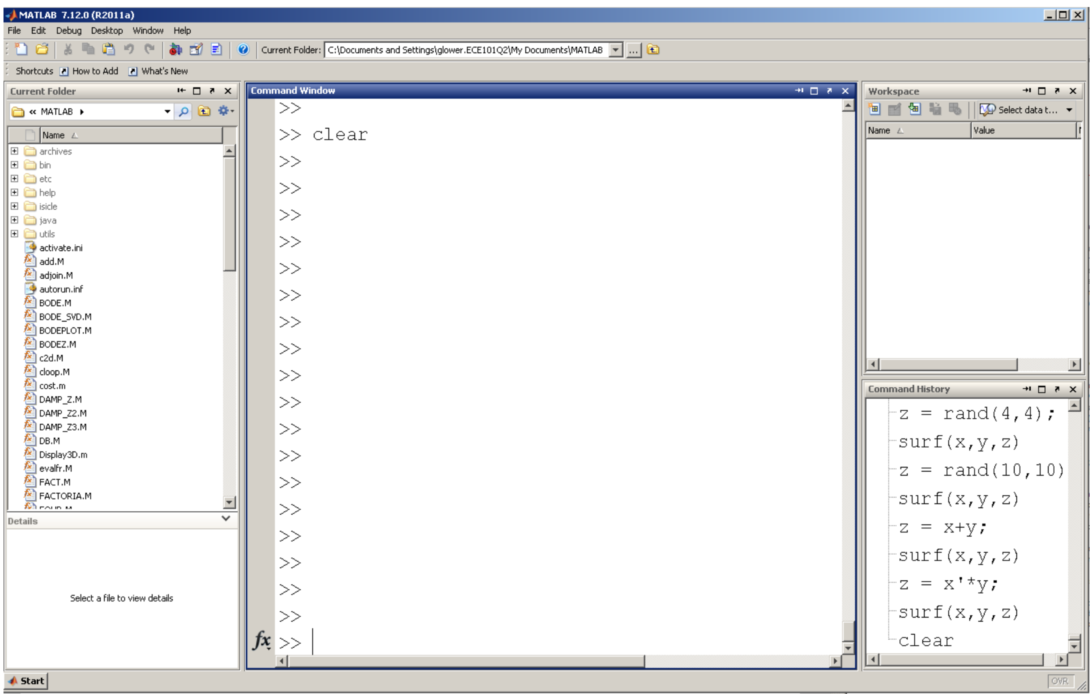
Introduction to Matlab

Becoming familiar with MATLAB

- The console
- The editor
- The graphics windows
- The help menu
- Saving your data (diary)

General environment and the console

When you start up Matlab, the screen should look something like this:



Usually, I close all of the windows except the Command Window. Matlab can be used like a calculator - with some of the command options listed in the appendix. For example, if you want to compute

```
( 2 + 3 ) * 5
```

You type it the way it looks:

```
>> (2 + 3)*5

ans =    25
```

In Matlab, you can save the results and use them later - like the memory functions of your calculator. Valid names for your variables have to start with a letter. Note that Matlab is case sensitive. For example

```
>> a = (2+3)*5

a =  25

>> b = 1.3 * a^3

b =  2.0313e+004
```

Matrices in Matlab

Matlab is also a matrix language. An nxm matrix is an array of numbers arranged in n rows and m columns

$$A_{2x3} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \end{bmatrix}$$

The syntax to input a matrix are:

```
[           start of a matrix
,           next column (a space also works)
;           next row
]           end of matrix.
```

For example, to input a 2x3 matrix for A:

```
A = [1,2,3 ; 4,5,6]

    1     2     3
    4     5     6
```

Matrix Addition: When adding matrices, each element gets added. You can only add matrices of like dimensions.

```
A = [1,2,3 ; 4,5,6]

    1     2     3
    4     5     6

B = [2,2,2 ; 3,3,3]

    2     2     2
    3     3     3

C = A + B

    3     4     5
    7     8     9
```

Matrix Multiplication: When multiplying matrices, the inner dimension must match

$$C_{mn} = A_{mx} B_{xn}$$

Element (i,k) of matrix C is computed as:

$$c_{ik} = \sum a_{ik} b_{kj}$$

Sample Matlab Code

If you terminate a line with a semi-colon, the result is computed but isn't displayed. If you leave off the semi-colon, the results is displayed. For example:

```
x = 2*pi;            % result is computed and stored in x but isn't displayed
x = 2*pi             % ditto but the result is displayed.

   6.2832
```

If you want a different format for the display, you can use the 'sort', 'long', and 'shorteng' commands:

```
format short
pi

   3.1416

format long
pi

  3.141592653589793


format shorteng
pi^30

  821.2893e+012
```

Matrices

- [start of matrix
-] end of matrix
- , next element
- ; next row

```
A = [1,2,3]

   1     2     3



B = [1,2,3;4,5,6]

    1     2     3
    4     5     6

C = A'

    1
    2
    3

D = zeros(1,3)
```

```
     0     0     0

E = rand(3,2)

   0.5860    0.0835
   0.2467    0.6260
   0.6664    0.6609
```

for loops:

```
x = zeros(1,5);
for i=1:5
  x(i) = i*i;
  end
x

x =

     1     4     9    16    25
```

while

if

if else end

Plotting Functions in Matlab:

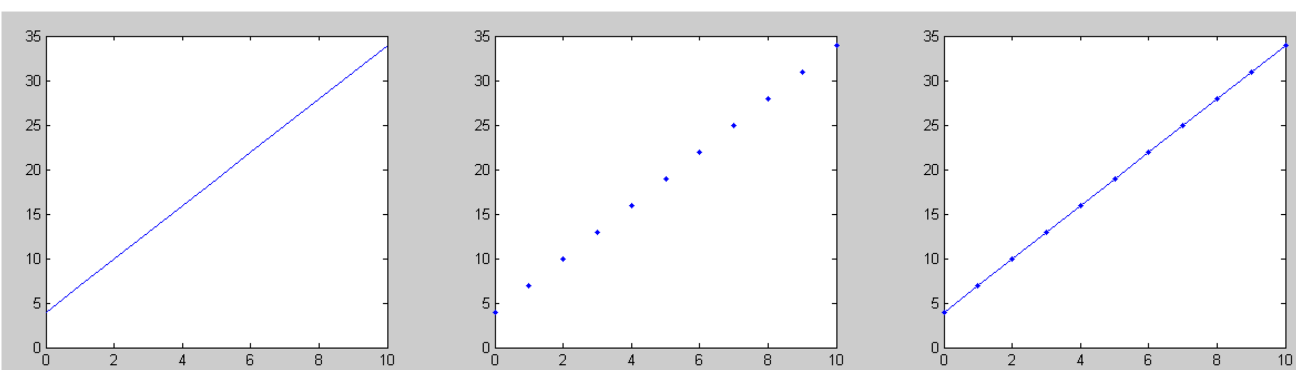
Matlab has some pretty good graphics capabilities.

Matlab Plot Command	x axis	y axis	type of function
`plot(x,y)`	linear	linear	$y = ax + b$
`semilogx(x,y)`	log()	linear	$y = a \cdot e^{bx}$
`semilogy(x,y)`	linear	log()	$y = a + b\ln(x)$
`loglog(x,y)`	log()	log()	$y = a \cdot b^{x}$
`subplot(abc)`	Create 'a' rows, 'b' columns of graphs. Starting at #c		

For example, plot the function

$$y = 3x + 4$$

```
x = [0:1:10]';
y = 3*x + 4;

subplot(131)
plot(x,y); % connect the points with a line

subplot(132)
plot(x,y,'.');       % plot a dot at each point

subplot(133);
plot(x,y,'.-');      % connect the points and add a dot
```



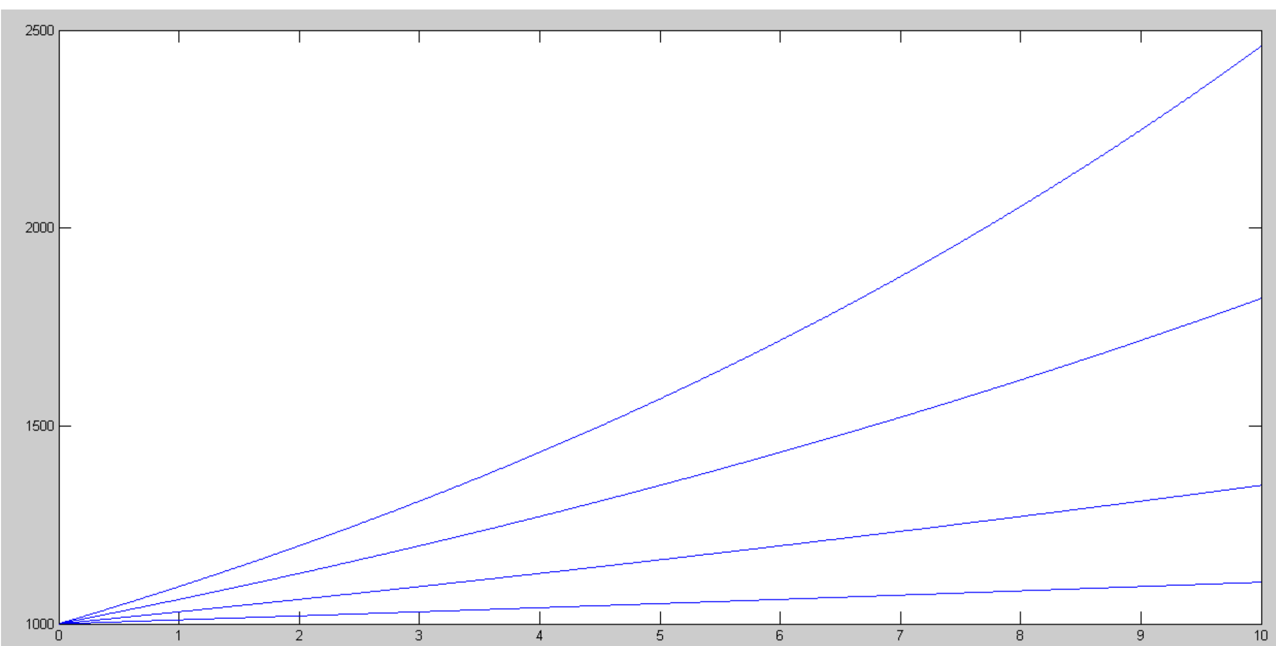
Multiple Plots on the same graph:

Plot how much money you'd have if you invested it for 10 years at

- 1% interest
- 3% interest
- 6% interest
- 9% interest

Three ways to do this:

```
t = [0:0.01:10]';
y1 = 1000 * exp(0.01*t);
y3 = 1000 * exp(0.03*t);
y6 = 1000 * exp(0.06*t);
y9 = 1000 * exp(0.09*t);

% Method #1
plot(t,y1,t,y3,t,y6,t,y9)

% Method #2
plot(t,[y1,y3,y6,y9])

% Method #3
plot(t,y1)
hold on
plot(t,y3)
plot(t,y6)
plot(t,y9)
hold off
```



If you invest at 9% interest, you have almost 2.5x more money after 10 years than you'd have at 1% interest.

Polynomials

- poly([a,b,c]) Give a polynomial with roots at (a, b, c)
- roots([a,b,c,d]) Find the roots of the polynomial

$$ax^3 + bx^2 + cx + d = 0$$

Example:

- Determine a polynomial with roots at (1, 2, 3)
- Plot that function,
- Verify that the roots are in fact at (1, 2, 3)

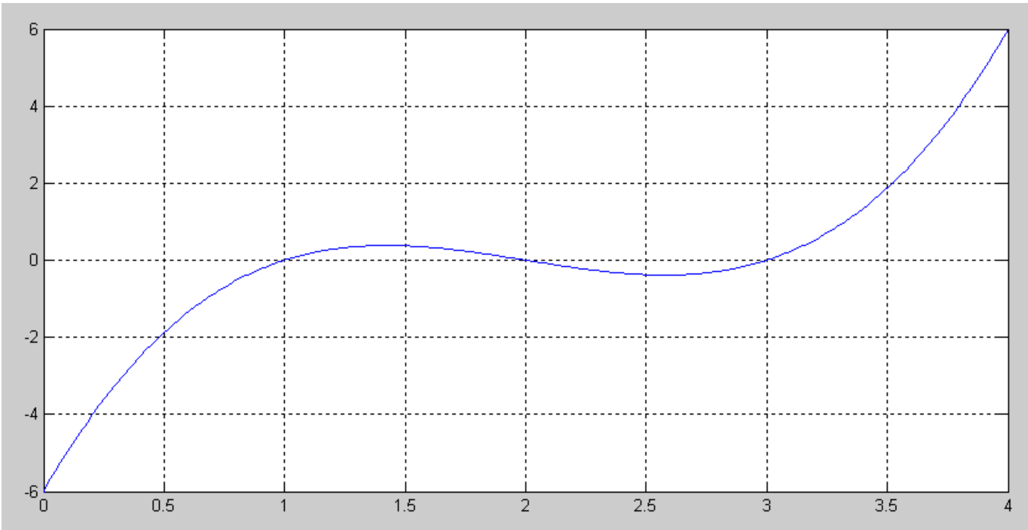
In Matlab:

```
poly([1,2,3])

     1    -6    11    -6
```

meaning

$$y = x^3 - 6x^2 + 11x - 6 = (x-1)(x-2)(x-3)$$

```
roots([1,-6,11,-6])

    3.0000
    2.0000
    1.0000


x = [0:0.01:4]';
y = x.^3 - 6*(x.^2) + 11*x - 6;
plot(x,y);
grid on
```



3-D Plots

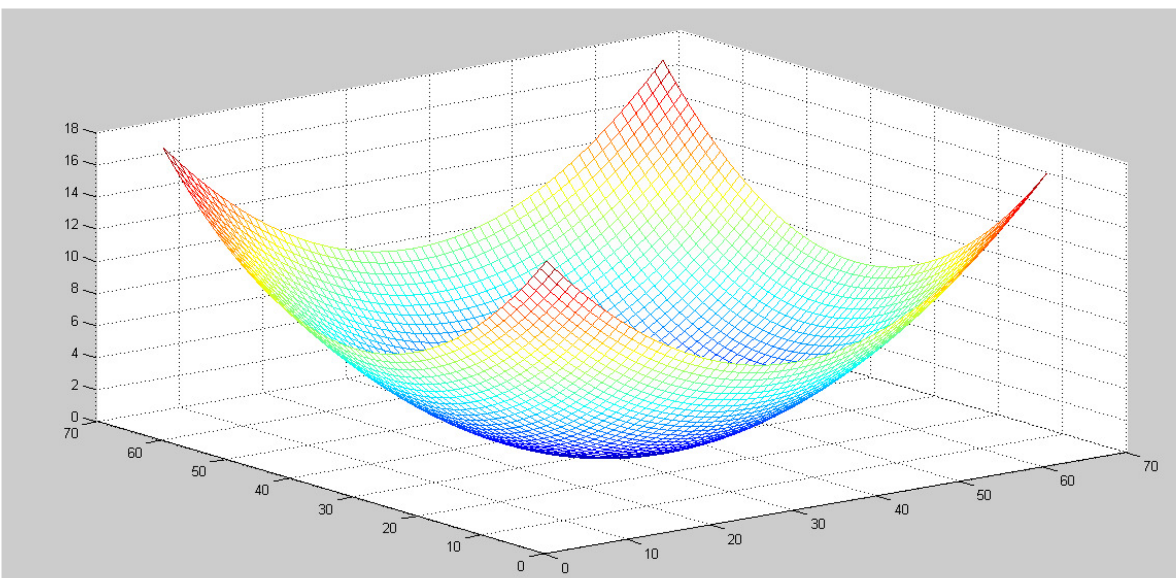
```
mesh(z)
```

Draw a 3-d mesh for the array 'z' with the height being the value in the array.

Example

$$z = x^2 + y^2$$

```
 x = [-3:0.1:3]';
 y = [-3:0.1:3]';
 size(x)

ans =

    61     1

 z = zeros(61,61);
 for i=1:61
   for j=1:61
      z(i,j) = x(i)^2 + y(j)^2;
      end
   end

 mesh(z)
```

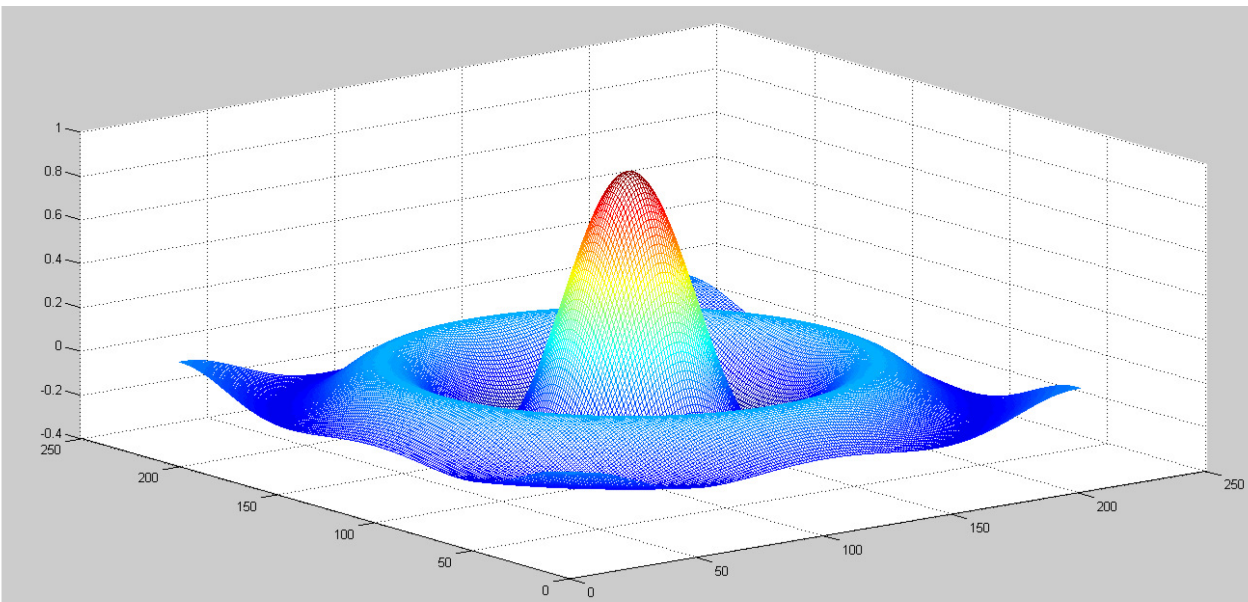


Another pretty plot:

$$r = \sqrt{x^2 + y^2}$$

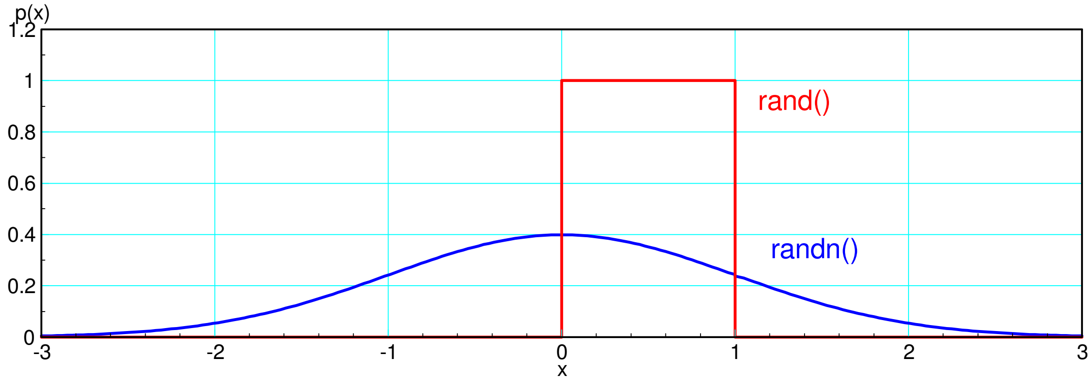
$$z(x, y) = \left(\frac{\sin(r)}{r}\right)$$

```
x = [-10:0.1:10]';
y = [-10:0.1:10]';
size(x)

  201     1

z = zeros(201,201);
for i=1:201
  for j=1:201
     r = sqrt(x(i)^2 + y(j)^2);
     z(i,j) = sin(r) / (r + 0.000001);
     end
  end
mesh(z)
```



Random Numbers: Rolling Dice

```
rand                    random number: (0,1)
randn          standard normal random #
```

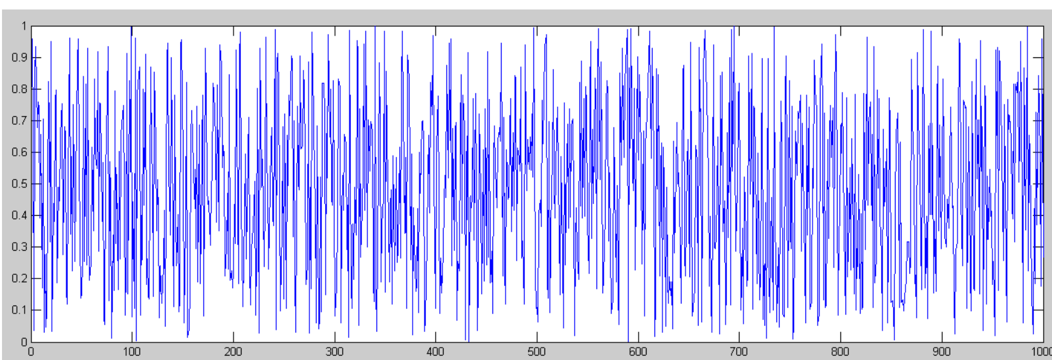


rand() produces a uniform distribution. rnadn() produces a Normal distribution

```
rand(1,5)              1x5 matrix of random #

ceil( 6*rand )         6-sided die

ceil( 8*rand(1,3) )    3d8

sum( 6*rand(5,1) )     sum of 5d6   (level 5 fireball)
```

Example: Generate 1000 random numbers and plot them

```
x = rand(1,1000);
plot(x)
```

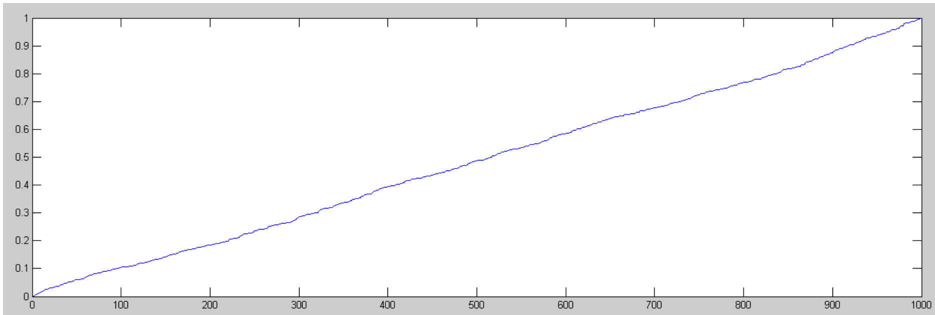


rand() produces a random number in the range of (0,1)

If you sort the numbers, you can see the cumulative distribution function

- approximately
- (rand < 0.6) approximately 60% of the time

```
y = sort(x);
plot(y)
```



sorting the results of rand shows that 20% of the time, rand() produces a number less than 0.2

Matlab Scripts

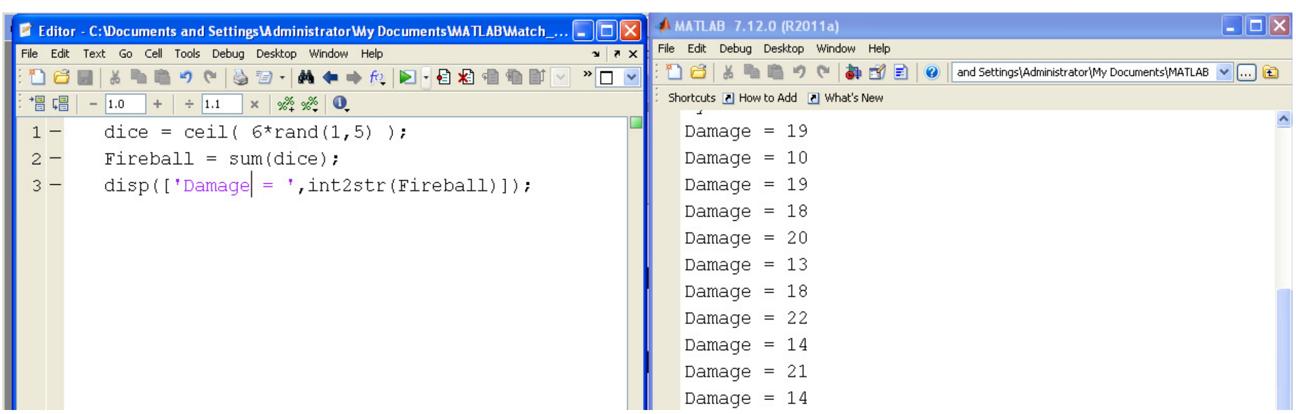
Instead of typing in the command window, you can use a Matlab Script. When executed, (green arrow in the icon bar), scripts act like you input those instructions in the command window.

This is useful

- It lets you build up your code
- It lets you modify existing code
- You can rerun the code over and over

For example,

- The window on the left (Matlab script) computes the damate for summing five 6-sided dice (i.e. a level 5 fireball for D&D fans).
- The window on the right (command window) shows the print-portions when the scipt is run
- Clicking on the run command (green arrow on the top of the script) results in the script executing several times.



Matlab Script (left) and Command (right).

For-Loops

```
for i=1:100
    statements
    end
```

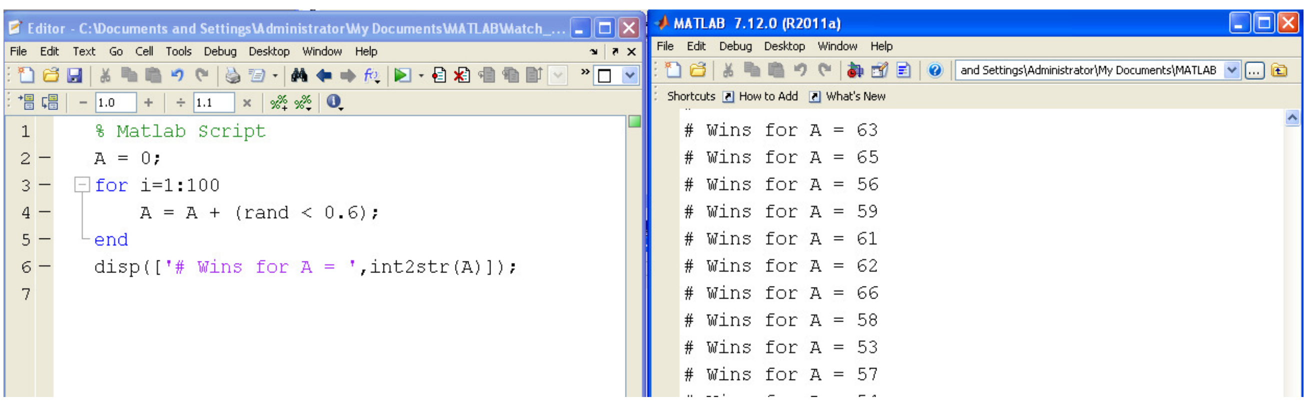
For-Loops repeat a set of instructions a fixed number of times. For example, assume A and B are playing a game.

- A has a 60% chance of winning any given game.
- How many games will A win in a 100 game match?

This can be done with a for-loop:

- (rand < 0.6) is a boolean operation: it's 1 if true, 0 if false.
- Each game, A has a 60% chance of earning one point (a win)
- 100 games are played in each match (the for-loop).

The resulting Matlab code (in a script window) and results of executing it are as follows:



For-Loop: (rand<0.6) is executed 100 times each pass.

Note:

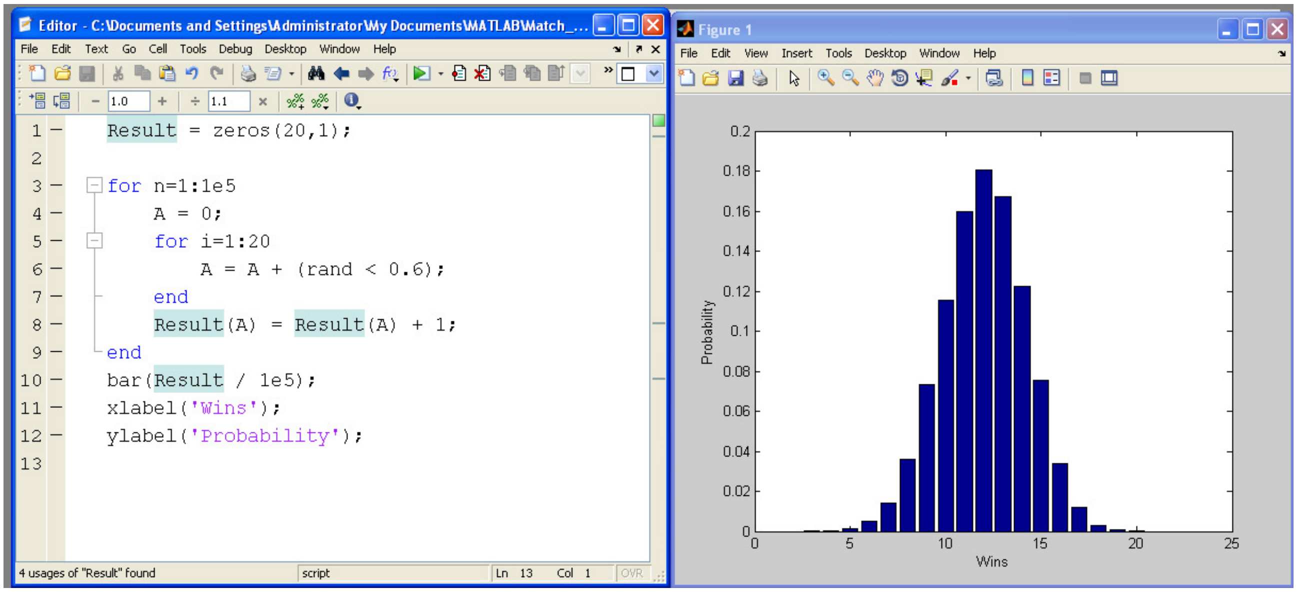
- 0 is false, 1 is true
- On average, A wins 60 games out of 100
- In any given match, A could win 0..100 games

For-Loops & Monte-Carlo Simulations: 20-game match

What is the probability of A winning X games in a 20 game match?

To solve this problem, change the for-loop from 100 to 20. Also keep track of how many times you won X games and then repeat this experiment 100,000 times (termed a Monte-Carlo simulation)

One Matlab program and it's results are as follows:



Monte-Carlo simultion: Repeat an experiment 100,000 times

Note: The resulting distribution is a bell-shaped curve. This is called a *Normal Distribution* and is something you'll see over and over and over again.

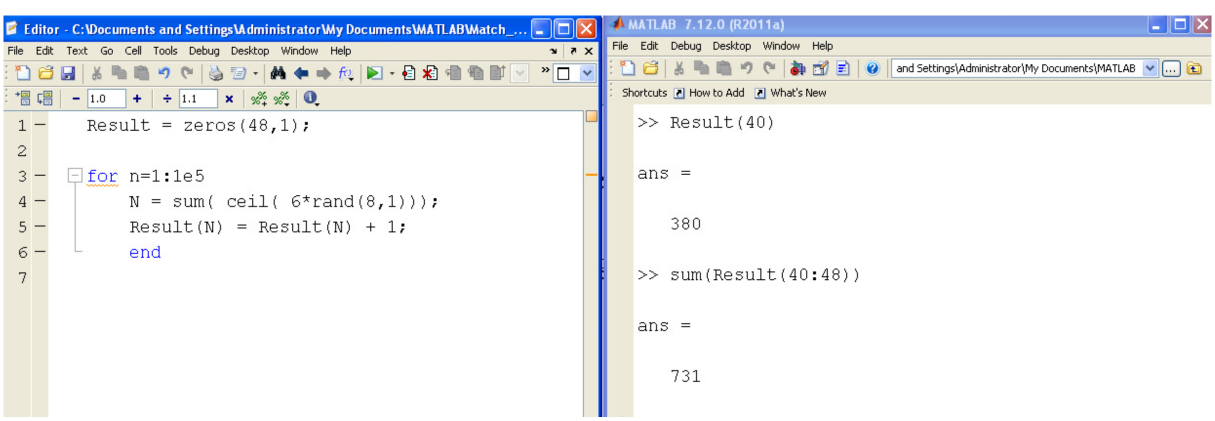
For-Loops: Level-8 Fireball

Using a similar technique, for-loops can determine the probability of

- Doing 40 damage with a level-8 fireball, or
- Doing 40+ damage with a level-8 fireball.

To solve these problems,

- First, cast a single level-8 fireball
- Determine if the damage was 40 or more than 40
- Then repeat 100,000 times, recording how many times the result was N



The resulting probability is (approximately)

- p = 380 / 100,000 to do 40 damage exactly
- p = 731 / 100,000 to do 40 or more damage.

If-Statements

```
if(boolean statement)
   statements to execute
   end
```

If-statements allow you to execute a set of instructions based upon a condition. Valid boolean statements are as follows:

```
(N == 3)
(N > 3)
(N >= 3)
(N != 3)
(N >= 3)*(N <= 7)
((N < 3) | (N > 7))
```

If-statements are useful for checking what conditions hold. For example, suppose A and B are playing a match

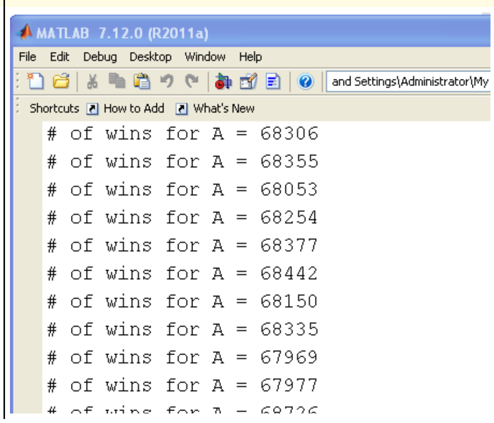
- Each match consists of 5 games
- A has a 60% chance of winning any given game
- Whoever wins 3+ games wins the match

What is the chance that A wins the match?

Matlab Script

```
Wins = 0;
for n=1:1e5
    A = 0;
    for i=1:5
        if(rand < 0.6)
            A = A + 1;
        end
    end
    if(A >= 3)
        Wins = Wins + 1;
    end
end
disp(['# of wins for A = ',int2str(Wins)]);
```

Matlab Command Window



Solution:

- Monte-Carlo simulation of 100,000 matches
- A wins about 68% of the time

If-Statements (cont'd)

Player A casts a level-8 fireball (8d6)

- What is the chance of doing 40 damage?
- What is the chance of doing 40+ damage?

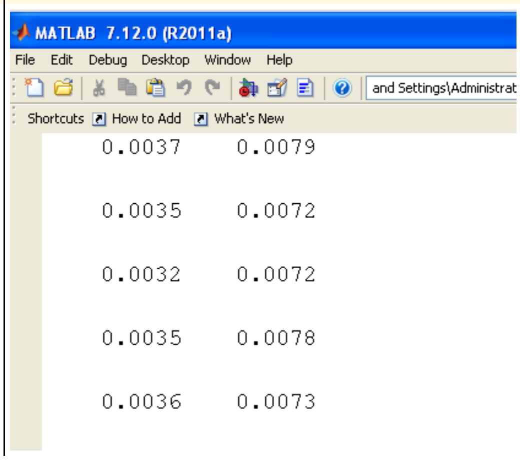
Solution:

- Monte-Carlo Simulation
- Cast 100,000 fireballs
- Count how many times you do 40 damage
- Count how many times you do 40+ damage

Matlab Script

```
eq40 = 0;
gt40 = 0;
for n=1:1e5
    A = sum(ceil(6*rand(8,1)));
    if(A == 40)
        eq40 = eq40 + 1;
    end
    if(A >= 40)
        gt40 = gt40 + 1;
    end
end
disp([eq40/1e5, gt40/1e5])
```

Matlab Command Window



Note:

- There are multiple ways to solve any given problem

If-Elseif-Else Statements

```
if(boolean statement)
   instrucitons #1
elseif(boolean statement)
   instructions #2
else
   instuctions #3
end
```

Execute a set of statements

- If the first condition is true, execute instructions #1 and skip the rest
- If the first condition is false , then check the second boolean statement
- If that is also false, excute instructions #3

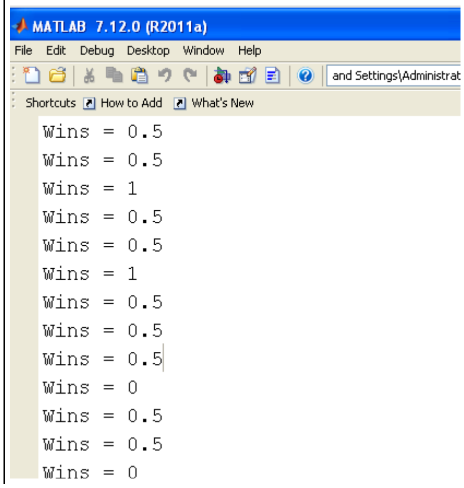
Example: A and B play a game

- A has a 30% chance of winning (+1 point)
- A has a 50% chance of a tie (+1/2 point)
- A has a 20% chanec of losing (0 points)

Matlab Script

```
Wins = 0;
X = rand;
if(X < 0.3)
    Wins = Wins + 1;
elseif(X < 0.8)
    Wins = Wins + 0.5;
else
    Wins = Wins + 0;
end
disp(['Wins = ',num2str(Wins)]);
```

Matlab Command Window



If-Else Statements (cont'd)

A die is loaded:

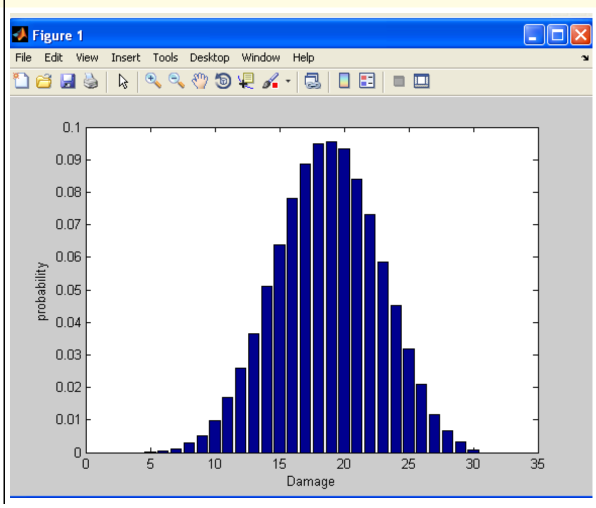
- 10% of the time, it always rolls a 6
- The rest of the time it's a fair die

What is the chance of doing X damage with a level-5 fireball?

Matlab Script

```
Damage = zeros(30,1);
for n=1:1e5
    X = 0;
    for i=1:5
        if(rand < 0.1)
            d6 = 6;
        else
            d6 = ceil(6*rand);
        end
        X = X + d6;
    end
    Damage(X) = Damage(X) + 1;
end
bar(Damage / 1e5);
xlabel('Damage');
ylabel('probability');
```

Matlab Plot Window



Note:

- Once again, the result is a bell-shaped curve
- This is *The Central Limit Theorem*
- Almost all distributions converge to this shape

While-Loop

```
while(statement is true)
  do the following
  end
```

While-loops are useful for keeping a program going until a condition is met. This can be

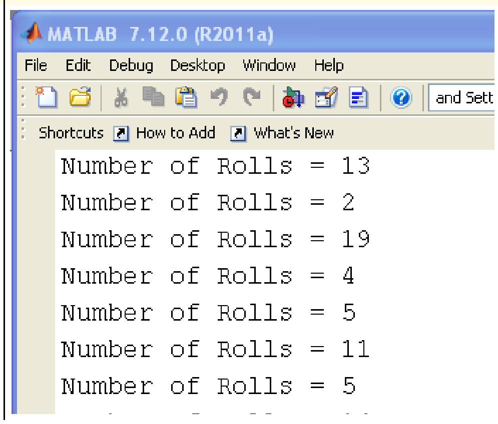
- Keep a simulation until time > 10 seconds,
- Keep playing a game until someone wins,
- Keep itterating until the error is less than 0.001

Example: Count how many times you roll a die until you get a 1

Matlab Script

```
N = 0;
d6 = 0;
while(d6 ~= 1)
    d6 = ceil(6*rand);
    N = N + 1;
end
disp(['Number of Rolls = ',int2str(N)])
```

Matlab Command Window



Note: in theory, N is unlimited. It could take millions of rolls until y ou get a 1.

While-Loop (cont'd)

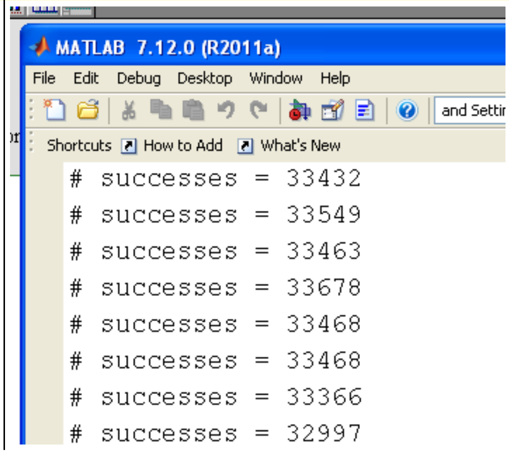
What is the chance that it will take 7 or more rolls to get a 1?

Solution:

- Count how many times you roll a die until you get a 1
- Keep track of the number of times this is 7 or more
- Repeat 100,000 times (i.e. run a Monte-Carlo Simulation)

Matlab Script	Matlab Command Window

```
X = 0;
for n=1:1e5
    N = 0;
    d6 = 0;
    while(d6 ~= 1)
        d6 = ceil(6*rand);
        N = N + 1;
    end
    if(N >= 7)
        X = X + 1;
    end
end
disp(['# successes = ',int2str(X)])
```



In 100,000 trials

- It took 7 or more rolls 33,343 times
- There is about a 33.34% chance it will take 7 or more rolls to get a 1

While-Loop (cont'd)

Player A and B are playing a match

- Player A has a 60% chance of winning any given game
- When a player is up 3 games, the match is over

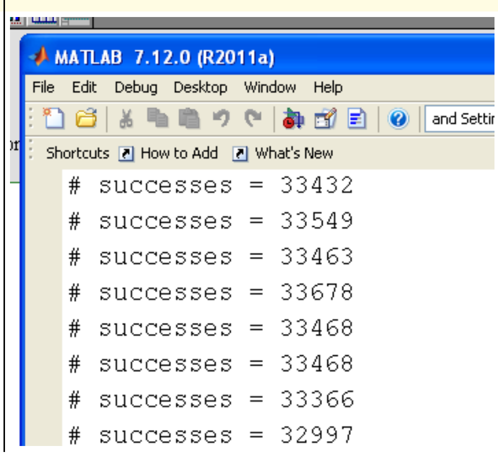
What is the chance player A wins the match?

Solution: Play a single match

- If A wins, A gains 1 point.
- If A loses, A loses 1 point.
- Keep playing until A is up 3 or down 3

Matlab Script	Matlab Command Window

```
A = 0;
while(abs(A) < 3)
    if(rand < 0.6)
        A = A + 1;
    else
        A = A - 1;
    end
end
if(A == 3)
    Wins = 1;
else
    Wins = 0;
end
disp(['Wins = ',int2str(Wins)])
```



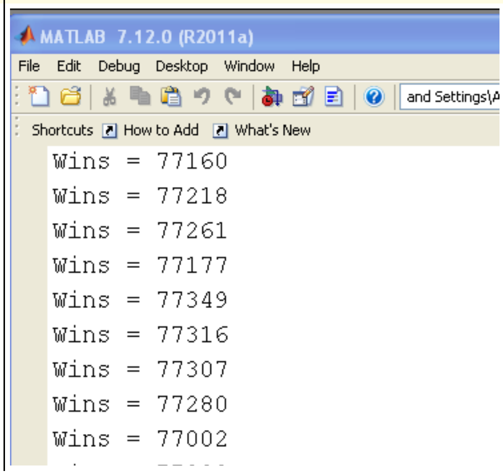
Now play 100,000 matches

- A wins about 77% of the time with this format
- TV hates this format since a match can take a very long time

Matlab Script

```
Wins = 0;
for n=1:1e5
    A = 0;
    while(abs(A) < 3)
        if(rand < 0.6)
            A = A + 1;
        else
            A = A - 1;
        end
    end
    if(A == 3)
        Wins = Wins + 1;
    end
end
disp(['Wins = ',int2str(Wins)])
```

Matlab Command Window



Sort Command

Sort data in either

- Ascending order (default), or
- Descending order

Return

- The sorted data (one returned parameter)
- The sort order (two returned parameters)

Matlab Command Window

```
X = rand(1,5)
X =     0.1744    0.7055    0.4435    0.1654    0.0592

a = sort(X)
a =     0.0592    0.1654    0.1744    0.4435    0.7055

a = sort(X, 'descend')
a =     0.7055    0.4435    0.1744    0.1654    0.0592

[a,b] = sort(X)
a =     0.0592    0.1654    0.1744    0.4435    0.7055
b =        5         4          1         3         2
```

Sort Command & Poker

Shuffle a deck of 52 playing cards

Deal out 5 cards (poker hand)

- Hand is the card number (1..52)
- Value is Ace..King (1..13)
- Suit is Club / Diamond / Heart / Spade (1...4)

Result:

- {4s, Jh, 3s, 7h, 6s}
- {4h, Jh, Ac, Jc, 5d}

Matlab Script	Matlab Command Window

`Deck = rand(1,52);`
`[a,b] = sort(Deck);`
`Hand = b(1:5)`
`Value = mod(Hand, 13) + 1`
`Suit = ceil(Hand / 13)`
	`Hand =   42   36   41   32   44`
	`Value =   4   11    3    7    6`
	`Suit =    4    3    4    3    4`
	
	`Hand =   29   36   13   10   17`
	`Value =   4   11    1   11    5`
	`Suit =    3    3    1    1    2`

Check for a Full-House

Problem: Determine if your hand is a full-house.

Solution:

- Count how many Aces, twos, etc. are in your hand (variable P)
- Sort P to determine the frequency of pairs in descending order

Matlab Script

```
Deck = rand(1,52);
[a,b] = sort(Deck);
Hand = b(1:5);
Value = mod(Hand, 13) + 1;
Suit = ceil(Hand / 13);

P = zeros(1,13);
for i=1:13
    P(i) = sum(Value == i);
end
P = sort(P, 'descend');

disp('--------')
disp(Value);
disp(P(1:5));
```

Matlab Command Window

```
--------
V      2     2    10     7     4
P      2     1     1     1     0

--------
V     11     5     5    12     4
P      2     1     1     1     0

--------
V      4     3     1    12     8
P      1     1     1     1     1

--------
V      4     4     1     4     2
P      3     1     1     0     0
```

Note:

- Hand #1 has a pair of 2's
- Hand #2 has a pair of 5's
- Hand #3 has no pairs
- Hand #4 has three 4's

Now checkI

- if P(1) = 3 (three of a kind) and P(2) = 2 (pair) then you have a full-house

Matlab Script	Matlab Command Window

<pre>FH = 0;
 	
for n=1:1e5
    Deck = rand(1,52);
    [a,b] = sort(Deck);
    Hand = b(1:5);
    Value = mod(Hand, 13) + 1;
    Suit = ceil(Hand / 13);
 	
    P = zeros(1,13);
    for i=1:13
        P(i) = sum(Value == i);
    end
    P = sort(P, 'descend');
 	
    if((P(1)==3)*(P(2)==2))
        FH = FH + 1;
    end
end
disp(['Full House = ',int2str(FH)])</pre>
	<pre>Full House = 141
	Full House = 133
	Full House = 162
	Full House = 124
	Full House = 119
	Full House = 154</pre>

Note:

- The number of full-houses you get in 100,000 hands of poker changes each time you run the Monte Carlo simulation (it's a random process)

With this, you can answer questions, such as

- What is the range in numbers I'll get?
- What is the actual probability of getting a full house?

This is something covered in ECE 341 Random Processes and week #12 in ECE 111.

Summary

Matlab is a fairly friendly computer language

You can use the command window as a calculator

- Adds, subtracts, multiplies, divides

Scripts allow you to try & modify code as you write it

For-loops let you run code multiple times

- Monte-Carlo simulations...

If-statements allow you to check for conditions

- If the sum is 25 or more...

While-loops let you run code until an event happens

- repeat until you roll a 1

Matlab Commands

Display

• format short	display results to 4 decimal places
• format long	display results to 13 decimal places
• format short e	display using scientific notation
• format long e	display using scientific notation

Polynomials

- poly(x)
- roots(x)
- conv(x,y)

Analysis

- sqrt(x) square root of x
- log(x) log base e
- log10(x) log base 10
- exp(x) e^x
- exp10(x) 10^x
- abs(x) |x|
- round(x) round to the nearest integer
- floor(x) round down (integer value of x)
- ceil(x) round up to the next integer
- real(x) real part of a complex number
- imag(x) imaginary part of a complex number
- abs(x) absolute value of x, magnitude of a complex number
- angle(x) angle of a complex number (answer in radians)
- unwrap(x) remove the discontinuity at pi (180 degrees) for a vector of angles
- sum(x) sum the columns of x
- prod(x) multiply the columns of x

Trig Functions

- sin(x) sin(x) where x is in radians
- cos(x) cos()
- tan(x) tan()
- asin(x) arcsin(x)
- acos(x) arccos(x)
- atan(x) arctan(x)
- atan2(y,x) angle to a point (x,y)

Probability and Statistics

- factorial(x) x!
- gamma(x) x!
- rand(n,m) create an nxm matrix of random numbers between 0 and 1
- randn(n,m) create an nxm matrix of random numbers with a normal distribution
- length(x) return the dimensions of x
- mean(x) mean (average) of the columns of x
- std() standard deviation of the columns of x

Display Functions

- plot(x) plot x vs sample number
- plot(x,y) plot x vs. y

Rolling Dice:

```
rand        generate a random number in the range of (0, 1)
rand(1,5)   generate a 1x5 matrix of random numbers in the range of (0, 1)

randn       generate a random number with a normal distribution with mean=0, std=1
```

Example: Generate a random number between 0 and 1:

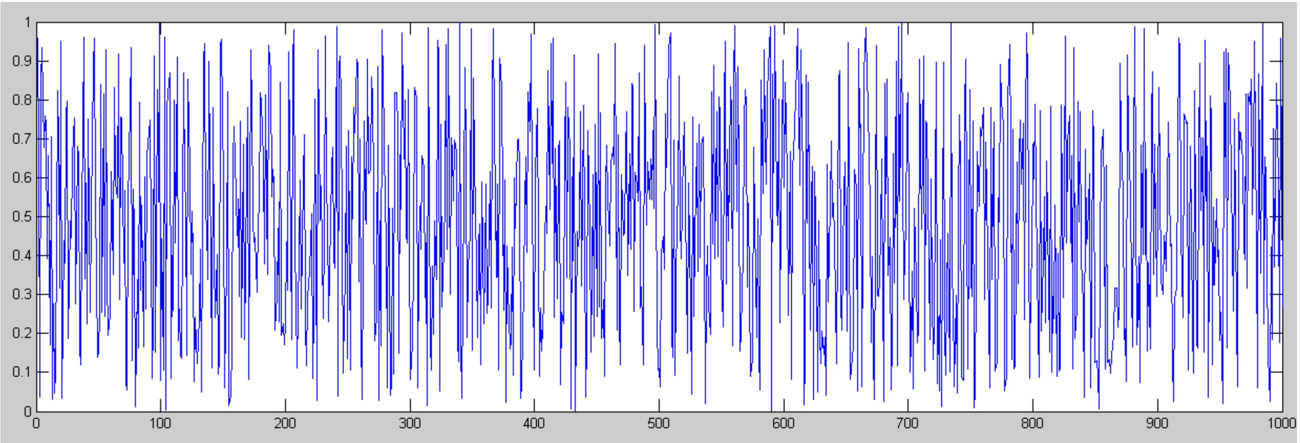
```
rand

   0.8147

rand

   0.9058
```

Generate 5 random numbers between 0 and 1

```
rand(1,5)

    0.8003    0.1419    0.4218    0.9157    0.7922
```

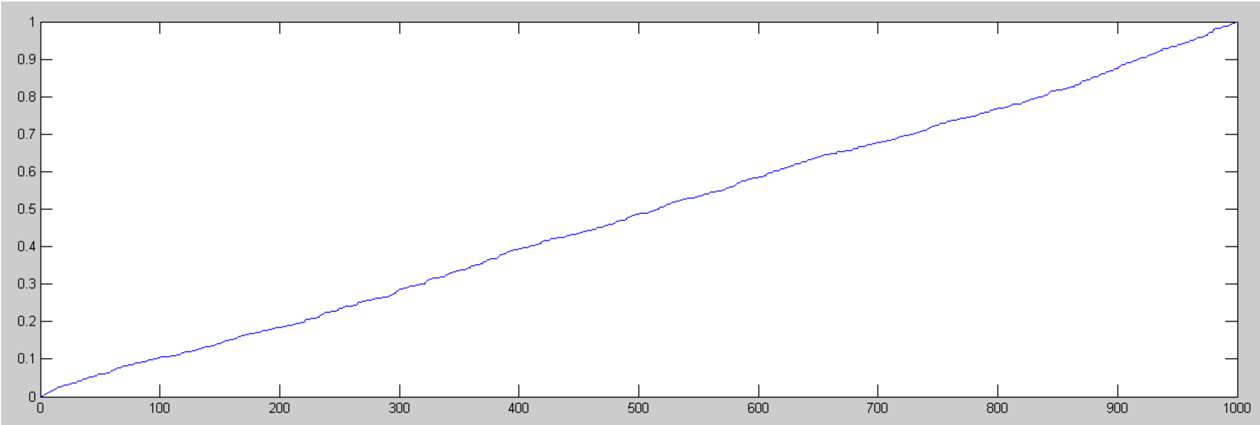
Generate 1000 random numbers and plot them

```
x = rand(1,1000);
plot(x)
```



If you sort the numbers, you can see the probability distribution function (approximately)

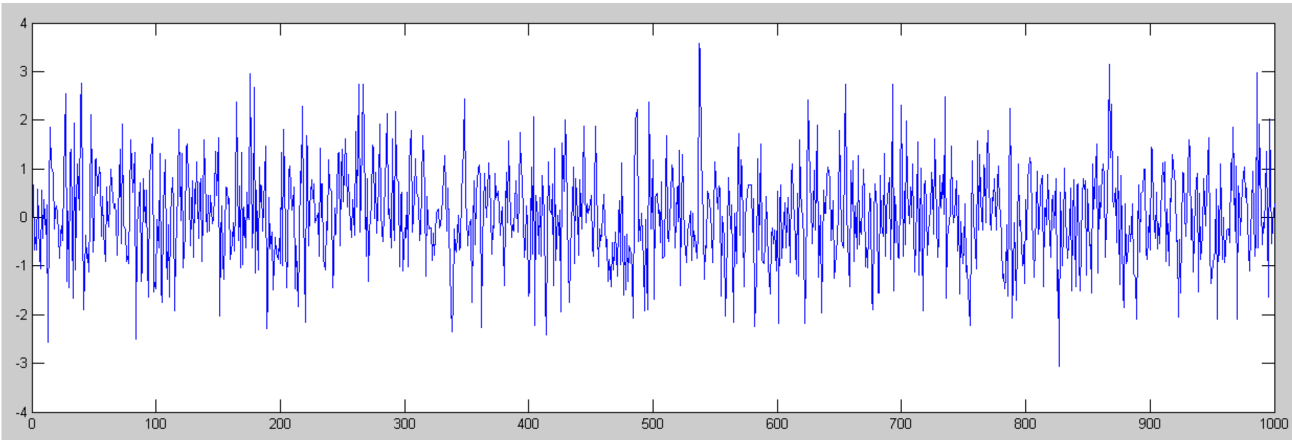
```
y = sort(x);
plot(y)
```



Each number from (0, 1) should have the same likelihood of coming up, meaning when you sort the numbers, the result should be a straight line

Compare this to a Normal distribution

```
x = randn(1,1000);
plot(x)
```



This is more what you'd see for

- Stock prices
- Temperatures
- Height of people,
- etc.

You have to watch which random number generator you're using. *rand()* is different from *randn()*

With this you can have fun with rolling dice:

Problem: Find the sum or rolling five six-sided dice. (5d6)

Solution: Generate five random numbers in the range of (0,1)

```
rand(1,5)

   0.7298    0.8908    0.9823    0.7690    0.5814
```

Looks right. Now generate five random integers in the range of (1,6)

```
dice = ceil( 6*rand(1,5) )

     3     6     2     4     4

dice = ceil( 6*rand(1,5) )

     1     4     3     1     3
```

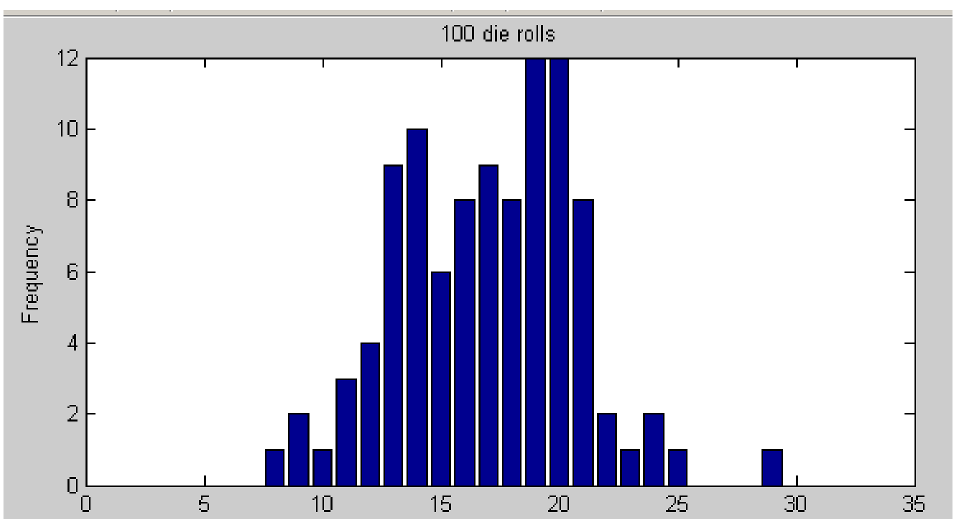
Looks right. Now, find the total:

```
sum( ceil( 6*rand(1,5) ) )

     8

sum( ceil( 6*rand(1,5) ) )

    16
```

Each time you roll the dice, you get a different answer. It's random.

Problem: Roll 5d6 one-hundred times and record how many rolls you get for each total:

```
X = zeros(30,1);
for i=1:100
  D = sum( ceil( 6*rand(1,5) ) );
  X(D) = X(D) + 1;
  end
bar(X)
xlabel('Die Total');
ylabel('Frequency');
title('100 die rolls')
```

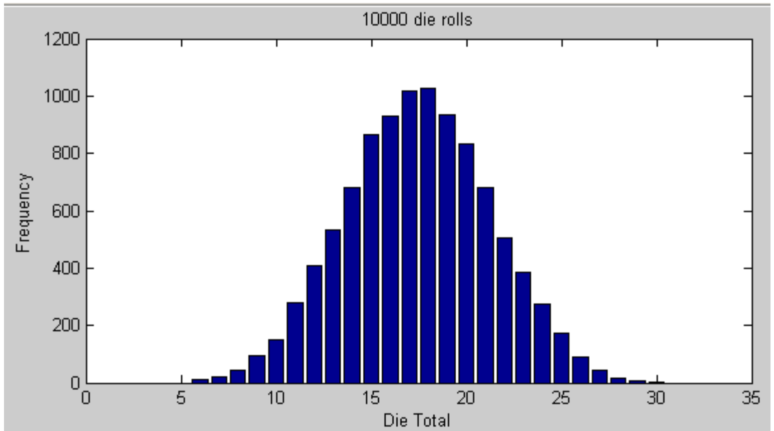


This looks pretty erratic. If you roll the dice 10,000 times, it becomes much better behaved:

Roll 5d6 10,000 times and record the frequency of each outcome:

```
X = zeros(30,1);
for i=1:10000
  D = sum( ceil( 6*rand(1,5) ) );
  X(D) = X(D) + 1;
  end
bar(X)
```

```
xlabel('Die Total');
ylabel('Frequency');
title('10000 die rolls')
```



This is the *Central Limit Theorem*. As the sample size goes to infinity, you get a Normal distribution.

Problem: What's the probability of rolling a 25 or higher with 5d6?

Solution: Toss the dice 1,000,000 times and count the number of times you got 25 or higher. The probability is then approximately this result divided by 1,000,000

```
X = 0;
for i=1:1000000
  D = sum( ceil( 6*rand(1,5) ) );
  if (D >= 25)
     X = X + 1;
     end
  end

X

      32348

X / 1e6

   0.0323
```

There is approximately a 3.23% chance of rolling a 25 or higher with 5d6

Problem: Instead of adding the total of five 6-sided dice (5d6), add d6 + d8 + d10 + d12 + d20. What's the distribution look like?

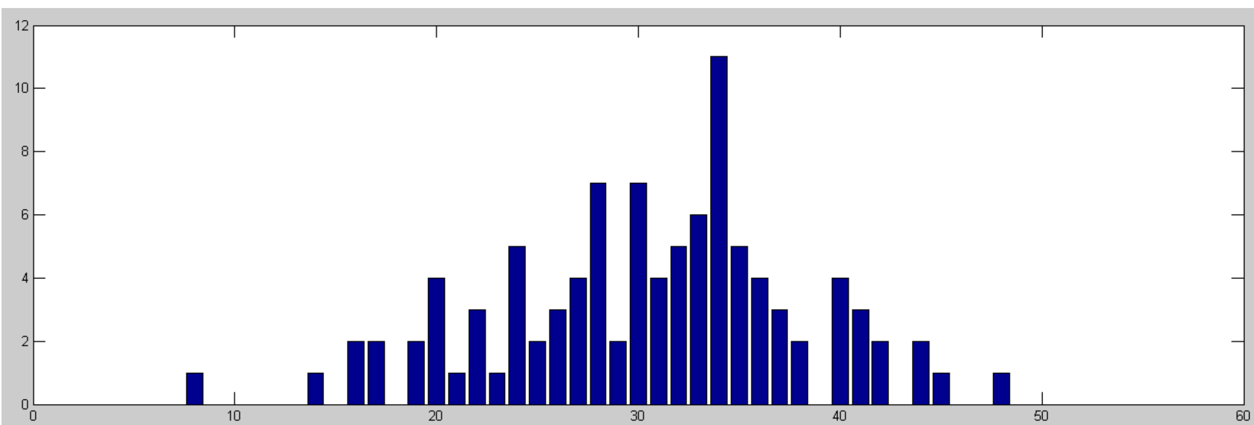
Solution: Roll the dice once

```
d6 = ceil(6*rand);
d8 = ceil(8*rand);
```

```
d10 = ceil(10*rand);
d12 = ceil(12*rand);
d20 = ceil(20*rand);

[d6,d8,d10,d12,d20]

    1     5     4     1     2

ROLL = sum([d6,d8,d10,d12,d20])

   13
```

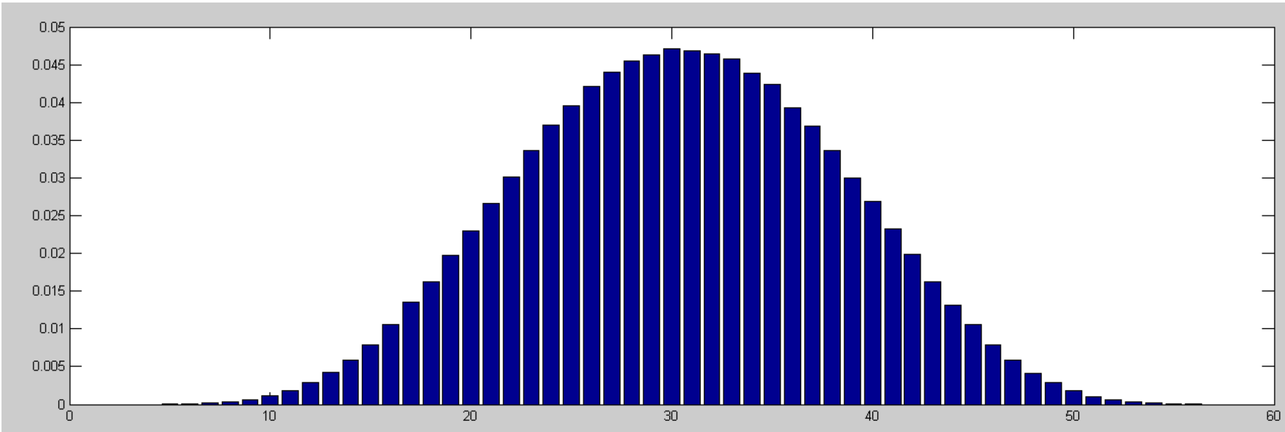
Now do it 100 times

```
RESULT = zeros(56,1);
for i=1:100
   d6 = ceil(6*rand);
   d8 = ceil(8*rand);
   d10 = ceil(10*rand);
   d12 = ceil(12*rand);
   d20 = ceil(20*rand);
   ROLL = sum([d6,d8,d10,d12,d20]);
   RESULT(ROLL) = RESULT(ROLL) + 1;
   end
bar(RESULT)
```



This is pretty erratic. To get a smoother plot, use the Central Limit theorem and roll the dice a lot mode (1,000,000 times):

```
RESULT = zeros(56,1);
for i=1:1000000
   d6 = ceil(6*rand);
   d8 = ceil(8*rand);
   d10 = ceil(10*rand);
   d12 = ceil(12*rand);
   d20 = ceil(20*rand);
   ROLL = sum([d6,d8,d10,d12,d20]);
   RESULT(ROLL) = RESULT(ROLL) + 1;
   end

bar(RESULT / 1000000)
```



What's the probability of rolling a 17?

```
RESULT(17) / 1e6

    0.0135
```

There's a 1.35% chance of rolling a 17.

What's the probability of rolling a 50 or higher?

```
sum(RESULT(50:56)) / 1e6

    0.0040
```

There's a 0.40% chance of rolling a 50 or higher.

Matlab Commands

Display

- format short display results to 4 decimal places
- format long display results to 13 decimal places
- format short e display using scientific notation
- format long e display using scientific notation

Analysis

- sqrt(x) square root of x
- log(x) log base e
- log10(x) log base 10
- exp(x) e^x
- exp10(x) 10^x
- abs(x) |x|
- round(x) round to the nearest integer
- floor(x) round down (integer value of x)
- ceil(x) round up to the next integer
- real(x) real part of a complex number
- imag(x) imaginary part of a complex number
- abs(x) absolute value of x, magnitude of a complex number
- angle(x) angle of a complex number (answer in radians)
- unwrap(x) remove the discontinuity at pi (180 degrees) for a vector of angles

Polynomials

- poly(x)
- roots(x)
- conv(x,y)

Trig Functions

- sin(x) sin(x) where x is in radians
- cos(x) cos()
- tan(x) tan()
- asin(x) arcsin(x)
- acos(x) arccos(x)
- atan(x) arctan(x)
- atan2(y,x) angle to a point (x,y)

Probability and Statistics

- factorial(x) (x-1)!
- gamma(x) x!
- rand(n,m) create an nxm matrix of random numbers between 0 and 1
- randn(n,m) create an nxm matrix of random numbers with a normal distribution
- sum(x) sum the columns of x
- prod(x) multiply the columns of x
- sort(x) sort the columns of x from smallest to largest

- length(x) return the dimensions of x
- mean(x) mean (average) of the columns of x
- std() standard deviation of the columns of x

Display Functions

- plot(x) plot x vs sample number
- plot(x,y) plot x vs. y
- semilogx(x,y) log(x) vs y
- semilogy(x,y) x vs log(y)
- loglog(x,y) log(x) vs log(y)
- mesh(x) 3d plot where the height is the value at x(a,b)
- contour(x) contour plot
- bar(x,y) draw a bar graph
- xlabel('time') label the x axis with the word 'time'
- ylabel() label the y axis
- title() put a title on the plot
- grid() draw the grid lines

Useful Commands

- hold on don't erase the current graph
- hold off do erase the current graph
- diary create a text file to save whatever goes to the screen
- linepace(a, b, n) create a 1xn array starting at a, increment by b
- logspace(a,b,n) create a 1xn array starting at 10^a going to 10^b, spaced logarithmically
- subplot() create several plots on the same screen
- disp('hello') display the message *hello*

Utilities

- format set the display format
- zeros(n,m) create an nxm matrix of zeros
- eye(n,m) create an nxm matrix with ones on the diagonal
- ones(n,m) create an nxm matrix of ones
- help help using different functions
- pause(x) pause x seconds (can be a fraction). Show the graph as well
- clock the present time
- etime the difference between to times
- tic start a stopwatch
- toc the number of seconds since tic