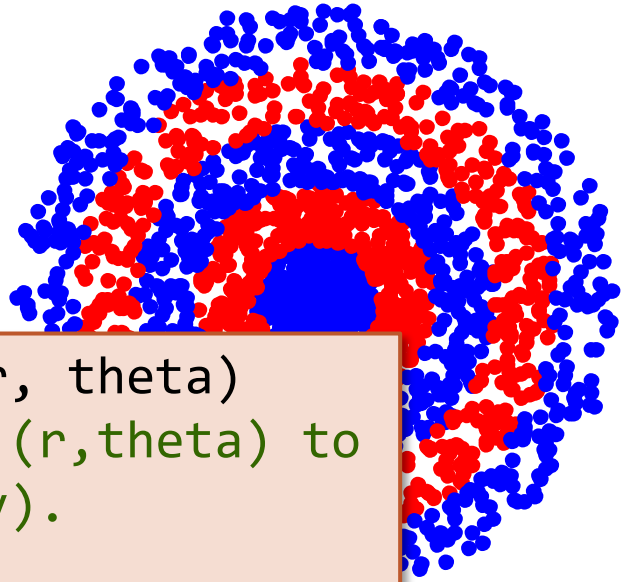
Lecture 9: User-defined functions II

- Previous lecture:
  - Functions vs. scripts
  - When and how to write functions
- Today:
  - Declaring and invoking functions
  - Subfunctions
  - Function scope (MatTV)

- Announcements:
  - Project 3, part A released after lecture, due Mar 24
  - Prelim 1 on Tue, Mar 30 – check for conflicts *now*

```
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 (pola
    theta= _______
    r= _______

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

    % Use plot to draw dot
  end
end
```



polar2xy.m

```
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);
```

```
[x,y] = polar2xy(r,theta);
```

Two perspectives: User vs. Provider

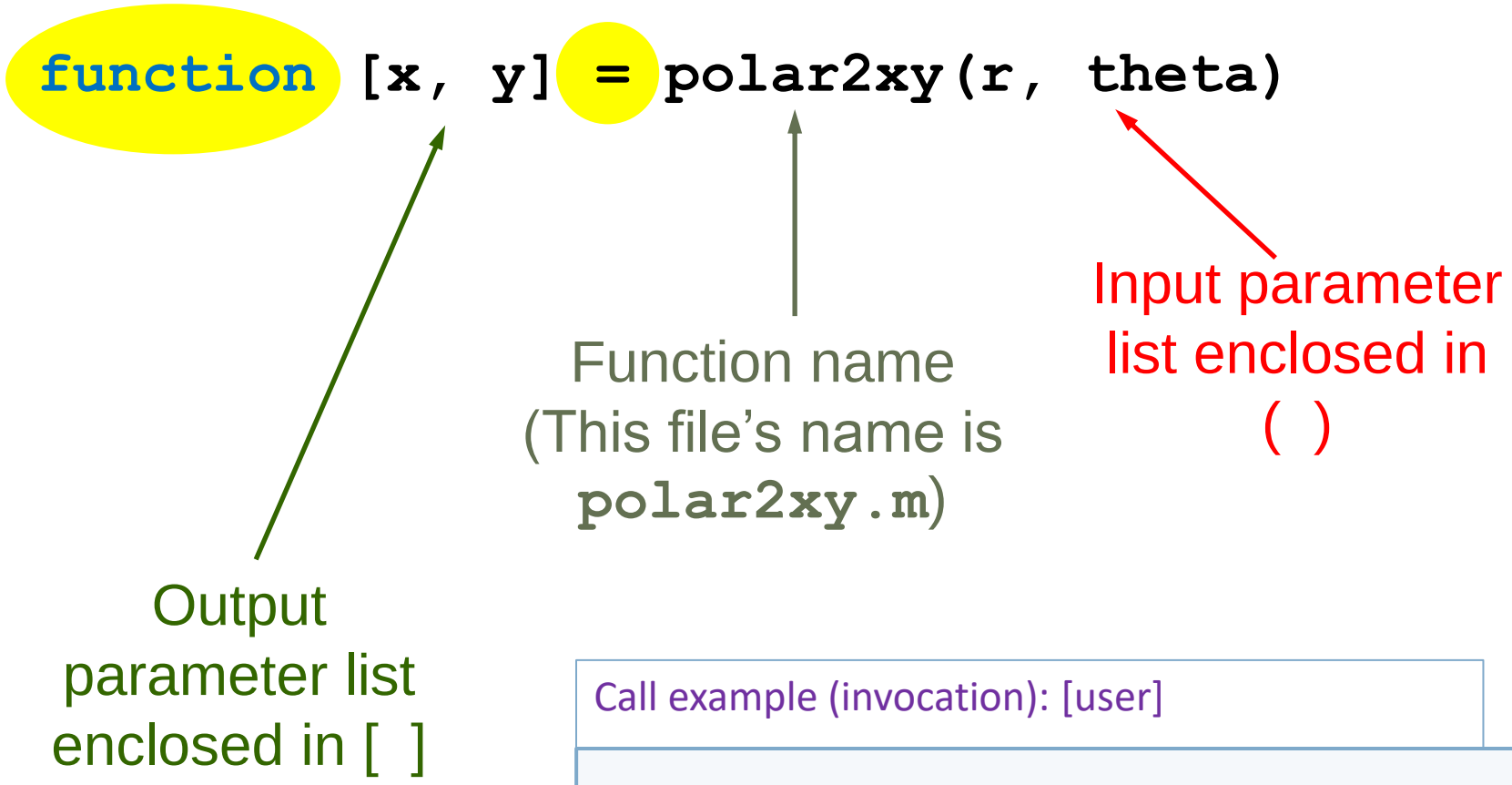
User wants to write:

```
% Generate random polar position
dist= r0 + (r1 – r0)*rand();
angle= 360*rand();


% Convert position to Cartesian
[xDart, yDart]= ...
   polar2xy(dist, angle);


% Mark position with red circle
plot(xDart, yDart, 'ro')
```

Provider must write:

```
function [x,y] = polar2xy(r,th)
% Convert polar coordinates to
Cartesian
% r is radius, th is angle in
degrees.
rads= th*pi/180;
x= r*cos(rads);
y= r*sin(rads);
```

Header example (declaration): [provider]



Call example (invocation): [user]

```
...
[ret1, ret2]= polar2xy(arg1, arg2);
...
```

General form of a user-defined function [provider]

```
function [out1, out2, …] = functionName (in1, in2, …)
% 1-line comment to describe the function
% Additional description of function and parameters

   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 values of 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.

Comments in functions

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

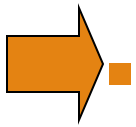
  `help <functionName>`

  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 concisely what the function does and what the parameters mean

Returning a value ≠ printing a value

You have this function: [provider]

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

Code to call the above function: [user]

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

Returning a value ≠ printing a value

You have this function: [provider]

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

Function prints instead of returns values

Code to call the above function: [user]

```
% 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 header:

```
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);
```

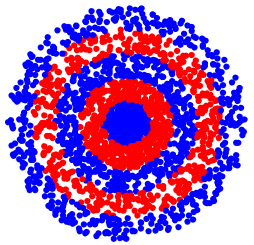
A: 1 | B: 2 | C: 3 | D: 4 | E: 5 or 0

Functions step-by-step

1. Identify candidates
   - Look for opportunities to reuse logic or improve clarity
2. Design interface
   - Name, inputs, outputs, side effects
3. Implement function
   - “Write code”
4. Test
   - Try it out (and try to break it)
5. Use

Reasons to use functions

- Code can be reused
- Easier to test
- Clearer to read
  - Reflects top-down design
- Separates concerns (“what” vs. “how”)
  - Can divide work [user] [provider]
- More maintainable



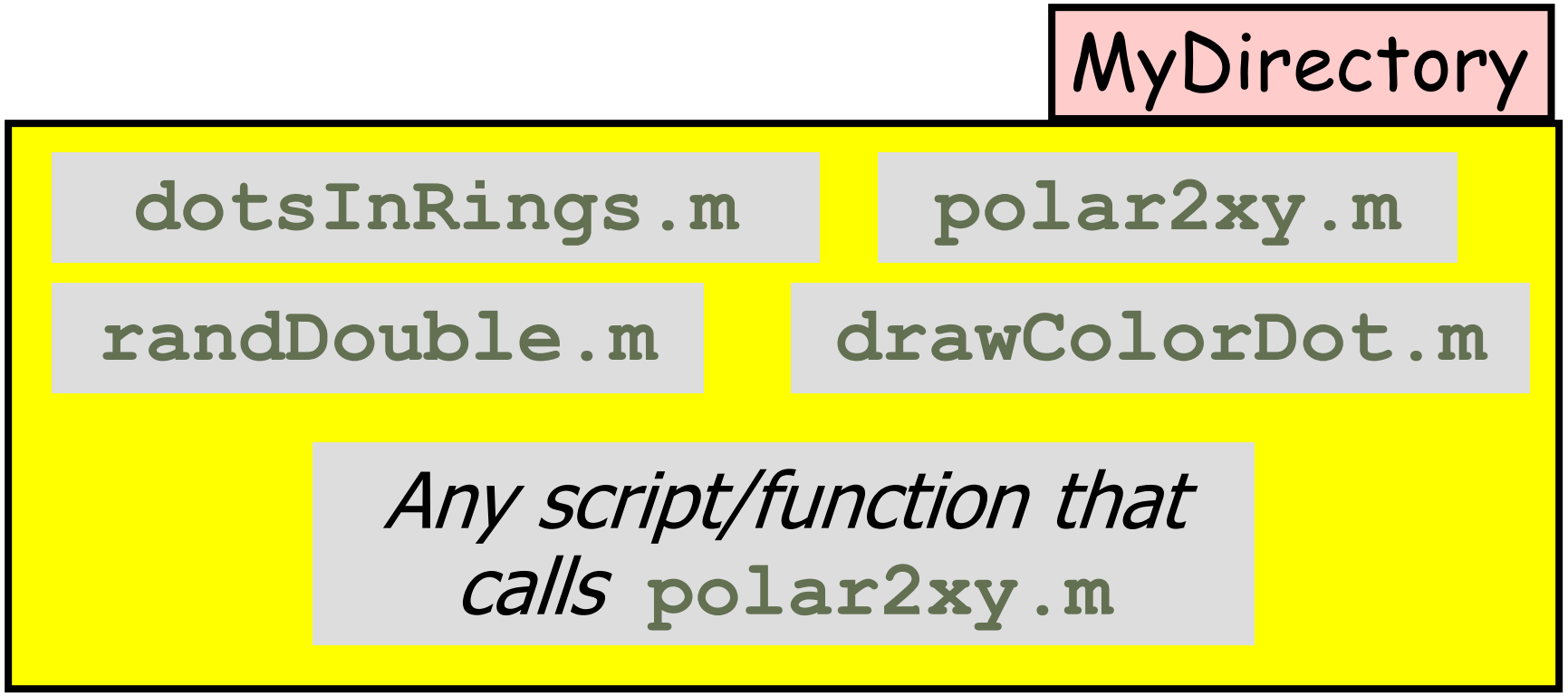
```
c= input('How many concentric rings? ');
d= input('How many dots per ring? ');

% 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.)



    % Convert coord from polar to Cartesian



    % Use plot to draw dot
  end
end
```

Each task becomes a function that can be implemented and tested independently

Demo

Accessing your functions

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



*The **path** function gives greater flexibility

Subfunctions, aka “local functions”

- 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, but if you use it, use it *consistently*

Reasons to use functions

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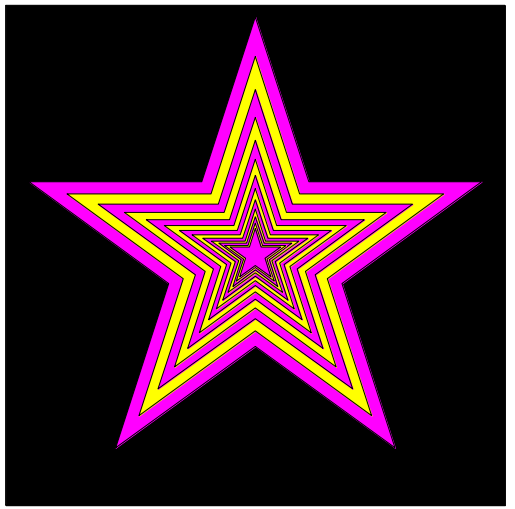
  - Can divide work
- More maintainable

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)));
for k=1:11
    theta = (2*k - 1)*pi/10;
    if rem(k,2) == 1
      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 about the new syntax shown here—you'll learn about it soon.

Reasons to use functions

- Code can be reused
- Easier to test
- Clearer to read
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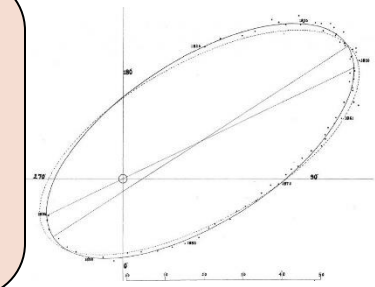
Software Management

Today: I write a function **`ePerimeter(a,b)`**

that computes the perimeter of the ellipse $\left(\frac{x}{a}\right)^2+\left(\frac{y}{b}\right)^2=1$



During this year: You write software that makes extensive use of **`ePerimeter(a,b)`**. Imagine hundreds of programs that call (use) **`ePerimeter()`**

Next year: I discover a better way to approximate ellipse perimeters. I change the implementation of **`ePerimeter(a,b)`**. You do not have to change your programs that call function **`ePerimeter()`** 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

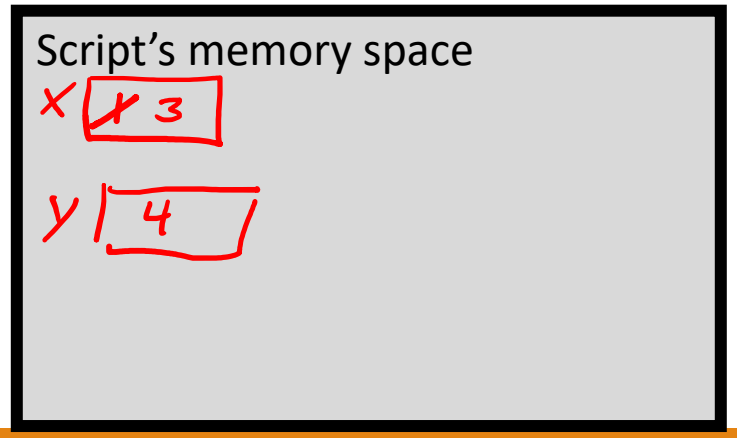
Did you watch MatTV?

Trace 1: What is displayed?


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

```
function y = f(x)
y= x + 1;
x= x + 2;
```

A: 1 | B: 2 | C: 3 | D: 4 | E: 5



Execute the statement

```
y= foo(x)
```

```
function w = foo(v)
w= v + rand;
```

File `foo.m`

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