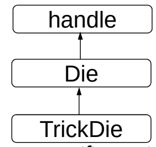
- Previous Lecture:
  - Inheritance in OOP
  - Overriding methods
- Today's Lecture:
  - Recursion
    - Remove all occurrences of a character in a string
    - A mesh of triangles
- Announcements:
  - Discussion in the lab this week. Attendance is optional but be sure to do the posted exercise.
  - Project 6 due Thurs Dec 1 at 11pm. Remember academic integrity!
  - Office/consulting hours end Tuesday (tonight) for Thanksgiving Break and will resume Monday

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

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?

```
classdef Die
 …
  function D=Die(…)
    …
    D.roll()
  end

  function roll(self)

  end
 …
end
```

```
classdef TrickDie < Die
  …
  function TD=TrickDie(…)
    …
    TD@Die(…);
    …
  end

  function roll(self)

  end
  …
end
```


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" ⇒ "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.)

End of Matlab OOP in CS1112

OOP is a concept; in different languages it is expressed differently.

In CS (ENGRD) 2110 you will see Java OOP

Recursion

- The Fibonacci sequence is defined recursively:
  F(1)=1, F(2)=1,
  F(3)= F(1) + F(2) = 2
  F(4)= F(2) + F(3) = 3 } **F(k) = F(k-2) + F(k-1)**
  It is defined in terms of itself; its definition invokes itself.
- Algorithms, and functions, can be recursive as well. I.e., a function can call itself.
- Example: remove all occurrences of a character from a string
  `'gc aatc gga c '` → `'gcaatcggac'`

Example: removing all occurrences of a character

- Can solve using iteration—check one character (one component of the vector) at a time

s	1	2	…	k	…		
	'c'	's'	' '	'1'	'1'	'1'	'2'

Subproblem 1:
Keep or discard s(1)

Subproblem 2:
Keep or discard s(2)

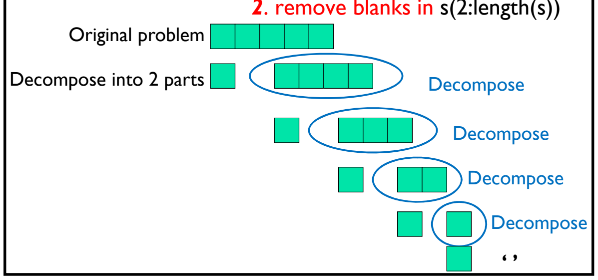
Subproblem k:
Keep or discard s(k)

Iteration:
Divide problem into sequence of equal-sized, identical subproblems

See RemoveChar_loop.m

Example: removing all occurrences of a character

- Can solve using ***recursion***
  - Original problem: remove all the blanks in string s
  - Decompose into two parts: *1*. remove blank in s(1)
    2. remove blanks in s(2:length(s))



```
function s = removeChar(c, s)
% Return string s with character c removed

if length(s)==0  % Base case: nothing to do
    return
else
  if s(1)~=c
    % return string is
    % s(1) and remaining s with char c removed

  else  % s(1)==c
    % return string is just
    % the remaining s with char c removed

  end
end
```

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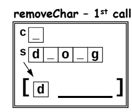
```
function s = removeChar(c, s)
if length(s)==0
  return
else
  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
  else
    s= removeChar(c, s(2:length(s)));
  end
end
```

s d _ o _ g

c _

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  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
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  end
end
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s d _ o _ g

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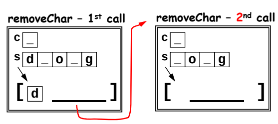


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    s= [s(1) removeChar(c, s(2:length(s)))];
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  end
end
```

s d _ o _ g

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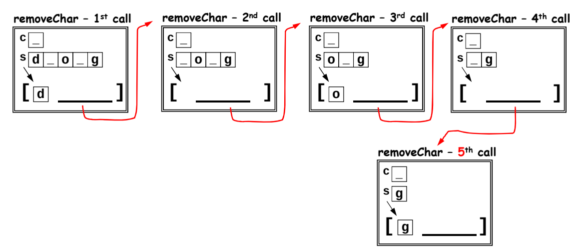


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end
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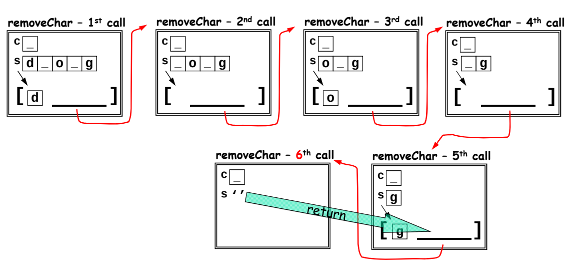
s d _ o _ g

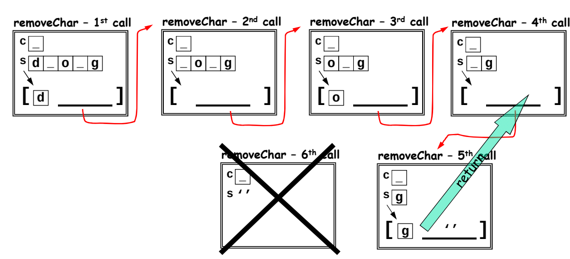
c _




```
function s = removeChar(c, s)
if length(s)==0
  return
else
  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
  else
    s= removeChar(c, s(2:length(s)));
  end
end
```

s d _ o _ g

c _



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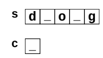
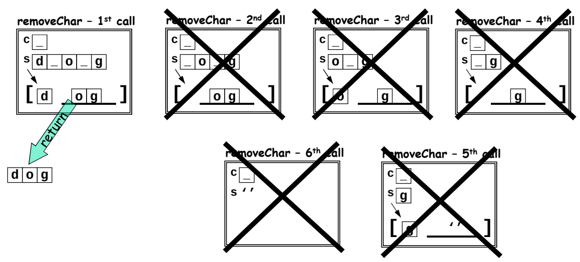
if length(s)==0
  return
else
  if s(1)~=c
    s= [s(1) removeChar(c, s(2:length(s)))];
  else
    s= removeChar(c, s(2:length(s)));
  end
end
```



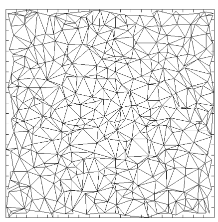


Key to recursion

- Must identify (at least) one base case, the "trivially simple" case
  - no recursion is done in this case
- The recursive case(s) must reflect progress towards the base case
  - E.g., give a shorter vector as the argument to the recursive call – see `removeChar`

Divide-and-conquer methods, such as recursion, is useful in geometric situations

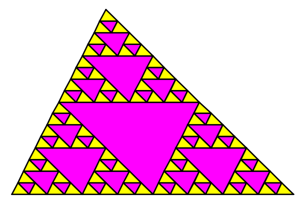
Chop a region up into triangles with smaller triangles in "areas of interest"



Recursive mesh generation

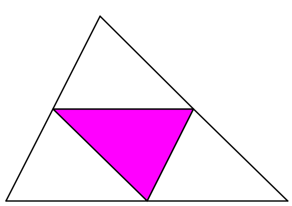
Why is mesh generation a divide-&-conquer process?

Let's draw this graphic



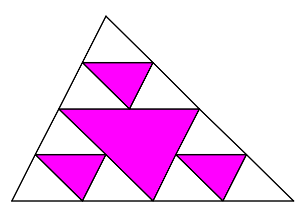
A "level-1" partition of the triangle

(obtained by connecting the midpoints of the sides of the original triangle)

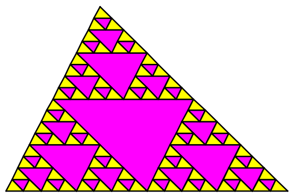


Now do the same partitioning (connecting midpts) on each corner (white) triangle to obtain the "level-2" partitioning

The "level-2" partition of the triangle



The “level-4” partition of the triangle



The basic operation at each level

if *the triangle is small*

Don’t subdivide and just color it yellow.

else

Subdivide:

Connect the side midpoints;

color the interior triangle magenta;

apply same process to each outer triangle.

end

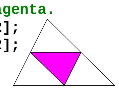

```
function MeshTriangle(x,y,L)
% x,y are 3-vectors that define the vertices of a triangle.
% Draw level-L partitioning.  Assume hold is on.

if L==0
  % Recursion limit reached; no more subdivision required.
    fill(x,y,'y')  % Color this triangle yellow

else
  % Need to subdivide:  determine the side midpoints; connect
  % midpts to get “interior triangle”; color it magenta.
    a = [(x(1)+x(2))/2 (x(2)+x(3))/2 (x(3)+x(1))/2];
    b = [(y(1)+y(2))/2 (y(2)+y(3))/2 (y(3)+y(1))/2];
    fill(a,b,'m')

  % Apply the process to the three "corner" triangles...


end
```

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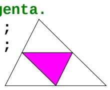
    fill(x,y,'y')  % Color this triangle yellow

else
  % Need to subdivide:  determine the side midpoints; connect
  % midpts to get “interior triangle”; color it magenta.
    a = [(x(1)+x(2))/2 (x(2)+x(3))/2 (x(3)+x(1))/2];
    b = [(y(1)+y(2))/2 (y(2)+y(3))/2 (y(3)+y(1))/2];
    fill(a,b,'m')

  % Apply the process to the three "corner" triangles...
    MeshTriangle([x(1) a(1) a(3)],[y(1) b(1) b(3)],L-1)
    MeshTriangle([x(2) a(2) a(1)],[y(2) b(2) b(1)],L-1)
    MeshTriangle([x(3) a(3) a(2)],[y(3) b(3) b(2)],L-1)
end
```



Key to recursion

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  - No recursion is done in this case
- The recursive case(s) must reflect progress towards the base case
  - E.g., give a shorter vector as the argument to the recursive call – see **removeChar**
  - E.g., ask for a lower level of subdivision in the recursive call – see **MeshTriangle**