- Previous Lecture:
  - Nested loops
  - Developing algorithms and code

- Today's Lecture:
  - Review nested loops
  - User-defined functions

- Announcements:
  - Project 2 due today at 11pm
  - This weekend is a great time to review, get caught up

Rational approximation of π

- π = 3.141592653589793…
- Can be closely approximated by fractions,
  e.g., $\pi \approx 22/7$
- Rational number: a quotient of two integers
- Approximate π as p/q where p and q are positive integers $\leq$M
- Start with a straight forward solution:
  - Get M from user
  - Calculate quotient p/q for all combinations of p and q
  - Pick best quotient → smallest error

```
% Rational approximation of pi

M = input('Enter M: ');




% Check all possible denominators
```

```
% Rational approximation of pi

M = input('Enter M: ');




% Check all possible denominators
for q = 1:M








end
```

```
% Rational approximation of pi

M = input('Enter M: ');



% Check all possible denominators
for q = 1:M

    For current q find best numerator p...
    Check all possible numerators



end
```

```
% Rational approximation of pi

M = input('Enter M: ');




% Check all possible denominators
for q = 1:M
   % At this q, check all possible numerators
   for p = 1:M






   end
end
```

```
% Rational approximation of pi

M = input('Enter M: ');
% Best q, p, and error so far
qBest=1;  pBest=1;
err_pq = abs(pBest/qBest - pi);

% Check all possible denominators
for q = 1:M
   % At this q, check all possible numerators
   for p = 1:M






   end
end

myPi = pBest/qBest;
```

```
% Rational approximation of pi

M = input('Enter M: ');
% Best q, p, and error so far
qBest=1;  pBest=1;
err_pq = abs(pBest/qBest - pi);

% Check all possible denominators
for q = 1:M
   % At this q, check all possible numerators
   for p = 1:M
      if abs(p/q - pi) < err_pq  % best p/q found
         err_pq = abs(p/q - pi);
         pBest= p;
         qBest= q;
      end
   end
end

myPi = pBest/qBest;
```

```
% Complicated version in the book

M = input('Enter M: ');
% Best q, p, and error so far
qBest=1;  pBest=1;
err_pq = abs(pBest/qBest - pi);

% Check all possible denominators
for q = 1:M
   % At this q, check all possible numerators
   p0=1;  e0=abs(p0/q - pi); % best p & error for this q
   for p = 1:M
      if abs(p/q - pi) < e0  % new best numerator found
        p0=p;  e0 = abs(p/q - pi);
      end
   end
   % Is best quotient for this q is best over all?
   if e0 < err_pq
      pBest=p0;  qBest=q; err_pq=e0;
   end
end
myPi = pBest/qBest;
```

```
% Rational approximation of pi

M = input('Enter M: ');
% Best q, p, and error so far
qBest=1;  pBest=1;
err_pq = abs(pBest/qBest - pi);

% Check all possible denominators
for q = 1:M
   % At this q, check all possible numerators
   for p = 1:M
      if abs(p/q - pi) < err_pq  % best p/q found
         err_pq = abs(p/q - pi);
         pBest= p;
         qBest= q;
      end
   end
end

myPi = pBest/qBest;
```

Algorithm: Finding the best in a set

```
Init bestSoFar
Loop over set
   if current is better than bestSoFar
      bestSoFar ← current
   end
end
```

Analyze the program for efficiency

- See Eg3_1 and FasterEg3_1 in the book

```
for a = 1:n
   disp('alpha')
   for b = 1:m
      disp('beta')
   end
end
```

How many times are "alpha" and "beta" displayed?

- A: n, m
- B: m, n
- C: n, n+m
- D: n, n*m
- E: m*n, m

Built-in functions

- We’ve used many Matlab built-in functions, e.g., `rand`, `abs`, `floor`, `rem`
- Example: `abs(x-.5)`
- Observations:
  - `abs` is set up to be able to work with any valid data
  - `abs` *doesn’t prompt us for input; it expects that we provide data* that it’ll then work on
  - `abs` *returns* a value that we can use in our program

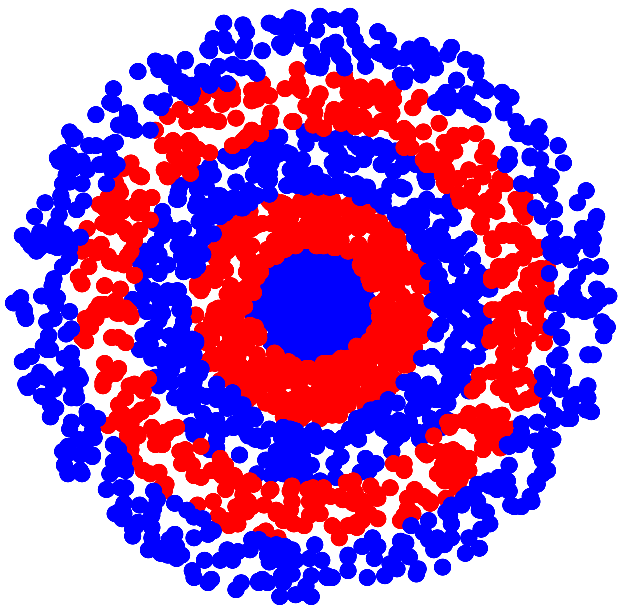
```
yDistance= abs(y2-y1);

while  abs(myPi-pi) > .0001
    ...
```

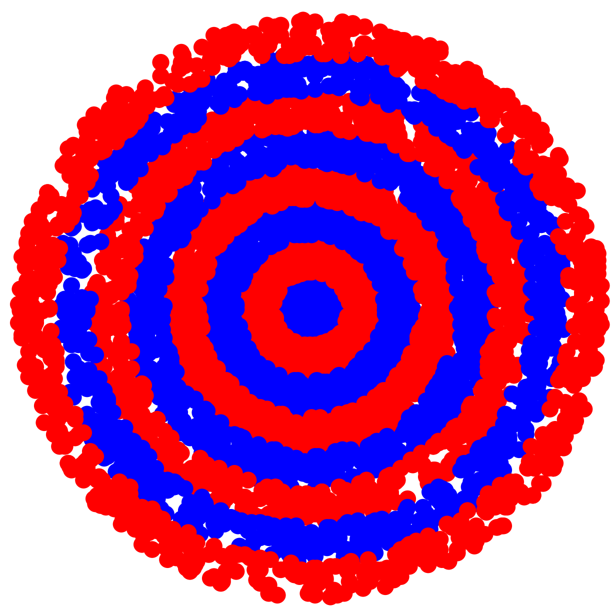
User-defined functions

- We can write our own functions to perform a specific task
  - Example: draw a disk with specified radius, color, and center coordinates
  - Example: generate a random floating point number in a specified interval
  - Example: convert polar coordinates to x-y (Cartesian) coordinates

Draw a bulls eye figure with randomly placed dots



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



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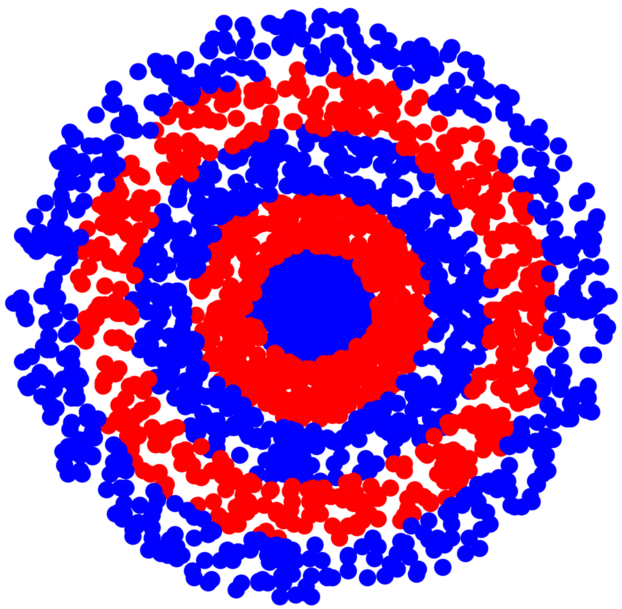
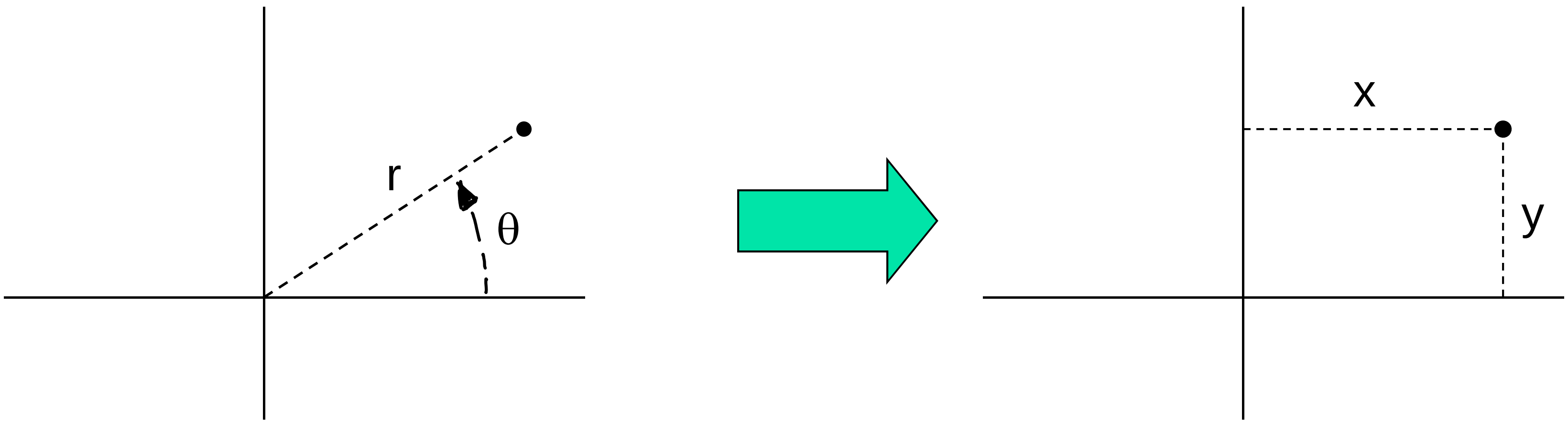


- What are the main tasks?
- Accommodate variable number of rings—loop

- For each ring
  - Need many dots
  - For each dot
    - Generate random position
    - Choose color
    - Draw it

Convert from polar to Cartesian coordinates



Polar coordinates　　　　Cartesian coordinates

```
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
```

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

```
% Generate random dot location (polar)
theta= _____
r= _________

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

Part of a script

```
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**

```
function [x, y] = polar2xy(r,theta)
% Convert polar coordinates (r,theta) to
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rads= theta*pi/180;  % radian
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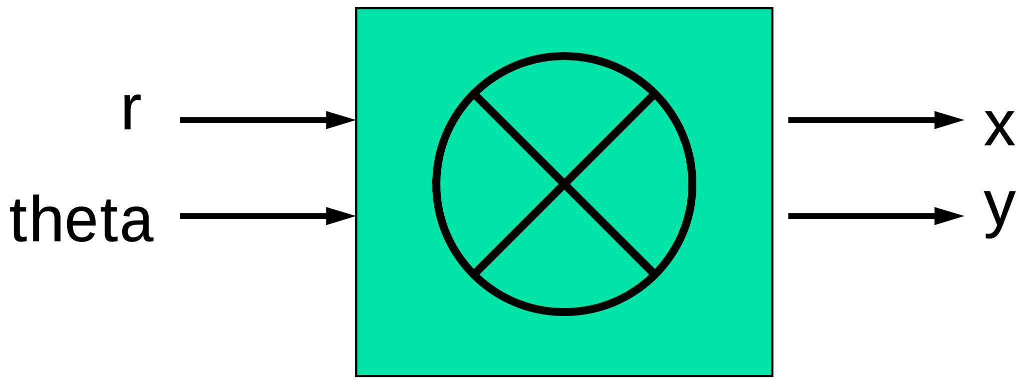
A function file **polar2xy.m**

Think of **polar2xy** as a factory



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A function file **polar2xy.m**

```
r= input('Enter radius: ');
theta= input('Enter angle in degrees: ');

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(Part of) a script file

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(Part of) a script file

```
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
```

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

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

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

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

Input parameter list enclosed in ( )

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

Output 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
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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*')
…
```

dotsInRings.m

(functions with multiple input parameters)

(functions with a single output parameter)

(functions with multiple output parameters)

(functions with no output parameter)

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.