Integrating QuantLib and *Mathematica*

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Objectives

- Develop tools for students to explore properties of options and derivatives.
- Create an open source, high-level programming environment for rapid prototyping and implementation of financial instruments.
- Provide opportunities for undergraduate research projects in financial mathematics.
- Similar projects are available, but are commercial (*e.g.* Derivatives Expert (URL: www.ifs.dk/DerivativesExpert/) , UnRisk (URL: www.unrisk.com), *etc.*).

Software Components

- QuantLib, an open source, C++ library of code for financial instruments, pricing engines, and numerical routines (URL: www.quantlib.org).
- *Mathematica*, a commercial computer algebra system and tool for doing mathematics (URL: www.wolfram.com).
- *MathLink*, *Mathematica*'s communication protocol for dynamically loading externally compiled executable functions.

Adding an External Function to *Mathematica*

1. Create source code for external function (C/C++/FORTRAN/Java).
2. Compile source code with an interface "stub" which specifies how *Mathematica* expressions will be communicated to the external function.
3. Load the external routine into a running *Mathematica* kernel.
4. Evaluate the function as if it were a native function.

Challenges

- Conflicting data structures between QuantLib and *Mathematica*.
  - QuantLib has an extensive object-oriented library.
  - *Mathematica*'s basic data structure is the list, functions are evaluated by matching patterns and applying rules.
- Limited support for date and calendar calculations in *Mathematica*.

Dates and Calendars

- QuantLib supports calendars for a collection of stock exchanges.
  - Dates can be tested for being business days.
  - Dates can be rolled to the nearest business day.
  - Date arithmetic can be performed.
- *Mathematica* supports a date list data structure and date arithmetic, but no international holiday calendars.

Testing for Business Days

```
In[158]:= Options[BusinessDayQ]
Out[158]= {Calendar → UnitedStates, JointCalendarConvention → JoinHolidays}

In[159]:= BusinessDayQ[{2008, 5, 1}, "Calendar" → "Mexico"]
Out[159]= False

In[160]:= BusinessDayQ[{2008, 8, 5},
           "Calendar" → {"Canada", "UnitedStates", "Mexico"}]
Out[160]= True
```

Rolling to Nearest Business Day

```
In[161]:= Options[RollDate]

Out[161]= {Calendar → UnitedStates, JointCalendarConvention → JoinHolidays,
           BusinessDayConvention → Unadjusted}

In[162]:= RollDate[{2008, 5, 26}, "BusinessDayConvention" → "Preceding"]

Out[162]= {2008, 5, 23}

In[163]:= RollDate[{2008, 5, 26}, "BusinessDayConvention" → "Following",
           "Calendar" → {"Mexico", "UnitedStates"},
           "JointCalendarConvention" → "JoinHolidays"]

Out[163]= {2008, 5, 27}
```

Shifting Dates

```
In[210]:= Options[ShiftDate]
Out[210]= {Calendar → UnitedStates, JointCalendarConvention → JoinHolidays}

In[211]:= ShiftDate[{2008, 5, 27}, {1, 1, 1}]
Out[211]= {2009, 6, 30}

In[212]:= ShiftDate["May 27, 2008", {-1, 1, -1}, "Calendar" → "Finland"]
Out[212]= {2007, 6, 27}
```

Counting Days/Years Between Dates

```
In[191]:= BusinessDaysBetween[{2008, 5, 27}, {2018, 5, 30}, "Calendar" → "Brazil"]
Out[191]= 2517

In[192]:= BusinessDaysBetween[{2008, 5, 27}, {2018, 5, 30}, "Calendar" → "Argentina
Out[192]= 2511

In[193]:= BusinessYearsBetween[{2007, 5, 27}, {2008, 5, 30},
           "DayCounter" → "Business252"]
Out[193]= 0.996032

In[194]:= BusinessYearsBetween[{2007, 5, 27}, {2008, 5, 30},
           "DayCounter" → "ActualActual"]
Out[194]= 1.00984
```

Options and Derivatives

- Quantlib implements a variety of financial instruments and pricing engines for valuing them.
- Financial instruments possessing a closed form, analytic pricing formula can be programmed directly in the *Mathematica* language.
- Financial instruments requiring a numerical scheme to price could also be programmed in *Mathematica*, but this duplicates work already done in QuantLib.

Multilevel Interfaces to QuantLib Routines

- Low level “command line interface” where all variables and parameters of an instrument must be specified.
- Medium level interface provides default values for some optional parameters.
- High level interface provides a form-based GUI to QuantLib routines.

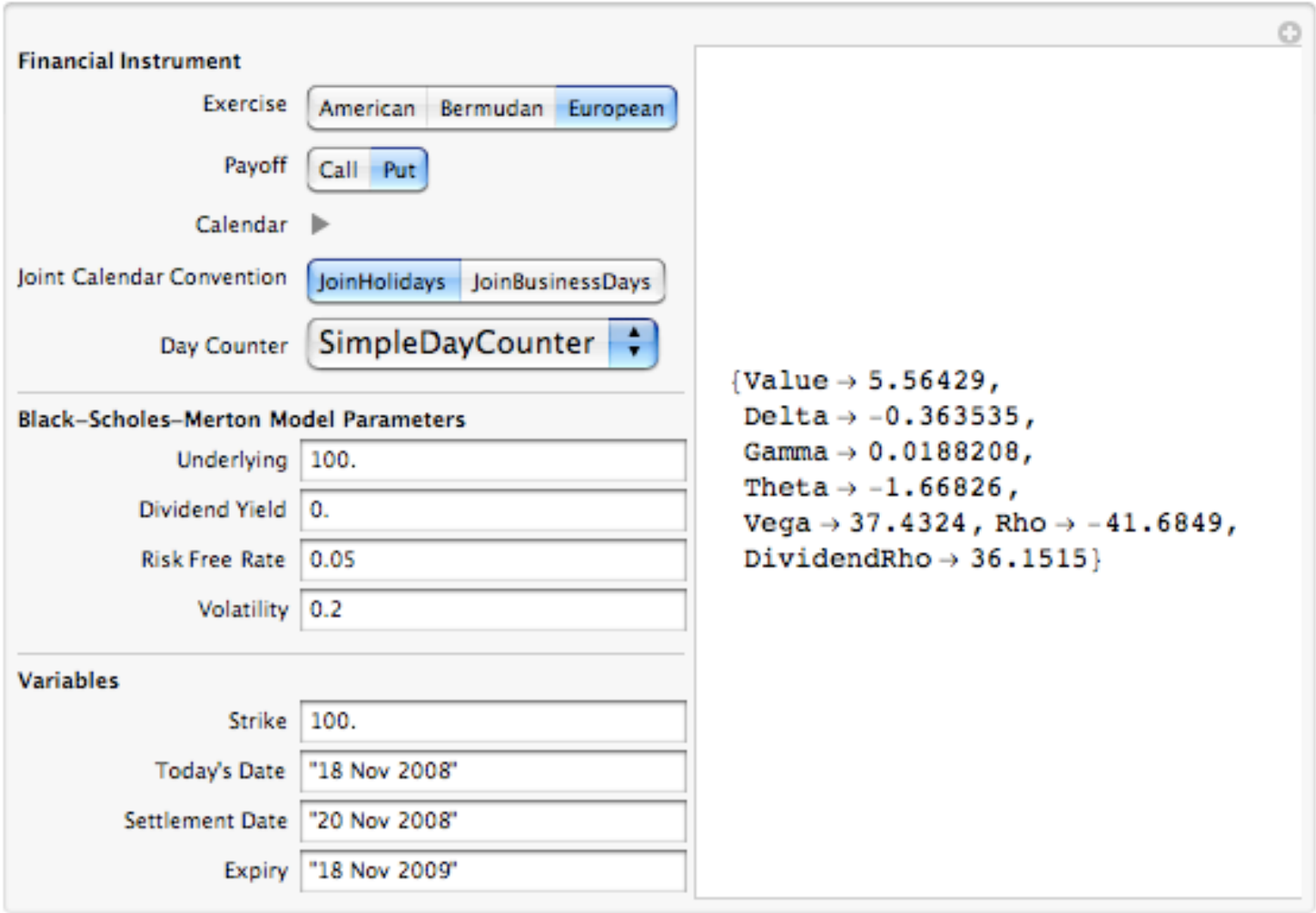
Low and Medium Level Interface Examples

```
In[20]:= qlVanillaOption[3, 2, 81.0, {80.0, 0.0, 0.050, 0.20}, {35}, 1, 4,
          {{2008, 11, 18}, {2008, 11, 20}, {2009, 11, 20}}]

Out[20]= {Value → 4.87931, Delta → -0.387344, Gamma → 0.0240286,
          Theta → -1.28231, Vega → 30.5125, Rho → -35.5822, DividendRho → 30.7416}

In[21]:= VanillaOption["European", "Put", 81, BlackScholesModel[80, 0.05, 0.20],
          Table[DatePlus[DateList[], n], {n, {0, 2, 365}}]]

Out[21]= {Value → 4.88235, Delta → -0.387155, Gamma → 0.0239964,
          Theta → -1.2788, Vega → 30.5447, Rho → -35.6556, DividendRho → 30.8004}
```

High Level Example

In[22]:= **VanillaOptionGUI[]**

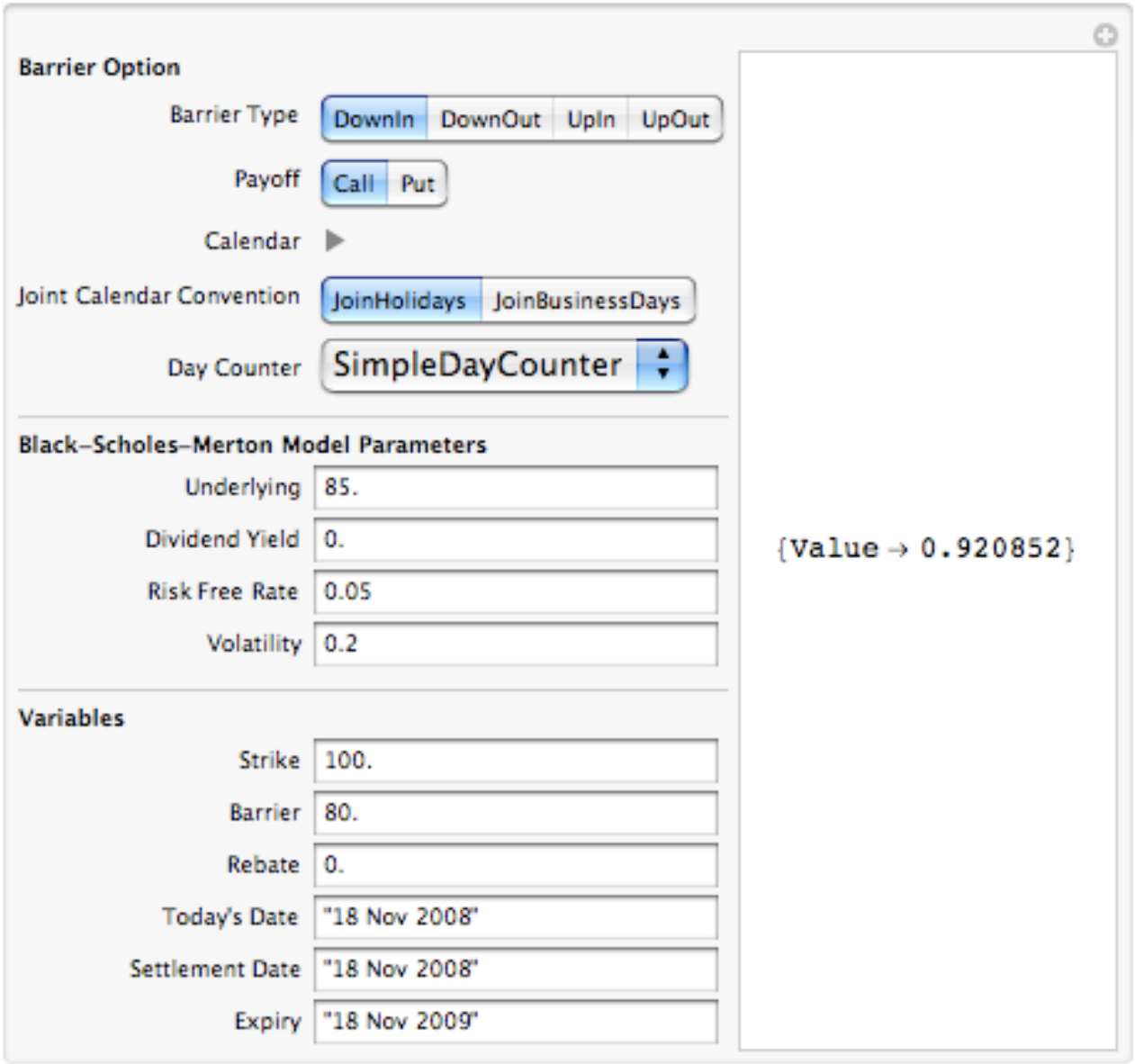
Out[22]=



Barrier Option Example

In[24]:= `BarrierOptionGUI[]`

Out[24]=



Design Questions

- Which interface level is the most useful?
- Would multiple return values be useful?