Big Data with MATLAB

CME 192 Lecture 4

01/29/2025

Stanford University

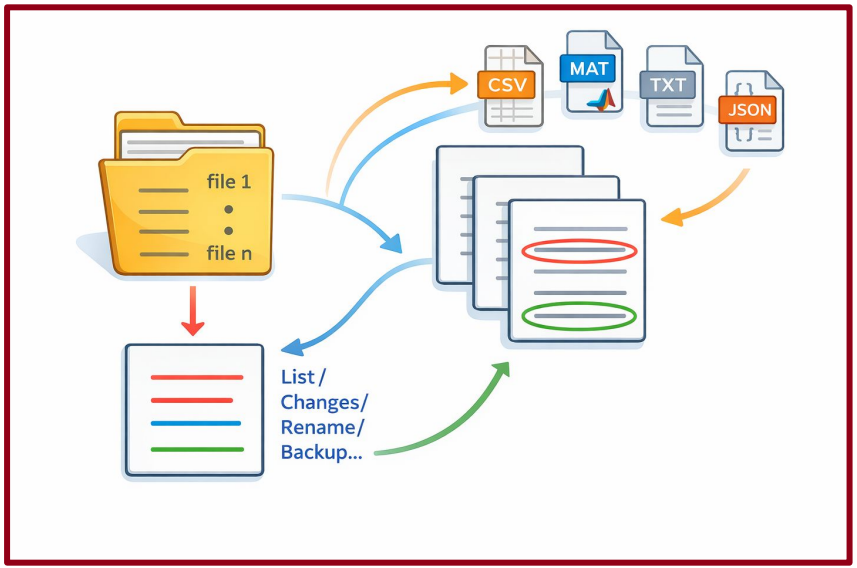
Outline

File Manipulation and System Interaction
- Search path
- Data import/export & file commands
- Operating system

Handling Big Data
- Efficient use of memory
- Datastore and tall arrays
- MapReduce

Integration with Other Languages

File Manipulation and System Interaction



Search Path

Search path is a subset of all folders on the file system that MATLAB uses to efficiently locate files used with MathWorks products.

- All files in the folders on search path can be accessed by MATLAB.

Order of folders on search path is important:

- When files with same filename exist in different folders, MATLAB uses the one in the folder nearest the top of the search path.

Search path includes:

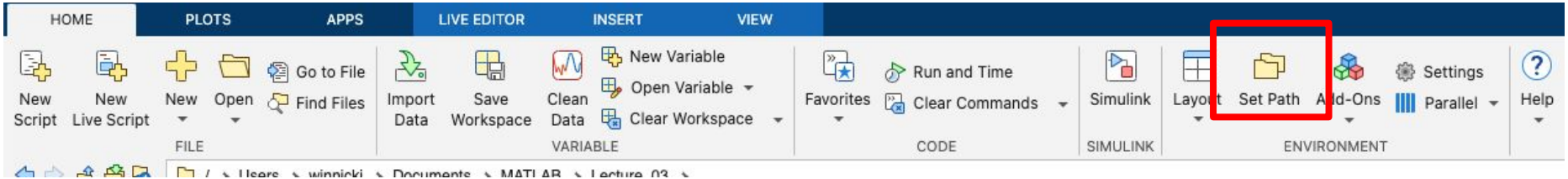
- The MATLAB userpath folder (platform-specific)
  - added to the search path at startup
  - the default location for storing user files
- The folders defined as part of the `MATLABPATH` environment variable
- The folders provided with MATLAB and other MathWorks products, which are under `matlabroot/toolbox`.

Check Whether File or Folder on Search Path

• To determine whether a file is on the search path, run `which filename`. If the file is on the search path, MATLAB returns the full path to the file. Or,
• Use the Current Folder browser. Files and folders not on the path are dimmed.

View Entire Search Path

• Run the path command to view all the folders on the MATLAB search path, or,
• Use the Set Path dialog box.



Search Path Commands

- `addpath`: Add folders to search path
- `rmpath`: Remove folders from search path
- `path`: View or change search path
- `savepath`: Save current search path
- `userpath`: View or change user portion of search path
- `genpath`: Generate path string
- `pathsep`: Search path separator for current platform

Import/Export Data

Text File

- `importdata`: Load data from file
- `dlmread`: Read ASCII-delimited fie of numeric data into matrix
- `dlmwrite`: Write matrix to ASCII-delimited file
- `textscan`: Read formatted data from text file or string
- `type`: Display contents of file

Some supported file formats for import and export

File Content	Extension	Description	Import Function	Export Function
MATLAB formatted data	MAT	Saved MATLAB workspace	`load`	`save`
		Partial access of variables in MATLAB workspace	`matfile`	`matfile`
Text	any, including: CSV TXT	Delimited numbers	`readmatrix`	`writematrix`
		Delimited numbers, or a mix of text and numbers	`textscan`	none

		Column-oriented delimited numbers or a mix of text and numbers	`readtable`
			`readcell`
			`readvars`
				`writetable`
				`writecell`

		Plain text	`readlines`	`writelines`

Spreadsheet	XLS
	XLSX
	XLSM
	XLSB (Systems with Microsoft® Excel® for Windows® only)
	XLTM (import only)
	XLTX (import only)
	ODS (Systems with Microsoft Excel for Windows only)
		Column-oriented data in worksheet or range of spreadsheet	`readmatrix`
			`readtable`
			`readcell`
			`readvars`
				`writematrix`
				`writetable`
				`writecell`

Compressed data	ZIP
	GZ
	TAR
		Compressed and archived files	`readtable`
			`readcell`
			`readmatrix`
			`readstruct`
			`readtimetable`
			`readdictionary`
			`readlines`
			`readvars`
			See File Compression
				See File Compression

Some supported file formats for import and export

Extensible Markup Language	XML	XML-formatted text	`readstruct`
			`readtable`
			`readtimetable`
				`writestruct`
				`writetable`
				`writetimetable`

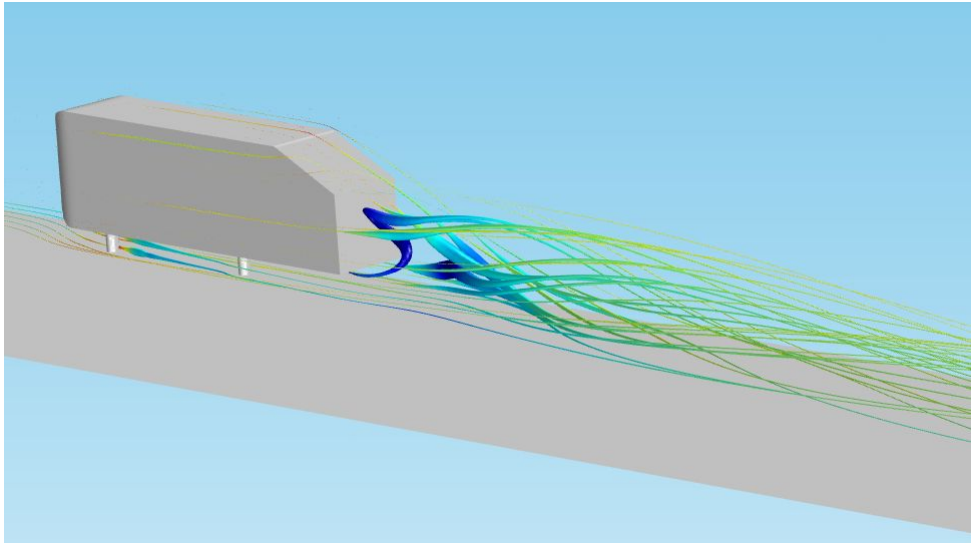
JavaScript® Object Notation	JSON	JSON-formatted text	`readstruct` `readdictionary`	`writestruct` `writedictionary`
Parquet formatted data	PARQUET	Column-oriented data in Parquet format	`parquetread`	`parquetwrite`
Data Acquisition Toolbox™ file	DAQ	Data Acquisition Toolbox	`daqread`	none
Scientific data	CDF	Common Data Format	See CDF Files	See CDF Files
	FITS	Flexible Image Transport System	See FITS Files	See FITS Files
	HDF	HDF4 or HDF-EOS2	See HDF4 Files	See HDF4 Files
	H5	HDF5	See HDF5 Files	See HDF5 Files
	NC	Network Common Data Form (netCDF)	See NetCDF Files	See NetCDF Files
Image data	BMP	Windows Bitmap	`imread`	`imwrite`
	GIF	Graphics Interchange Format		
	HDF	Hierarchical Data Format		
	JPEG JPG	Joint Photographic Experts Group		
	JP2 JPF JPX J2C J2K	JPEG 2000		
	PBM	Portable Bitmap		
	PCX	Paintbrush		
	PGM	Portable Graymap		
	PNG	Portable Network Graphics		
	PNM	Portable Any Map		
	PPM	Portable Pixmap		
	RAS	Sun® Raster		
	TIFF TIF	Tagged Image File Format		
	XWD	X Window Dump		
	CUR	Windows cursor resources	`imread`	none
	ICO	Windows icon resources		

Some supported file formats for import and export

Audio (all platforms)	AU SND	NeXT/Sun sound	`audioread`	none
	AIFF	Audio Interchange File Format		
	AIFC	Audio Interchange File Format, with compression codecs		
	FLAC	Free Lossless Audio Codec	`audioread`	`audiowrite`
	MP3	MPEG-1 Audio Layer III MPEG-2 Audio Layer III MPEG-2.5 Audio Layer III		
	OGG	Ogg Vorbis		
	OPUS	Ogg Opus		
	WAV	Microsoft WAVE sound		
Audio (Windows)	M4A MP4	MPEG-4 Part 3 AAC	`audioread`	`audiowrite`
	any	Formats supported by Microsoft Media Foundation	`audioread`	none
Audio (Mac)	M4A MP4	MPEG-4 Part 3 AAC	`audioread`	`audiowrite`
Audio (Linux®)	any	Formats supported by GStreamer	`audioread`	none
Video (all platforms)	AVI	Audio Video Interleave	`VideoReader`	`VideoWriter`
	MJ2	Motion JPEG 2000		
Video (Windows)	MPG	MPEG-1	`VideoReader`	none
	ASF WMV	Windows Media®		
	any	Formats supported by Microsoft DirectShow®		
Video (Windows 7 or later)	MP4 M4V	MPEG-4	`VideoReader`	`VideoWriter`
	MOV	QuickTime®	`VideoReader`	none
	any	Formats supported by Microsoft Media Foundation		
Video (Mac)	MP4 M4V	MPEG-4	`VideoReader`	`VideoWriter`
	MPG	MPEG-1	`VideoReader`	none
	MOV	QuickTime		
	any	Formats supported by QuickTime, including `.3gp`, `.3g2`, and `.dv`		
Video (Linux)	any	Formats supported by your installed GStreamer plug-ins, including `.ogg`	`VideoReader`	none
Triangulation	STL	Stereolithography	`stlread`	`stlwrite`
Low-level files	any text format	Low-level binary text data	`fread`	`fwrite`
	any	Low-level binary	`fscanf`	`fprintf`
	any text format	Formatted data from a text file or string	`textscan`	none

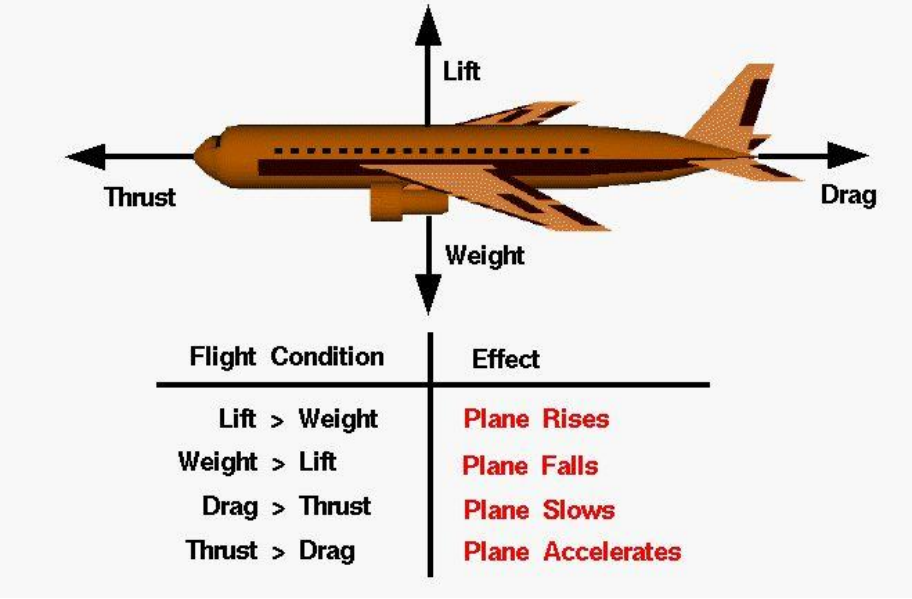
Demo:
Lift-drag history for the flow around the Ahmed body

The Ahmed body is a generic car body (a simplified vehicle model).
https://www.comsol.com/blogs/studying-the-airflow-over-a-car-using-an-ahmed-body/ and
https://www.comsol.com/blogs/how-do-i-compute-lift-and-drag/.



Lift force & drag force:

• Lift is the force generated perpendicular to the direction of travel for an object moving through a fluid (gas or liquid).
• Drag is the force generated parallel and in opposition to the direction of travel for an object moving through a fluid. It can be broken down into the following two components:
  • Form drag (or pressure drag) - dependent on the shape of an object moving through a fluid
  • Skin friction - dependent on the viscous friction between a moving surface and a fluid, derived from the wall shear stress
CFD: computational fluid dynamics
ROM: reduced-order model



Low-Level File Commands

- `fopen`: Open file
- `fclose`: Close one or all open files
- `feof`: Test for end of file
- `ferror`: Information about file IO errors
- `fgetl`: Read line from file, remove newline character
- `fgets`: Read line from file, keep newline character
- `fileread`: Read contents of file into string
- `textscan`: Read formatted data from text file or string
- `fprintf`: Write data to text file
- `fread`: Read data from binary file
- `frewind`: Move file position indicator to beginning of open file
- `fscanf`: Read data from text file
- `fseek`: Move to specified position in file
- `ftell`: Position in open file
- `fwrite`: Write data to binary file

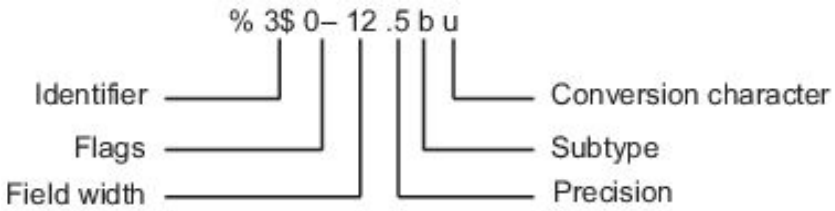
Format

`fprintf(FID, FORMAT, A, ...)`

Formatting operator

- Starts with a percent sign, %, and ends with a conversion character.
- Required conversion character
- Optional identifier, flags, field width, precision, and subtype
- No space between operators

Specifier	Description
c	Single character.
d	Decimal notation (signed).
e	Exponential notation (using a lowercase e, as in `3.1415e+00`).
E	Exponential notation (using an uppercase E, as in `3.1415E+00`).
f	Fixed-point notation.
g	The more compact of `%e` or `%f`. (Insignificant zeros do not print.)
G	Same as `%g`, but using an uppercase E.
o	Octal notation (unsigned).
s	Character vector or string array.
u	Decimal notation (unsigned).
x	Hexadecimal notation (unsigned, using lowercase letters `a–f`).
X	Hexadecimal notation (unsigned, using uppercase letters A–F).



Format

`fprintf(FID, FORMAT, A, ...)`

Formatting operator

- Starts with a percent sign, %, and ends with a conversion character.
- Required conversion character
- Optional identifier, flags, field width, precision, and subtype
- No space between operators

Character	Description	Example
Minus sign (–)	Left-justify the converted argument in its field.	`%–5.2d`
Plus sign (+)	For numeric values, always print a leading sign character (+ or –). For text values, right-justify the converted argument in its field.	`%+5.2d` `%+5s`
Space	Insert a space before the value.	`% 5.2f`
Zero (`0`)	Pad with zeros rather than spaces.	`%05.2f`
Pound sign (#)	Modify selected numeric conversions: • For `%o`, `%x`, or `%X`, print `0`, `0x`, or `0X` prefix. • For `%f`, `%e`, or `%E`, print decimal point even when precision is 0. • For `%g` or `%G`, do not remove trailing zeros or decimal point.	`%#5.0f`

Format

`fprintf(FID, FORMAT, A, ...)`

Formatting operator

- Starts with a percent sign, %, and ends with a conversion character.
- Required conversion character
- Optional identifier, flags, field width, precision, and subtype
- No space between operators

Formatting Operator	Description
`%*f`	Specify width as the following input argument, 15.
`%.*f`	Specify precision as the following input argument, 3.
`%*.*f`	Specify width and precision as the following input arguments, 6, and 4.

Special Character	Representation in Format Specifier
Single quotation mark	`''`
Percent character	`%%`
Backslash	`\\`
Alarm	`\a`
Backspace	`\b`
Form feed	`\f`
New line	`\n`
Carriage return	`\r`
Horizontal tab	`\t`
Vertical tab	`\v`
Character whose Unicode® numeric value can be represented by the hexadecimal number, N	`\xN` **Example:** `sprintf('\x5A')` returns `'Z'`
Character whose Unicode numeric value can be represented by the octal number, N	`\N` **Example:** `sprintf('\132')` returns `'Z'`

Quiz

What is the position of the end of the file
(e.g., data/liftdrag/unsteady.hdm.LiftDrag)?
Write a few lines of code to find this out. Consider the fgetl function.

Quiz

What is the position of the end of the file
(e.g., data/liftdrag/unsteady.hdm.LiftDrag)?
Write a few lines of code to find this out. Consider the fgetl function.

```
fid = fopen('data/liftdrag/unsteady.hdm.LiftDrag');
while (fgetl(fid)~=-1); end
fprintf("File location = %d\n",ftell(fid));
fprintf('At end of file? = %d\n',feof(fid));
```

Binary File vs. Text File

- All files can be categorized into one of two file formats — binary or text.
- They encode data differently.
  - While both contain data stored as a series of bits, the bits in text files represent characters, while the bits in binary files represent custom data.
  - While text files contain only textual data, binary files may contain both textual and custom binary data.

- Binary files typically contain a sequence of bytes (ordered groupings of 8 bits).
- Binary files often contain headers, which are bytes of data at the beginning of a file that identifies the file's contents. Headers often include the file type and other descriptive information.
- Text files are more restrictive than binary files since they can only contain textual data.
- Comparing to text files, binary files require less storage.

Demo: (surface) mesh data in the FRG format

- First line of each file contains header information (number of nodes/elements, etc).
- Nodes contained in columns 2 - 4 for nodes file.
- Elements contained in columns 2 - 5 of elements file.

Spreadsheets

- `xlsfinfo`: Determine if file contains Microsoft Excel spreadsheet
- `xlsread`: Read Microsoft Excel spreadsheet file
- `xlswrite`: Write Microsoft Excel spreadsheet file

[STAT, MSG] = xlswrite(FNAME, M, SHEET, RANGE)

- Writes the data in matrix M to the fie FNAME in the sheet specified by SHEET to the range of cells specified by RANGE
- SHEET can be numeric specifying worksheet index or quoted string
- RANGE is of the form 'X:Y' where X indicates the upper left corner of the writable range and Y is the lower right corner (i.e. 'B2:D4' is the 3-by-3 block of cells from row B to D and columns 2 to 4)

Requires ability to use Excel as COM server; otherwise, saves to CSV file.

Workaround:

- Convert data to a table and use writetable

`[NUM,TXT,RAW]=xlsread(FILE,SHEET,RANGE)`

- Reads the data specified in RANGE from the worksheet SHEET, in the Excel file specified in FILE.
- The full functionality of xlsread depends on the ability to start Excel as a COM server from MATLAB.

`[NUM,TXT,RAW]=xlsread(FILE,SHEET,RANGE,'basic')`

- Uses basic input mode. This is the mode used on UNIX platforms as well as on Windows when Excel is not available as a COM server.
- In this mode, xlsread does not use Excel as a COM server, which limits import ability.
- Without Excel as a COM server, RANGE will be ignored and, consequently, the whole active range of a sheet will be imported.
- Also, in basic mode, SHEET is case-sensitive and must be a string.

Image IO

- imfinfo: Information about graphics file
- imread: Read image from graphics file
- imwrite: Write image to graphics file

Operating System

- `clipboard`: Copy/paste strings to/from sys clipboard
- `computer`: Information about computer
- `dos`: Execute DOS command and return output
- `getenv`: Environment variable
- `perl`: Call Perl script
- `setenv`: Set environment variable
- `system`: Execute operating system command and return output
- `unix`: Execute UNIX command and return output
- `winqueryreg`: Item from Windows registry
- `bang` (!): Shell escape

System Calls: power of operating system available inside MATLAB

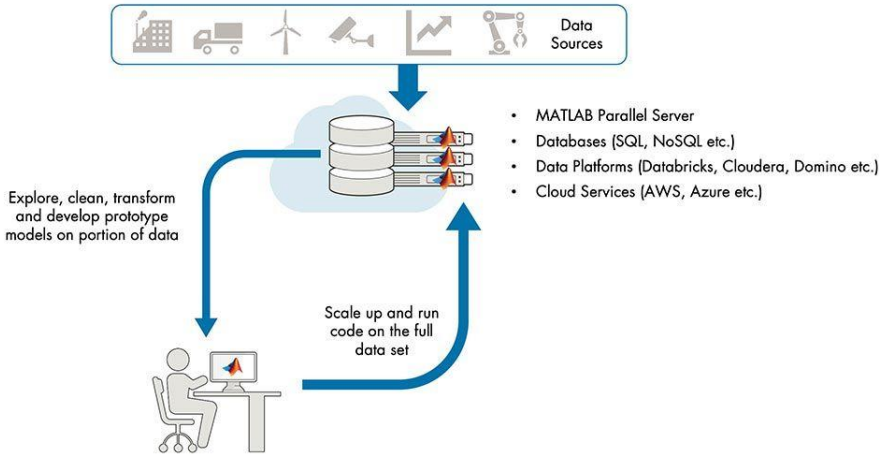
- Call executable from within MATLAB
- Use MATLAB's file management to write input files and read output files
- Provide non-intrusive alternative to integrating stand-alone code with MATLAB via MEX interface

```
[status,result] = system('command')
```

- Calls upon the operating system to execute the given command. The resulting status and standard output are returned.

Handling Big Data

More challenging than normal data



When your variables are large in dimensions…

life becomes difficult!

Efficient Use of Memory

Use Appropriate Data Storage: data classes are of different sizes.

1. Choice of Numeric Class

- Example:
    - Default floating-point class: double (8 bytes)
    - Alternatives with limitations on math operations: single (4 bytes)
- Size of numeric classes:
    - logical, int8, uint8 (1)
    - int16, uint16 (2)
    - int32, uint32 (4)
    - int64, int64 (8)

2. Overhead when storing data

- Simple numeric arrays (comprising one mxArray) have the least overhead, so we should use them wherever possible.

- Cell arrays are comprised of separate mxArrays for each element, so cell arrays with many small elements have a large overhead.

- Structures require a similar amount of overhead per field. Structures with many fields and small contents have a large overhead and should be avoided. A large array of structures with numeric scalar fields requires much more memory than a structure with fields containing large numeric arrays.

3. Importation of data

- When reading data from a binary file with fread, it is a common error to specify only the class of the data in the file, and not the class of the data MATLAB uses once it is in the workspace.
- Example:
    - The default double is used even if you are reading only 8-bit values.
    - Should do: a = fread(fid, 1e3, 'uint8=>uint8');
    - The default for 'precision' is ‘uint8=>double'. It means the input values are of the class specified by uint8. The class of the output matrix is specified by double.

4. Use sparse arrays whenever possible

Avoid Temporary Copies of Data

1. Avoid creating temporary arrays

- avoid creating large temporary variables
- clear temporary variables when they are no longer needed

```
clear A
```

2. Use nested Functions to pass fewer arguments

- When working with large data sets, be aware that MATLAB makes a temporary copy of an input variable if the called function modifies its value. This temporarily doubles the memory required to store the array, which causes MATLAB to generate an error if sufficient memory is not available.
- One way to use less memory in this situation is to use nested functions. A nested function shares the workspace of all outer functions, giving the nested function access to data outside of its usual scope.

Reclaim Used Memory

1. Clear large arrays that are no longer used.

2. Save large data periodically to disk

If the program generates very large amounts of data, consider writing the data to disk periodically. After saving that portion of the data, use the clear function to remove the variable from memory and continue with the data generation.

3. Clear old variables from memory when no longer needed

When working with a very large data set repeatedly or interactively, clear the old variable first to make space for the new variable. Otherwise, MATLAB requires temporary storage of equal size before overriding the variable.

Out of Memory

- MATLAB is a 64-bit application that runs on 64-bit operating systems. It returns an error message whenever it requests a segment of memory from the operating system that is larger than what is available.

- MATLAB has built-in protection against creating arrays that are too large. By default, MATLAB can use up to 100% of the RAM (not including virtual memory) of your computer to allocate memory for arrays, and if an array would exceed that threshold, then MATLAB returns an error.

Solutions to "Out of Memory"

1. Leverage `tall` Arrays

- Cast the array to a tall array if the large array fits in memory, but calculations run out of memory.
- Create a datastore from file or folder-based data, and then create a tall array on top of the datastore.

MATLAB works with small blocks of the data at a time, automatically handling all of the data chunking and processing in the background.

2. Leverage the Memory of Multiple Machines

- Use the Parallel Computing Toolbox™ and Distributed Arrays.

3. Load Only as Much Data as You Need

- This is a common problem with loading large flat text or binary files. The datastore function can help with this by allowing working with large data sets incrementally.

4. Increase System Swap Space

The total memory available to applications on your computer is composed of physical memory (RAM), plus a page file, or swap file, on disk. The swap file can be very large (for example, 512 terabytes on 64-bit Windows®). The operating system allocates the virtual memory for each process to physical memory or to the swap file, depending on the needs of the system and other processes. Increasing the size of the swap file can increase the total available memory, but also typically leads to slower performance.

5. Set the Process Limit on Linux Systems

The process limit is the maximum amount of virtual memory a single process (or application) can address. 64-bit operating systems support a process limit of 8 terabytes. On Linux systems, use ulimit to view and set limits including virtual memory.

6. Disable Java VM on Linux Systems

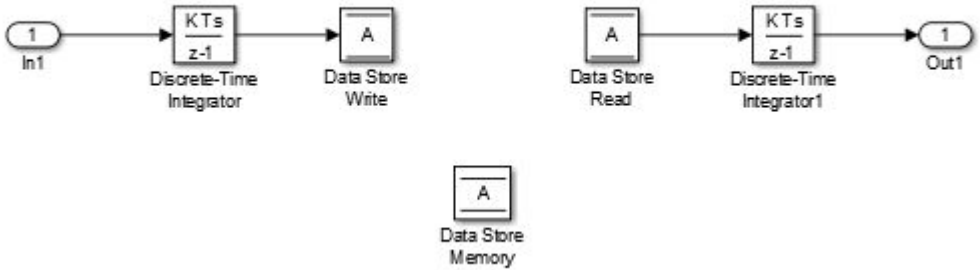
On Linux systems, starting MATLAB without the Java JVM can increase the available workspace memory by approximately 400 megabytes and increase the size of the largest contiguous memory block by about the same amount. To start MATLAB without Java JVM, use the command-line option -nojvm.

Datastore

A datastore is an object for reading a single file or a collection of files or data.

The datastore acts as a repository for data that has the same structure and formatting.

For example, each file in a datastore must contain data of the same type (such as numeric or text) appearing in the same order and separated by the same delimiter.

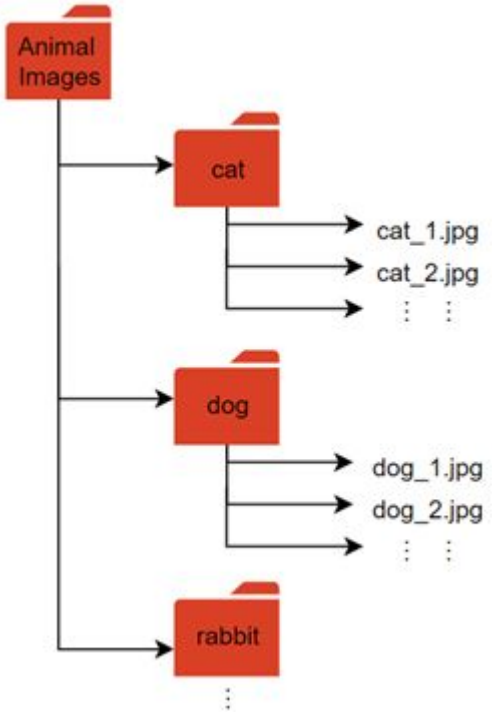


Create a Datastore

```
DS = datastore(LOCATION,'Type',TYPE)
```

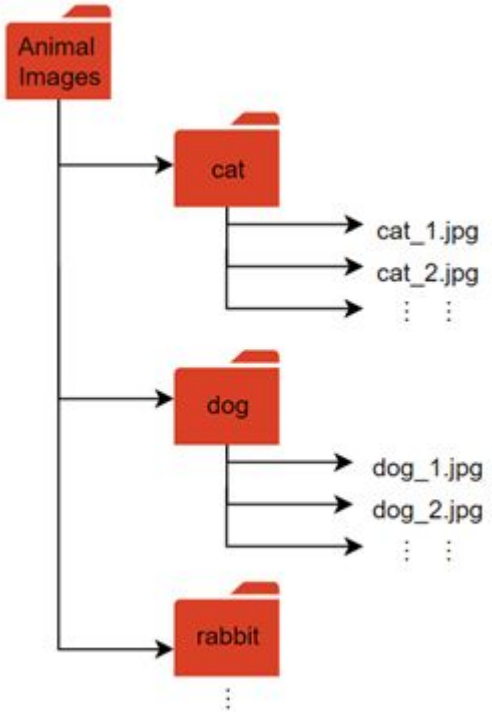
creates a datastore DS based on the LOCATION of the data and specifies the type of the datastore.
The supported types are:

- '**tabulartext**' - For tabular text files
- '**image**' - For image files
- '**spreadsheet**' - For spreadsheet files
- '**file**' - For custom format files
- '**tall**' - For tall data files from tall/write
- '**keyvalue**' - For use with key-value data from mapreduce
- '**database**' - For use with Database Toolbox



Read from a datastore

- If all of the data in the datastore for the variables of interest fit in memory, we can read it using the readall function.
- reset(ds) resets the datastore specified by ds to the state where no data has been read from it. Resetting allows re-reading from the same datastore.
- When data size is large, we can choose to read the data in smaller subsets that do fit in memory via the read function. Change the number of rows reading in a time by assigning a new value to the ReadSize property.



Tall Array on top of the datastore

Since the data is not loaded into memory all at once, tall arrays can be arbitrarily large in the first dimension (having any number of rows).

Many core operators and functions work the same with tall arrays as they do with in-memory arrays.

- MATLAB works with small blocks of the data at a time, handling all of the data chunking and processing in the background, so that common expressions, such as A+B, work with big data sets.

Benefit - deferred evaluation:

- Unlike in-memory arrays, tall arrays typically remain unevaluated until the request to perform the calculations using the gather function.
- MATLAB then combines the queued calculations where possible and takes the minimum number of passes through the data.
- Request output only when necessary.

MapReduce

`mapreduce` is a programming technique which is suitable for analyzing large data sets that otherwise cannot fit in the computer's memory.

`mapreduce` uses a datastore to process data in small blocks that individually fit into memory.

- Each block goes through a Map phase, which formats the data to be processed.
- Then the intermediate data blocks go through a Reduce phase, which aggregates the intermediate results to produce a final result.

How MapReduce Works

- mapreduce uses a datastore to process data in small blocks that individually fit into memory.
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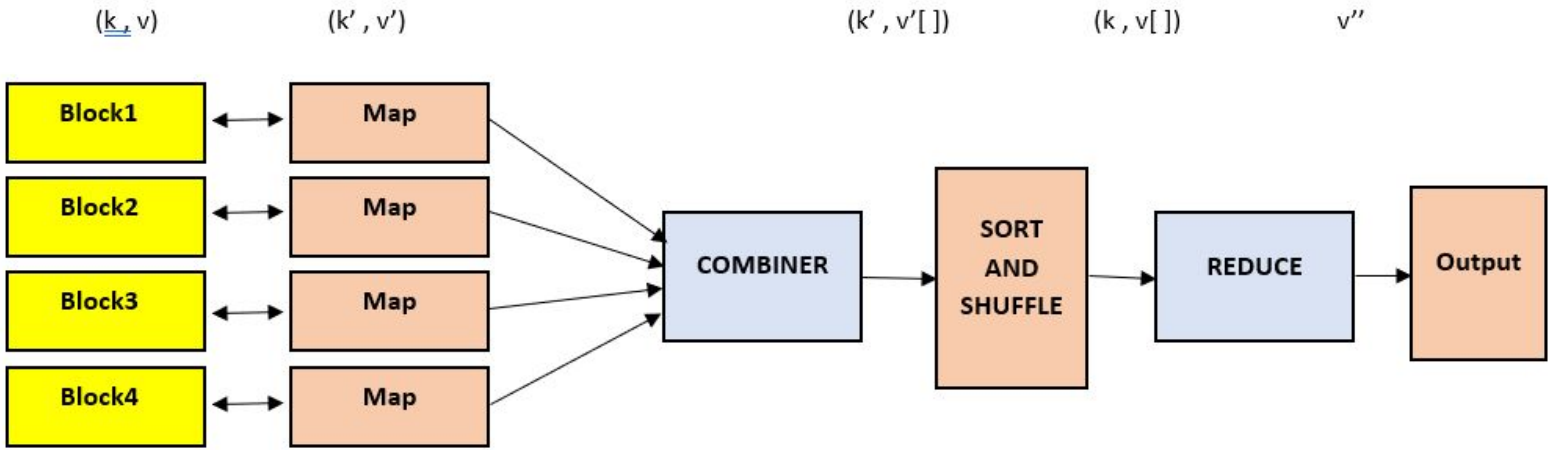


outds = mapreduce(ds,mapfun,reducefun)

- The Map and Reduce phases are encoded by map and reduce functions.
- There are endless combinations of map and reduce functions to process data.

The **reducefun** function loops through the values for each key using the **hasnext** and **getnext** functions. Then, after performing some calculation(s), it writes key-value pairs to the final output.

```
function myReducer(intermKey, intermValIter,
outKVStore)
while hasnext(intermValIter)
X = getnext(intermValIter);
%do a calculation with the current value, X
end
add(outKVStore, key, value)
end
```

The **mapfun** receives blocks from input datastore ds, and then uses the add and addmulti functions to add key-value pairs to an intermediate KeyValueStore object.

```
function myMapper(data, info,
intermKVStore)
%do a calculation with the
data block
add(intermKVStore, key, value)
end
```

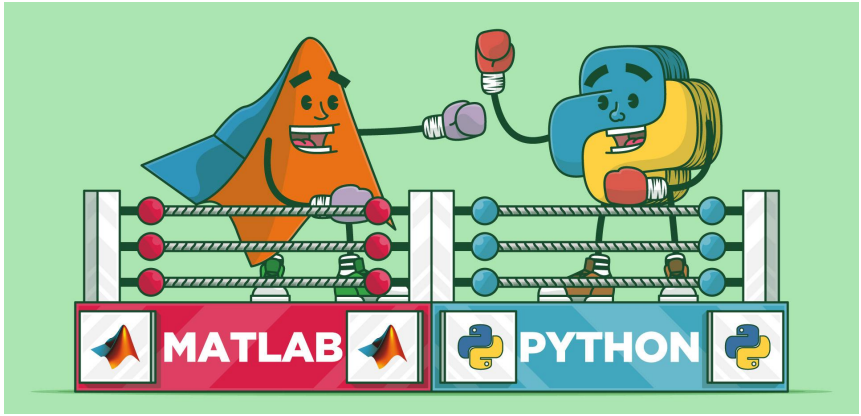
Database Toolbox

The Database Toolbox provides functions and an app for exchanging data with relational and nonrelational databases. It enables this exchange by automatically converting between database and MATLAB data types.
E.g.,

- Import data from and export data to relational databases directly within MATLAB. Use knowledge of SQL to exchange data programmatically, or interact with data without using SQL.
- Use the MATLAB Interface to SQLite to create, read, and write relational data from SQLite database files without installing or administering database software or drivers.
- Access and import columnar data using the Database Toolbox interface for the Apache Cassandra database.
- Store, query, and retrieve unstructured and structured data using the Database Toolbox interface for MongoDB.
- Explore, manage, and store graph data in Neo4j databases using the MATLAB interface to Neo4j. Perform graph network analysis with or without existing knowledge of the Cypher® graph query language.

Integration with Other Languages

How to build Python and C++ into your MATLAB engineering workflows



Calling Python from MATLAB

Directly call Python functionality from MATLAB
Add the **py.** prefix to the Python name to access Python libraries.

Python standard library: **py.** in front of the Python function or class name
Available modules: **py.** in front of the Python module name followed by the Python function or class name.

Current environment of Python interpreter:

```
pyenv
```

Calling MATLAB from Python

Install MATLAB Engine API for Python

https://www.mathworks.com/help/matlab/matlab_external/install-the-matlab-engine-for-python.html

```
cd (fullfile(matlabroot,'extern','engines','python'))
system('python setup.py install’)
```

Calling MATLAB from Python

- Start Python, import the package :

```
import matlab.engine
```

- Start a new MATLAB process

```
eng = matlab.engine.start_matlab()
```

- Stop Engine

```
eng.quit()
```

- Call MATLAB Functions from Python

```
tf = eng.isprime(37)
print(tf)
```

- Return Multiple Output Arguments

```
t = eng.gcd(100.0,80.0,nargout=3)
print(t)
```

Calling C/C++ from MATLAB

Get source code example arrayProduct.cpp.

This multiplies an array by a scalar input and returns the resulting array.

```
copyfile([matlabroot
'/extern/examples/cpp_mex/arrayProduct.cpp'],'.','f')
```

You may edit the file by

```
edit([matlabroot
'/extern/examples/cpp_mex/arrayProduct.cpp']);
```

Take a look at the . cpp file.

The usage of the file is

```
outMatrix = arrayProduct(multiplier, inMatrix)
```

Build the MEX file by

```
mex arrayProduct.cpp
```

Calling MATLAB from C/C++

Use the feval and fevalAsync member functions of the matlab::engine::MATLABEngine class to evaluate MATLAB statements using variables in the MATLAB base workspace.

```
#include "MatlabEngine.hpp”
// Start MATLAB engine synchronously
std::unique_ptr<MATLABEngine> matlabPtr = startMATLAB();

// Call MATLAB function and return result
matlab::data::Array results = matlabPtr->feval(u"func", args);
```