Model Efficiency Through Data Compression

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Agenda

• The need for model efficiency
• Types of model efficiency
• Data compression by Clustering
  • How it works
  • Possible refinements to basic method
  • Advantages and disadvantages
  • Comparison to traditional grouping
Model Efficiency – the challenge

- Run time vs. resource cost challenge is faced by many applications, especially:
  - Existing valuation and required capital calculations for VA’s (AG 43, C3 Phase II, FAS 133, SOP 03-1)
  - Pending valuation and required capital calculations for Life products under PBA
  - Economic Capital, MCEV, and future Solvency II
  - Hedging (Greek Calculation) and simulated hedging within actuarial valuation and projections
    - On projected inforce to simulate hedging strategy
    - Double nested projections for current valuation/capital
    - Triple nested projections for projected valuation/capital
  - Any large scale, time consuming modeling application
As a result, Actuarial Models are rapidly growing in size, complexity and demand for IT resources …

Inspiration:
Audrey II from “Little Shop of Horrors
Building a Larger Grid

- Adding more cores to your farm is not always the best option
  - Expensive – servers, memory, network connections, operating software, power, cooling, security, IT support
  - Hardware has limited lifetime – performance, reliability
  - Scalability may be an issue with some software
  - Consolidating results becomes more difficult as Grids increase
    - More nodes feeding results simultaneously into single DB
    - Stretches capacities and speed of disk drives
  - Disaster recovery implies duplicate facility built, tested, then kept idle for guaranteed availability within a day
How to Find Greater System Efficiency?

1. Improved performance hardware, new technology
   • May require redesigning software, recoding in new language
   • May place restrictions on size or design
2. Optimize software implementation for greater efficiency
   • Should have no impact on results
3. Model Efficiency Techniques (find ways to do less work and achieve acceptable model accuracy)

Note: Model Efficiency Work Group (MEWG) created in 2007 by the AAA SVL2 Committee to support PBA project
   • Main MEWG web page on AAA website:
     www.actuary.org/content/academy%E2%80%99s-model-efficiency-work-group
Preferred Model Efficiency Techniques

Attractive characteristics:

• Greatest efficiency for least amount of “error” added
• Both mathematical and intuitive support
• Impact should be fully understood, readily quantifiable
• Easily incorporated in regular production routines without manual intervention
• Flexibility in application
  – option to specify reduction factor and turn on/off
• Useful throughout projections with nested stochastics and not just for current date calculations
• Useful for multiple applications and purposes
How to Find Greater System Efficiency?

What types of Model Efficiency Techniques are used?

- Model simplifications and approximations
  - Less frequent time steps
  - Ignoring or simplifying assumptions
- Scenario generation and selecting reduced scenarios
- Compressing asset and liability inforce models
- Hybrid techniques (data and scenario compression)
- All the above in combination
Model Compression Techniques

• Many companies use traditional grouped data approach:
  o Groups of similar or identical policies treated as one model point
  o Groupings formed by predefined criteria such as specific values or ranges of values; for example:
    • average issue age reflecting 5 or 10 year issue age range
    • average issue date within 3 months or full calendar year
    • similar plan codes represented by most common plan code
  o Model point is a set of identical policies reflecting the average or most common characteristics of the grouping
  o Scaling factor based typically on policy count to reflect the group
• Traditional grouping approach may still be simplest and best method in some cases!
Model Compression Techniques

• “Clustering” is an advanced compression technique
  • Some attractive features vs. traditional grouping
  • Reported to have potential for significant efficiencies in some lines of business, and some applications
  • Included in 2011 SOA funded research project
    o See report by Ernst & Young available from: www.soa.org/Research/Research-Projects/Life-Insurance/research-2011-11-model-eff.aspx

• Also reported in various Section newsletter articles in recent years; e.g. *The Financial Reporter* June 2010 issue:
Clustering Compression Technique

• “Clustering” is a generic technique used in data analysis

• For Model Compression useful for actuarial applications, typically “agglomerative” clustering algorithm is used:
  o Each policy starts as its own “cluster”
  o Distance (similarity) between every pair is calculated using chosen location values (characteristics) for each policy
  o Least important cluster by size and distance from nearest cluster is merged into nearest cluster
  o Original policy in cluster is representative policy of cluster; scaling factor calculated to reflect total volume of cluster
  o Clustering process continues until target ratio (# of clusters) met
  o Better representative policies may be found when finished
Clustering Process Illustration

- Step 1: Seriatim data assigned location variables and size

- 20 seriatim policies of varying sizes and characteristics
- Target compression ratio of 20% (5:1)
Clustering Process Illustration

- Step 2: Distances between all pairs calculated

Distances determine order of clustering from closest to furthest
• Step 3: Closest pairs identified
Clustering Process Illustration

• Step 4: Least important clustered with larger adjacent point
Clustering Process Illustration

• Step 5: Next closest pairs identified
Clustering Process Illustration

- Step 6: Least important clustered with larger adjacent point

Clustered policies
Step 7: Remaining closest pairs identified to reach target
Clustering Process Illustration

- Step 8: Final clustering performed

Target compression level of 20% reached
Clustering Process Illustration

- Result: Highly compressed model and original model

- 20 original policies compressed into 4 clusters
- Representative policies may need to be reset
Refinements to Basic Clustering

- Total portfolio divided into segments; clustering applied only within each segment
  - Different target compression ratios may be set by segment
  - Segments with zero compression target left as seriatim
  - Segment sizes may impact performance of clustering step since distance table (triangle) size is based on N squared

- Multiple clustering processes with different target ratios may be used to generate compressed models for different purposes, or for research into impact
  - one compression run may generate multiple compressed models
Refinements to Basic Clustering

• Choices of Distance measure – measure of similarity that determines order of clustering
  o Distance calculations based on comparing location variables
  o Choices include:
    - Euclidean distance (Square root of sum of squares)
    - Square of Euclidean distance
    - Sum of absolute values of differences
  o Different measures may isolate or combine outliers more effectively
  o Will need to normalize each location variable
    – may also want to apply weightings
• Choosing Measure of Size and Importance
  - A volume or size “Measure” must be selected to accumulate the total size of each cluster and the scaling factor to apply to the representative policy
    - Usually Face Amount or Fund Value, but others possible
    - Only the measure used for scaling can exactly replicate the portfolio; other measures will be approximate
  - A variation would be to allow each Representative Policy values to be adjusted to the cluster average
    - Greater effort, increased risk (need to assure that the adjusted policy is internally consistent, realistic, etc.)
Refinements to Basic Clustering

• Using Different Linkage Rules (How to define distance to a cluster?)
  • Which policy to use?
    – Original representative policy when first merged?
    – Nearest policy, or largest policy?
    – Policy closest to centroid?
  • How often is this representative policy reset for the cluster?
    – Only after target ratio reached?
    – At predefined stages of compression or numbers of steps?
    – Every step?
    – Note: all relevant distances may have to be recalculated for changed clusters unless original distance table retained
Clustering vs. Grouping

• Like traditional grouping, a “central” policy represents the whole cluster, by scaling up the calculated policy results
  o Grouping typically scales by policy count
  o Clustering scales by user selected measure

• Clustering differs from traditional grouping in that:
  o It can work across typical boundaries (sex, UW class, plan)
  o No need to predefine groupings, ranges of ages, issue dates
  o Target compression ratio may be set and compression continues until met
  o Easy to increase or decrease compression ratio to achieve acceptable distortion vs. full seriatim
  o Easy to generate multiple Data Models of different compression levels for different purposes in one process
Clustering Case Study in FR Section Newsletter

- Variable Annuity block with GMAB, GMDB, GMIB, GMWB
  - 100,000 plus policies, $9.5 billion fund value

Figure 3
Impact of Modeling on AG 43 Results ($ millions)

<table>
<thead>
<tr>
<th>Compression ratios:</th>
<th>Liability Cell Count</th>
<th>Stochastic Reserve</th>
<th>Ratio to Seriatim</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>Seriatim</td>
<td>$143.6</td>
<td>100.0%</td>
</tr>
<tr>
<td>5.0%</td>
<td>5,000</td>
<td>$144.2</td>
<td>100.4%</td>
</tr>
<tr>
<td>2.5%</td>
<td>2,500</td>
<td>$143.9</td>
<td>100.2%</td>
</tr>
<tr>
<td>1.0%</td>
<td>1,000</td>
<td>$141.6</td>
<td>98.6%</td>
</tr>
<tr>
<td>0.25%</td>
<td>250</td>
<td>$140.6</td>
<td>97.9%</td>
</tr>
<tr>
<td>0.05%</td>
<td>50</td>
<td>$136.7</td>
<td>95.2%</td>
</tr>
</tbody>
</table>
Clustering Case Study in FR Section Newsletter

- Variable Annuity block running AG 43
  - 100,000 plus policies, $9.5 billion fund value
  - GMAB, GMDB, GMIB, GMWB
  - Case study used following location variables calculated across 5 representative scenarios:
    - initial GMB face amount for each benefit type and guarantee type,
    - initial account value in-force by fund,
    - present value of net revenue,
    - present value of commission income,
    - present value of revenue sharing,
    - present value of maintenance expenses,
    - present value of M&E fee income, and
    - present value of net benefit costs for each GMB type (benefits paid less associated charges).

  Easily obtained from in force files

  Requires some seriatim preprocessing
### Figure 1
Analysis of Fit Variables as of Valuation Date
($ millions)

<table>
<thead>
<tr>
<th>Weight</th>
<th>Seriatim</th>
<th>Ratio to Seriatim for Differing Cell Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Inforce GMB Face Amounts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GMDB Ratchet</td>
<td>1</td>
<td>$7,733</td>
</tr>
<tr>
<td>GMDB Rollup</td>
<td>1</td>
<td>$4,058</td>
</tr>
<tr>
<td>GMDB ROP</td>
<td>1</td>
<td>$4,515</td>
</tr>
<tr>
<td>GMIB Ratchet</td>
<td>1</td>
<td>$7,545</td>
</tr>
<tr>
<td>GMIB Rollup</td>
<td>1</td>
<td>$8,181</td>
</tr>
<tr>
<td>GMAB ROP</td>
<td>1</td>
<td>$281</td>
</tr>
</tbody>
</table>

Note the varying impact of compression by benefit type
Clustering Investigation or Implementation

- Clustering algorithms are generally available in software used for data analysis, statistics (e.g. MatLab)
- Available in at least two common modeling platforms
- Preferably it should be easily integrated into your production process and require little manual intervention
- You will need research to discover
  - optimal choices for segments, location variables and target ratios in each product portfolio and application
  - the corresponding distortion in application results
THANK YOU!