Previous lecture
- User-defined functions
  - Function header
  - Input parameters and return variables

Today’s lecture
- User-defined functions
  - local memory space
  - Subfunction

Announcement
- Discussion this week in classrooms as listed in Student Center
Draw a bulls eye figure with randomly placed dots

- Dots are randomly placed within concentric rings
- User decides how many rings, how many dots
Function header is the “contract” for how the function will be used (called)

You have this function:

```matlab
function [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r, theta) to
% Cartesian coordinates (x,y). Theta in degrees.
...
```

Code to call the above function:

```matlab
% Convert polar (r1,t1) to Cartesian (x1,y1)
rl = 1; t1 = 30;
[x1, y1] = polar2xy(r1, t1);
polar2xy(r1, t1);
plot(x1, y1, 'b*')
...
```
dotsInRings.m

(functions with multiple input parameters)
(functions with a single output parameter)
(functions with multiple output parameters)
(functions with no output parameter)
Returning a value ≠ printing a value

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[r1, t1] = polar2xy(r1, t1);
plot(x1, y1, 'b*')
```

Code to call the above function:

```matlab
rl = 1; tl = 30;
[xl, yl] = polar2xy(rl, tl);
plot(xl, yl, 'b*')
```

Now, although you can see the coordinates, this script cannot use them.
Given this function:

```matlab
def function m = convertLength(ft,in)
% Convert length from feet (ft) and inches (in)
% to meters (m).
. . .
```

How many proper calls to `convertLength` are shown below?

```matlab
% Given f and n
d= convertLength(f,n);
d= convertLength(f*12+n);
d= convertLength(f+n/12);
x= min(convertLength(f,n), 1);
y= convertLength(pi*(f+n/12)^2);
```

A: 1
B: 2
C: 3
D: 4
E: 5 or 0
Comments in functions

- Block of **comments after the function header** is printed whenever a user types:
  
  ```matlab
  help <functionName>
  ```

  at the Command Window.

- 1st line of this comment block is searched whenever a user types:

  ```matlab
  lookfor <someWord>
  ```

  at the Command Window.

- Every function should have a comment block after the function header that says **what the function does concisely**.
Accessing your functions

For now*, put your related functions and scripts in the same directory.

*The path function gives greater flexibility
Why write user-defined function?

- Easy code re-use—great for “common” tasks
- A function can be tested independently easily
- Keep a driver program clean by keeping detail code in functions—separate, non-interacting files

Facilitate top-down design
c = input('How many concentric rings? '); 
d = input('How many dots? ');

% Put dots btwn circles with radii rrRing and (rrRing-1)
for rrRing= 1:c
    % Draw d dots
    for count= 1:d
        % Generate random dot location (polar coord.)
        theta=_______
        r=_______

        % Convert from polar to Cartesian
        x=_______
        y=_______

        % Use plot to draw dot
    end
end

Each task becomes a function that can be implemented and tested independently
Facilitates top-down design

1. Focus on how to draw the figure given just a specification of what the function DrawStar does.

2. Figure out how to implement DrawStar.
To **specify** a function...

... you describe how to use it, e.g.,

```matlab
function DrawStar(xc,yc,r,c)
% Adds a 5-pointed star to the figure window. Star has radius r, center(xc,yc) and color c where c is one of 'r', 'g', 'y', etc.
```

*Given the specification, the user of the function doesn’t need to know the detail of the function—they can just use it!*
To **implement** a function…

… you write the code so that the function “lives up to” the specification. E.g.,

```matlab
r2 = r/(2*(1+sin(pi/10))); for k=1:11
    theta = (2*k-1)*pi/10;
    if 2*floor(k/2)~=k
        x(k) = xc + r*cos(theta);
        y(k) = yc + r*sin(theta);
    else
        x(k) = xc + r2*cos(theta);
        y(k) = yc + r2*sin(theta);
    end
end
fill(x,y,c)
```

Don’t worry—you’ll learn more about graphics functions and vectors soon.
Why write user-defined function?

- Easy code re-use—great for “common” tasks
- A function can be tested independently easily
- Keep a driver program clean by keeping detail code in functions—separate, non-interacting files
- Facilitate top-down design

Software management
Software Management

Today:

I write a function

\[ \text{EPerimeter}(a,b) \]

that computes the perimeter of the ellipse

\[
\left( \frac{x}{a} \right)^2 + \left( \frac{y}{b} \right)^2 = 1
\]
Software Management

During this year:

You write software that makes extensive use of $E_{\text{Perimeter}}(a,b)$

Imagine hundreds of programs each with several lines that reference $E_{\text{Perimeter}}$
Software Management

Next year:

I discover a more efficient way to approximate ellipse perimeters. I change the implementation of EPerimeter(a,b)

You do not have to change your software at all.
Script vs. Function

- A script is executed line-by-line just as if you are typing it into the Command Window
  - The value of a variable in a script is stored in the Command Window Workspace

- A function has its own private (local) function workspace that does not interact with the workspace of other functions or the Command Window workspace
  - Variables are not shared between workspaces even if they have the same name
What will be printed?

% Script file
p = -3;
q = absolute(p);
disp(p)

function q = absolute(p)
% q is absolute value of p
if (p<0)
    p = -p;
end
q = p;

A: -3  B: 3  C: error
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Command Window Workspace
p
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Command Window Workspace

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| p | -3 |

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Function absolute’s Workspace

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Command Window Workspace

Function absolute’s Workspace

<table>
<thead>
<tr>
<th>p</th>
<th>-3</th>
</tr>
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<tbody>
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Command Window Workspace

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q
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A value is passed to the function parameter when the function is called.

The two variables, both called p, live in different memory space and do not interfere.
When a function reaches the end of execution (and returns the output argument), the function space—local space—is deleted.
What is the output?

```matlab
x = 1;
x = f(x+1);
y = x+1;
disp(y)
```

```matlab
function y = f(x)
x = x+1;
y = x+1;
```

A: 1  B: 2  C: 3  D: 4  E: 5
What is the output?

x = 1;
x = f(x+1);
y = x+1;
disp(y)

function y = f(x)
x = x+1;
y = x+1;

A: 1  B: 2  C: 3  D: 4  E: 5
Execute the statement \( y = \text{foo}(x) \)

- Matlab looks for a function called \textit{foo} (m-file called \textit{foo.m})
- Argument (value of \( x \)) is copied into function \textit{foo}'s local parameter
  - called “pass-by-value,” one of several argument passing schemes used by programming languages
- Function code executes \textbf{within its own workspace}
- At the end, the function’s \textit{output argument} (value) is sent from the function to the place that calls the function. E.g., the value is assigned to \( y \).
- Function’s \textit{workspace} is deleted
  - If \textit{foo} is called again, it starts with a new, empty workspace
Subfunction

- There can be more than one function in an M-file
- top function is the main function and has the name of the file
- remaining functions are subfunctions, accessible only by the functions in the same m-file
- Each (sub)function in the file begins with a function header
- Keyword end is not necessary at the end of a (sub)function