Using MATLAB to Develop and Deploy Financial Models

Financial Products Group

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Topics

- Introduction
- Application Examples
- Overview of MATLAB
  - Data I/O
  - Data Analysis
  - Modeling
- Break
- Algorithm Deployment and Reporting
- Distributed Computing
- Wrap up
The MathWorks at a Glance

Headquarters: Natick, Massachusetts USA

USA:
California, Michigan, Washington DC, Texas

Europe:
UK, France, Germany, Switzerland, Italy, Spain, Benelux, Nordic

Asia-Pacific:
Korea

Worldwide training and consulting

Distributors in 20 countries
The MathWorks Today

- Revenues of ~$300M in 2004
- Privately held
- Over 1000 employees worldwide, 1/3 in product development
- Worldwide revenue balance: 50% North America, 50% International
- More than 1,000,000 users in 175+ countries
Business Challenges

- Development time
- Computational speed
- Deployment time

Lost opportunity or added risk
"MathWork's products have saved us significant time in developing our return forecast models. MATLAB, coupled with the deployment capabilities available, enables us to distribute sophisticated models to portfolio managers and researchers much quicker than we could have with other solutions."

Eric Kisslinger
Barclays Global Investors
Customer Quote

“MATLAB can reduce programming time by about 75 percent. In some cases it would be weeks before we could run the calculations in C++.”

“MATLAB is virtually the only program that can handle the large-scale problems that we model. It is a powerful tool that provides a very flexible Environment in which to build models rapidly.”

Alexander Eydeland
Mirant
Customer Quote

By using MATLAB as the computation engine for our Excel models, we have been able to significantly improve the accuracy of our simulations and reduce computing time by up to 95%.

Don Mango
American Reinsurance
Customer Quote

“We found the development cycle in MATLAB to be 10 times shorter than in C++, dramatically reducing project costs without any significant penalties to computation speed.”

Zaf Bhuia
Credit Suisse First Boston
Trading Application
A statistical arbitrage trading system for a London hedge fund

High speed data analysis and trading application
- Custom Reuters datafeed
- Read and analyze data
- Estimate risks
- Execute trades

ROI
Developed for 20% of their expected cost in only 3 months.
Data Analysis Applications

Economic charting system for a major insurance company

- Macro economic trending tool for economists
- Read data from a databases
- Filter using custom user interface
- Report using either Microsoft Excel or Word
Energy Trading Applications

Analysis and reporting tool for energy trading companies

- Customized database access routines
- Extensive use of object oriented programming
- Hierarchical structure for books, deals, derivatives, etc…
- Distribution of nightly position reports to senior management via their intranet.
- Display of market curves, sensitivities, etc…
Asset allocation Application

Analysis tool for Privately managed investment company

- An environment for detailed analysis of their holdings.
- Analysis includes:
  - Visualizing efficient frontiers
  - Monte-Carlo simulation
  - Performance reporting

Final application provided:
- Asset and group constraints.
- Statistic calculation against benchmarks
- Reporting back to Excel
- Extensibility
Re-Insurance Application

Pricing and risk tool for major re-insurance company

- Used Excel as front end user interface
- Needed access to several databases
- Analysis includes:
  - Statistical routines
  - Monte-Carlo simulations
  - Cash flows

ROI

- Calculation time reduced from 2 hours to 3 minutes
- Won $130M order due to quick response time
Securities Trading Application

Analysis and development tool for major investment banking

- Application to analyse large volumes of data to determine daily trading strategies
  - Implement new strategies
  - Link to Excel
  - Link to trading platform

ROI

- Reduce model execution time from 10 hour to 2.5 minutes
  - Analyze 500 stocks, up from 150
- Increase trading volume from £30million to £120million
- Pilot study, using Consulting Services and implemented in 3 days, paid for itself in 2 trading days.
Overview of MATLAB and Toolboxes
Typical Process Flow

Data

Data

Analysis & Visualization

Financial Modeling

Financial

Statistics

Optimization

Fixed-Income

Financial Derivatives

GARCH

Fin Time Series

Reports

Deploy Applications

Excel Link

Datafeed

Database

MATLAB
The Power of MATLAB

MATLAB is both

A Computational Environment:
Financial professional develop complex financial models using MATLAB and its family of toolboxes

and

An Application Development Environment:
Models developed in MATLAB by financial professionals are translated into components using the MATLAB Compiler and distributed as stand-alone applications or quickly integrated into new or existing legacy applications by Information Technology Engineers
Why MATLAB?

- Quick Prototyping environment
  - Less Programming
  - Matrix Based
  - Easy Syntax (no overhead)
  - 1000’s Math & Graphics

- Fast computational engine

- Work with various data sources

- Integrate with other programs
  - Excel, VB, & C/C++
Data I/O Overview

- Data importing functions
- Support for ODBC and JDBC compliant database
- Interface with data providers
- Many Interfaces to Excel
Core MATLAB Data I/O functionality

- Save and load command
- Low-level file I/O functions
- COM/ActiveX
- DDE function
- textscan
- xlsread

Save options
- 8-digit or 16-digit ASCII format
- Delimits with tabs or spaces
- Text data (ASCII)
- Binary data (MAT-file)
Connections to Data Providers

- Supported connections:
  - Bloomberg, FactSet,
  - Financial Times Interactive Data (IDC)
  - Yahoo, and Hyperfeed

- Potential connections
  - Reuters and Datastream

- GUI Tool (DFTOOL)

- Need connection/license
Database Connections

- ODBC or JDBC compliant database
  - ODBC and JDBC on PC
  - JDBC on UNIX

- Data types are preserved

- Retrieval of large/partial data sets

- Access multiple connections (same or different DB)

- Database connections remain open
Database Connections

Visual Query Builder

- Access data without knowing SQL
  - Scroll through tables and fields
  - Customize your query using Where/Group

- Built-in visualization tools
  - Plotting and charting
  - Creating HTML reports
  - Handling date strings

- Reuse SQL statements in your own program
Data Analysis in MATLAB (library of functions)

- **Statistics**
  - analyzing historical data, modeling data, simulating systems, and developing statistical algorithms.

- **Curve Fitting**
  - routines for preprocessing data, as well as creating, comparing, analyzing, and managing models.

- **Optimization**
  - proven algorithms for general and large-scale optimization
  - linear programming, quadratic programming, nonlinear least-squares, and nonlinear equations.
  - Genetic algorithm tools with numerous options for creation, fitness scaling, selection, crossover, and mutation

- **Signal Processing, Neural Networks, Wavelets ..**
Complete Development Environment

- MATLAB Editor/Debugger
  - Capture work from history
  - Color coded
  - Break points

- Performance Tools
  - Profiler
  - M-Lint

- GUI Builder
  - Drag and drop graphical user interface

- Multi-platform Support
  - Windows, Unix, Linux, & Mac
Financial Modeling with MATLAB (library of functions)

- Financial
  - perform portfolio optimizations, risk analyses, asset allocations, fixed income pricing, and much more
- Fixed Income
  - determine the price, yield, and cash flows for many types of fixed-income securities including mortgage-backed
- Financial Derivatives
  - analyzing and modeling equity and fixed-income derivatives and securities contingent on interest rates
- GARCH
  - perform Monte Carlo simulation of univariate returns, perform pre- and post-estimation diagnostic and hypothesis testing, estimate parameters of general ARMAX/GARCH models
Examples

- Option modeling
- Fixed Income Analysis
  - Interest rate curves
- Volatility modeling
- Monte Carlo Simulations
  - Value at Risk (VaR)
  - Credit Risk
- Technical Analysis
Faster Simulation Times

Spread Sheet Applications

- MATLAB Excel Link can be the computational engine behind your Excel applications

- Faster scalable solution

Collective Risk Model
4.6 Seconds v.s 204.2 Seconds
Why MATLAB?

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- Work with various data sources
  - Integrate with other programs
    - Excel, VB, & C/C++
Break
Application Deployment
Model Development Process

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excel</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Excel, C/C++, VB</td>
<td>Deployment</td>
</tr>
<tr>
<td>Application Specific Software</td>
<td>Functionality</td>
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<tr>
<td></td>
<td>Limited functionality</td>
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<tr>
<td></td>
<td>Learning curve</td>
</tr>
<tr>
<td></td>
<td>Deployment</td>
</tr>
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MATLAB Prototype to Production

Traditional prototype to production system port … development timeline 2 weeks ~ 6+ months

MATLAB prototype to production system … single command at the command line
The MATLAB Compiler

- Works with C/C++ compilers (Microsoft Visual Studio)
- Creates executables, components, or libraries
- Supports the entire MATLAB language (OOP’s, JAVA, EVAL, ActiveX)
- Deploy applications at no cost

Your MATLAB App

Your MATLAB Functions

Deploy as a standalone

Integrate into other environments
The Distributed MATLAB Application

• MATLAB Compiler command issued at the command prompt creates an executable, COM, or Lib

  • Create a stand-alone executable
    \texttt{mcc \ -m \ yourapp.m}

  • Integrate with other applications (.dlls, .so, etc)
    \texttt{mcc \ -W \ lib:libfunction \ -T \ link:lib}
    \texttt{yourfunc1.m, yourfunc2.m}

• MATLAB does not need to be available on the target user’s desktop

• Generated binary, CTF, and MCR can be packaged and freely distributed to the target user’s desktop
Compiler architecture ... 3 Components

1. Executable, Component or Library
2. Component Technology File (CTF)
   - CTF file contains all supporting m files, mex files, java files, MAT files, etc. that are needed to allow application to run.
   - Enables customers to protect their IP due to new encryption model used in building the CTF archive.
3. MATLAB Component Runtime (MCR)

Components built by the compiler (usually 300KB)
Deployed once onto the desktop (100 MEG)
A Stand-alone Example

MATLAB Editor/GUI Builder

Stand-alone application

>> mcc -m rwalk2a.m
Integration With Other Environments

- MATLAB Compiler generated shared libraries (lib and DLL’s) may be integrated with...
  - C/C++
  - Visual Basic
  - Excel
MATLAB Builder for Excel

MATLAB Builder for Excel works with the MATLAB Compiler to generate stand-alone Excel add-ins from MATLAB algorithms.
MATLAB Builder for COM works with the MATLAB Compiler to automatically generate COM wrappers for MATLAB algorithms.
MATLAB Builder for COM enables the development and distribution of Web-based MATLAB applications via ASP.
Deploying with MATLAB

C/C++ Shared Objects

Stand-alone

COM

Excel

Web
Reporting

- Documents for compliance and model verification
- Generating custom daily/nightly reports
Compliance and Model Verification

- Documentation of code
  - Display code and comments
  - Headings, links, and fonts
  - Graphics
  - Multi-output formats
    - HTML, XML, Word, LaTeX, PowerPoint

- Create dependency reports
  - Understand parent/child relationships

- Performance reports
  - Recommendations for improvements
  - Check unused variables
Custom Report Generation

- Template based report design
  - Develop report outline
  - Reusable templates

- Scripting features
  - Chapters
  - Text, tables, links, graphs, code, etc

- Multiple output formats
  - HTML
  - XML
  - RTF
Distributed Computing
Applications for Distributed Computing

Address the need to solve computationally intensive problems:

- Enhance productivity
- Improve performance

Examples: (Monte Carlo simulations)

- Risk management simulations
- Derivatives pricing simulations
- Portfolio optimization problems
Coarse-grained Distributed Computing

- MATLAB
- Toolboxes

Client machine

Job Manager

- Task
- Result Task
- Result Task
- Result Task
- Result

CPU1
CPU2
CPU3
CPU4
Coarse-grained Distributed Computing Solution

Functionality:
- Queue Jobs
- Dynamically license workers

Functionality:
- Create Jobs
- Create Tasks
- Pass data
- Retrieve results

MATLAB Distributed Computing Engine

Client

MATLAB
Toolboxes

Distributed Computing Toolbox

Job Manager

Worker

Worker

Worker
Dynamic Licensing

Client 1
MATLAB
Statistics
Optimization

Distributed Computing Toolbox

Stats
Optim

Job

Result

Client 2
MATLAB
Wavelets
Neural Network

Distributed Computing Toolbox

Stats
Optim

Wavelets

Job

Result

MATLAB Distributed Computing Engine

Job Manager

Worker

Task

Result

Worker

Task

Result

Worker

Task

Result
Key Features

- Dynamic licensing
  - Engine is the *only* product required in the cluster
  - Eliminates the need to buy multiple toolboxes licenses for worker nodes

- Access to single or multiple clusters by single or multiple users

- Distributed processing on both homogeneous and heterogeneous platforms

- Support for both synchronous and asynchronous operations

- Control of the distributed computing process via a function-based or object-based interface
Demonstration

Toolbox
- Client interface
- Job creation
- Graphics display

Engine
- Job manager
- 2 Worker

- Functional interface
- Object interface
- Single CPU
- Multi-CPU
Portfolio Optimization (non-distributed)
Portfolio Optimization (distributed)

```
>> distcomp_optim_dist([],[],[],'narfi')
Elapsed Time is 29.583 seconds
```

3 Workers
Distributed Computing Tools Summary

- Execute independent MATLAB algorithms models in a computer cluster
  - Performance improvement
  - Enhanced productivity
- This is the first release of a milestone product
  - Supports coarse-grained applications
- Trial versions are now available!
Wrap Up
### MATLAB for Business Applications

#### Business Tools on the Desktop
- Excel
- Word
- Browsers
- Live Market Data
- Databases
  - Oracle
  - Microsoft Access
  - Microsoft SQL Server
  - Sybase SQL Server
  - ...

#### MATLAB Tools
- Excel Link & Data Import Tool
- Publisher, copy figure
- Publisher and Report Generator
- Datafeed Toolbox
- Database Toolbox
  - ODBC & JDBC
  - ...

...
Benefits of MATLAB

- Interactive environment
- An extensive library of viewable code that can be used “as is” or modified to incorporate business models
- Matrix based — handle and manipulate large data sets
- First rate graphics engine
- A considerably shorter application development process resulting in rapid delivery of model to the end user desktop
The MATLAB Advantage

- Develop models faster
- Run large scale simulations
- Reduces the costs of model integration
Representative Customers

- Federal Reserve Bank
- Goldman Sachs
- J.P. Morgan Chase
- State Street
- Salomon Smith Barney
- Merrill Lynch
- Ernst & Young
- Deloitte & Touche
- Lehman Brothers

- Putnam Investments
- Prudential Securities
- Bank of America
- Freddie Mac
- Fannie Mae
- Moody’s Investors
- Scudder Investment
- Price Waterhouse Coopers
Insurance and Energy Trading Companies

- Allstate Insurance
- American RE
- AXA
- Element RE
- John Hancock
- Kemper RE
- Liberty Mutual
- New York Life
- Zurich RE
- Williams Energy
- Reliant Energy
- TXU
- Mirant
- ExxonMobil
- Entergy Koch
- Constellation Power Source
- Sempra Energy
- Allegheny Energy
- Dominion Energy
Representative U.K. & US Business Schools

- Judge Institute, University of Cambridge
- Cornell University, Johnson School of Business
- Sloan School (MIT)
- Carnegie Mellon University
- London Business School
- Harvard Business School
- Imperial College, Centre for Quantitative Finance
- Warwick Business School
- University of California at Berkeley
- University of Chicago, GSB
- Cass Business School
Support and Community

The MathWorks Connections Program

The MathWorks Consulting Services

The MathWorks Book Program

The MathWorks Training Services

MATLAB Central
Consulting Services

- Engineering expertise and deep product knowledge, specializing in:
  - Application development using MATLAB
  - Model-based design using Simulink and Stateflow
  - Embedded-system development
  - Enterprise-wide integration of MathWorks products into engineering process and systems
  - Jumpstart services

- Project-based services for a growing number of industries, including Aerospace and Defense, Automotive, Communications, Power and Marine, and Financial Services
Three ways to get training

- **Public Training**
  - Offered throughout the world
  - Schedule and course information at [http://www.mathworks.com/training](http://www.mathworks.com/training)

- **On-Site Training**
  - Bring training to your site, with course customization available

- **Web-Based Training**
  - Instructor-led e-learning
  - Train at work or at home, with flexible dates and times
File exchange and newsgroup access for MATLAB and Simulink users

- 130,000 visits per month
- Over 2,800 files in the exchange
  - General-purpose functions, industry- and application-specific tools and examples
  - 100 new submissions per month
  - 5,000 downloads per day
- 5,000 posts to “CSSM” (comp.soft-sys.matlab) per month, 60% routed through MATLAB Central
The MathWorks Connections Program

Over 300 add-on products and services from partners that complement and extend MathWorks products

- Specialized third-party toolboxes for MATLAB
- Interfaces to partners’ software and hardware products
- Specialized training courses and consulting services
- System integrators and suppliers that incorporate MathWorks products
750+ textbooks for educational and professional use, in 20 languages

- An Introduction to Market Risk Measurement
- Applied Computational Economic and Finance
- Pricing Derivatives Securities
- Black Scholes and Beyond

www.mathworks.com/books
Technical Support

- **Technical Support**
  - 90% of problems solved in 24 hours
  - 60+ Application Engineers on staff, ½ with Masters Degrees

- **World Wide Web (www.mathworks.com)**
  - 24x7 self-service technical support
  - over 9,000 technical solutions
  - software archive (ftp.mathworks.com)
  - MATLAB Digest – electronic newsletter

- Newsgroup (**comp.soft-sys.matlab**)

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The MathWorks
MATLAB® & SIMULINK®
Further information

- Stay for questions
- Visit MATLAB Central for some of the tools you’ve seen today
- Trials, onsite demonstrations, technical literature:
  John.Cunningham@mathworks.com
  508.647.7122 or visit:
  http://www.mathworks.com/products/industry/finance

- Company and product information:
  www.mathworks.com