Deployment of Real-Time MATLAB Models in Web Applications

*On-Demand Balance Sheet Simulation*

MATLAB Computational Finance Conference 2017

Presenters: Sean Woodworth and Kyle Pastor, Scotiabank
1. Introduction to Balance Sheet Management and Treasury Asset Liability Management

2. What are the problems we are trying to solve in Treasury Analytics using MATLAB?

3. Overview of an in-house built platform for on-demand balance sheet simulation by integrating MATLAB with web technologies

4. Integration of MATLAB Production Server and Parallel and Distributed Computing Toolboxes
QUICK OVERVIEW: WHO ARE WE?

- Scotiabank is Canada’s 3rd largest bank
- Total Assets of over $906 billion (as at July 31, 2017), with 24 million customers
- International footprint – Scotiabank operates in 55+ countries
- We are part of the ALM & Balance Sheet Management team within Scotiabank’s Group Treasury
- The ALM Analytics & Development team creates custom analytics solutions to enable management decisions
- The team is comprised of quants with backgrounds in Physics, Computer Science, and Financial Engineering
The goal of (ALM) is to manage the risk related to changes in interest rates, the mix of balance sheet assets and liabilities, and the use of derivatives to adjust the risk profile, in order to protect and enhance margin.

- The central theme of ALM is the coordinated – and not piecemeal – management of a bank’s entire balance sheet.
- The immediate focus of ALM is interest-rate risk and return as measured by a bank’s net interest margin.
- The primary forms of interest rate risk include:
  - Repricing risk (assets and liabilities do not reprice at the same time or magnitude)
  - Yield curve risk (changes in the slope or level of the curve impact profitability)
  - Basis risk (eg Prime-CDOR)
  - Optionality (Customers exercise options when they are least convenient for the Bank)
- More broadly, the scope of ALM covers the management of liquidity and interest rate risk, Off-balance sheet strategies and can be used to create synthetic hedges to manage asset/liability mismatches.
What is the Typical Structure of a Bank Balance Sheet?

**Assets**
- Residential Mortgages Fixed
- Personal Loans
- Residential Mortgages Variable
- ICA/IBA
- Non-Personal Loans
- Bonds
- Other

**Liabilities**
- Savings/Chequing Accounts
- Personal Term Deposits
- Midterm Wholesale Funding
- Current Accounts
- Wholesale Funding
- Other Liabilities
- Arbitrage Position

Figures shown above are for illustration purposes only.
THE CHALLENGE: Model and Performance Considerations

Scaling from Portfolio Records to Modeling Cash Flows

Sample Portfolio Data Example

<table>
<thead>
<tr>
<th>Product Class</th>
<th># Portfolio Records</th>
<th># of Principal Cash Flows</th>
<th># of Interest Cash Flows</th>
<th>Total Cash Flows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amortizers</td>
<td>135,000</td>
<td>3,900,000</td>
<td>3,900,000</td>
<td>7,800,000</td>
</tr>
<tr>
<td>Bullets</td>
<td>40,000</td>
<td>40,000</td>
<td>1,440,000</td>
<td>1,480,000</td>
</tr>
<tr>
<td>NMDs</td>
<td>100,000</td>
<td>9,600,000</td>
<td>9,600,000</td>
<td>19,200,000</td>
</tr>
<tr>
<td>NRS</td>
<td>25,000</td>
<td>25,000</td>
<td>-</td>
<td>25,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>300,000</strong></td>
<td><strong>13,565,000</strong></td>
<td><strong>14,940,000</strong></td>
<td><strong>28,505,000</strong></td>
</tr>
</tbody>
</table>

- The above table shows an example portfolio and total # of computed cash flows at a single simulation step
- For dynamic ALM modeling we are interested in simulating the portfolio over many time steps (i.e. 3yrs -> 36 monthly steps) and many scenarios (i.e. 20+)
- A single 36 step simulation would require enough processing power and RAM to handle > 1 Billion cash flows through the simulation
THE CHALLENGE: Model and Performance Considerations

From Cash Flows to Metrics

- **DV01 (-1 bps)**
  - Various coupons (0%, 2%, 5%, 10%)

- **Macaulay Duration**
  - Different interest rate scenarios

- **PV**
  - PV vs. time for different coupons

- **NII**
  - Net Interest Income for varying coupons

- **Market Object**
- **Metrics Object**
- **Portfolio Objects**

**Deterministic Curve Path**

**Interest Rate Scenario Generator**

**Yield Curve and Product Pricing Models**
THE CHALLENGE: Model and Performance Considerations

All of the external models are interchangeable and flexible.
THE CHALLENGE: Model and Performance Considerations

TREASURY

- Daily liquidity portfolio management
- Daily P/L expectation
- Risk/earnings forecasting and optimization
- Balance sheet simulation & forecasting
- Hedge optimization
- Regulatory impacts

RISK MGMT

- Capital analysis
- Model review and implementation testing
- Custom simulations
OUR SOLUTION: Balance Sheet Analytics Platform

MATLAB
MATLAB Compiler + SDK

Toolboxes
• Database
• Optimization
• Statistics & Machine Learning
• Parallel Computation

Servers
• Production Server
• Distributed Computing Server
OUR SOLUTION: Example Simulation Step

Forecasting Algorithm

1. Generate Cashflows
2. GenerateReport

Cashflow Data

Reporting

1. CalculateMetrics
2. GenerateReport

Portfolio Statistics

<table>
<thead>
<tr>
<th></th>
<th>Notional</th>
<th>Coupon</th>
<th>Age</th>
<th>Time To Maturity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>5,129</td>
<td>2.37</td>
<td>1.19</td>
<td>3.02</td>
</tr>
<tr>
<td>Liabilities</td>
<td>5,201</td>
<td>1.95</td>
<td>2.74</td>
<td>0.72</td>
</tr>
<tr>
<td>Off Balance Sheet A</td>
<td>337</td>
<td>1.99</td>
<td>3.17</td>
<td>4.78</td>
</tr>
<tr>
<td>Off Balance Sheet L</td>
<td>1,880</td>
<td>0.00</td>
<td>2.23</td>
<td>3.06</td>
</tr>
</tbody>
</table>

NET Interest Margin

1.98 PERCENT
MPS AND THE WEB: High-Level Architecture

Heavy numerical calculations

Interface between the server and the data is used to pre-process data

User sends a request for information (data, simulation etc.)

Processed data is passed back to interface

Data is sent back to the user in a clear concise format
PARALLELIZING THE MODEL: Distributed Cluster Network

- Command line interface to execute many jobs on DCN
- Number of scenarios/hour increased by **10 fold**
- Next Steps: Integrate the DCN into the web
PARALLELIZING THE MODEL: Distributed Cluster Network

<table>
<thead>
<tr>
<th>Number of Parallel Scenarios</th>
<th>Overhead (sec/scen)</th>
<th>Simulation (sec/scen)</th>
<th>Data Transfer (sec/scen)</th>
<th>Total Time (sec/scen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.40</td>
<td>85.86</td>
<td>0.49</td>
<td>94.75</td>
</tr>
<tr>
<td>2</td>
<td>4.45</td>
<td>44.69</td>
<td>0.38</td>
<td>49.51</td>
</tr>
<tr>
<td>3</td>
<td>2.88</td>
<td>30.59</td>
<td>0.32</td>
<td>33.78</td>
</tr>
<tr>
<td>4</td>
<td>2.20</td>
<td>24.60</td>
<td>0.29</td>
<td>27.09</td>
</tr>
<tr>
<td>5</td>
<td>1.76</td>
<td>20.16</td>
<td>0.28</td>
<td>22.20</td>
</tr>
<tr>
<td>10</td>
<td>0.91</td>
<td>11.85</td>
<td>0.27</td>
<td>13.03</td>
</tr>
<tr>
<td>12</td>
<td>0.76</td>
<td>9.95</td>
<td>0.27</td>
<td>10.98</td>
</tr>
</tbody>
</table>
Appendix
CURRENT MPS ARCHITECTURE: Concurrency and MPS

Currently we use multiple MPS instances. Results stored in volatile memory for fast access and calculations.