- Previous lecture:
  - Array of objects
  - Methods that handle variable numbers of arguments
- Today's lecture:
  - Why use OOP?
  - Attributes for properties and methods
  - Inheritance: extending a superclass
  - Overriding methods in superclass
- Announcement:
  - Final exam on Fri, Dec 7th, at 9am. Email Randy Hess (rbh27) now if you have an exam conflict. Specify your entire exam schedule (course numbers/contacts and the exam times). We must have this information by Nov 25th.

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
- 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

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—constructor, 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

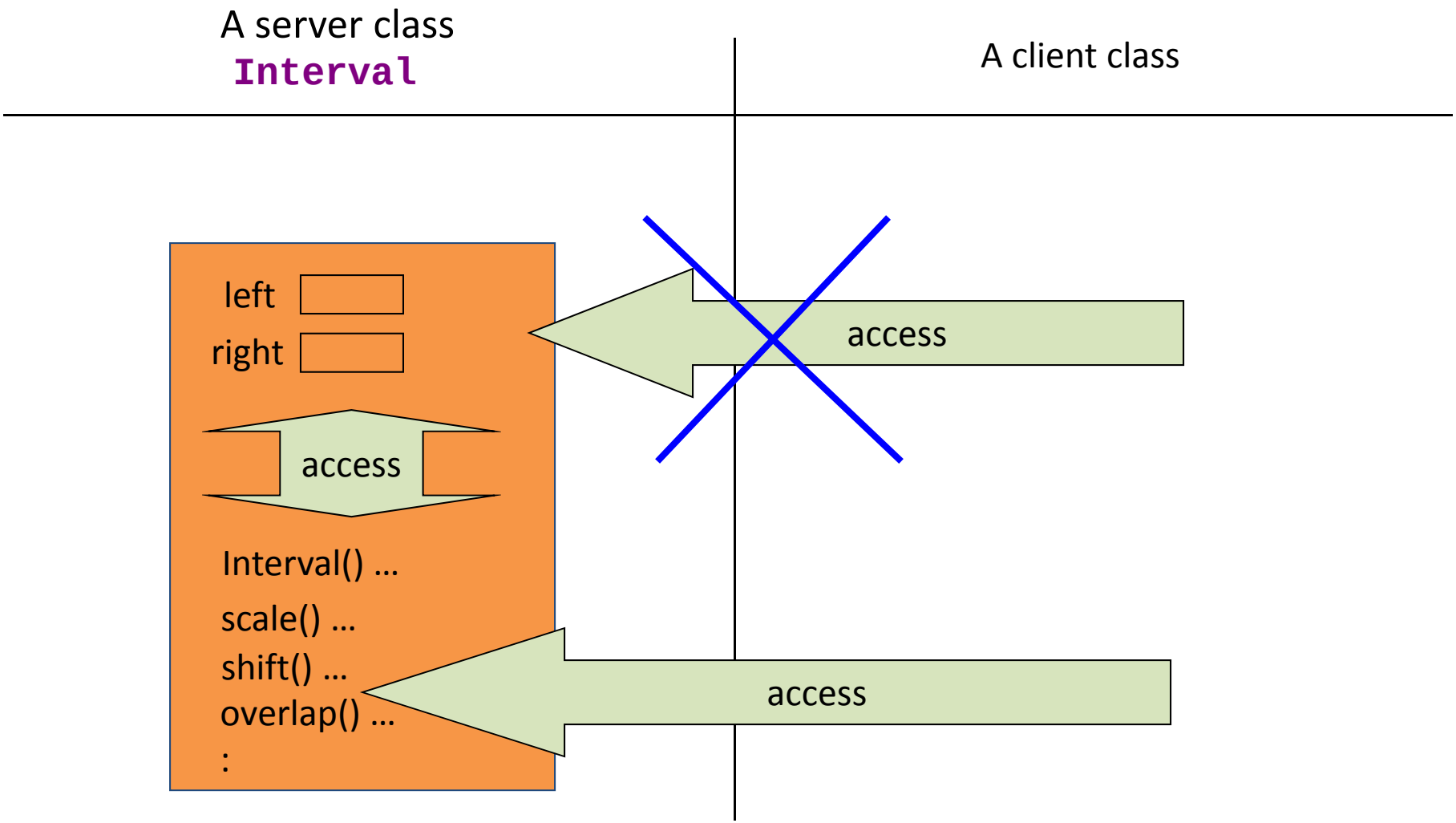
```
classdef  Interval < handle
  properties
    left
    right
  end

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

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



      end
    end
    . . .
  end
end
```

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
```

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.



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”

```
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

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
```

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, 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
```

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
- 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

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
```

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
```

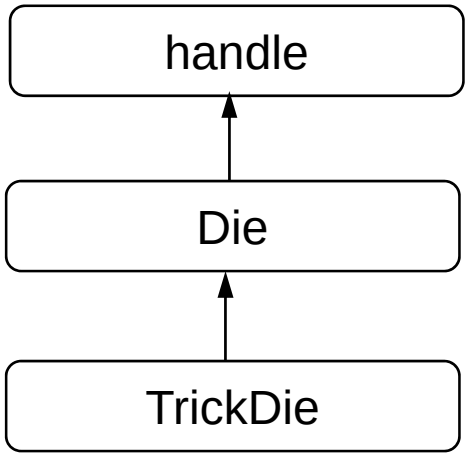
Yes! Make TrickDie a subclass of Die

```
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

Syntax

```
classdef Child < Parent

 properties
  propC
 end

 methods

  function obj = Child(argC, argP)

     obj = obj@Parent(argP)

     obj.propC = argC;
  end

  ...
 end

end
```

See constructor in **`TrickDie.m`**

Which components get "inherited"?

- public components get inherited
- private components exist in object of child class, but cannot be directly accessed in child class $\Rightarrow$ 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

```
td = TrickDie(2, 10, 6);
disp(td.sides);
% disp statement is incorrect because
```

A Property sides is private.

B Property sides does not exist in the TrickDie object.

C Both a, b apply

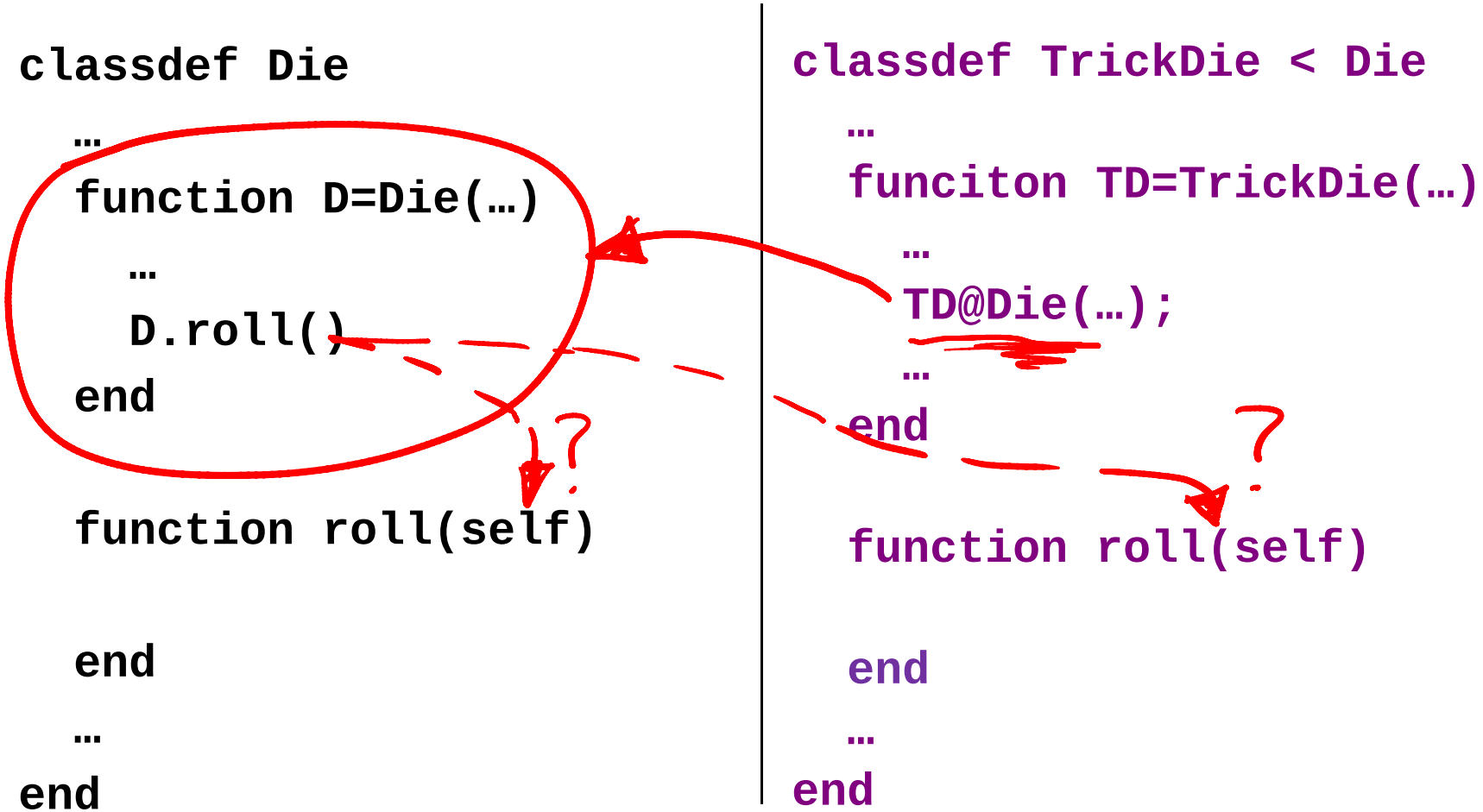
Overriding methods

- Subclass can *override* definition of inherited method
- New method in subclass has the same name (but has different method body)

See method **`roll`** in **`TrickDie.m`**

Overridden methods: which version gets invoked?

To create a TrickDie: call the TrickDie constructor, which calls the Die constructor, which calls the roll method. Which roll method gets invoked?



Overriding methods

- Subclass can *override* definition of inherited method
- New method in subclass has the same name (but has different method body)
- Which method gets used??

  *The **object** that is used to invoke a method determines which version is used*
- Since a TrickDie object is calling method **`roll`**, the TrickDie's version of **`roll`** is executed
- In other words, the method most specific to the type (class) of the object is used

Accessing superclass' version of a method

- Subclass can override superclass' methods
- Subclass can access superclass' version of the method

Syntax

```
classdef Child < Parent

 properties
  propC
 end

 methods
  …

  function x= method(arg)

      y= method@Parent(arg);

      x = … y … ;
  end

  …
 end
end
```

See method **`disp`** in **`TrickDie.m`**

Important ideas in inheritance

- Keep common features as high in the hierarchy as reasonably possible
- Use the superclass' features as much as possible
- "Inherited" $\Rightarrow$ "can be accessed as though declared locally"

  (`private` member in superclass *exists* in subclasses; they just cannot be accessed directly)
- Inherited features are continually passed down the line

(Cell) array of objects

- A cell array can reference objects of different classes

```
A{1}= Die();
A{2}= TrickDie(2,10);   % OK
```

- A simple array can reference objects of only one single class

```
B(1)= Die();
B(2)= TrickDie(2,10);   % ERROR
```

- (Assignment to B(2) above would work if we define a "convert method" in class TrickDie for converting a TrickDie object to a Die. We won't do this in CS1112.)