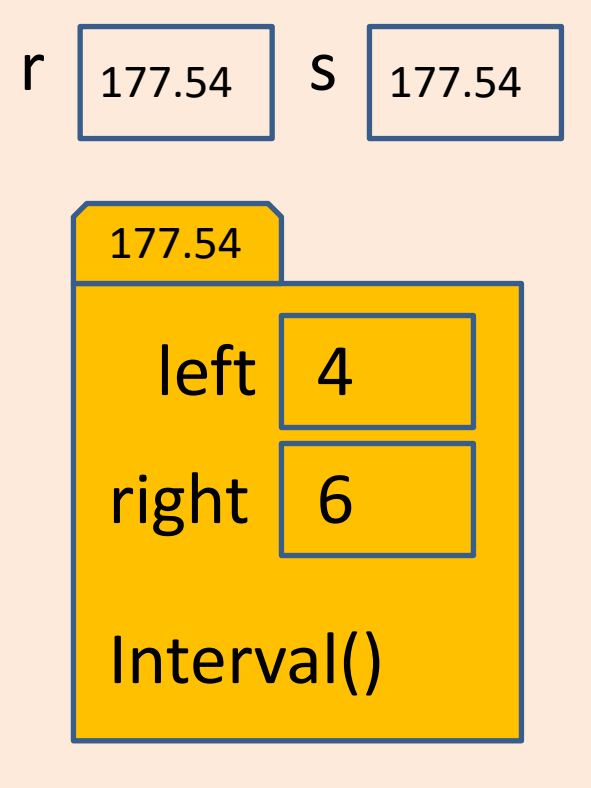
- Previous lecture:
  - Array of objects
  - Methods that handle a variable number of arguments
  - Using a class in another
- Today's lecture:
  - Why use OOP?
  - Attributes (`private`, `public`) for properties and methods
  - Inheritance: extending a class
- Announcement:
  - Project 5 due tonight
    - Submissions accepted tomorrow with small penalty

# 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

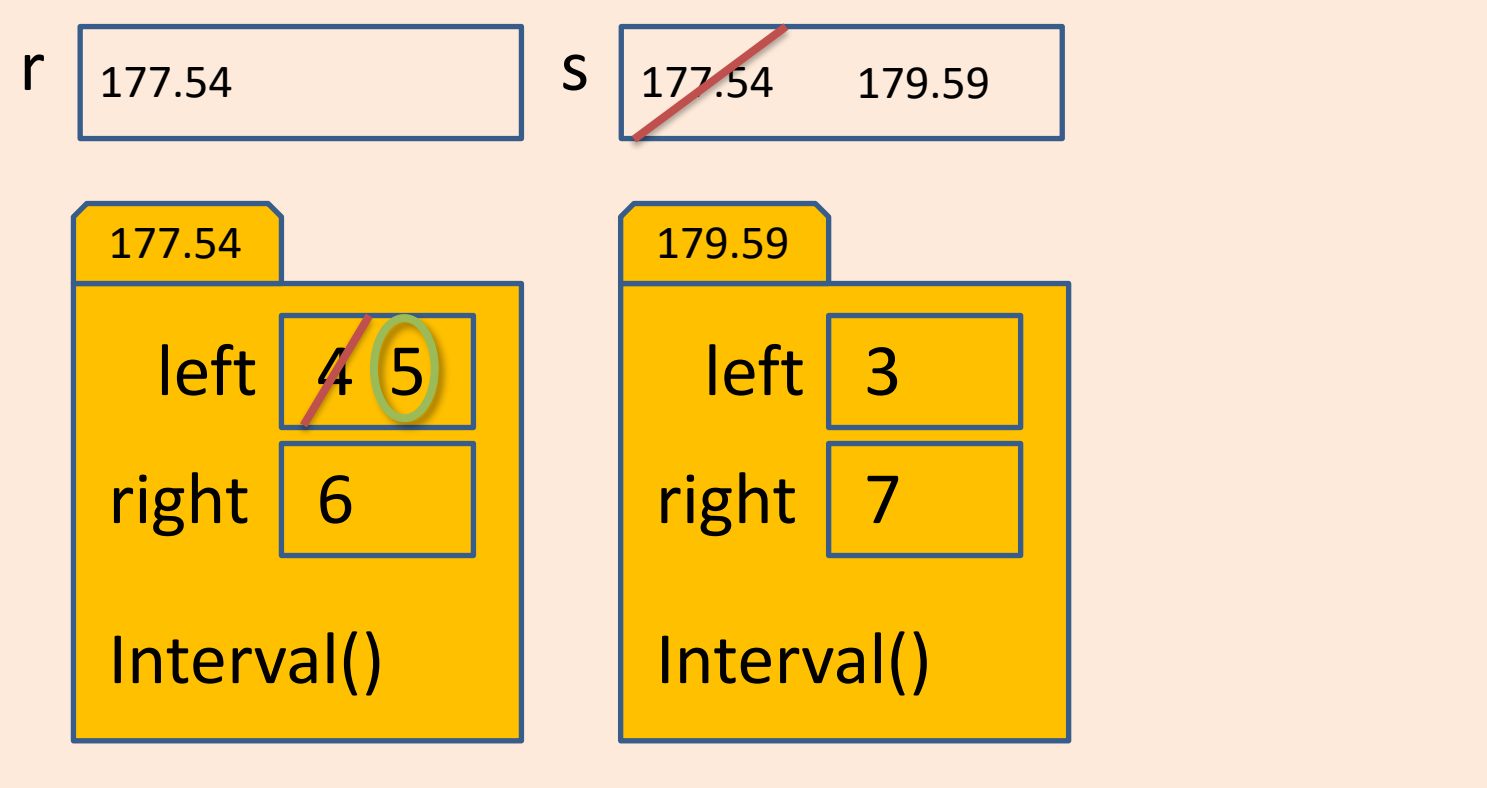
D: 7

```
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

# Poll: Assigning handles

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




```
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

```
classdef  LocalWeather < handle

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

  methods
    function lw = LocalWeather(fname)
      …
    end

    …
  end

end
```

# Method 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

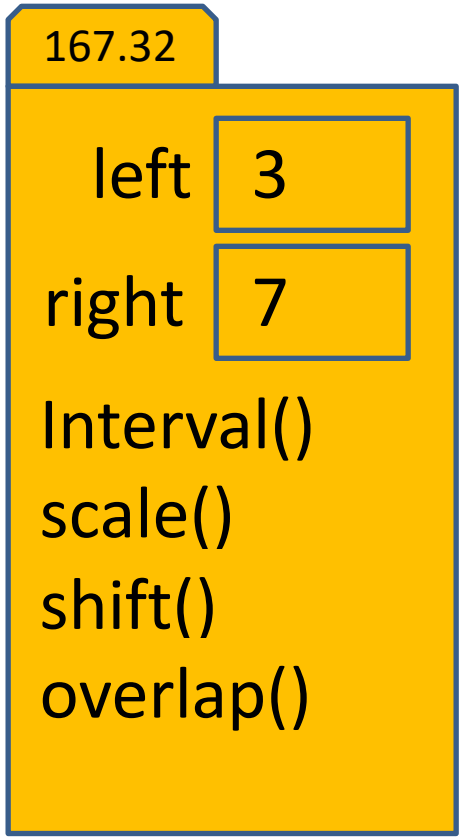
# Method to show data of a month of `LocalWeather`

```
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
```

# 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
```

# 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!
- Objects (instances of a class) are *self-governing* (protect and manage themselves)
  - Hide details from clients while exposing the services they need
  - Don't allow clients to invalidate data and break those services

# Engineering software ≠ software engineering

**Engineering software**

- Solve a technical problem or provide insight into data
- Be confident that answers are correct – clear, documented code; testing
- Used mostly by yourself or your team

**Software engineering**

- Build large, reliable systems that operate continuously
- Used mostly by other people
- Make components easy to (re)use correctly, hard to use incorrectly

The *design* of code becomes at least as important as its output

*Best of both worlds: a well-engineered engineering application*

# Restricting access to properties and methods

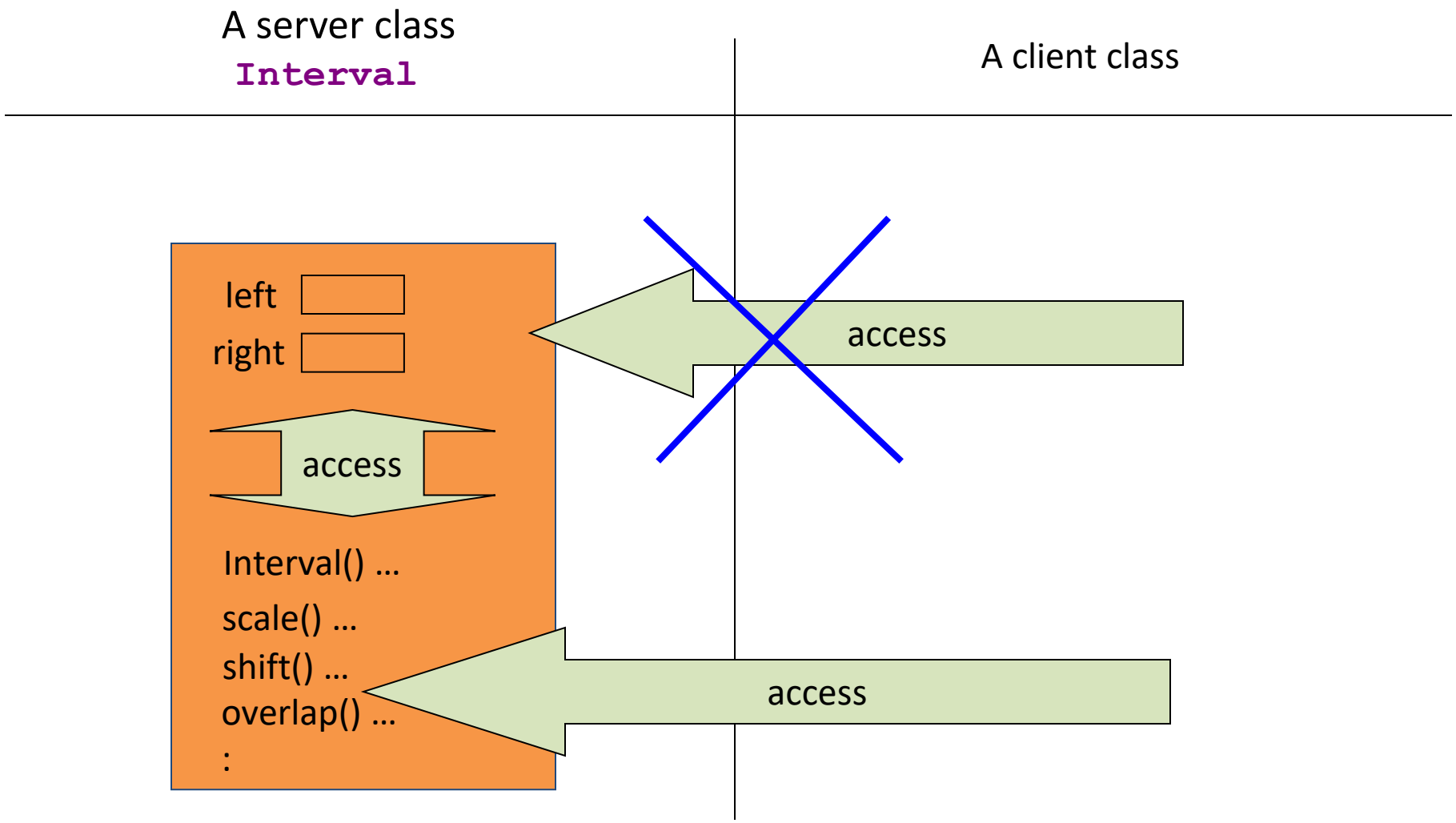
- Hide implementation details from "outside parties" who do not need to know how things work—depend on behavior, not representation
- E.g., we decide that users of Interval class cannot directly change `left` and `right` once the object has been created. Force users to use the provided methods—`scale()`, `shift()`, etc.—to cause changes in the object data
- Protect data from unanticipated user action—keep properties self-consistent
- Information hiding is very important in large projects
  - Helps avoid brittle code

```
classdef  Interval < handle

   properties
      left
      right
    end

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

      function Inter = overlap(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”

# Preserving relationships between properties

```
classdef  Interval < handle
   properties
      left = 0;
      right = 0;  % Invariant: right >= left
   end

   methods
      function  Inter = Interval(lt, rt)
         if nargin == 2

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




         end
      end
      . . .
   end
end
```

Don't neglect the default constructor (if any); either pick a sensible default state, or make it so that nothing works.

# Constructor can be written to do error checking!

```
classdef  Interval < handle
   properties
      left = 0;
      right = 0;  % Invariant: right >= left
   end

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

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.

# 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

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

# Public "getter" method

- Provides client the ability to <u>get</u> 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
```

# Prefer to 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

New Interval implementation

```
classdef  Interval < handle
  properties (Access=private)
    left; width
  end
  methods
    function  Inter = Interval(lt, rt)
      …
    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
```

Rewrite old getters/setters; add new getters/setters. BUT everything else stays the same! Cool! Happy clients!

# Getters and setters: what have we achieved?

- Getters let us change properties without changing interface
- Setters (or lack thereof) let us control how properties can change
  - Read-only
  - Methods that keep them "in sync" (e.g. `shift()`, `scale()`, …)
  - Error checking on attempts to write
- Both allow interactions to be "intercepted"
  - Track how many times they are changed?
  - Break points when debugging

# Quiz: access control

Which of these lines are legal?

A: None

B: 1

C: 1 & 2

D: 1-3

E: All

```
classdef Square < handle
   properties (Access=private)
      s = 1  % side length
   end
   methods (Access=public)
      function obj = Square(side)
         if nargin == 1
         1 obj.s = side;
         end
      end
      function a = area(self)
      2 a = self.s*self.s;
      end
   end
end
```

```
shape = Square(2);
a1= shape.area();
3 a2= shape.s*shape.s;

4 shape.s= 1;
```

# 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 clients while exposing the services they need
  - Don't allow clients to invalidate data and break those services
- Maximize code reuse

# 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
```

# 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 code 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
```