OPEN RISK ENGINE

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AGENDA

Open Risk Engine Summary

QuantLib Extension Library

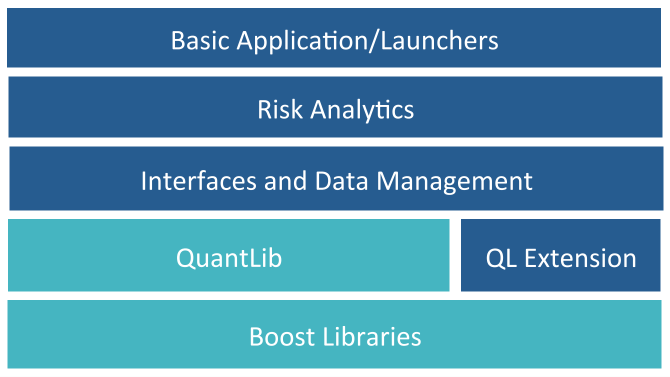
Data Library

Analytics Library

OPEN RISK ENGINE SUMMARY

OPEN RISK ENGINE ...

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).


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

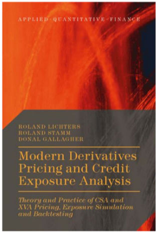
1. Portfolio pricing, cash flows, sensitivity analysis, stress testing
2. Derivative portfolio analytics based on Monte Carlo simulation
   - Credit exposure evolution taking netting and collateral into account (EE, EPE, EEPE, PFE) supporting regulatory capital charge calculation under internal model 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

PRODUCTS

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



SCOPE

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

ROADMAP

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 - 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

STRUCTURE

The directory structure is like in QuantLib

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

Library	Files	Lines of Code	Unit Test Cases
QuantLib	~ 2400	360k	646
QuantExt	~ 200	20k	36
OpenRiskEngineData	~ 160	20k	20
OpenRiskEngineAnalytics	~ 60	7k	21
Sum	~ 420	47k	77

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

TEST SUITE

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

PROPOSAL #1 FLOATING TERMSTRUCTURES

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

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[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

PROPOSAL #3 OBSERVABILITY

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

PROPOSAL #4 SIMULATED FIXINGS

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[4] necessary when adding a simulated fixing
- pathwise generation of future fixings and publishing them can be automated by an extension of `Index`
- no need for changes in pricing engines
- (almost) zero overhead when simulated fixings mode is disabled

[4]typically floating rate coupons

DATA LIBRARY

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

XML EXAMPLE

```xml
<Trade id=”123456”>
 <TradeType>Swap</TradeType>
 <Envelope>
  <CounterParty>CP_A</CounterParty>
  <NettingSetId>CP_A_NS_1</NettingSetId>
 </Envelope>
 <SwapData>
  <LegData>
   <LegType>Fixed</LegType>
   <Payer>true</Payer>
   <Currency>EUR</Currency>
   <Notionals>
    <Notional>70000000</Notional>
   </Notionals>
   <DayCounter>30/360</DayCounter>
   <PaymentConvention>
    Following
   </PaymentConvention>
   <FixedLegData>
    <Rates>
     <Rate>0.035000</Rate>
    </Rates>
   </FixedLegData>
   <ScheduleData>
    <Rules>
     <StartDate>20120530</StartDate>
     <EndDate>20160704</EndDate>
     <Tenor>1Y</Tenor>
     <Calendar>TARGET</Calendar>
     <Convention>
      Following
     </Convention>
     <TermConvention>
      Following
     </TermConvention>
     <Rule>Forward</Rule>
     <EndOfMonth/>
     <FirstDate>20120704</FirstDate>
     <LastDate/>
    </Rules>
   </ScheduleData>
  </LegData>
 </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
-
```
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

ANALYTICS LIBRARY

- 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.

SCENARIOSIMMARKET

- `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 `TermStrutures` 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

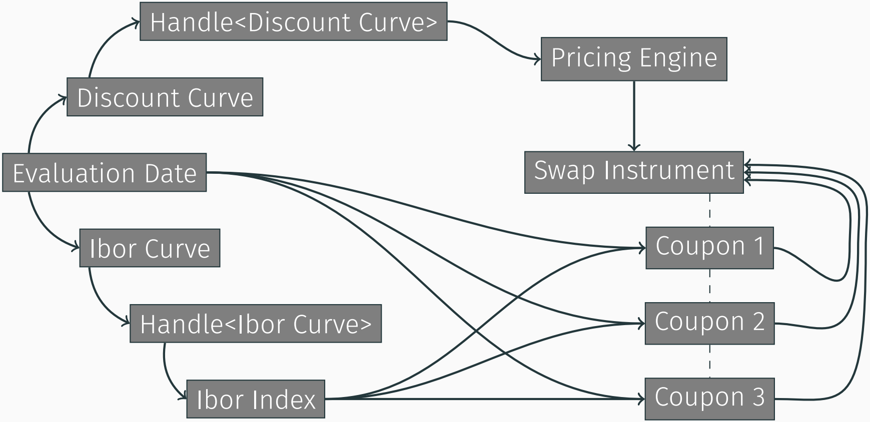
  Con Need to do multiple asof date changes, not cheap

OBSERVATIONS

- `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 $\Rightarrow$ 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

OBSERVATION - SINGLE SWAP

- 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

OBSERVATION - SOLUTIONS

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

Mode	1 Swap	100 Swaps
None	12.64	320.99
Minimise	12.46	227.91
Disable	11.4	229.45
Defer	13.32	349.07

Questions?