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

Front-end scaling
- Scale with increasing access requests

Back-end scaling
- Scale with increasing computational intensity
- Scale with increasing data volumes
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
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

Share With People Who do Not Have MATLAB

MATLAB User

Group Members

Suppliers

Clients

Collaborators

MATLAB EXPO 2017
Share Applications Built Completely in MATLAB

1. Application Author
   - MATLAB
   - Toolboxes

2. MATLAB Compiler
   - MATLAB Application
   - Standalone Application
   - Excel Add-in
   - Hadoop

3. End User
   - MATLAB Runtime

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

R_s = a (1 + bH)(1 − e^{-c DT})

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. Software Developer

   • Royalty-free Sharing
   • IP Protection via Encryption
Scaling up: Load Forecasting Demo

MATLAB Production Server(s)

HTML
XML
Java Script

Web Server(s)
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

- 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

Global financial institution with European HQ

MATLAB EXPO 2017
Industrial IoT Analytics on AWS

Industrial Equipment
- Networked communication
- Embedded sensors
- Data reduction

Global industrial equipment manufacturer

MATLAB Production Server

Request Broker

MATLAB

MATLAB Compiler SDK

Business Systems

Users

Algorithm Developers

Global industrial equipment manufacturer

Networked communication

Embedded sensors

Data reduction
Building Automation IoT Analytics on Azure

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

MATLAB Production Server
- Azure EventHub
- Azure Blob
- Azure SQL

Global heavy duty electrical equipment manufacturer

Business Systems

Users

Algorithm Developers

MATLAB EXPO 2017
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

Production
- Web Application
  - Function Calls
- MATLAB Production Server
  - Deployable Archives
Technology Stack

Data

Databases
- neo4j
- MongoDB
- SQL Server

Cloud Storage
- Azure Blob
- S3

IoT
- Kafka

Analytics

MATLAB Distributed Computing Server

Business System

Visualization
- Qlik

Web
- WebSphere

Custom App
- Apache Tomcat

Platform

Public Cloud
- Microsoft Azure
- Amazon Web Services
- Rackspace

Private Cloud
- OpenStack
- VMware

MATLAB EXPO 2017
MATLAB at Scale

Front-end scaling
- Scale with increasing access requests

Back-end scaling
- Scale with increasing computational intensity
- Scale with increasing data volumes
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**
- **Computer Vision**
- **Communication Systems Toolbox**
- **Simulink/Embedded Coder**
- **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
Develop unique technology for generating electric power from ocean waves

“…we can run simulations in parallel, and with a twelve-core computer we see an almost twelvefold increase in speed.”

Jonathan Fiévez
Carnegie Wave Energy

Improve asset allocation strategies with machine learning techniques

“…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

MathWorks
MATLAB EXPO 2017

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

![Graph showing Speed-up X vs. Number of Workers](image)

<table>
<thead>
<tr>
<th>Workers in pool</th>
<th>160e3 values</th>
<th>400 values</th>
<th>25 values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>140</td>
<td>0.38</td>
<td>0.03</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>20</td>
<td>8.0</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>40</td>
<td>4.2</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>80</td>
<td>2.1</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>100</td>
<td>1.8</td>
<td>0.02</td>
<td>0.01</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
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
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 EXPO 2017
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
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

MATLAB EXPO 2017
Summary - Scale your applications beyond the desktop

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<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](#)
MATLAB at Scale

Front-end scaling
- Scale with increasing access requests

Back-end scaling
- Scale with increasing computational intensity
- Scale with increasing data volumes