Facilitating On-Demand Risk and Actuarial Analysis in MATLAB

Timo Salminen, CFA, FRM
Model IT
It is common that insurance companies can valuate their liabilities only quarterly.
  - Sufficient for official valuation and capital calculations

Market (consistent) value of liabilities can be quite volatile.

Need for
  1. knowing liability / equity value today
  2. risk analysis and stress testing
  3. hedge planning / re-balancing
  4. business forecasting
Facilitating on-demand calculations

Current challenges

System A
ESG Calibration simulation

System B
Liability projection

System C
Proxy generation

System D
Stress testing Risk analysis

weeks
MATLAB

ESG Calibration simulation
Liability projection
Proxy generation
Stress testing Risk analysis

minutes seconds
Agenda

Building blocks for on-demand analysis

Building models with Business Language

High-Performance Simulation of the model

Interactive visualization

Case: Life Insurance

Policy-by-policy simulation

Proxy Modeling

%% Define Variable Annuity product terms
myVAProduct_2007 = ... 
cFrame.CashFlowEngine.ContractType(...
   'Name', 'VA Terms 2B/2007');

%% Add claim cash flow
life.AddCashFlow(...
   'Id', 'CLAIM_DEATH', ...
   'Name', 'Death claim', ...
   'Payer', 'company', ...
   'Receiver', 'customer', ...
   'TriggerEvent', 'death_of_customer', ...
   'Amount', @vaClaimAmountFcn );
Building models with "business language"
Business language

• Natural language designed to create realistic contract-by-contract cash flow simulation models
  • 100% replication of real-life contract terms
  • Ability to use real data

• Define all financial contracts as cash-flow exchange agreements
  • Cash flows depend on stochastic events
Example: Defining the death benefit
max(savings account, cumulative net payments)

myProduct.AddCashFlow(...
... Cash flow ID links cash flow to balance sheet
'Id', 'DEATH_BENEFIT', ...
... Long name makes analyzing results easier
'Name', 'Death Benefit payment', ...
... Company pays the claim
'Payer', 'company', ...
... Customer receives the claim
'Receiver', 'customer', ...
... Cash flow is triggered when event 'death' occurs
'TriggerEvent', 'death', ...
... The amount function can be any MATLAB function
'Amount', @(model, customer, contract, eventdata)...
  max(eventdata.investmentFund, eventdata.cumNetPayments));
Example: Defining the death event

Event: Death

Cash Flow: Death benefit

```plaintext
cfModel.DefineRandomVariable(...
    ... This links this random variable to product definitions
    'Name',    'death', ...
    ... This event "happens" to customer and affects all customer's contracts
    'Target',  'customer', ...
    ... This is an event (can also be a process)
    'Type',    'event', ...
    ... This event can happen only once
    'Occurrence',  'single', ...
    ... A function that returns monthly intensities for this event
    'IntensityFun', @deathIntensity;
```
Completing the model
some example objects

- **Event**: Death
- **Cash Flow**: Death benefit
- **Account**: Investment fund
- **Calculation**: Annuity calculation
- **State Variable**: Cumulative net payments
- **Event**: Retirement
- **Cash Flow**: Annuity payment
- **State Variable**: Fixed annuity amount

- **Economic scenarios**
Define death benefit payment

The cash flow

- is paid by company and received by the customer
- is triggered by death event (defined earlier)
- is paid only before retirement period
- amount is greater of cumulative net investments and current investment account value

myProduct.AddCashFlow(...
... Cash flow ID links cash flow to balance sheet
'Id', 'DEATH_BENEFIT', ...
... Long name makes analyzing results easier
'Name', 'Death Benefit payment', ...
... Company pays the claim, the amount is also reduced from savings
'Payer', 'company', ...
... Customer receives the claim
'Receiver', 'customer', ...
... Cash flow is triggered when event 'death' occurs
'TriggerEvent', 'death', ...
... The amount function can be any MATLAB function
'Amount', {'PP', @(model, customer, contract, eventdata)... max(eventdata.investmentFund, eventdata.cumulativeNetPayments), ... 'PU', @(model, customer, contract, eventdata)... max(eventdata.investmentFund, eventdata.cumulativeNetPayments)} ...

Surrender cash flow

file://E:/MATLAB/cFrame Testing/NY cFrame VA/html/VA_FullSim.html
## Making contract-by-contract possible
Comparison using 10 000 scenarios, n computation nodes

<table>
<thead>
<tr>
<th></th>
<th>Traditional systems</th>
<th>Our approach</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Designed for deterministic modelling</td>
<td>Designed for stochastic modelling</td>
</tr>
<tr>
<td>Model is run</td>
<td>10 000 times</td>
<td>1 time</td>
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<td></td>
<td>With full overhead for each scenario</td>
<td>Overhead from model logic and contract terms only once</td>
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<td></td>
<td></td>
<td>Stochastic items (accounts, state variables) are handled efficiently with matrix mathematics</td>
</tr>
<tr>
<td>One node handles</td>
<td>All contracts</td>
<td>1/n of policies</td>
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<tr>
<td></td>
<td>Close to impossible to use real data of millions of contracts</td>
<td>Any number of contracts can be handled with distributed computing</td>
</tr>
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Parallel computing

- Distributable to clusters and Amazon EC2 cloud using MATLAB Distributed Computing Server
  - Accessible from MATLAB workspace
  - Close to linear speedup

- However, contracts may not be independent
  - e.g. company profit sharing to policies depends on performance of the total liability portfolio
  - need to synchronize all policies between company decision points (typically 60)

- MATLAB provided “synchronization” functions (gop) gather results very efficiently
  - Still each second spent increases total time by 60 seconds!
  - Usually not efficient to target simulation times of under 10 minutes.
Use Case: Fennia Life

- **60 000 policies**: With profit annuity
- **30 cash flow and balance sheet items**

**1 desktop computer**
- 12 cores
- 24 GB RAM
- ~ EUR 3 000

**1 000 scenarios**

**60 years**
- 150 Variable time steps from 1 month to 1 year

**30 minutes**

3000 scenarios
Proxy modeling

- Still calculating market (consistent) value for liabilities takes minutes or even hours
- For risk analysis, we need thousands of valuations in seconds ➔ Proxy modeling

Diagram:
- Contract data
- Risk factor scenarios
- Proxy model
- Cash Flows
Traditional way: Regression Analysis

Shocks to initial market conditions

Valuation Scenarios

- Shocked liability values
- Fitted polynomial
- True liability value

- Lots of scenarios required (typically at least 50,000)
- Still only a fraction of space covered
- Fitting points and function form must be decided beforehand
Least Squares Monte Carlo

Valuation Scenarios

Shocks to initial market conditions

- Shocked liability values
- Fitted polynomial

- Independent error terms with zero expected value
- Much less scenarios required (typically 5000)
- No need for selecting fitting points or function form beforehand
Validation

- Proxy model can be always validated by running full valuations at selected validation points and comparing results to proxy value.

- 2500 shocks
- 5 validation points
- On proxy line, cash flow model and proxy model produce the same result.
- Liability value as a function of risk drivers

Value: -2 876 410.52
Change: -20 531.32
Time-decomposition

• Fitting an independent polynomial for each future time step provides a new level information about the liability time structure and sensitivities
Shock Generation

DEMO
Stress generation
See how fully customizable interest rate shocks combined with other market and non-market shocks affect liability exposure (greeks) and profit.
Combining pieces

Proxy Model + Asset portfolio + Real World Scenarios → Liability sensitivity analysis

Proxy Model + Asset portfolio + Real World Scenarios → Balance sheet sensitivity analysis

Proxy Model + Asset portfolio + Real World Scenarios → Full Balance sheet risk analysis and projections
Visualization

DEMO
Example: Balance Sheet sensitivities
Net exposure to joint shocks in mortality and interest rates
Example: Balance Sheet Correlations
Net interest rate sensitivity with two different investment strategies
Example: Balance Sheet projections

Stochastic path dependent multi-year projection of solvency ratio including deterministic stress scenarios

![Graphical analyses of solvency ratio](image)
Summary

- Business Language
  - Rapid development, separate the model and the engine
  - Documentable, auditable
- High-Performance simulation
  - Use real contract data
  - Get results in minutes
- Proxy modeling
  - Run thousands of valuations in seconds
  - On-Demand risk analysis for complex balance sheets
- Visualization
  - Interactive drill down into results
  - Create stress tests, change asset allocation
Thank you!

QUESTIONS?
Contact details

Timo Salminen, tel. +358 50 528 2359 timo.salminen@modelit.fi

Model IT Ltd, Unioninkatu 13 3rd floor, 00130 Helsinki, Finland

www.modelit.fi