OPEN RISK ENGINE

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QuantLib User Meeting, London, 12 July 2016
AGENDA

Open Risk Engine Summary

QuantLib Extension Library

Data Library

Analytics Library
OPEN RISK ENGINE SUMMARY
1. is a transparent platform for pricing and risk analysis, serves as
   · benchmarking, validation, training, teaching reference
   · extensible foundation for tailored risk solutions
2. extends QuantLib (simulation models, instruments, engines)
3. adds contemporary risk analytics and value adjustments
4. adds simple interfaces for trade/market data and system config
5. adds simple launchers in Excel, LibreOffice, Python, Jupyter
6. is free/open software, provided under the Modified BSD License
7. is sponsored by Quaternion Risk Management (www.quaternion.com).
COMPONENTS

- Basic Application/Launchers
- Risk Analytics
- Interfaces and Data Management
- QuantLib
  - QL Extension
- Boost Libraries
TIMELINE

Milestones

· Beta Release: 11 July 2016

· Release: September 2016
ORE provides

1. Portfolio pricing, cash flows, sensitivity analysis, stress testing

2. Derivative portfolio analytics based on Monte Carlo simulation
   - Credit exposure evolution taking netting and collateral into account (EE, EPE, EEPE, PFE) supporting regulatory capital charge calculation under internal model methods
   - Market risk measures (VaR, ES)
   - Derivative value adjustments (CVA, DVA, FVA, COLVA)

3. Parametric (non-simulation) analytics for risk and capital
   - Initial Margin methods to benchmark ISDA’s SIMM
   - SA-CCR, the new standard method for derivatives capital
ORE’s initial product scope comprises Interest Rate and FX products

- Interest Rate Swaps
- Caps/Floors
- Swaptions
- Cross Currency Swaps
- FX Forwards
- FX Options

The simulation models applied in ORE are based on: Modern Derivatives Pricing and Credit Exposure Analysis Palgrave MacMillan 2015
ORE comes with extensive tests, examples and documentation

- Test suites with good coverage from the start
- Various examples which demonstrate typical use cases
- Several ways to launch ORE and visualise results
- A detailed user guide covering examples and parametrisation
- Comprehensive source code documentation
A series of further releases is scheduled, covering:

- Sensitivity analysis, stress testing capability
- Credit simulation, Credit Derivatives and Loan products
- Default risk modeling and credit portfolio analysis
- Inflation simulation and Inflation Derivatives
- Equity simulation, Equity Derivatives
- Commodity simulation, Commodity Derivatives
- Open Risk Engine Book
Connect with ORE

- Follow us on Twitter @OpenRiskEngine
- Watch announcements on www.openriskengine.org

Once released:

- Fetch ORE from github.com/openriskengine
- Use ORE
- Share feedback
- Send pull requests
QUANTLIB EXTENSION LIBRARY
QuantExt adds supplementary building blocks to QuantLib

- a cross asset model and associated pricing engines
- rate helpers for bootstrapping cross currency and tenor basis curves
- a few instruments like currency swaps, basis swaps and average OIS swaps
- additional currencies and indexes
The directory structure is like in QuantLib

QuantExt / qle / cashflows
currencies
indexes
instruments
math
methods
models
pricingengines
processes
quotes
termstructures

QuantExt / test /
<table>
<thead>
<tr>
<th>Library</th>
<th>Files</th>
<th>Lines of Code</th>
<th>Unit Test Cases</th>
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<tr>
<td>OpenRiskEngineAnalytics</td>
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<td>Sum</td>
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<td>47k</td>
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QuantExt provides an implementation of a cross asset model

- multi-Gaussian IR-FX (-INF-CR-EQ-COM)\(^1\)
- exact discretization of the underlying stochastic process for large step simulations
- utilizing Joshi’s Sobol Brownian bridge generator provided in QuantLib’s market model implementation
- analytic vanilla option engines for fast calibration
- extensible - other models can be plugged in (Heston, multifactor LGM, stochastic basis models, ...)

\(^1\)INF, CR, EQ, COM will be part of later releases
Extensive test suite, e.g. for the model part

- consistency with finite difference and Gaussian1D pricing engines in QuantLib
- recovery of analytical moments by Euler Monte Carlo
- martingale property of deflated payoffs
- repricing of calibration baskets with Monte Carlo
QuantLib 1.8 can be used for efficient XVA simulations

- no modifications in QuantLib necessary - this is fantastic
- but we use workarounds at some places, which are efficient in practice, but not clean
- in the following we derive proposals for future QuantLib development from this
We make extensive use of evaluation date shifts during simulation

- provide floating and fixed reference date term structures consistently throughout the library
- expose `TermStructure::moving_` to make fixed and floating term structures distinguishable during run time\(^2\)
- add floating lags for NPV and settlement date parameters in pricing engines, for example and notably in the `DiscountingSwapEngine`
- provide fixed and floating bootstrap helpers

\(^2\)Note that in addition there are the term structures that manage their reference date themselves
PROPOSAL #2 QUOTES

Quotes are the central tool to apply scenarios to term structures during simulation

- support quotes in ExchangeRateManager
- provide quote based constructors in term structures consistently
Observability is used to propagate quote updates to term structures and instruments during simulation

- A naive use yields correct results, but may be slow
- Deferral of notifications\(^3\) does not seem to speed up our simulation or even slows it down in cases
- Our workarounds are
  - Disable Notifications and manually update term structures and instruments
  - Unregister coupons from evaluation date observation
- Goal: Can we tape the notification graph on a small subset of simulation paths (or one path) and derive a minimal set of objects that needs to be updated from that?

\(^3\)Introduced in QuantLib 1.8
During simulation, future fixings have to be generated and published

- required fixings are implicitly known from pricing on the original evaluation date.

- no global notification of all observers\textsuperscript{4} necessary when adding a simulated fixing

- pathwise generation of future fixings and publishing them can be automated by an extension of \textit{Index}

- no need for changes in pricing engines

- (almost) zero overhead when simulated fixings mode is disabled

\textsuperscript{4}typically floating rate coupons
DATA LIBRARY
· OpenRiskEngineData is a C++11 library that manages market and trade data

· Configured via API or XML (using RapidXML)

· Flexible curve bootstrap can be configured for Libor, OIS, XOIS, etc leaving the choice to users

· Curve configuration defined for all market curves (option surfaces/cubes) which maps to QL TermStructures

· Lightweight portfolio data model

· Again trade XML maps to QL Instruments
<Trade id="123456">
  <TradeType>Swap</TradeType>
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  </Envelope>
  <SwapData>
    <LegData>
      <LegType>Fixed</LegType>
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        <TermConvention>
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  </SwapData>
</Trade>
· Interface `openriskengine::data::Market` defines a complete set of all the market instruments and curves (as Handles to QL objects) needed for pricing

```cpp
class Market {
    //...
    virtual Handle<YieldTermStructure> discountCurve(const string& ccy) = 0;
    virtual Handle<IborIndex> iborIndex(const string& indexName) = 0;
    virtual Handle<Quote> fxSpot(const string& ccypair) = 0;
}
```

· `TodaysMarket` implements this interface using curves bootstrapped as on previous slide

· `openriskengine::data::EngineFactory` takes a Market and generates QuantLib::PricingEngines for the portfolio (Actual engine choice and parameters are configurable via API/XML)

· TodaysMarket + EngineFactory + Portfolio = T0 pricing
OpenRiskEngineAnalytics is a smaller library built on top of QuantLib, QuantExt and OpenRiskEngineData.

Provides a framework for Monte-Carlo simulation of future NPVs, aggregation and (in the future) market risk sensitivities.

We use the following common definitions:

- **DateGrid** a set of future dates we wish to calculate exposure on
- **Cube** the 3-D matrix of trade NPVs for the portfolio on each path and each date in the date grid
- **Scenario** A set of simulated market data points represented as a set of `QuantLib::Real` values
- **ScenarioGenerator** A class that combines a model, date grid and PRNG to generate Scenarios.

Scenarios can be generated by a CrossAssetModel, a Real world model or a set of defined sensitivities.
analytics::ScenarioSimMarket is a concrete implementation of the data::Market interface that is Quote based.

The method ScenarioSimMarket::update() retrieves a Scenario from a ScenarioGenerator and updates the underlying Quotes.

When a portfolio's EngineFactory uses this Market, then all Instruments will be directly linked to the Market's TermStructures and Quotes.

Therefore, to price under a scenario we simply call update() and then loop over the portfolio calling Instrument::NPV()

This relies heavily on QuantLib's Lazy Object and Observer patterns.
LOOP ORDER

- To compute a Cube, we essentially have three nested loops
- Innermost loop is over portfolio ⇒ two options remain

- Option 1 - Outer Loop over Dates, then Paths
  Pro  Minimise date changes - Rebuild static TermStructures at each date and so can use both floating or fixed reference dates.
  Con  Need to cache scenarios, creates a memory constraint on the number of paths we can run
  Con  Fixings are difficult to do properly
  Con  Need to maintain state for path dependant trades

- Option 2 - Outer Loop over Path
  Pro  Can price on a path and maintain fixings easily
  Pro  Can stream scenarios, no memory constraints
  Con  All TermStructures must have a floating reference date
  Con  Need to do multiple asof date changes, not cheap
· **Settings::evaluationDate** is observed a lot.
· Analysis from an early version of OpenRiskEngine:
  · 100 Fixed vs. Floating Swaps, Average maturity = 16.2 years
  · Total of 3,778 Floating Rate Coupons
  · Single call to `Settings::instance().evaluationDate()` = `d`; takes 1,500 microseconds.
  · 1,000 samples and 80 dates ⇒ 120 seconds.
  · Update time is all notification, does not change even at later grid dates when trades are expired.
  · `evaluationDate` is observed by 4,915 observers.
  · Total number of notifications is 34,848
  · Each notification is fast (we are doing 24 per microsecond).
  · However total number is massive (over 2.7 Billion)
  · Deepest chain is of depth 6
· There is a lot of overlap in the notification chain.
· Consider a simple 3 coupon swap.

· Swap is notified 7 times \((2n + 1)\) of a change in the eval date
All of the following solutions are available in OpenRiskEngine

1. Do nothing.
   · everything is working as designed and all values are correct
   · it can be slow

2. Minimise notification chain
   · Reduce the notification chain by careful selection or implementation of market data objects
   · remove duplication by unregistering connected observers with common observables (e.g. floating rate coupon and index)

3. Disable all notifications
   · Use `ObservableSettings::disableUpdates(false);`
   · Disable notifications and maintain a separate list of observers that require explicit notification
   · Notification still preformed, but the large chains do not kick in.

4. Defer all notifications
   · Use `ObservableSettings::disableUpdates(true);`
   · Defer notifications until all market quotes and fixings have been updated. This is generally slower than (1)!
· Swap exposure benchmark test runs a portfolio of vanilla swaps over 1,000 samples and 80 dates.

· Cube generation time in seconds

<table>
<thead>
<tr>
<th>Mode</th>
<th>1 Swap</th>
<th>100 Swaps</th>
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</thead>
<tbody>
<tr>
<td>None</td>
<td>12.64</td>
<td>320.99</td>
</tr>
<tr>
<td>Minimise</td>
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<td>Disable</td>
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<tr>
<td>Defer</td>
<td>13.32</td>
<td>349.07</td>
</tr>
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</table>
Questions?