



# UniCredit

Markets & Investment Banking

## **Pricing Structured Derivatives**

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Experiences with High-Performance Computing at HVB/Unicredit MIB

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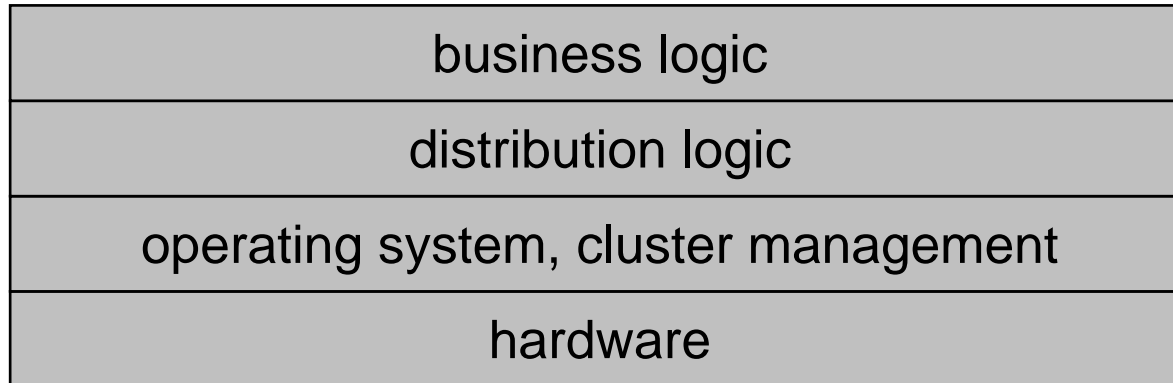
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Stuttgart, 27 May 2008

# What this talk will be about

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- Computing prices and sensitivities of structured derivatives
- Parallelization of CPU-intensive Monte-Carlo simulations
- Component stack:



This presentation will concentrate on distribution and business logic.

# Recap: Monte-Carlo Pricing of Structured Derivatives

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- Structured derivative:
    - A contract about future payments depending on future market prices (of stock, commodities, ...).
    - More complex constructions are possible.
  
  - Monte-Carlo pricing:
    - Randomly generate a high number of possible future market developments.
      - E.g., simulate prices for relevant stock and relevant future dates.
      - The stochastic distribution of the samples must fit with certain model assumptions and market observations.
    - For each generated possible future:
      - Compute the resulting future payments.
      - Discount them to their present value.
      - Add them up (if there are multiple payments).
    - Take the average over all generated futures as an approximation of the "fair price".
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# Properties of the Monte-Carlo Approach

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- computationally expensive
  - short simulation steps
  - slow convergence:  $O(1/\sqrt{n})$
  
- still the best solution for many complex derivatives
  
- easy to parallelize  
(see next slide)

# Levels of Parallelization

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- Parallel pricing of different instruments
    - simple
    - limited granularity
    - sufficient for simple pricing models
  
  - Parallelization of Monte-Carlo simulations
    - necessary for more complex pricing models  
(Monte-Carlo simulations are CPU-intensive!)
    - still relatively simple:
      - Each subjob calculates a subset of the MC samples.
      - Communication happens only at the beginning and the end of a subjob.
      - No synchronization is needed.
      - This allows for flexible job scheduling.
    - sufficient granularity
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# Speeding Things Up

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- Hardware
  - more blades
  - newer/better blades
- Software
  - low-level tuning
  - elimination of redundant computations
  - mathematical optimizations

Tradeoff:

- Hardware
    - more plannable (as long as the distribution logic and the network scales)
  - Software
    - cheaper (at least initially)
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## Speeding Things Up (cont.)

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- Any speedup will immediately be consumed by more computations:
  - more Monte-Carlo samples for more accurate results,
  - more sensitivities ("Greeks" and risk scenarios),
  - more frequent recomputation of instrument prices,
  - more business.

# Failure Tolerance

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The reliability of the cluster is ensured on multiple levels:

- Hardware:
    - replicated central components
    - distributed over two locations
    - redundant networks
  
  - System level:
    - heartbeat, automated failover
  
  - Distribution logic  
(see next slide)
  
  - Administration tools:
    - logging
    - system monitoring
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# Failure Tolerance in the Distribution Logic

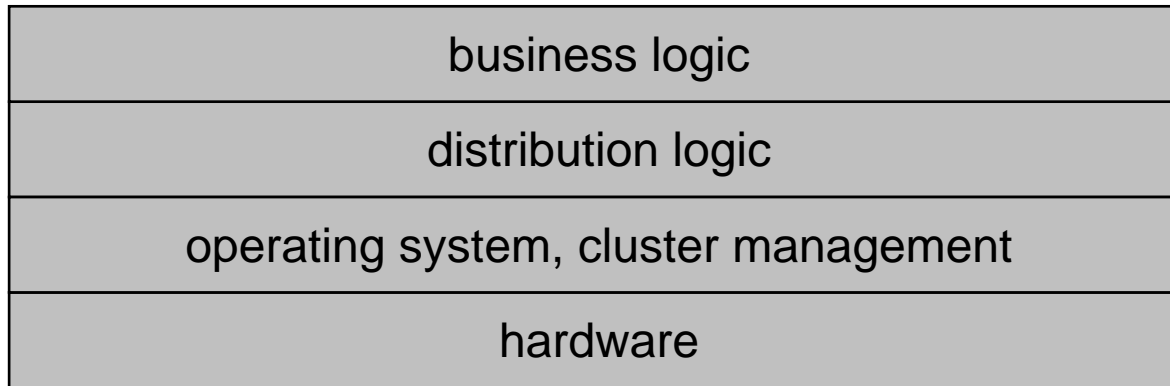
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- Possible failures:
    - hardware or system level
    - application level (highly volatile code!)
      - crashes
      - runaway computations (e.g., infinite loops)
      - hang-ups (e.g., due to memory exhaustion)
        - Delimit impact to the problematic calculation jobs.
  - Possible reactions:
    - Restart worker process or reboot blades.
    - (Stop and) retry failed (sub)jobs.
    - Give up after a few attempts.
  - Choice of granularity:
    - How frequently do failures occur?
    - How much investment of CPU time are we willing to lose?
    - How expensive are safety measures?
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# Specialized and Standard Software Components

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- Component stack:



- Component provenance:

- standard components (commercial or open-source)
- specifically (but externally) developed components
- in-house development

# Specialized and Standard Software Components (cont.)

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- Further up in the stack, components tend to become more specific.
  - Over time, innovative approaches may become standardized.  
But:
    - Never touch a running system.
    - Do standard components really fit our needs?  
Examples:
      - Flexibility of job submission/scheduling not needed.
      - Job synchronization and communication not needed.
  - Over the lifetime of a component, it moves
    - from fundamental design and implementation
    - towards incremental improvements and tuning.This implies a change in the development model:
    - Initial design requires deeper expertise → external development.
    - Small changes take less overhead when handled in-house.
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# Heterogeneity

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- Reasons:
    - to meet different user needs
    - to preserve investments
  
  - Heterogeneous hardware:
    - Intel vs. AMD
    - hyperthreading vs. multi-core processors
    - mixed number of cores per CPU
    - diskless vs. disks
  
  - Heterogeneous software:
    - Linux vs. Windows
    - C++ vs. Java vs. .NET
    - different kinds of financial derivatives
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# History of Parallelized Pricing at HVB

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- early 2003:
    - several PCs without a dedicated network
    - instrument-level parallelization only
  - mid 2003:
    - several PCs with a dedicated switch
    - parallelization of Monte-Carlo simulations
  - late 2003:
    - a small blade-based cluster, two-level MC parallelization
  - 2004:
    - a serious blade-based cluster
  - meanwhile:
    - several cluster extensions
    - more functionality, optimizations, improved robustness
    - another cluster with different operating-system, distribution, and application layers
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# Your contacts

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## **Imprint**

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as of 19 May 2008