a set of methods for **`public`** access.

The "client-server model"

Attributes for properties and methods

- **`public`**
  - Client has access
  - Default
- **`private`**
  - Client cannot access

```
% Client code
r= Interval(4,6);
r.scale(5); % OK
r= Interval(4,14); % OK
r.right=14; % error
disp(r.right) % error
```

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

 properties (SetAccess=private, GetAccess=private)
    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
```

Within the class, there is always access to the properties, even if private

Attributes for properties and methods

- **`public`**
  - Client has access
  - Default
- **`private`**
  - Client cannot access

```
% Client code
r= Interval(4,6);
r.scale(5); % OK
r= Interval(4,14); % OK
r.right=14; % error
disp(r.right) % error
```

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

 properties (Access=private)
    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
```

Both GetAccess and SetAccess are private

Public "getter" method

- Provides client the ability to get a property value

```
% Client code
r= Interval(4,6);
disp(r.left) % error
disp(r.getLeft()) % OK
```

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

 properties (Access=private)
    left
    right
 end

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

    function lt = getLeft(self)
    % lt is the interval's left end
       lt= self.left;
    end
    function rt = getRight(self)
    % rt is the interval's right end
       rt= self.right;
    end
    :
 end
end
```

Public "setter" method

- Provides client the ability to set a property value
- Don't do it unless really necessary! If you implement public setters, include error checking (not shown here).

```
% Client code
r= Interval(4,6);
r.right= 9; % error
r.setRight(9) % OK
```

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

 properties (Access=private)
    left
    right
 end

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

    function setLeft(self, lt)
    % the interval's left end gets lt
       self.left= lt;
    end
    function setRight(self, rt)
    % the interval's right end gets rt
       self.right= rt;
    end
    :
 end
end
```

Always use available methods, even when within same class

```
classdef Interval < handle
 properties (Access=private)
  left; right
 end
 methods
  function Inter = Interval(lt, rt)
    …
  end
  function lt = getLeft(self)
     lt = self.left;
  end
  function rt = getRight(self)
     rt = self.right;
  end
  function w = getWidth(self)
     w= self.getRight() – self.getLeft() ;
  end
  …
 end
end
```

In here… code that always uses the getters & setters

```
% Client code
…
A = Interval(4,7);
disp(A.getRight() )
…
% … lots of client code that uses
%     class Interval, always using the
%     provided public getters and
%     other public methods …
```

Always use available methods, even when within same class

```
classdef Interval < handle
 properties (Access=private)
  left; right
 end
 methods
  function Inter = Interval(lt, rt)
    …
  end
  function lt = getLeft(self)
     lt = self.left;
  end
  function rt = getRight(self)
     rt = self.right;
  end
  function w = getWidth(self)
     w= self.getRight() – self.getLeft() ;
  end
  …
 end
end
```

New Interval implementation

```
classdef Interval < handle
 properties (Access=private)
  left; width
 end
 methods
  function Inter = Interval(lt, w)
    …
  end
  function lt = getLeft(self)
     lt = self.left;
  end
  function rt = getRight(self)
     rt = self.getLeft() + self.getWidth();
  end
  function w = getWidth(self)
     w= self.width ;
  end
  …
 end
end
```

In here… code that always uses the getters & setters

Rewrite the getters/setters. Everything else stays the same! Cool! Happy clients!

OOP ideas → Great for managing large projects

- 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. Important for large data sets!
- Objects (instances of a class) are self-governing (protect and manage themselves)
  - Hide details from client, and restrict client's use of the services
  - Provide clients with the services they need so that they can create/manipulate as many objects as they…

Rewrite the getters/setters. Everything else stays the same! Cool! Happy clients!

A fair die is…

```
classdef Die < handle
 properties (Access=private)
  sides=6;
  top
 end
 methods
  function D = Die(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
 end
 methods (Access=private)
  function setTop(…)  …
 end
end
```

What about a trick die?

Separate classes—each has its own members

```
classdef Die < handle
 properties (Access=private)
  sides=6;
  top
 end
 methods
  function D = Die(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
 end
 methods (Access=private)
  function setTop(…)  …
 end
end
```

```
classdef TrickDie < handle
 properties (Access=private)
  sides=6;
  top
  favoredFace
  weight=1;
 end
 methods
  function D = TrickDie(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
  function f = getFavoredFace(…) …
  function w = getWeight(…)  …
 end
 methods (Access=private)
  function setTop(…)
 end
end
```


Can we get all the functionality of Die in TrickDie without re-writing all the Die components in class TrickDie?

```
classdef Die < handle
 properties (Access=private)
  sides=6;
  top
 end
 methods
  function D = Die(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
 end
 methods (Access=private)
  function setTop(…)  …
 end
end
```

```
classdef TrickDie < handle
```

"Inherit" the components of class Die

```
 properties (Access=private)
  favoredFace
  weight=1;
 end
 methods
  function D = TrickDie(…)  …
  function f =getFavoredFace(…) …
  function w = getWeight(…)  …
 end
end
```

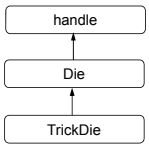
Yes! Make TrickDie a subclass of Die

```
classdef Die < handle
 properties (Access=private)
  sides=6;
  top
 end
 methods
  function D = Die(…)  …
  function roll(…)  …
  function disp(…)  …
  function s = getSides(…)  …
  function t = getTop(…)  …
 end
 methods (Access=protected)
  function setTop(…)  …
 end
end
```

```
classdef TrickDie < Die

 properties (Access=private)
  favoredFace
  weight=1;
 end

 methods
  function D = TrickDie(…)  …
  function f=getFavoredFace(…)…
  function w = getWeight(…)  …
 end

end
```


Inheritance

Inheritance relationships are shown in a *class diagram*, with the arrow pointing to the parent class



An ***is-a*** relationship: the child ***is a*** more specific version of the parent. Eg., a trick die *is a* die.

Multiple inheritance: can have multiple parents ← e.g., Matlab
Single inheritance: can have one parent only ← e.g., Java

Inheritance

- Allows programmer to *derive* a class from an existing one
- Existing class is called the *parent class*, or *superclass*
- Derived class is called the *child class* or *subclass*
- The child class *inherits* the (public and protected) members defined for the parent class
- Inherited trait can be *accessed as though it was* ***locally*** *defined*

Must call the superclass' constructor

- In a subclass' constructor, call the superclass' constructor before assigning values to the subclass' properties.
- Calling the superclass' constructor cannot be conditional: explicitly make one call to superclass' constructor

See constructor in `TrickDie.m`

Syntax

```
classdef Child < Parent

 properties
  propC
 end

 methods

  function obj = Child(argC, argP)
    obj = obj@Parent(argP)
    obj.propC = argC;
  end

  …
 end

end
```


Which components get "inherited"?

- public components get inherited
- private components exist in object of child class, but cannot be directly accessed in child class ⇒ we say they are not inherited
- Note the difference between inheritance and existence!
- Let's create a TrickDie and play with it …

`protected` attribute

- Attributes dictate which members get inherited
- **`private`**
  - Not inherited, can be *accessed* by local class only
- **`public`**
  - Inherited, can be *accessed* by all classes
- **`protected`**
  - Inherited, can be *accessed* by subclasses
- *Access*: access as though defined locally
- All members from a superclass *exist* in the subclass, but the **`private`** ones cannot be *accessed* directly—can be accessed through inherited (public or protected) methods