9.07 Matlab Tutorial

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Aim

- Transform students into Matlab ninjas!

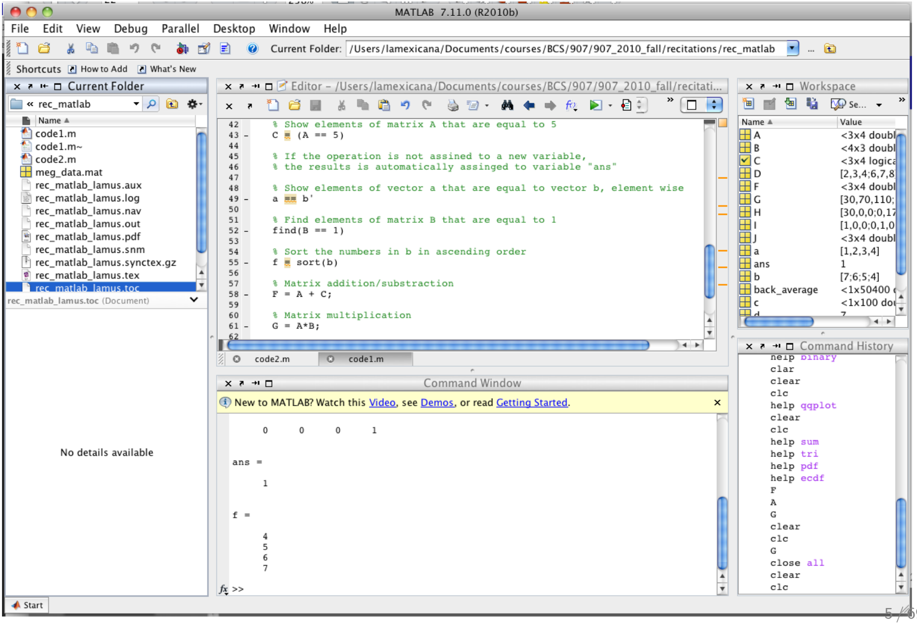
Contents

- Matrix operations: `a + b, a*b, A.*B, A.^B, sort, etc`
- Loops: `for i=1:n, while "statement is true"`
- Some useful functions: `rand, randn, min, max, etc`
- Function for displaying results:
  `figure, plot, subplot, bar, hist, title, xlabel, etc`
- Translating algorithms into Matlab code.

Getting started

- Getting Matlab: http://web.mit.edu/student-matlab/
- Matlab support: http://www.mathworks.com/support/, in search support box select "Function list for all products"
- Matlab support: Goto Help>Product Help
- In command prompt type: `help <name of funct>`

The Matlab interface



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- Generate the row vector $c = [1\ 2\ \ldots\ 100]$

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c = [1:1:100];
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- Generate the 3×4 matrix $A = \begin{bmatrix} 1 & 2 & 3 & 4 \\ 5 & 6 & 7 & 8 \\ 9 & 10 & 11 & 12 \end{bmatrix}$

```
A = [1 2 3 4;5 6 7 8;9 10 11 12];
```

Constructing matrices

- Accessing a portion of the matrix A
  - Take the element in the 2nd row and 3rd column of matrix A

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    d = A(2,3);
    ```

  - Take the elements in the 1st through 2nd rows and 2nd through 4th columns

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- Load data from a ".mat" file meg_data.mat

  ```
  load meg_data
  ```

Matrix operations

- Show the elements of matrix A that are equal to 5

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C = (A == 5)
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- Sort the numbers in b in ascending order

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f = sort(b)
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- Add matrices A and C, i.e., $F = A + C$

```
F = A + C;
```

- Multiply the matrices A and B, i.e., $G = A * B$

```
G = A*B;
```

Matrix operations

- Multiply element-wise matrix G and the identity matrix I, i.e.,

$$G = \begin{bmatrix} 130 & 70 & 110 \\ 70 & 174 & 278 \\ 110 & 278 & 446 \end{bmatrix}, I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$H = \begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,1} & h_{3,2} & h_{3,3} & h_{3,4} \end{bmatrix} = \begin{bmatrix} 130 * 1 & 70 * 0 & 110 * 0 \\ 70 * 0 & 174 * 1 & 278 * 0 \\ 110 * 0 & 278 * 0 & 446 * 1 \end{bmatrix}$$

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```
H = G.*I;
```

- Find the cube of the elements of matrix A

```
J = A.^3;
```

Loops

- Load the MEG data from meg_data.mat and compute the sample mean of the first 500 samples with a `for` loop: $\bar{y} = \frac{1}{500}\sum_{i=1}^{500} y_i$

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```
% load the meg data
load('meg_data.mat');
% Take the required values
y = back_average(1:500);
% Initialize a variable accumulate the sum
acum = 0;
for i=1:500
    % Accumulates the sum of the data
    acum = acum + y(i);
end
% Divide by number of samples
y_bar1 = acum / 500;
```

Loops

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```
% Initialize a temporary variable
acum = 0;
counter = 0;
while counter < 500
    % Updates the counter
    counter = counter + 1;
    % Accumulates the sum of the data
    acum = acum + y(counter);
end
% Divide by number of samples
y_bar2 = acum / 500;
```

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```
% Draw 500 samples from Bernoulli distribution
p = 0.5;
b = rand(1,500) > 0.5;
```

Some useful functions

- Computed the minimum, maximum, mean, standard deviation, and variance from simulated sample from the standard Gaussian distribution: x_i, $i = 1, 2, \ldots, 500$, where the sample variance is $\hat{\sigma}^2 = \frac{1}{500}\sum_{i=1}^{500}(x_i - \bar{x})^2$, and the sample standard deviation is $\hat{\sigma}$

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```
% The minimum
x_min = min(x);

% The maximum
x_max = max(x);

% The sample mean
x_bar = mean(x);

% The sample variance
sigma2_hat = var(x);

% The sample standard deviation
sigma_hat = sigma2_hat^(1/2);
```

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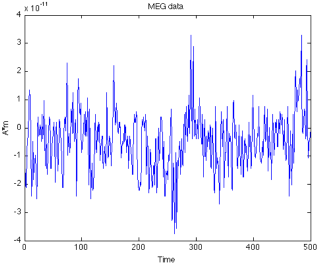

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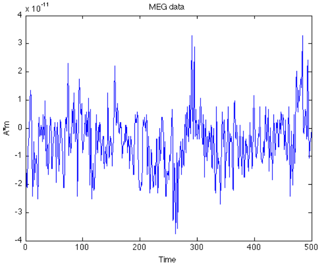

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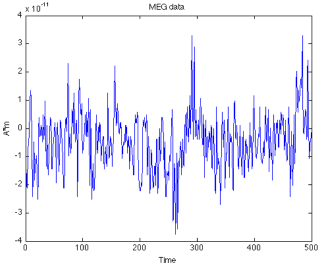

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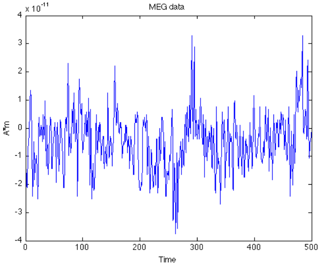

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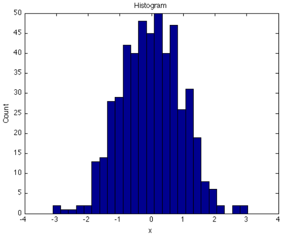

Translating a problem to an algorithm to a code

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  - With the “fair” coin we can obtain a samples from the Bernoulli distribution with parameter $p = 0.5$. Recall that the pdf of the Bernoulli is given by:
    $f_{ber}(b) = p^b(1-p)^{(1-b)}$, where $b \in \{0, 1\}$

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- And from the uniform sample simulate a new sample of the exponential distribution using the Inverse Transform method!

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- And from the uniform sample simulate a new sample of the exponential distribution using the Inverse Transform method!
  - Find an algorithm
  - Write the code

From the problem to an algorithm

- To find the algorithm we should note that a number u between 0 and 1 can be represented with the binary expansion $0.b_1b_2b_3\ldots$, i.e:

$$u = \sum_{i=1}^{\infty} b_i/2^i, \text{where } b_i \in \{0, 1\}$$

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- For example:
  - If $u = 0.75$ then $b_1 = 1$, $b_2 = 1$, $b_j = 0$, $j = 3, 4, \ldots$, since $u = 1/2 + 1/2^2 + 0/2^3 + \cdots$

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  - If $u = 0.958$ then $0.b_1 b_2 b_3 \ldots = 0.1111010101\bar{0}$

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  - If $u = 0.958$ then $0.b_1 b_2 b_3 \ldots = 0.1111010101\bar{0}$
  - If $u = 0.3288$ then $0.b_1 b_2 b_3 \ldots = 0.0101010000101001001\bar{0}$

From the problem to an algorithm

- The million dollar question: If the binary coefficients b_i in expansion $u = \sum_{i=1}^{\infty} b_i/2^i$ come from a Bernoulli distribution with $p = 0.5$ (the "fair" coin), what is the distribution of u?

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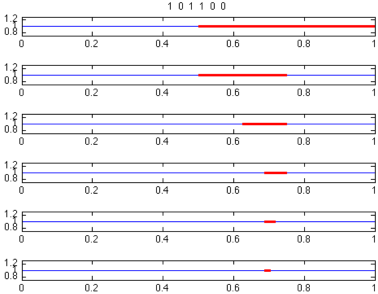
- The answer is: u is a uniform random variable. But this is difficult to show!
- We will use a heuristic argument to convince our selves
- If $b_1 = 1 \rightarrow u >= 0.5$ and if $b_1 = 0 \rightarrow u < 0.5$
- More generally, with a figure we see that:



From the algorithm to the code

- Simulate a sample of size 1000 from the uniform distribution using samples from the Bernoulli distribution with parameter $p = 0.5$:

$$u_j = \sum_{i=1}^{500} b_{i,j}/2^i, \text{ where } j = 1, 2, \ldots, 1000, \ i = 1, 2, \ldots, 500$$

and $b_{i,j}$ are iid Bernoulli with parameter p

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and $b_{i,j}$ are iid Bernoulli with parameter p

```
% Sample size
n = 1000;
% Compute the denominators expansion
m = 500;
d = 1./2.^[1:m];
% For loop to obtain the 500 uniform rvs
for i =1:n
    % Simulate 100 Bernoulli rvs (b_{i,j})
    b = rand(1,m)>0.5;
    % Compute the summation
    u(i) = sum(b.*d);
end
```

From the algorithm to the code

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```

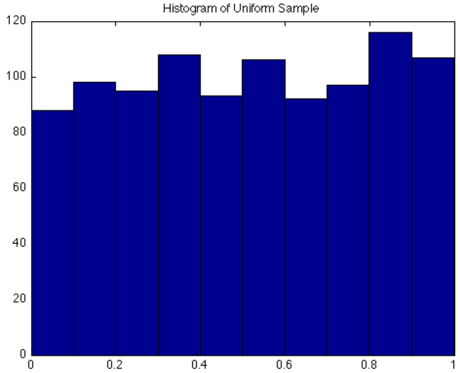

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- Now we can obtain F_{exp}^{-1} as:

$$F_{exp}^{-1}(u) = -\frac{\log(1-u)}{\lambda}$$

From the algorithm to the code

- Generate a sample of size 1000 of the exponential distribution with parameter $\lambda = 3$ using a sample from the uniform distribution (u_j) using the Inverse Transform method:

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- Make a histogram of the sample simulated from the exponential distribution

```
figure, hist(t)
title('Histogram of Exponential Sample')
```

Did it WORK???

- Raise you hand if you think it did work

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