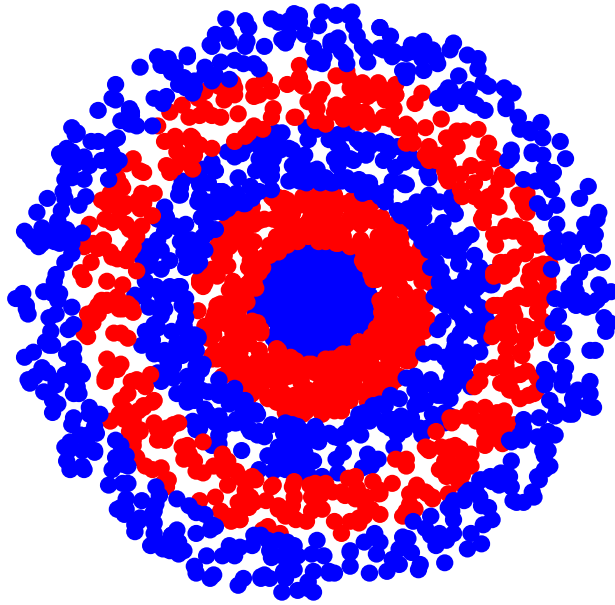


- Previous lecture
 - Finite/inexact arithmetic
 - Plotting continuous functions using vectors and vectorized code
 - User-defined functions
 - Function header

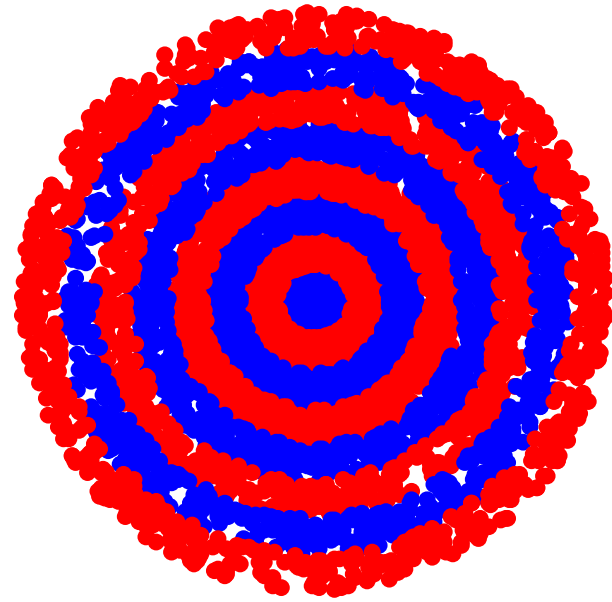
- Today's lecture
 - User-defined functions
 - Input parameters and return variables
 - local memory space
 - Subfunction

- Announcement
 - Prelim I tonight at 7:30pm Statler Auditorium

Draw a bulls eye figure with randomly placed dots



- Dots are randomly placed within concentric rings
- User decides how many rings, how many dots



```

c= input('How many concentric rings? ');
d= input('How many dots? ');

% Put dots btwn circles with radii rRing and (rRing-1)
for rRing= 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
end

```

```

c= input('How many concentric rings? ');
d= input('How many dots? ');

% Put dots btwn circles with radii rRing and (rRing-1)
for rRing= 1:c
    % Draw d dots
    for count= 1:d

        % Generate random dot location (polar coord.)
        theta=_____
        r=_____

        % Convert from polar to Cartesian
        rads= theta*pi/180;
        x= r*cos(rads);
        y= r*sin(rads);

        % Use plot to draw dot
    end
end
end

```

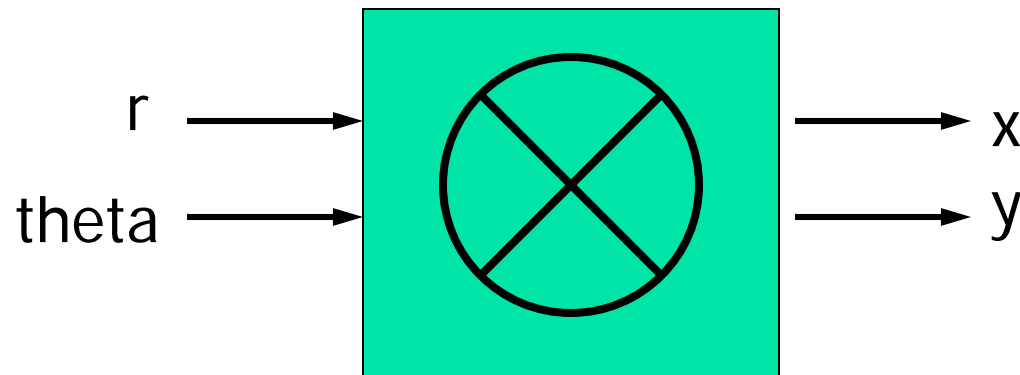
A common task! Create a function `polar2xy` to do this. `polar2xy` likely useful in other problems as well.

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

```
rads= theta*pi/180; % radian
x= r*cos(rads);
y= r*sin(rads);
```

A function file
`polar2xy.m`

Think of `polar2xy` as a factory



```

% Put dots btw circles with radii rRing and (rRing-1)
for rRing= 1:c
    % Draw d dots
    for count= 1:d

        % Generate random dot location
        theta= _____
        r= _____

        % Convert from polar to Cartesian
        rads= theta*pi/180;
        x= r*cos(rads);
        y= r*sin(rads);
        [x,y] = polar2xy(r,theta);

        % Draw the dot

    end
end
end

```

function [x, y] = polar2xy(r, theta)

Output
parameter list
enclosed in []

Function name
(This file's name is
polar2xy.m)

Input parameter
list enclosed in
()

Function header is the “contract” for how the function will be used (called)

You have this function:

```
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:

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


Function header is the “contract” for how the function will be used (called)

You have this function:

```
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:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)  
r1=10 t1=30;  
[x1, y1]= polar2xy(r1, t1);  
plot(x1, y1, 'b*')  
...
```

Returning a value \neq printing a value

You have this function:

```
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:

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

...

Returning a value \neq printing a value

You have this function:

```
function [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y). Theta in degrees.
... fprintf ('(%.1f, %.1f)\n', x, y)
```

Function prints instead of returns values

Code to call the above function:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)
```

```
r1 = 1; t1 = 30;
```

```
[x1, y1] = polar2xy(r1, t1);
```

```
plot(x1, y1, 'b*')
```

→ Not possible to do

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

Given this function:

```
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?

% 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

General form of a user-defined function

```
function [out1, out2, ...]= functionName (in1, in2, ...)
```

```
% 1-line comment to describe the function
```

```
% Additional description of function
```

Executable code that at some point assigns values to output parameters out1, out2, ...

- *in1, in2, ...* are defined when the function begins execution. Variables *in1, in2, ...* are called function *parameters* and they hold the function *arguments* used when the function is invoked (called).
- *out1, out2, ...* are not defined until the executable code in the function assigns values to them.

dotsInCircles.m

(functions with multiple input parameters)

(functions with a single output parameter)

(functions with multiple output parameters)

(functions with no output parameter)

Comments in functions

- Block of **comments after the function header** is printed whenever a user types

`help <functionName>`

at the Command Window

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

`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.

MyDirectory

`dotsInCircles.m`

`polar2xy.m`

`randDouble.m`

`drawColorDot.m`

*Any script/function that
calls `polar2xy.m`*

*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 rRing and (rRing-1)
for rRing= 1:c
    % Draw d dots
    for count= 1:d

        % Generate random dot location (polar coord.)
        theta=_____
        r=_____

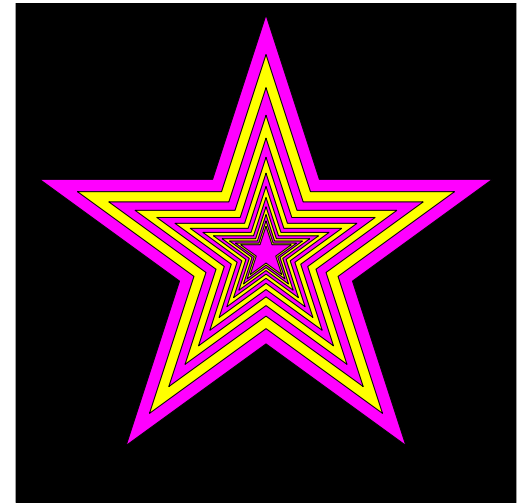
        % Convert from polar to Cartesian
        x=_____
        y=_____

        % Use plot to draw dot
    end
end
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.,

```
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.,

```
r2 = r/(2*(1+sin(pi/10)));  
tau = pi/5;  
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 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

`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

EPerimeter(a,b)

Imagine hundreds of programs each with several lines that reference **EPerimeter**

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

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

What will be printed?

```
% Script file
```

```
▶ p = -3;  
q = absolute(p);  
disp(p)
```

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

Command Window Workspace



p -3

What will be printed?

```
% Script file
```

```
p = -3;
```

```
▶ q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace



p -3

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
|---|----|

Function absolute's Workspace

| | |
|---|--|
| p | |
|---|--|

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
|---|----|

Function absolute's Workspace

| | |
|---|----|
| p | -3 |
|---|----|

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

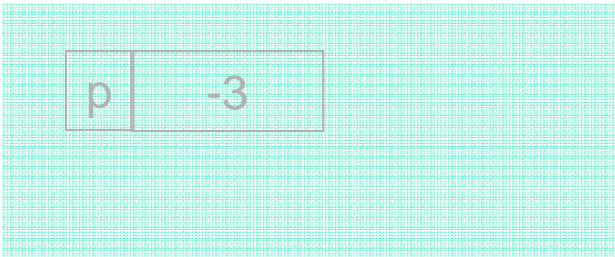
```
if (p < 0)
```

```
    p = -p;
```

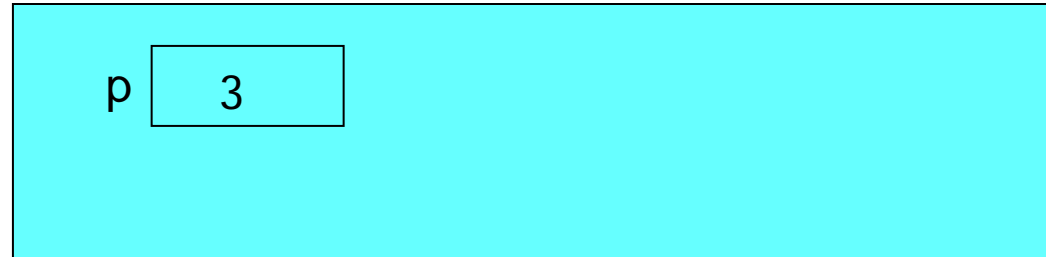
```
end
```

```
q = p;
```

Command Window Workspace



Function absolute's Workspace



What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

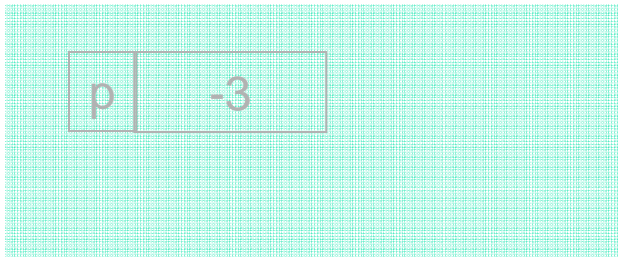
```
if (p < 0)
```

```
    p = -p;
```

```
end
```

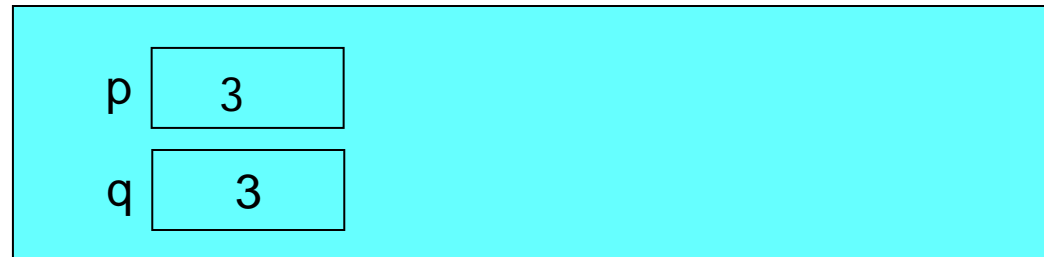
```
q = p;
```

Command Window Workspace



| | |
|---|----|
| p | -3 |
|---|----|

Function absolute's Workspace



| | |
|---|---|
| p | 3 |
| q | 3 |

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
|---|----|

Function absolute's Workspace

| | |
|---|---|
| p | 3 |
| q | 3 |

What will be printed?

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
| q | 3 |

Function absolute's Workspace

| | |
|---|---|
| p | 3 |
| q | 3 |

What will be printed?

```
% Script file
```

```
p = -3;
```

```
▶ q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
| q | 3 |

What will be printed?

```
% Script file  
p= -3;  
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```
function q = absolute(p)  
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if (p<0)  
    p= -p;  
end  
q= p;
```

Command Window Workspace

| | |
|---|----|
| p | -3 |
| q | 3 |

REVIEW!!!

```
% Script file
```

```
p = -3;
```

```
q = absolute(p);
```

```
disp(p)
```

```
function q = absolute(p)
```

```
% q is the absolute value of p
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
q = p;
```

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.

Command Window Workspace

| | |
|---|----|
| p | -3 |
|---|----|

Function

| | |
|---|----|
| p | -3 |
|---|----|

REVIEW!!!!

```
% Script file
```

```
p = -3;
```

```
▶ q = absolute(p);
```

```
disp(p)
```

```
function q = absolute
```

```
% q is the absolute
```

```
if (p < 0)
```

```
    p = -p;
```

```
end
```

```
▶ q = p;
```

When a function reaches the end of execution (and returns the output argument), the function space—local space—is deleted.

Command Window Workspace

| | |
|---|----|
| p | -3 |
| q | 3 |

Function absolute's Workspace

| | |
|---|---|
| p | 3 |
| q | 3 |

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

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