MATLAB EXPO 2017
Scaling MATLAB
for Your Organisation and Beyond
Rory Adams
MATLAB at Scale

Front-end scaling

- Scale with increasing access requests

Back-end scaling

- Scale with increasing computational intensity
- Scale with increasing data volumes

MATLAB at Scale

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MATLAB at Scale

Front-end scaling
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Key Takeaways

1. Share applications and algorithms with anyone

2. Integrate MATLAB functions into existing workflows and development platforms.

3. Deploy MATLAB applications to service simultaneous requests via web or cloud frameworks.
MATLAB Programs Can be Shared With Anyone

Share With Other MATLAB Users

Share With People Who do Not Have MATLAB

MATLAB User

Group Members

Suppliers

Clients

Organization

Collaborators

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Share with MATLAB Users

- Directly share MATLAB files
- Package an App
- Package Entire Toolboxes
Scale Up Sharing with MATLAB Users

Icons from www.flaticon.com

File Exchange: MATLAB Minimart
MATLAB Programs Can be Shared With Anyone

Share With Other MATLAB Users

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Share Applications Built Completely in MATLAB

1. MATLAB Application
2. MATLAB Compiler
3. End User

- Royalty-free Sharing
- IP Protection via Encryption
Excel Add-In – Solar Analysis

![Excel screenshot with data analysis and equation]

**Equation:**

\[ R_s = a (1 + bH)(1 - e^{-c \Delta T}) \]

**Run Analysis**
Integrate MATLAB-based Components With Your Own Software

MATLAB
Toolboxes

1. Application Author
2. MATLAB Compiler SDK
   - C/C++
   - .NET
   - Python
   - Java
3. MATLAB Production Server
4. MATLAB Runtime

- Royalty-free Sharing
- IP Protection via Encryption

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Scaling up: Load Forecasting Demo
MATLAB and MATLAB Production Server

- The easiest and most productive environment to *take your enterprise analytics or IoT solution* from *idea* to a *scalable production solution*
MATLAB Production Server
Enterprise Class Framework For Running Packaged MATLAB Programs

- Server software
  - Manages packaged MATLAB programs and worker pool

- MATLAB Runtime libraries
  - Single server can use runtimes from different releases

- RESTful JSON interface and lightweight client library
  - Isolates the MATLAB processing
  - Access using native data types
Scale Up with MATLAB Production Server™

- Scalable and reliable
  - Service large numbers of concurrent requests
  - Add capacity or redundancy with additional servers

- Directly deploy MATLAB programs into production
  - Automatically deploy updates without server restarts
  - Most efficient path for creating enterprise applications
Customer examples: Financial customer advisory service

Global financial institution with European HQ

- Saved **€ 2 million annually** for an external system
- Quicker implementation of adjustments in source code by the quantitative analysts
- Knowledge + MATLAB = Build your own systems
Industrial IoT Analytics on AWS

Industrial Equipment
- Networked communication
- Embedded sensors
- Data reduction

MATLAB Production Server

Request Broker

Business Systems

Global industrial equipment manufacturer

Users

Algorithm Developers

MATLAB

MATLAB Compiler SDK
Building Automation IoT Analytics on Azure

Building/HVAC automation control system
- Variety of sensors and controls
- Networked communication
- Data reduction

Global heavy duty electrical equipment manufacturer

Business Systems

Users

Algorithm Developers

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Production Deployment Workflow

Development

MATLAB Developer

Initial Test Application

Debug Algorithm

MATLAB Algorithm

MATLAB Compiler SDK

Deployable Archive

Enterprise Application Developer

Web Application

Function Call

MATLAB Production Server

Deployable Archives

Function Calls

Production

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MATLAB at Scale

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Key Takeaways

1. Leverage parallel computing

2. Handle big data

3. Seamlessly scale from your desktop to clusters or the cloud
Classification learner demo

Run classification learner quick to train classifiers in parallel instead of one by one.

One click to toggle the use of parallel.
Parallel-enabled Toolboxes
Enable acceleration by setting a flag or preference

- Image Processing
- Statistics and Machine Learning
- Neural Networks
- Simulink Control Design
- Signal Processing and Communications
- Optimization
- Simulink Design Optimization
- Computer Vision
- Communication Systems Toolbox
- Simulink/Embedded Coder

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Other Parallel-enabled Toolboxes
Independent Tasks or Iterations
Simple programming constructs: **parfor**, **parfeval**

- Examples: parameter sweeps, Monte Carlo simulations
- No dependencies or communications between tasks
Run multiple parallel simulations from the `parsim` command

Run Simulink multiple simulations in parallel with simplified workflow
Parallel Computing
Multicore Desktops
“...we can run *simulations in parallel,* and with a twelve-core computer we see an almost *twelfe-fold increase in speed.*”

Jonathan Fiévez
Carnegie Wave Energy

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“... *can develop prototypes* to test machine learning techniques *quickly... get rapid, reliable results* by running the algorithms with large financial data sets on a *distributed computing cluster.*”

Emilio Llorente-Cano
Aberdeen Asset Management
Why parallel computing matters
Scaling case study with a compute cluster

\[ M\ddot{x} + C\dot{x} + Kx = F \]

![Graph showing the relationship between the number of workers and compute time.](image)

<table>
<thead>
<tr>
<th>Workers in pool</th>
<th>Compute time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>160e3 values</td>
<td>400 values</td>
</tr>
<tr>
<td>1</td>
<td>140</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>20</td>
<td>8.0</td>
</tr>
<tr>
<td>40</td>
<td>4.2</td>
</tr>
<tr>
<td>80</td>
<td>2.1</td>
</tr>
<tr>
<td>100</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Processor: Intel Xeon E5-class v2
16 physical cores per node
MATLAB R2016a
Parallel Computing – Scaling Up
Clusters/Cloud

Parallel Computing Toolbox
MATLAB Distributed Computing Toolbox

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Considerations When Scaling to Clusters

- Workers need access to your code
- Workers need access to the data
- Operating system independent file path management
  - fileparts, fullfile, filesep
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Large Data Options

Data fits in memory of pool
- Distributed arrays
  - Look like normal MATLAB variables

Data does not fit in memory (Big Data)
- Tall arrays
  - Looks like normal MATLAB variables
- Custom map-reduce functions
  - Can be painful to learn
tall arrays

- Data doesn’t fit into memory
- Lots of observations - “tall”

- Looks like a normal MATLAB array
  - Numeric types, tables, datetimes, strings, etc…
  - Basic math, stats, indexing, etc.
  - Statistics and Machine Learning Toolbox
    (clustering, classification, etc.)
tall arrays

- Automatically breaks data up into small “chunks” that fit in memory
- “Chunk” processing is handled automatically
- Processing code for tall arrays is the same as ordinary arrays
tall arrays - Scaling

- Process several “chunks” at once
- Scale up to clusters
Big Data workflow

**ACCESS**
More data and collections of files than fit in memory

**PROCESS AND ANALYZE**
Adapt traditional processing tools or learn new tools to work with Big Data

**SCALE**
To Big Data systems like Hadoop
Example: Scaling up to Spark and Hadoop

**tall Arrays for Big Data in MATLAB**

Predict Cost of Taxi Ride in New York City

This example explores NYC taxi data and predicts the fare based on distance and the time of day.

The data come from .csv files containing taxi trip information, separated by month. The data set is freely available from the City of New York.

Set up execution environment

Use local environment for prototype. This will later be scaled to run on a Spark-enabled Hadoop cluster.

```matlab
% prep local:
```

Create a datastore to represent the data

A datastore is a repository for data and allows you to read part of the data, all of the data, or create a tall array to work with the data out-of-memory.

```matlab
fileread(fullfile('taxiData','.csv'));
```
Using Tall Arrays

- Tall arrays
  MATLAB
- 100’s of functions supported
  MATLAB
  Statistics and Machine Learning Toolbox
- Run in parallel
  Parallel Computing Toolbox

Run in parallel on compute clusters
MATLAB Distributed Computing Server

Run in parallel on Spark clusters
MATLAB Distributed Computing Server

Deploy MATLAB applications as standalone applications on Spark clusters
MATLAB Compiler

Local disk
Shared folders
Databases
HDFS

Spark + Hadoop
## Summary - Scale your applications beyond the desktop

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Explicit desktop scaling</td>
<td>Scale to clusters</td>
<td>Scale to EC2 with some customization</td>
<td>Scale to custom cloud</td>
<td>Scale to custom cloud</td>
</tr>
<tr>
<td>Maximum workers</td>
<td>No limit</td>
<td>No limit</td>
<td>256</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td>Hardware</td>
<td>Desktop</td>
<td>Any</td>
<td>Amazon EC2</td>
<td>Amazon EC2, Microsoft Azure, Others</td>
<td>Hadoop + Spark</td>
</tr>
<tr>
<td>Availability</td>
<td>Worldwide</td>
<td>Worldwide</td>
<td>United States, Canada and other select countries in Europe</td>
<td>Worldwide</td>
<td>Worldwide</td>
</tr>
</tbody>
</table>

Learn More: [Parallel Computing on the Cloud](Parallel%20Computing%20on%20the%20Cloud)
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