Parallel VTFR

Riccardo Gismondi   Christian Kremnitzer

May 30, 2008

High Performance Computing in Finance and Insurance
Research Institute for Computational Methods
Vienna University of Economics and B.A.

HPCFaI

Contents

HPCFal

Team HPCFaI

- Teamlead: Riccardo Gismondi
- Researchers:
  - Kujtim Avdiu
  - Bernhard Bruckner
  - Christian Kremnitzer
  - Peter Kreuzinger
  - Johannes Menzel
- start in June 2007

Our Projects

- PVTFR (Parallelized Valutazione Trattamento Fine Rapporto) - **to be presented at OR 2008 in Augsburg, September 2008**
- Application of Parallel Genetic Algorithms for the Calibration of Financial Models (FIRM presentation in June 2008)
- Model Risk and Calibration Risk
- Just-In-Time Implied Volatility Estimation of Stock Options applying Parallel Computing
- Asset Liability Management, Stochastic Optimization and Parallel Computing
- Optimal Trading Strategies through Genetic Programming
- Parallel SPES (Standard Pricing Estimator System)

today, we will provide an insight into PVTFR

HPCFaI

An Introduction to VTFR

- VTFR: Valutazione Trattamento Fine Rapporto
- target of VTFR:
  - to calculate a robust estimation of future pension liability for a dedicated company for all its employees
  - in Italy, as well as in other European countries it is a legal obligation (see IAS 19)

HPCFal

Input Values of VTFR

- **interest rate**
- **inflation rate**
- basic salary growth rate
- salary growth rate dependent on employee qualification level
- **death probabilities**
- probabilities of invalidity
- **probabilities of dismissal**
- hypothesis for payments in advance

- we have to deal with a great number of input factors
- input factors are stochastic
- we do not know the joint distribution of the input factors

$\Rightarrow$ Monte Carlo Approach

HPCFal

Monte Carlo Approach in VTFR

- employees stay in a company and the pension liabilities increase, until an employee
  - dies,
  - becomes invalid,
  - leaves the company (dismissal) or
  - retires
- we estimate the pension liabilities by
  - generating a huge number of employee's life paths
  - estimate future pension liabilities
  - discount future liabilities to current time

    => taking the average gives us the MC estimator

HPCFal

Specification of Input Parameters

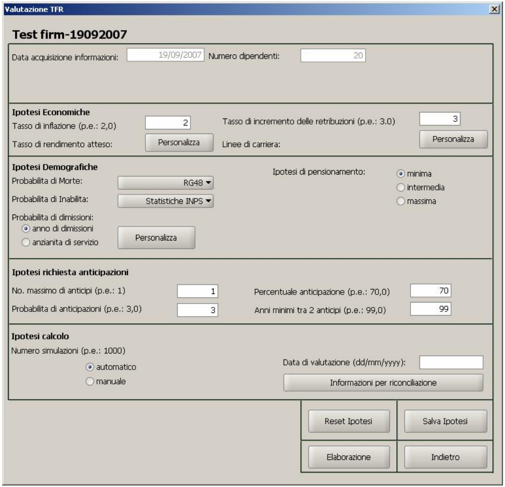

Figure: Specification of Input Parameters

HPCFaI

Specification of Input Parameters II

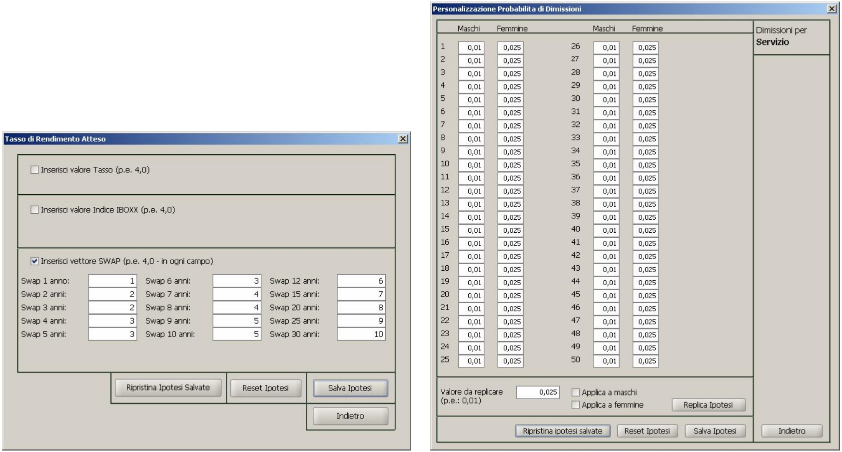

Figure: Specifying Interest Rate and Probability of Dismissal

HPCFaI

Results

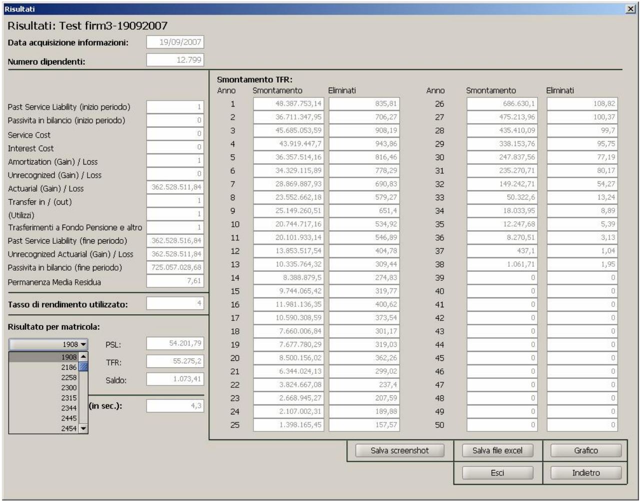

Figure: Results of VTFR Estimation

HPCFaI

VTFR technology

JAVA

- primarily the implementation was based on JAVA, since
  - JAVA is fast, platform independent and today the de facto standard in programming

C

- computing intensive applications were sourced out to C, since
  - C is machine oriented and
  - especially for huge companies that have lots of employees, the computational time can be reduced substantially
  - using JNI (JAVA Native Interface)
  - this is where the Cluster@WU and PVTFR comes in

HPCFal

What factors mostly affect the results?

- question:
  - **What are the factors that most influence the results of VTFR?**
- answer:
  - **Interest Rate**
  - **Inflation Rate**
  - **Probabilities of Dismissal**
- also the death probabilities are time variant
- the population more and more grows older
- i.e. e.g. a 30-year old man in 2008 has generally a higher death probability than a 30-year old in 2010
- dynamic death tables considering future death probabilites are included

HPCFal

What factors mostly affect the results?

- include scenario analysis for the 3 risk factors
- this enables a more robust estimation of future pension liabilities
- we have to care about the restrictions of the Cluster@WU
  - since we still have $68 \times 2 = 136$ processors, we can not run as much scenarios as we want in a reasonable time
  - consequently, we have to apply adequate sampling techniques

Sketch of Program Sequence

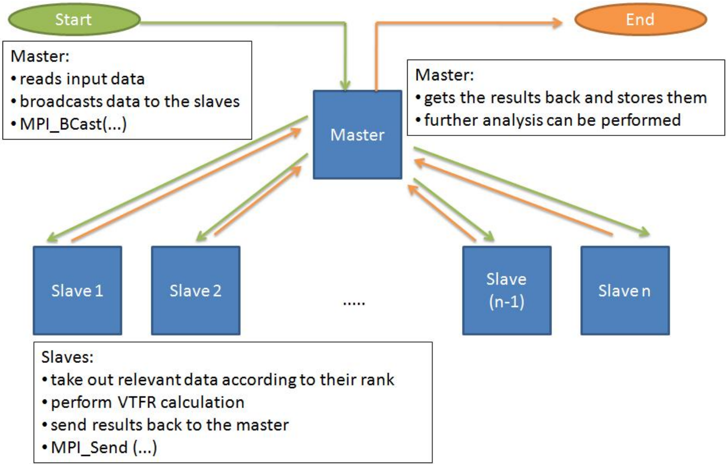

Figure: Sketch of Program Sequence

HPCFaI

Short Explanation of Program Sequence

- currently, the application uses a 21 node framework (1 master + 20 slaves)
- the number of scenarios is equivalently shared between the slaves
- e.g. 100 scenarios $\div$ 20 slaves = 5 scenarios per node
- the VTFR calculation lies completely on the slaves
- no communication between the slaves necessary
- each slave returns its results to the master
- the master bundles the results into one array and saves the results to the output file
- further analysis can be performed

Running VTFR in an MPI Environment

- an excerpt of our mpi.job file:
  - #$ -N vtfr
    #$ -pe lam 21
    #$ -q node.q

    mpirun -t -np 21 ./mm -t –pdata parameters.txt –cdata company.txt –sdata scenariodata.txt -e 12799 -s 100

    lamtrace -mpi trace.ltr

HPCFaI

Running and Debugging an MPI Task

- debugging parallel applications is a very challenching task
- visualization can help you
- XMPI - `http://www.lam-mpi.org/software/xmpi/`
- bar chart:
    - RED: blocked, waiting on communication
    - YELLOW: time spent inside an MPI function
    - GREEN: node is running
- additional analyse tools:
    - pie charts
    - traffic lights

HPCFal

Graphical Debugging Tools

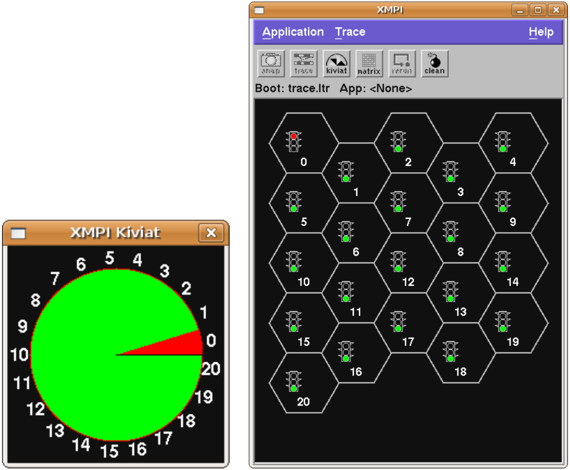

Figure: Pie Charts and Traffic Lights can be very helpful

HPCFaI

Visualized Program Sequence observed with MPI Trace

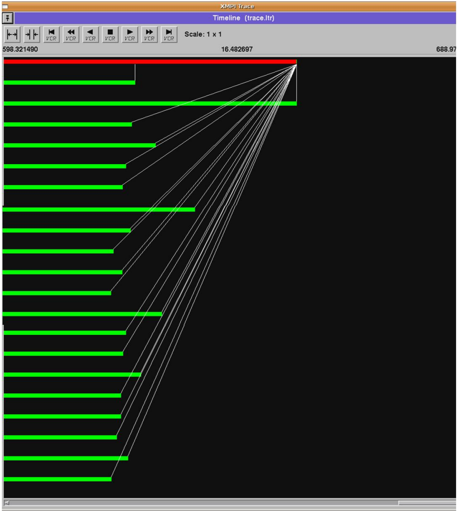

Figure: PVTFR Program Sequence

A theoretical computational example

- given a company (Italian bank) with 12.799 employees
- and let us assume that our cluster offers approximately 100 free nodes

	Computational_Time@Cluster@WU
1 simulation within a single scenario	0.03 sec.
10.000 simulations necessary for robust estimations	10.000 * 0.03 sec. = 300 sec. = 5 min.

HPCFal

A theoretical computational example

- we started out with

100 scenarios for	interest rate
100 scenarios for	inflation
100 scenarios for	probabilities of dismissal

- this leads to a computational time of

100 scenarios $\times$ 5 min. per scenario / 100 nodes = 5 min.

- there is no problem running the interest-, inflation-, dismissal-scenarios separately
- even when fewer nodes are in use
(e.g. for 20 available nodes:
100 overall nodes / 20 nodes available $\times$ 5 min/scenario = 25 min)

HPCFaI

A theoretical computational example

- the combination of all the $100 \times 100 \times 100 = 10^6$ scenarios will be a serious problem
- theoretically:

$$\boxed{\begin{array}{c} 10^6 \text{ scenarios} \times 5 \text{ min/scenario} / \text{ } 100 \text{ nodes} = \\ 50.000 \text{ min} = 833{,}33 \text{ hours} = 34{,}72 \text{ days} \end{array}}$$

- this is definitely too long
- coming from the other side and asking
  - "How long is the application allowed to run?"
    and
  - "How many scenarios can be performed within this time?"

HPCFaI

A theoretical computational example

- the reduction of e.g. 60 % of the relevant scenarios will lead to
- $40 \times 40 \times 40 = 64 \times 10^3$ scenarios and this will take
- theoretically:

$$64 \times 10^3 \text{ scenarios} \times 5 \text{ min/scenario} / \ 100 \text{ nodes} = \\ 3.200 \text{ min} = 53{,}33 \text{ hours} = 2{,}22 \text{ days}$$

- even not using all the nodes from the Cluster@WU, this will be a reasonable compromise
- consequence:
  - **provided that the underlying problem is designed badly, not even an expensive high performance computer can help you**

HPCFal

First Results of Estimation

- starting with 100 basic scenarios
  - inflation rate: 0.02
  - interest rate: EUR SWAP
  - probabilities of dismissal: observed data from customer
  - number of simulations: 10000

Mean	3.47339229×10^8
Std. Deviation	1.78273464×10^3
Skewness	-0.16631471
Kurtosis	3.52817135
Min.	3.47334258×10^8
Max.	3.47344773×10^8

Interest Rate Scenarios

- generate scenarios by applying a base point shift of ± 50 BP on the EUR SWAP curve

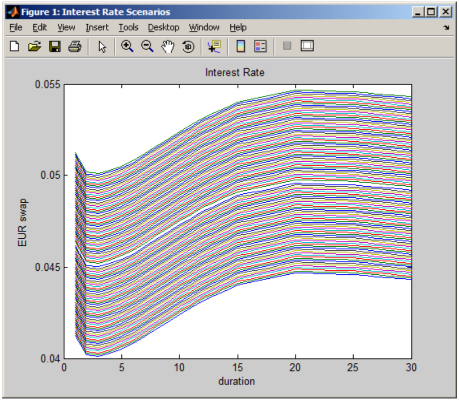

Figure: Generating Interest Rate Scenarios

HPCFal

Results for the Interest Rate Scenarios

- scenario: Variant Interest Rate
  - inflation rate: 0.02
  - interest rate: EUR SWAP $\pm$ 50 BP
  - probabilities of dismissal: observed data from customer
  - number of simulations: 10000

Mean	3.47216065×10^8
Std. Deviation	6.34285683×10^6
Skewness	0.03457363
Kurtosis	1.78334055
Min.	3.36624497×10^8
Max.	3.58166489×10^8
Max. - Min.	21.541992×10^6

HPCFal

Impact of Scenario Implementation

- scenario P/L relative to the mean of our base scenario
  - **best case:**

    absolute difference: 336.62 Mio - 347.34 Mio. = -10.72 Mio.
    relative difference: -3.08 %
  - **worst case:**

    absolute difference: 358.17 Mio - 347.34 Mio. = +10.83 Mio.
    relative difference: +3.12 %

HPCFai

Inflation Scenarios

- base on historical CPI (Consumer Price Index) data
- modeling the inflation as Geometric Brownian Motion

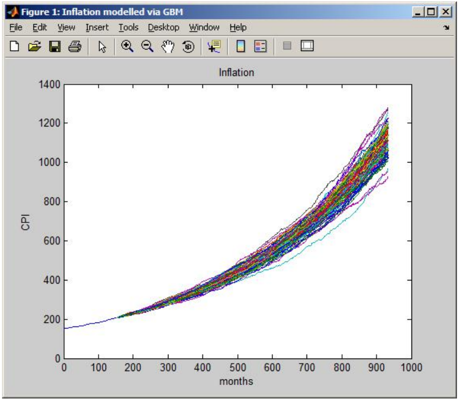

Figure: Inflation Scenarios

HPCFaI

Results for the Inflation Scenarios

- scenario: Variant Inflation Rate
  - inflation rate: modeled via Geometric Brownian Motion
  - interest rate: EUR SWAP
  - probabilities of dismissal: observed data from customer
  - number of simulations: 10000

Mean	3.56176609×10^8
Std. Deviation	3.53186509×10^6
Skewness	-0.04253140
Kurtosis	2.47621072
Min.	3.46543358×10^8
Max.	3.63930861×10^8
Max. - Min.	17.387503×10^6

HPCFal

Impact of Scenario Implementation

- scenario P/L relative to the mean of our base scenario
  - **best case:**

    absolute difference: 346.54 Mio - 347.34 Mio. = -0.80 Mio.
    relative difference: -0.23 %
  - **worst case:**

    absolute difference: 358.17 Mio - 347.34 Mio. = +16.59 Mio.
    relative difference: +4.78 %

HPCFal

Scenarios for Probabilities of Dismissal

- based on observed data from our customer
- dependent on the number of years an employee is with the company, the probability of dismissal reaches from 3.5 to 0.5 %
- adding some noise $N(0, 0.15)$ to the data generates our scenarios

Probabilities of Dismissal

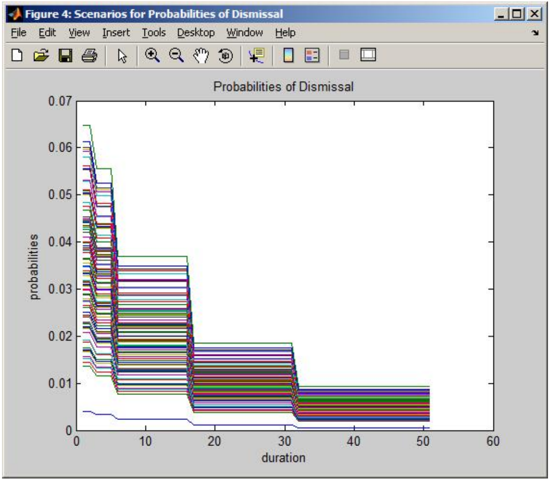

Figure: Scenarios for Probabilities of Dismissal

HPCFal

Basic and Extreme Scenarios

- just to point out the **basic**, **lowest** and **highest** scenario

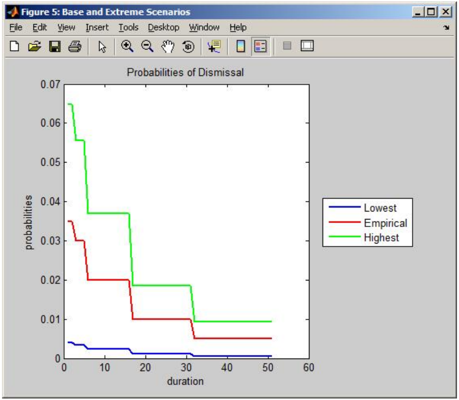

Figure: Showing the Extreme Scenarios Explicitly

HPCFaI

Results for the Dismissal Scenarios

- scenario: Variant Probability of Dismissal
  - inflation rate: 0.02
  - interest rate: EUR SWAP
  - probabilities of dismissal: observed data + a noisy component $N(0, 0.15)$
  - number of simulations: 10000

Mean	3.46967848×10^8
Std. Deviation	2.76540192×10^6
Skewness	-0.24027199
Kurtosis	3.08889392
Min.	3.40099136×10^8
Max.	3.54701025×10^8
Max. - Min.	14.601889×10^6

HPCFal

Impact of Scenario Implementation

- scenario P/L relative to the mean of our base scenario
  - **best case:**

    absolute difference: 340.10 Mio - 347.34 Mio. = -7.24 Mio.
    relative difference: -2.08 %
  - **worst case:**

    absolute difference: 354.70 Mio - 347.34 Mio. = +7.36 Mio.
    relative difference: +2.12 %

HPCFaI

Next steps

- combining scenarios
- applying adequate sampling techniques on multivariate stochastic processes
- combine sampled scenarios and
- perform a robust estimation of future pension liabilities

HPCFal

Thank you for your attention!