Machine Learning for Risk Management in MATLAB

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Agenda

What is machine learning?

- Machine learning in MATLAB
  - Bond classification
  - Credit classification
  - Trading strategy

- Moving models to production
What is machine learning?

“[Machine Learning] gives computers the ability to learn without being explicitly programmed”
Arthur Samuel, 1959
Machine learning overview

MACHINE LEARNING

UNSUPERVISED LEARNING
Group and interpret data based only on input data

SUPERVISED LEARNING
Develop predictive model based on both input and output data

CLUSTERING
CLASSIFICATION
REGRESSION
Deep learning is available too!

**Deep** refers to the number of hidden layers

**Neural Network**
2-3 Hidden Layers

**Deep Learning Models**
As many as 150!

```matlab
% Set options for training
opts = trainingOptions('sgdm');

% Train the network
net = trainNetwork ... (XTrain, TTrain, layers, opts);

% Make predictions
trainFeatures = ... activations(net, XTrain, 6);
```
Machine learning applications in finance

Input/Predictors → F(x) → Output/Response

- Trading
- Energy Forecasting

Rating score card

$EL = f(T, t, DP, ...)$
Machine learning challenges

Data challenges
- Volume of data is growing
- Velocity of data is accelerating
- Variety of data is dynamic
- Data cleaning is time consuming

Modeling challenges
- Data driven models
- No “one size fits” all solution
- Machine learning modeling is iterative

Production challenges
- Scalability – leveraging IT resources
- Flexibility – interfacing with systems
**Demo: Calibrating the Rating System**

- Overseeing a portfolio of bonds
- Improve rating engine using machine learning

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**Ratings**

- AA
- BBB
- A
- BBB
- BB
- AA
- A
- BB
- AA
- CCC
Demo: Trading strategy

“[Machine Learning] gives computers the ability to learn without being explicitly programmed”
Arthur Samuel, 1959

Standard Approach

Hand Written Program

If RSI > 70 then “SELL”
If MACD > SIG and RSI <= 70 then “HOLD”
...

Formula or Equation

\[ Y_{Trade} = \beta_1 X_{RSI} + \beta_2 X_{MACD} + \beta_3 X_{TSMom} + \ldots \]

Machine Learning Approach

Inputs → Outputs

Prediction = \( F(\text{factors, trade decision}) \)
Modeling is an art form
Modeling in MATLAB is visual and requires less code

- APPs facilitate analysis, but with autocodegen transparency
- Lots of high quality financial & machine learning functionality out of the box!
- You don’t have to be a programmer to do analysis
Agenda

- What is machine learning?
- Machine learning in MATLAB
  - Bond classification
  - Trading strategy

Moving models to production
MATLAB Programs Can be Shared With Anyone

Share With Other MATLAB Users

Share With People Who do Not Have MATLAB
Deployed Applications
MATLAB is flexible

With MATLAB Users

Apps
Files
Custom Toolbox

With People Who Do Not Have MATLAB

Standalone Application
Excel Add-in
Hadoop
C/C++
Java
.NET
Python
MATLAB Production Server

MATLAB
MATLAB Compiler
MATLAB Compiler SDK
MATLAB integrates with IT systems

**Data**

- **Databases**
  - Cassandra
  - MongoDB
  - SQL Server

- **Cloud Storage**
  - Azure Blob
  - Azure SQL
  - S3

- **IoT & Big Data**
  - Kafka
  - Azure IoT Hub
  - Hortonworks
  - Cloudera

**Business System**

- **Visualization**
  - Tableau
  - Qlik
  - Microsoft Power BI

- **Web**
  - Microsoft IIS
  - WebSphere
  - Apache Tomcat

- **Custom App**

**Platform**

- **Public Cloud**
- **Private Cloud**

- Microsoft Azure
- Amazon Web Services
- Rackspace
- OpenStack
- VMware
Machine learning challenges

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Production challenges
- Scalability – leveraging IT resources
- Flexibility – interfacing with systems
Why MATLAB for Machine Learning?

Data challenges
- MATLAB works with BIG data
- Lot of preprocessing functions
- Point & click speeds up exploration

Modeling challenges
- APPs simplify modeling
- Iterate quickly with parallel
- Interactive visuals generate insight

Production challenges
- Scalability – leverages cloud
- Flexibility – interfaces IT systems

[Image of various groups such as Traders, Management, Other groups, Quant Group, Financial Engineer, Regulators, Clients, Partners]
Machine learning workflow

Access
- Files
- Databases
- Datafeeds

Research and Quantify
- Data Analysis and Visualization
  - Financial Instruments
  - Risk Management
  - Statistics & Machine Learning
  - Financial
  - Econometrics
- Application Development

Share
- Reporting
- Applications
- Production

MATLAB
- Parallel Computing
- Neural Networks
- Symbolic Math
- MATLAB Distributed Computing Server
- Curve Fitting
- Signal Processing
Want to learn more?
Contact us!

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MathWorks Company Overview
MathWorks at a Glance

- Revenues ~$850M in 2016
- More than 60% from outside the U.S.
- Privately held
- 3500 employees worldwide
- More than 2 million users in 175+ countries

Office locations

Distributors serving 16 countries
Key Industries

- Aerospace and defense
- Automotive
- Biological sciences
- Biotech and pharmaceutical
- Communications
- Electronics
- Energy production
- Financial services
- Industrial automation and machinery
- Medical devices
- Metals, materials, and mining
- Neuroscience
- Railway systems
- Semiconductors
- Software and internet
Deeply Rooted in Education

- 5000+ universities around the world
- 1800+ MATLAB and Simulink based books
- Academic support for research, fellowships, student competitions, and curriculum development

Benefits for Industry

- Every year, tens of thousands of engineers enter the workforce with MATLAB and Simulink product skills and experience.
- Students learn theory and techniques while using MATLAB and Simulink.

“Everyone that comes in as a new hire already knows MATLAB, because they all had it in college. The learning curve is significantly lessened as a result.”

Jeff Corn, Chief of Engineering Projects Section, U.S. Air Force
Core MathWorks Products

MATLAB®
The leading environment for technical computing

- The industry-standard, high-level programming language for algorithm development
- Numeric computation
- Parallel computing, with multicore and multiprocessor support
- Data analysis and visualization
- Toolboxes for signal and image processing, statistics, optimization, symbolic math, and other areas
- Tools for application development and deployment
- Foundation of MathWorks products
Training Services

Exploit the full potential of MathWorks products

Flexible delivery options:
- Public training available worldwide
- Onsite training with standard or customized courses
- Web-based training with live, interactive instructor-led courses
- Self-paced interactive online training

More than 50 course offerings:
- Introductory and intermediate training on MATLAB, Simulink, Stateflow, code generation, and Polyspace products
- Specialized courses in machine learning, control design, signal processing, parallel computing, code generation, communications, financial analysis, and other areas
Technical Support

Resources

- Over 100 support engineers
  - Most with MS degrees (EE, ME, CS)
  - Local support in North America, Europe, and Asia
- Comprehensive, product-specific web support resources

High customer satisfaction

- 95% of calls answered within three minutes
- 70% of issues resolved within 24 hours
- 90% of customers surveyed said they were satisfied or very satisfied
The MathWorks Advantage

- Mission to develop leading-edge tools
- Leading environments for technical computing and Model-Based Design
  - Unified, integrated computing environment
  - Modeling, simulation, and prototyping, combined with broad analysis capabilities
  - Implementation to desktop environments and embedded systems
  - Integrated design and test
- Open systems philosophy and architecture
- Multiplatform support and interoperability
The MathWorks Advantage

- Strong, customer-focused company
  - Heavy investments in R&D
  - Partnership with customers to help define product capabilities
- Breadth of supported applications
- Consistent, highly rated service and support
- Prominence of MATLAB in engineering education
- Partnerships with industry leaders
MathWorks User Stories
CAMRADATA Models Dependencies for Quantitative Risk Assessment with MathWorks Tools

Challenge
Rapidly develop quantitative tools for factor analysis, risk analysis, and defensive asset allocation

Solution
Use MATLAB to model complex non-linear dependencies between assets, liabilities, and economic variables using copulas

Results
- Development time reduced by 90 percent
- Risk calculated in hours, not weeks
- Diverse skill sets leveraged

“Using MATLAB we can build a model in one morning. It would take two weeks to write the equivalent code in Visual Basic.”

Martyn Dorey
CAMRADATA

Link to user story
Capgemini Helps Clients Achieve Basel II Compliance and Deliver Economic Capital, Risk, and Valuation Models with MATLAB

Challenge
Enable banking clients to meet Basel II regulatory guidelines and perform other risk management tasks

Solution
Use MATLAB to develop risk management models and to perform valuations of complex products

Results
- Strong competitive advantage established
- Scalable solution delivered
- Customer portfolio revalued

"With its computational power, matrix infrastructure, and ability to perform Monte Carlo simulations, MATLAB gives us a competitive advantage in performing complex risk analyses."

Dr. Marco Folpmers
Capgemini
Intuitive Analytics Uses MATLAB to Build Quantitative Tools to Help Bond Issuers Manage Risk

**Challenge**
Build and market a quantitative tool for reducing expected cost and risk for municipal bond issuers

**Solution**
Use MathWorks tools to develop algorithms, visualize results, and simplify deployment of an advanced analytical tool

**Results**
- Development productivity increased by 90%
- Deployment simplified
- Visual environment created

“Because MATLAB enables us to build and distribute applications to analysts that are accessible from Excel, we are quickly bringing to market products that are adopted and deployed by investment banks.”

Peter Orr
Intuitive Analytics

Link to user story
IPD Develops and Deploys Real Estate Cash Flow Models with MathWorks Tools

Challenge
Create cash flow models of real estate investment portfolios and project returns using Monte Carlo simulations

Solution
Use MATLAB and MATLAB Builder NE to develop optimization algorithms, build financial models, and deploy solutions

Results
- Development time cut by 16 weeks
- Updates completed in hours
- Deployment simplified

“The only other approach we seriously considered involved developing a class library in .NET and C#. Development, debugging, and testing would have taken us 37 weeks. Using MATLAB, we completed the project in 21 weeks.”

Peter McAnena
Investment Property Databank

MATLAB graph generated to indicate how total returns from industrial property are likely to behave.
Nykredit Develops Risk Management and Portfolio Analysis Applications to Minimize Operational Risk

Challenge
Enable financial analysts to make rapid, fact-based decisions by providing them with direct access to risk management and portfolio analysis information

Solution
Develop and deploy easy-to-use graphical financial analysis applications using MATLAB and MATLAB Compiler

Results
- Productivity increased threefold
- Operational risk mitigated
- Analysis time reduced from days to hours

“Data handling, programming, debugging, and plotting are much easier in MATLAB, where everything is in one environment. For performance calculation GUIs, MATLAB provides a real error-checked application that makes cool customized plots for client reports. This has turned a several-hour task in a spreadsheet into a two-minute no-brainer.”

Peter Ahlgren
Nykredit Asset Management

Link to user story
Macroeconomic Modeling and Inflation Rate Forecasting at the Reserve Bank of New Zealand

Challenge
Support New Zealand monetary policy with a theoretically well-founded model

Solution
Use MATLAB to analyze and forecast macroeconomic variables, and communicate results to stakeholders

Results
- Entire workflow completed in a single environment
- Code shared with other central banks and financial institutions
- Technical rigor of macroeconomic forecasting increased

“With all RBNZ models now implemented in MATLAB, the RBNZ has a common platform for evaluating the economy and making informed decisions.”

Jaromir Benes
International Monetary Fund

Sample fancharts produced by RBNZ’s macroeconomic model.
Robeco Develops Quantitative Stock Selection and Portfolio Optimization Models with MathWorks Tools

Challenge
Develop, distribute, and maintain quantitative tools for portfolio construction and management

Solution
Use MATLAB and MATLAB Builder NE to develop algorithms, build quantitative models, and deploy solutions

Results
- Applications updated faster
- Black-box solutions eliminated
- Scalability and flexibility increased

“Unlike companies that rely on off-the-shelf quantitative analysis solutions, we can see our process improving all the time. We have the flexibility to continuously improve our algorithms and models in MATLAB—and that is a big advantage.”

Willem Jellema
Robeco

Link to user story
Case Study

Halliburton Makes Oil Exploration Safer Using MATLAB and Neural Networks

“Using MATLAB and MATLAB Compiler, I can develop an application at least 100 times faster than I could with Visual Basic or C. The time we saved on the very first application that we wrote in MATLAB more than paid for the software.”

— Roger Schultz, Halliburton Energy Services
Extra Slides
Machine learning is used everywhere!

• **Computational finance**, for *credit scoring* and *algorithmic trading*

• **Image processing and computer vision**, for *face recognition*, motion detection, and *object detection*

• **Computational biology**, for tumor detection, drug discovery, and DNA sequencing

• **Energy production**, for price and *load forecasting*

• **Automotive, aerospace, and manufacturing**, for *predictive maintenance*

• **Natural language processing**, for voice recognition applications
Machine learning vs. Deep learning

MACHINE LEARNING

Manual Feature Extraction -> Classification

Machine Learning

CAR ✔
TRUCK ❌
BICYCLE ❌

DEEP LEARNING

Convolutional Neural Network (CNN)

Learned Features

95%
93%
3%
2%

CAR ✔
TRUCK ❌
BICYCLE ❌
Write Your Programs Once
Then Share To Different Targets

MATLAB

MATLAB Compiler

MATLAB Compiler SDK

Apps
Files
Standalone Application
Excel Add-in
Hadoop
C/C++
Java
.NET
Python
MATLAB Production Server

Custom Toolbox

With MATLAB Users

With People Who Do Not Have MATLAB
Value of MATLAB Production Server

- Directly deploy MATLAB programs into production
  - Supports multiple MATLAB programs and MCR versions

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

- Use with web, database & application servers
  - Lightweight client library isolates MATLAB processing
Predictive Modeling Workflow

**Train:** Iterate till you find the best model

**Predict:** Integrate trained models into applications
What does Trading Toolbox do?

Market Access

Bloomberg EMSX
X_Trader
Interactive Brokers
CQG

Trading Toolbox

Bloomberg EMSX

Risk Engine
Financial Toolbox
Statistics Toolbox

Pricing Engine
Fin. Instruments Tbx
Financial Toolbox

Trading Engine
Financial Toolbox
Optimization Toolbox
Demo: Lending club overview

- Create Credit Scorecards
- Determine Probability of Default
- Calculate Expected Loss
Demo: Consumer Credit Risk Modeling

- Create Credit Scorecards
- Determine Probability of Default
- Calculate Expected Loss
Demo: Volatility Modeling

Volatility Model Comparison

- Vol Historical
- Vol GARCH 1 - GARCH with bias offset
- Vol GARCH 2 - GARCH with no bias offset
- Neural Net
Sharing MATLAB Applications

- Share applications with those who do not need MATLAB
- Royalty free
- **MATLAB Production Server** provides most efficient path for secure and scalable enterprise applications
Machine learning workflow

Small/Big Data
- Access
  - Files
  - Databases
  - Datafeeds

Predictive Modeling
- Explore and Prototype
  - Data Analysis & Visualization
  - Financial Modeling
  - Application Development

Deploy
- Share
  - Reporting
  - Applications
  - Production

Scale
- Small/Big Data
- Predictive Modeling
- Deploy