ENGR 105: Introduction to Scientific Computing

Machine Model, Matlab Interface, Built-in Functions, and Arrays

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Answers to questions from last lecture

Office hours

- TA Mr. Jimmy Paulos: Tuesdays from 3-4pm, location TBD
- Dr. Graham Wabiszewski: Fridays from 4-5pm, 272 Towne

Hypothetically, could everyone in the class receive an A?

- Yes!
- You are competing with yourself and your own knowledge. Help your classmates - but no copying!

Answers to questions from last lecture

Lab quizzes

- No “Googling” during the lab quizzes - it should be just you and Canvas
- First lab quiz will be on 9/11

Course book / Ch.1

- Physical copy available at UPenn bookstore
- Digital copy “should” eventually be available through the UPenn library - no firm date as to when this will happen
- A pdf version of Ch. 1 will be uploaded to Canvas tonight

Answers to questions from last lecture

Can I give you the code to 207 Moore?

- Yes. The code is 5-3-4-2-1
- Do not use the space while other classes are occupying it, see the following for the reservation schedule: https://www.seas.upenn.edu/cets/forms/lab-request/availability.php?room=Moore_207_Public

Answers to questions from last lecture

Can I resubmit an assignment before the due date?

- Yes!
- Details of this can be found at: http://guides.instructure.com/s/2204/m/4212/l/41972-how-do-i-submit-an-online-assignment
- You may also find "How do I upload a file to my assignment submission" helpful: http://guides.instructure.com/s/2204/m/4212/l/54353-how-do-i-upload-a-file-to-my-assignment-submission

Upcoming work

First homework assignment

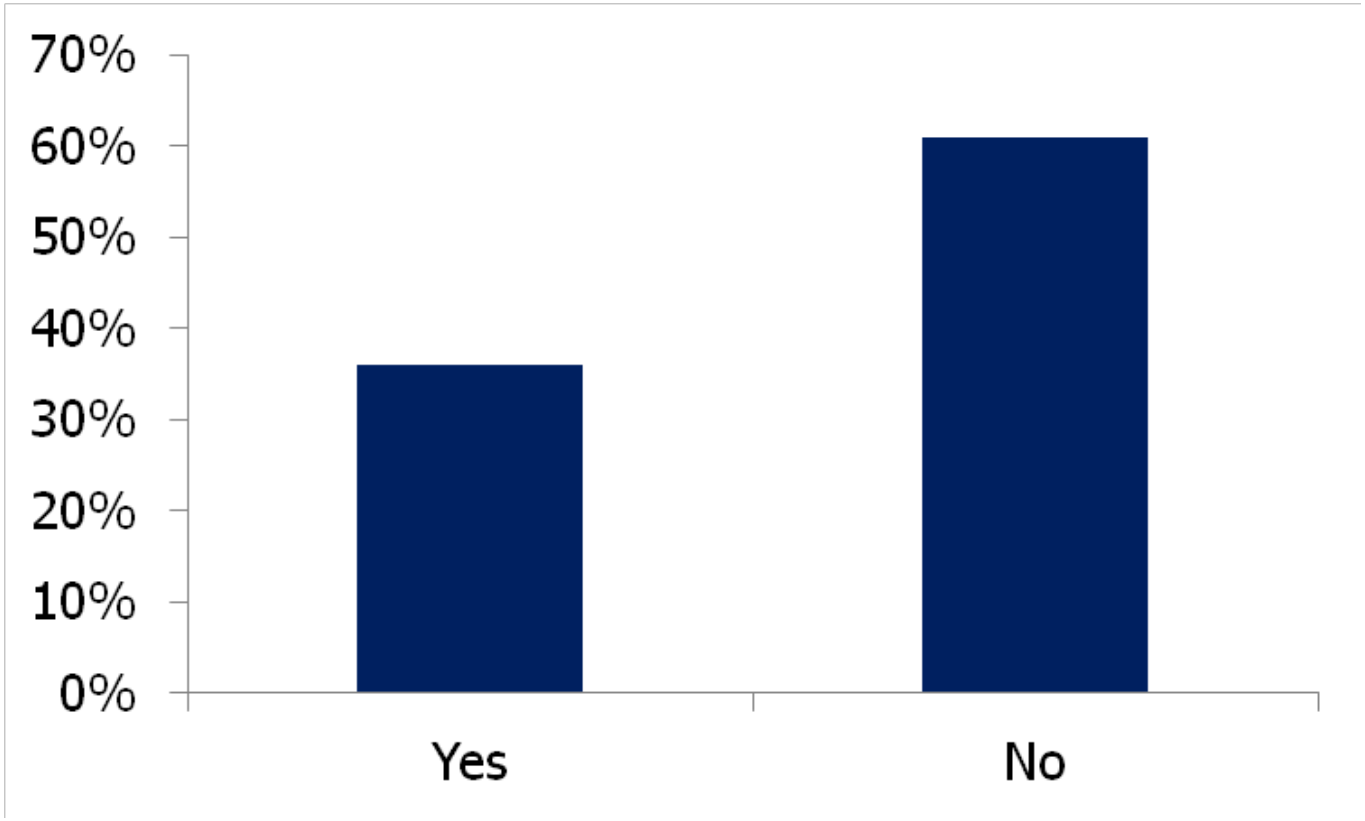
- Will be uploaded on ~Tuesday, 9/3
- Will be due Wednesday, 9/11
- Reading requirements
  - Ch. 1 & Ch. 2 of Essential Matlab
  - Article "Everything I need to know about pair programming I learned in kindergarten"

Questions?

Any questions?

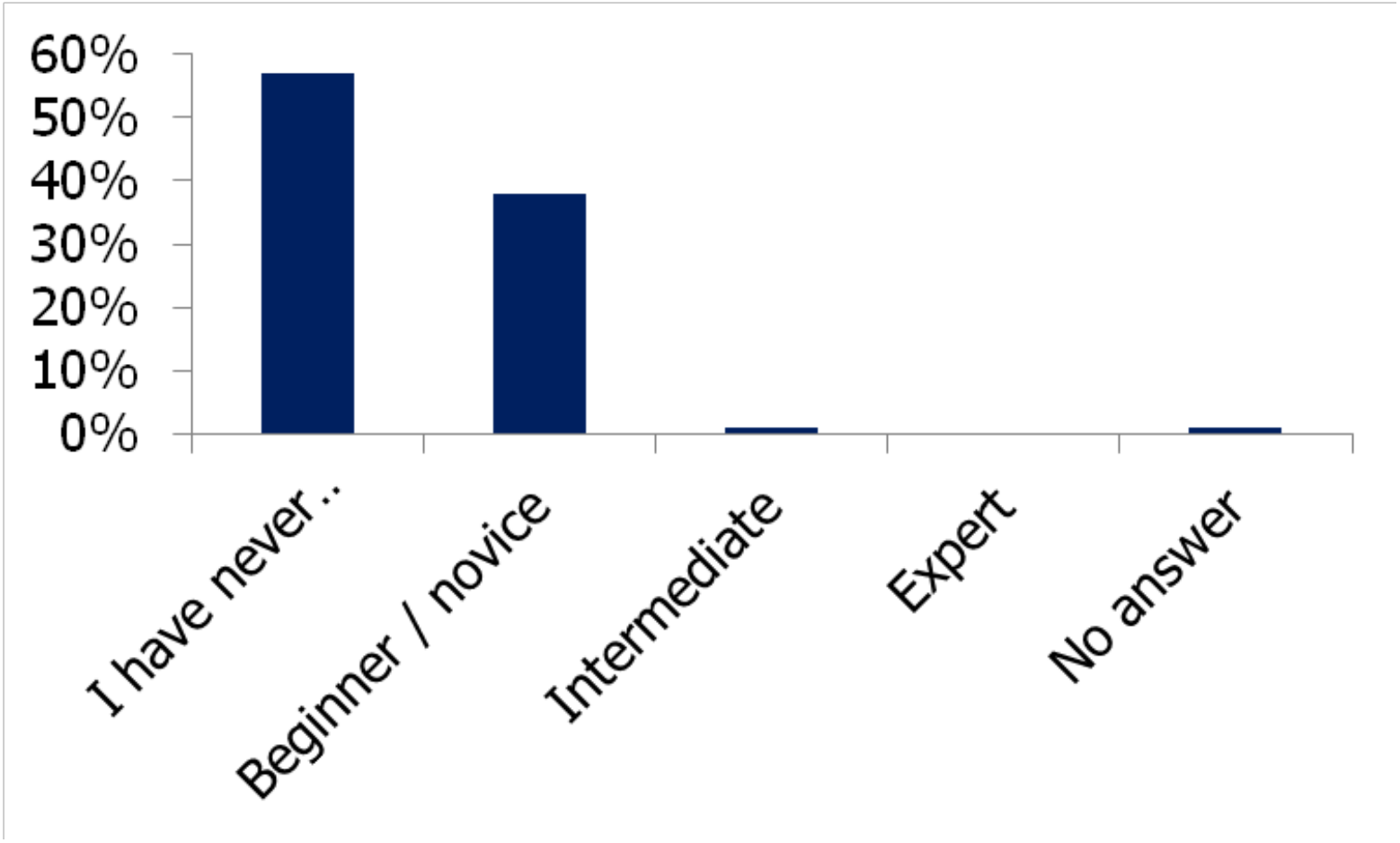
Results of the initial assessment

Have you used Matlab before this course?

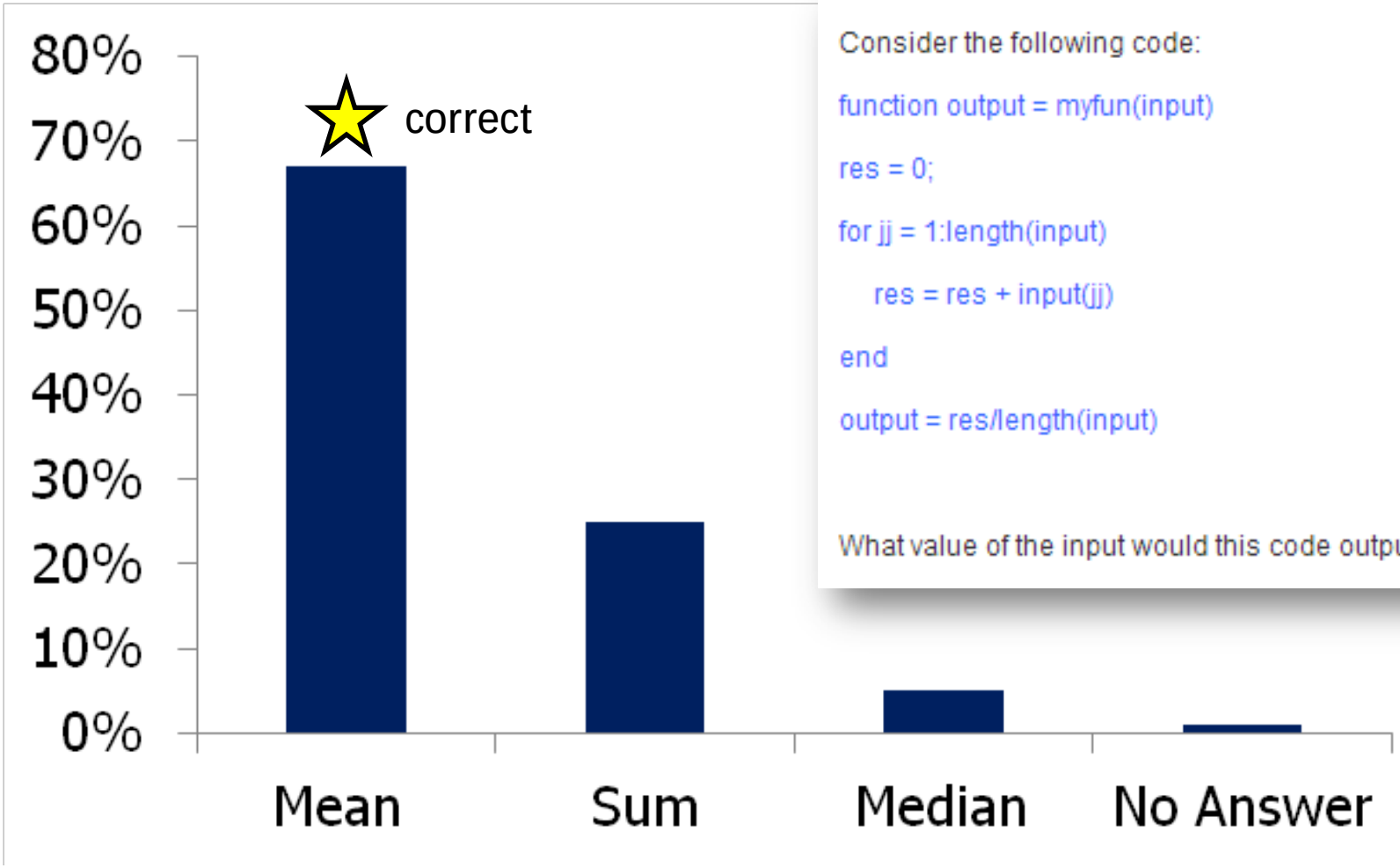


Results of the initial assessment

How would you rate your current Matlab expertise?



Results of the initial assessment



Consider the following code:

```
function output = myfun(input)
res = 0;
for jj = 1:length(input)
    res = res + input(jj)
end
output = res/length(input)
```

What value of the input would this code output?

Results of the initial assessment

Question 12

A partial derivative of the following equation

$$f(x, y, z) = 2x^2 + \frac{1}{4}y^{\frac{1}{2}} + z$$

could be represented as

- $4x + \frac{1}{8}y^{-\frac{1}{2}} + 1$ ← 38%
- $x + \frac{1}{2}y^{-\frac{1}{2}} + 1$
- $\frac{1}{8}y^{\frac{1}{2}}$
- $\frac{1}{8}y^{-\frac{1}{2}}$ ← 59% ★ correct

Results of the initial assessment

Question 13

The integral of

$f(x) = e^x + \sin(x)$

is:

- $e^x - \cos(x) + C$ ← 92% ★ correct
- $\ln(x) + \cos(x) + C$
- $\ln(x) - \sin(x) + C$
- $e^x + \sin(x) + C$

Results of the initial assessment

Question 19

Consider the same matrix as defined using Matlab syntax:

myMatrix = [1 6 2; 5 2 3; 9 5 2]

Typing myMatrix(:,2) would result in

- [6; 2; 5] ← 51% ★ correct
- [1; 2; 2]
- [5 2 3] ← 40%
- [1 5 2]

Results of the initial assessment

- Many students in ENGR 105 are new to Matlab
- Good grasp of math
- Great at inferring syntax

How does a computer process information?

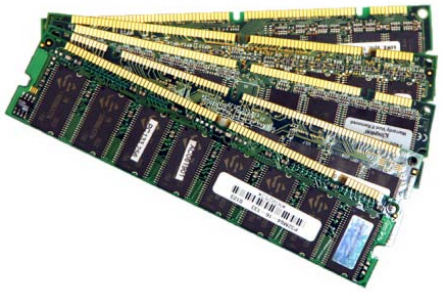
Peripherals / user interface

High density storage (hard drive)

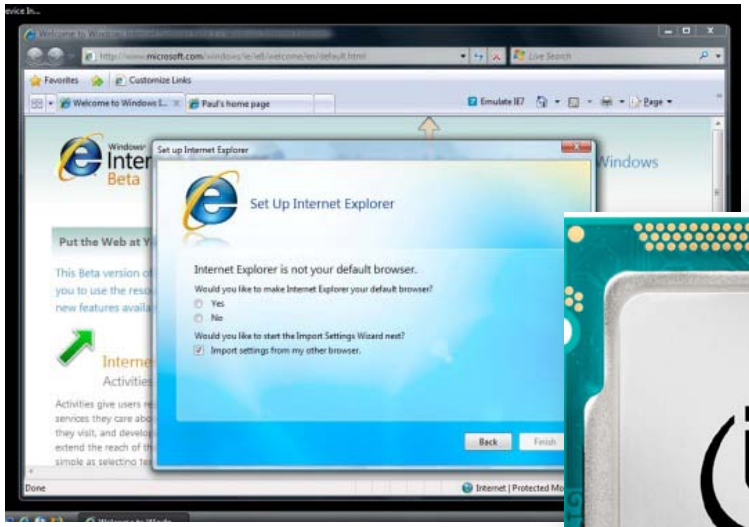
Motherboard and central processing unit (CPU)

Power supply

Random access memory (RAM)

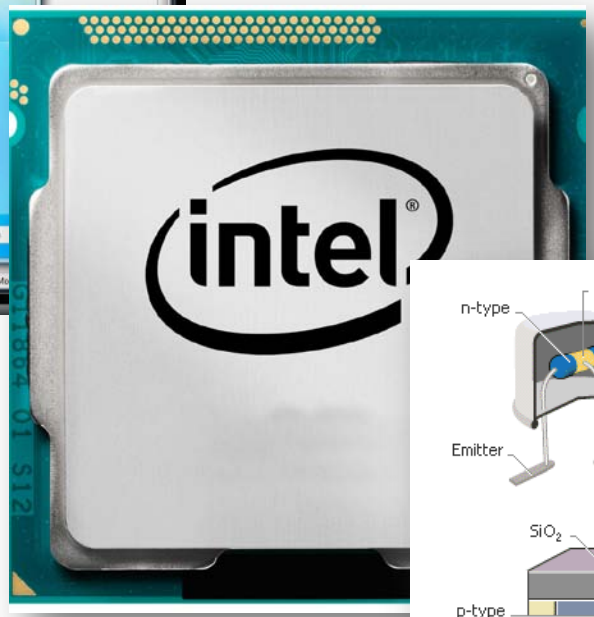


How does a computer process information?



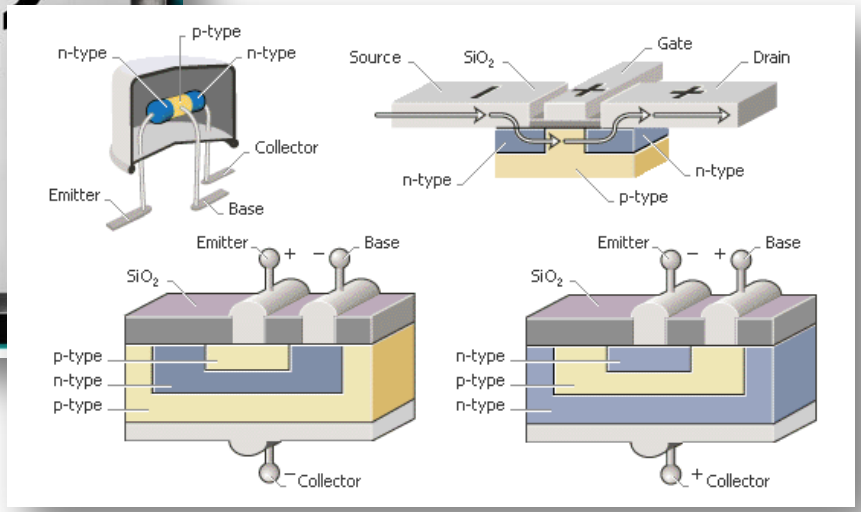
Applications

High level code
Assembly/machine code



Microprocessor

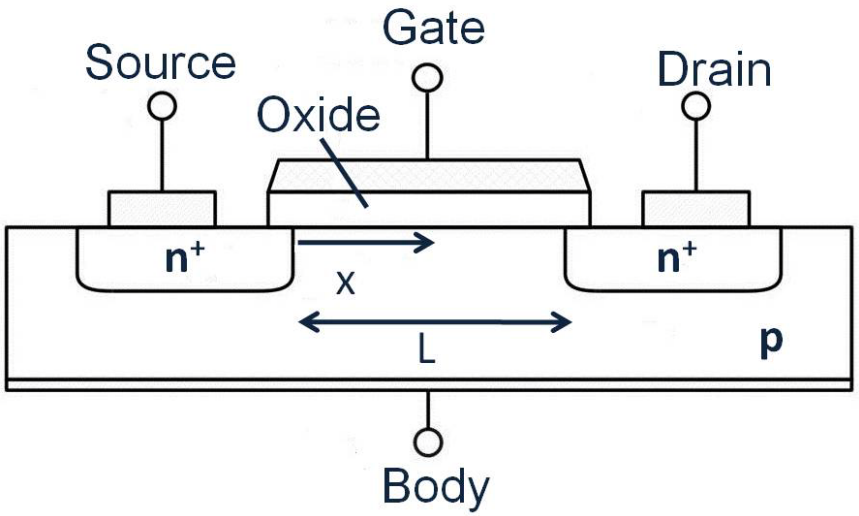
Voltages



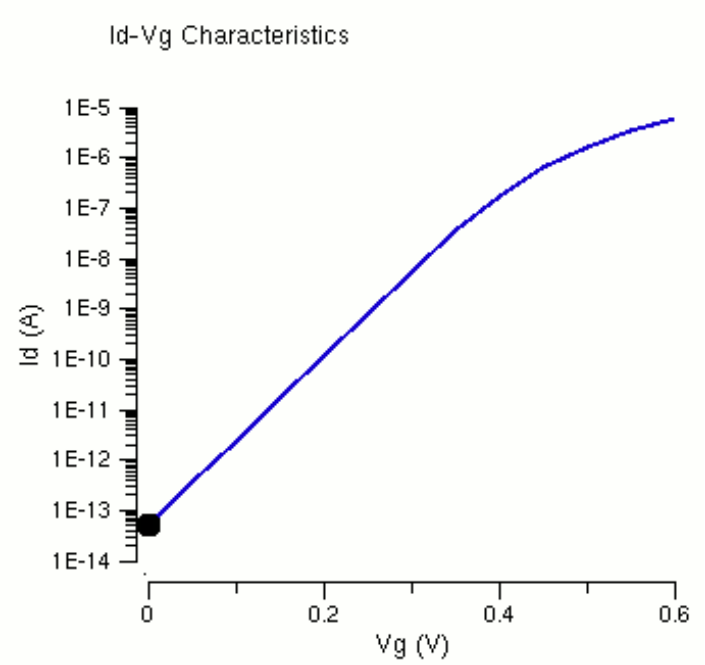
Individual transistors

Calculations at the transistor scale

Cross-section of a field effect transistor



Corresponding IV characteristics



What if we were programming at the machine/assembly language level?

Memory

$0	-20.04
$1	10.56
$2	-7.678
$3	8.0
$4	3.14159
$5	9

CPU

Instructions

0	ADD 0, -20.04, $0
1	ADD 0, 10.56 $1
2	ADD $0, $1, $0
3	ADD $0, $4, $0
4	ADD $0, $5, $0
5	DIV $0, 5, $0

Assembly Language

High level language programming

Programming in assembly language is a pain - that's why we developed higher level languages like Java, C and Matlab and developed programs called interpreters/compilers to translate from human readable text to low level instructions.

```
sum = 0;
for i = 1:500
  sum = sum + x(i);
end
avgVal= sum/500;
```

High Level Code
(machine independent)

Compiler/
Interpreter

0	ADD 0, 0, $1
1	ADD 0, 0, $2
2	ADD $3[$1], $2, $2
3	ADD $1, 1, $1
4	LT $1, 500, 2
5	DIV $2, 500, $2

Assembly Code
(machine dependent)

Why Matlab?

Matlab (Matrix Laboratory) is descended in part from the programming language FORTRAN which was designed to support FORmula TRANslation. As such Matlab makes it easy to evaluate complex mathematical expressions.

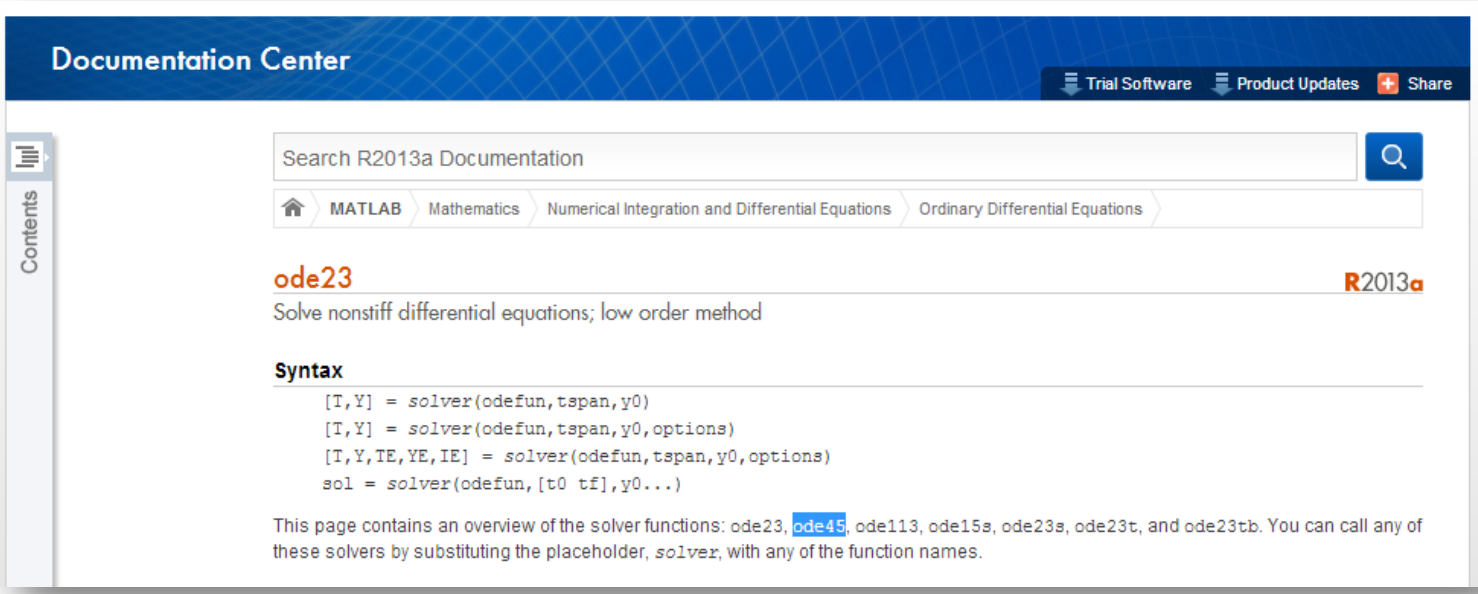
IBM, 1953
Alternative to assembly language

1 million users in 2004

University of New Mexico, 1970's
Alternative to Fortran

Matlab help system

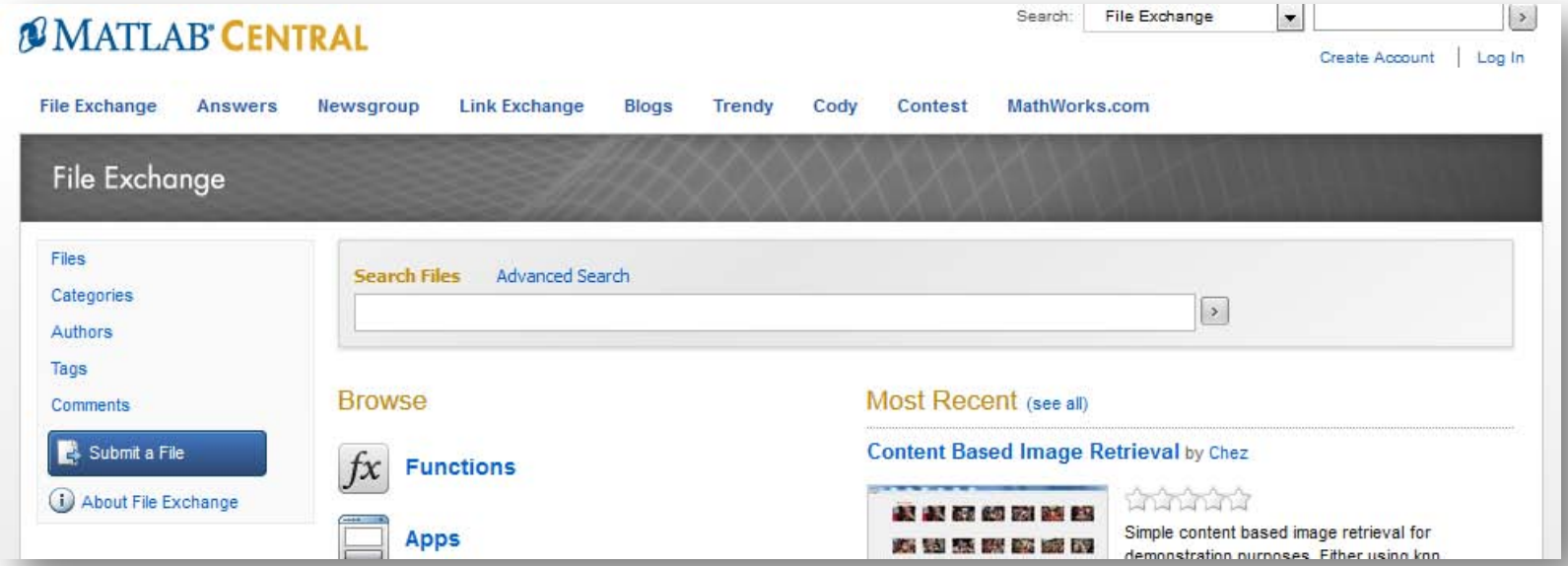
- You should get familiar with the MATLAB help system - it contains documentation on all of Matlab's functions
- I often use the "Google method"



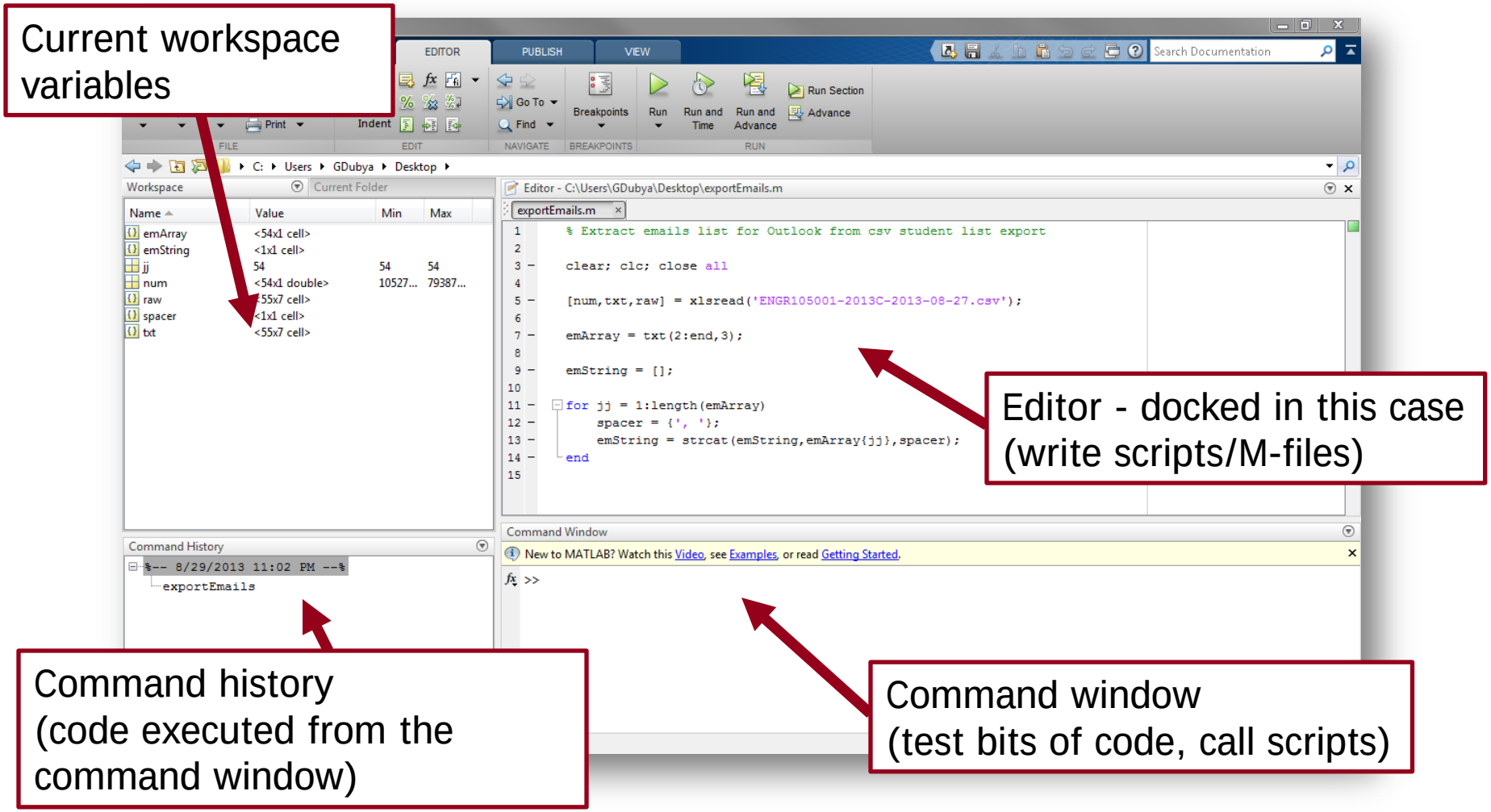
Matlab file exchange

- Great source of pre-built code and code examples

http://www.mathworks.com/matlabcentral/fileexchange/



Layout of the Matlab interface (2012 and 2013)



Statements

- The statement is the most basic kind of MATLAB command

```
Foo = x^2 + sin(5*y) / exp(67*z);
```

- It evaluates an expression – the right hand side of the equation - and assigns the result to a named variable – the left hand side of the equation.
- The semicolon at the end is optional. When present it suppresses output that would be printed to the command line.

Built-in Matlab functions

Befitting it's role as the premier scientific computing environment - Matlab has thousands of built-in functions for evaluating common mathematical and statistical functions

- `Sin(x)`, `cos(x)`, `exp(x)`, `log(x)`, `atan(x)`, `cosh(x)`, `sinh(x)`, `mean(x)`, `median(x)`, etc.
- Any function you can think of and many that you haven't imagined yet

Array basics

- In addition to normal, scalar, variables MATLAB is designed to work with arrays which you can think of as sequences of numbers.

  `x = [1, 3, 9, 11, -10.2];` create array with 5 numbers

- You can access members of the array via indexing

  `Foo = x(3);` extracts third element in the array

  `x(2) = 27;` reassign second element in the array

- Arrays are fundamental to MATLAB and we will have a lot more to say about them.

Creating arrays with slice notation

Since arrays are used so extensively in MATLAB there is special syntax for creating sequences

```
x = 1:15;
```

creates an array with the numbers 1 through 15

```
x = 4:2:28;
```

creates an array starting at 4 and going up by 2 until it gets to 28

```
x = -1.3:0.1:1.3;
```

creates an array starting at -1.3 and going up by 0.1 until it gets to 1.3

Creating arrays with slice notation

Say I type `x = 1:2:6;` into the command line. What is the last value of array `x`?

Answer: 5

```
x = [1,3,5]
```

Matlab will not include values above the upper bound!

Operations on arrays

You can perform mathematical operations on arrays just as you can scalar values.

`x = 0:0.1:10;` create an array of values

`y = exp(5*x).*sin(x);` evaluate an expression on every element in the array producing a new array called y

`plot (x, y);` produce a plot

Operations on arrays

You can add two arrays in Matlab as long as they are the same size - if they are not you will get an error

```
x = [1 2 3 4 5];
y = [7 8 9 10 11];
z = x + y;
```

pointwise addition adds corresponding elements

Subtraction works the same way

Operations on arrays

For multiplication and division the syntax is a little different

- `z = x.*y;` pointwise multiplication
- `z = x./y;` pointwise division

Here you need the '.' to specify a pointwise operation instead of matrix multiplication or division (we will explore this later)

Operations on arrays

Almost all of Matlab's built in functions will accept arrays as arguments and perform their operation in a pointwise manner

```
x = 1:10:1000;
y = sqrt(x);
```

compute the square root of each element in the array x

Scripts

- Sequences of MATLAB commands can be stored in script files and then executed by invoking the name of the script on the command line
- The effect of executing the script is pretty much the same as typing the commands in the file in one after another into the command window

Demo: writing a script

Current working directory

- When you are working with MATLAB you need to be aware that there is a current working directory which you can set
- You should begin by creating a directory in some appropriate part of your file system, and then setting your working directory to that location
- All the files you create will be stored there by default and that is where MATLAB will look first when you invoke scripts by name