

Getting Started with Matlab (in Computer Science at UBC)

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Outline

- Why Matlab?
 - Why not C / C++ / Java / Fortran?
 - Why not Perl / Python?
 - Why not Mathematica / Maple?
- A Brief Taste of Matlab
 - where to find it
 - how to run it
 - interactive Matlab
 - m-files & debugging
- Sources of Additional Information

Choosing Programming Languages

- Compare / contrast compiled languages C++ and Java

C++

- Fast: close to hardware
- Flexible: interfaces to almost any other language
- Flexible: pointers, references, explicit memory allocation
- Flexible: everybody provides C / C++ libraries
- Popular: commonly used, available everywhere
- Prone to bugs: complex syntax, memory leaks

Java

- Easy to use: references only, garbage collection
- Popular: commonly used, widely available
- Portable: common byte code
- Developed with a clear vision: Standard libraries for security, threading, distributed systems
- Slower: interpreted or JIT for byte code

The Right Tool for the Job

- C / C++ / Fortran:
 - Statically typed and compiled languages
 - Well developed algorithm, known platform, execution time is key
- Java:
 - Simpler, partially compiled language
 - Unknown platform, less experienced programmer, development time is important, broad standard library
- Perl / Python:
 - Interpreted “dynamic” languages: no typing, no compilation(?)
 - Unknown platform, development time is key, concise but powerful code, huge standard library
- Many others (8000+)

http://en.wikipedia.org/wiki/Comparison_of_programming_languages

The Job: Scientific Computing

- Why not use Numerical Recipes / LAPACK / BLAS?
 - “simple” CLAPACK routine for solving $\mathbf{Ax} = \mathbf{b}$ (general \mathbf{A}):

```
int dgesv_(integer *n, integer *nrhs, doublereal *a, integer *lda,  
          integer *ipiv, doublereal *b, integer *ldb, integer *info)
```
 - what library to use to plot $\sin(2\pi\mathbf{x})$ for $\mathbf{x} \in [0, 1]$?
 - too much programmer overhead: time consuming and too many opportunities for mistakes
- Why not use Mathematica / Maple?
 - Originally designed for symbolic mathematics
 - Some numerical capabilities, but not as efficient to code and/or execute

MATLAB[®]

- Why use Matlab?
 - robust, dependable, easy to use routines for all basic linear algebra
 - intuitive, untyped, imperative language with garbage collection
 - huge library (toolboxes) of mathematical functions and algorithms
 - fast implementation of vector/matrix operations
 - portable interpreted language widely used in applied mathematics, engineering & physical sciences
 - powerful combination of visualization and debugging
- Why not use Matlab?
 - proprietary system (Mathworks Inc.)
 - occasionally erratic syntax
 - toolbox quality varies widely
 - no support for references/pointers
- Alternatives?
 - Numerical computing: Octave, SciLab, Sage, SciPy, ...
 - Plotting: Gnuplot, XGraph, PLPlot, PGPLOT, matplotlib, ...

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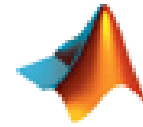
What is “Matlab”?

- Technically, a single product
 - Contains basic scientific computing tools
 - Linear algebra, quadrature, interpolation, approximation, differential equations
 - GUI, visualization and debugging
 - Programming data and control structures
- Domain specific algorithms packaged in separate “Toolboxes”
 - For example: multivariable optimization, advanced splines, image processing, neural networks, ... (40+ available)
 - Why? Separate product development (eg: \$\$\$)
- Additional products (not used in CS courses)
 - Simulink: simulation & model-based design
 - Engines, coders, targets, links, etc.

Where to find Matlab (UBC CS Dept)

- Undergraduate Labs
 - Unix or Windows
 - Release 7.14 (2012a)
 - Toolboxes: image processing, optimization & statistics
 - Licensed only for course work (grad or ugrad)
- Graduate Labs
 - Several releases available, 7.14 (2012a) the default
 - Toolboxes: image processing, image acquisition, statistics, wavelets, neural networks, optimization, PDEs, signal processing, control, robust control, identification, ...
 - Licensed for research work
- Purchase Student Version
 - Full basic Matlab, a few common toolboxes (sufficient for 302/303)
 - Available immediately at UBC Bookstore \$150(?)
 - Also available online (US \$99), but requires validation of student status for full activation

How to run Matlab



- Windows (or Mac): click Matlab icon to start the Matlab desktop
- Unix (Linux): type `matlab` to start the Matlab desktop
- Command line alternatives:
 - text interface: `matlab -nodesktop`
 - see all the options: `matlab -help`
 - text interface still allows graphical visualization
- Remote use
 - Other than in MS Windows, Matlab uses X Windows for graphics
 - If you are sitting at an X Windows capable machine, you can remotely log into the ugrad Unix machines and use Matlab
 - Linux & Mac already include X Windows support
 - All CS students can download XManager software for Windows: X Windows (remote graphics), Xshell (ssh), Xftp (file sync), ...
 - See https://www.cs.ubc.ca/support/toc/Undergrads/remote_login
 - For faster response times, use Matlab's text interface (and some method of editing the remote m-files)

Interacting with Matlab

- Examples
 - Getting `help`
 - Constants: `pi`, `i`, `eps`, `inf`, `nan`
 - Matrices & Arrays: `input`, `output`, `colon`, `concatenation`, `find`
 - Operators: `transpose`, `arithmetic`, `element-wise`, `logical`
 - `help` topics: `punct`, `ops`, `relop`, `arith`, `slash`
 - Functions: `zeros`, `ones`, `diag`, `eye`, `rand`, `reshape`, `size`, ...
 - Text I/O: `semicolon`, `ellipses`, `format`, `diary`
 - Visualization: `plot`, `legend`, `xlabel`, `ylabel`, `title`, `subplot`, `set`, `figure`, `gcf`, `gco`, `close`, `clf`, ...
 - Graphical I/O: `print`, `orient`, `imread`, ...
 - Workspace management: `who`, `whos`, `save`, `load`, `clear`, `addpath`, ...
 - Other data types: `strings`, `ints`, `sparse`, `structures`, `cells`
- Command line includes `tab` completion, `up` & `down` arrow to find previous similar commands, `ctrl-c` to break execution

Programming

- Standard programming control flow constructs
 - All compound statements finish with **end**
 - **if/elseif/else, for, while, switch/case/otherwise, try/catch, continue, break, return**
 - Be careful with boolean operators, matrices and control flow (use **any, all**)
- Sequences of commands can be stored as a script in an m-file
 - type name of file to execute commands (which run in the top level “workspace” scope)
 - Use “%” to denote comment lines
- Functions are m-files that start with **function** command
 - Have input and output parameters, local scope
 - May contain subfunctions and/or nested functions
 - Matlab also supports anonymous functions and a function handle datatype (**help function_handle**)

Data Structures

- No need to predefine variables
 - Variable is created in the current workspace when it appears on the left side of an assignment
- Many data types available
 - By default, all variables are two dimensional double precision floating point arrays
 - Higher dimensional arrays allowed (but no one-dimensional array)
 - Other types: single precision, integer, boolean, strings (specially interpreted double arrays), structures (actually more like dictionaries), cell arrays, function handles, classes
 - No pointers, (almost) no references
 - Dynamically typed: Matlab tries to determine a consistent type, but type errors can occur
- Function arguments are pass by value
 - Changes to input variables are not externally visible unless the same variables are returned as outputs
 - Copy on write implementation ensures fast execution if inputs are not modified

Debugging

- With Matlab desktop and editor
 - Breakpoints can be set and removed by clicking to the right of the (executable) line in the file
 - Single stepping can be accomplished with buttons at the top of the editor window
- Text based
 - Commands `dbstop` (set breakpoint), `dbstep` (single line step), `dbcont` (continue), `dbstatus` (current program counter), `dbstack` (examine call stack), etc.
 - see `help debug` for a full list
 - Extremely useful: `dbstop if error` causes Matlab to stop in the workspace (eg local scope) of the function that caused the error
 - Also: `keyboard` command is equivalent to setting a breakpoint
- In either version, you can examine the current workspace
 - Examine variable values (text or plots), call other Matlab functions, move up and down through the stack

Efficient Matlab Coding

- Use Matlab's built-in functions
 - eg: `total = 0; for k = 1 : 10; total = total + k; end`
`VS total = sum(1:10);`
- Preallocate arrays
 - eg: `n = 100; ys = zeros(n, 1);`
`for k = 1 : n; ys(i) = sin(2*pi*k/n); end`
- Use “vectorization”
 - rather than loops, try operations that work on entire array of data at once.
 - eg: element-wise operations (arithmetic or boolean),
`sin(2*pi*(0:0.1:1)), find`
 - version 7.0 onward: built-in JIT often makes loops fast
- Use functions, not scripts
- Use profiler to find slow code
- If all else fails, use MEX interface to C/C++/Fortran

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Sources of Further Information

- Matlab has extensive built-in documentation
 - Hyperlinked documentation: `helpdesk` and `doc <command>`
 - Basic textual command & function info: `help <command>`
 - Unknown command search: `lookfor <string>`
 - Implementation details: `type <command>`
- Online documentation
 - Mathworks website: `http://www.mathworks.com`
 - Community code: `http://www.matlabcentral.com`
 - Matlab resources website (including these slides):
`http://www.cs.ubc.ca/~mitchell/matlabResources.html`
 - YAGTOM (Yet Another Guide TO Matlab):
`http://code.google.com/p/yagtom/`

Getting Started with Matlab (in Computer Science at UBC)

For more information contact

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