CREDIT SUISSE

Experience Report:

Paradise

A two-stage DSL embedded in Haskell

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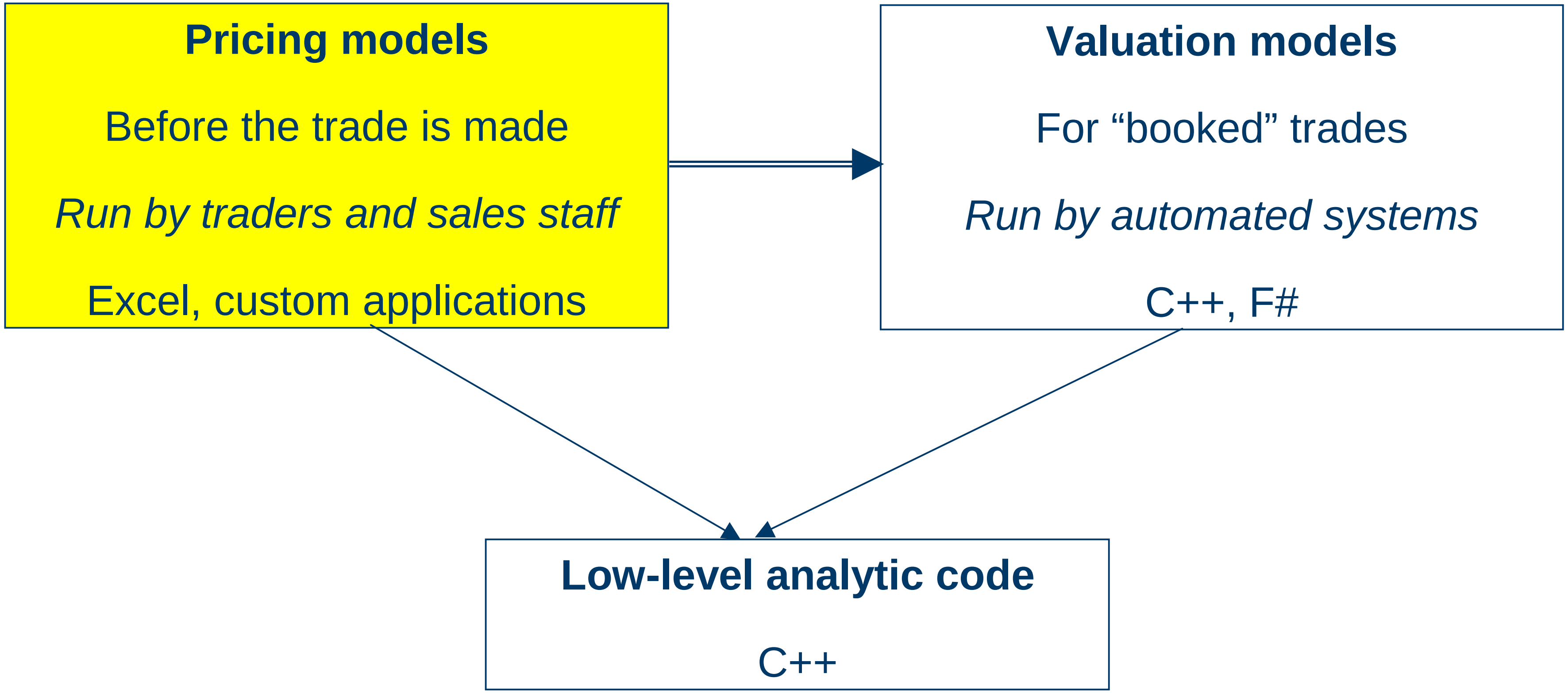
GMAG

- Credit Suisse: ~40,000 people: A large financial services firm
- Securities Division: ~6,000 people:

  Buys and sells financial products, including derivatives:
  - Potentially complex instruments based on underlying real asset(s), e.g.
    - Right to buy/sell some stock at price y at time z
    - Pay out x for every day in period z that some interest rate is above y
  - Used to hedge against liabilities, or “take a view” on market movements
- Global Modelling and Analytics Group: ~140 people

  Writes and delivers “analytics” for:
  - Pricing (what is this worth?)
  - Risk analysis (how will this value change if the market moves by x?)

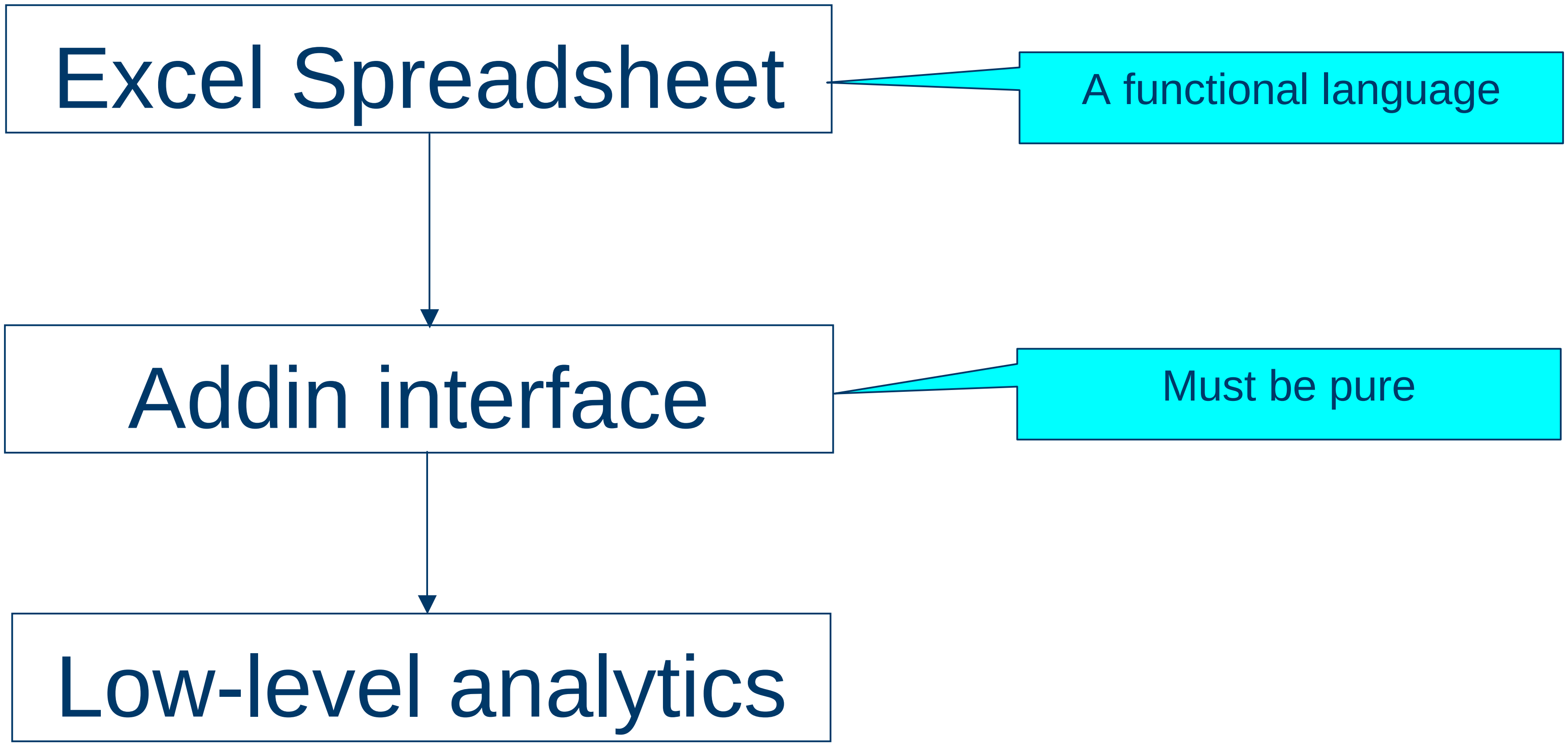
Delivering analytics



Excel as a platform for pricing models

- Users like it
  - Familiar
  - Can tweak it themselves
- Can be good for development too
  - Rapid prototyping
- BUT: a reusability nightmare
  - No modularity
  - No abstraction
  - No automated change tracking

Pricing Models



Paradise

- Generate pricing models
- Two DS(E)Ls
  - Model: describe how the addin calls are plumbed together
  - View: describe how the UI is laid out
- Target-independent
  - Excel
  - C#
  - Future: web application?
- Not specific to finance or pricing models
  - But that’s all we use it for

How does it work

- A two stage language: like Pan (Elliott et al)
  - The Paradise program is compiled into a Haskell executable
  - When run the Haskell executable produces the spreadsheet etc
- Type system distinguishes the stages
  - Second-stage is denoted by a type constructor “E”
- The bits with “Haskell” types (Double, [], …) run at Haskell runtime (stage 1)
- The bits with “Paradise” types (E Double, …) build an AST that will be compiled into the stage 2 program – Excel, C# etc
- The Paradise library contains
  - A type-safe interface to stage 2 + helper functions
  - a compiler for the Paradise DSL

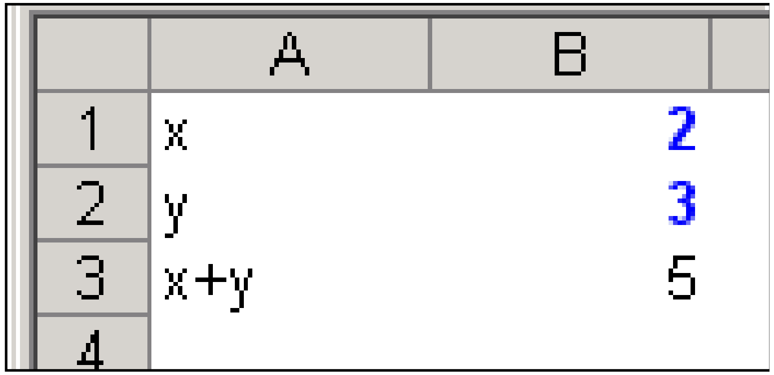
A very simple example

```
data Adder = Adder {
    x :: E Double,
    y :: E Double,
    z :: E Double
    }

adder = do
    x <- input 2
    y <- input 3
    z <- output (x+y)
    return Adder{..}

instance Viewable Adder where
    view Adder{..} =
        column [row [label "x",   view x],
                row [label "y",   view y],
                row [label "x+y", view z]]
```

Data structure



Plumbing DSL

UI DSL

Two adders

```
data TwoAdders = TwoAdders {
   adder1 :: Adder,
   adder2 :: Adder,
   result :: E Double
   }

twoAdders = do
    adder1 <- adder
    adder2 <- adder
    result <- output (z adder1 + z adder2)
    return TwoAdders{..}

instance Viewable TwoAdders where
    view TwoAdders{..} = row [view adder1,
                              view adder2,
                              view result]
```

The E type

This is all we expose to the users

```
data E a = E Exp
data Exp = EVar … | ELit … | ELam … | EApply …

instance Num (E Int) where …
instance Num (E Double) where …
instance IsString (E String) where …
(+++) :: E String -> E String -> E String
…
```

Higher-order functions

- Second-stage array type : E (Array a)

```
map :: (IsEType a, IsEType b)
    => (E a -> E b)
    -> E (Array a)
    -> E (Array b)
```

- User writes normal-looking functions
  - Higher-order abstract syntax
  - E type is abstract so the functions must be parametric
- Turned into explicit lambdas (ELam) for the backend

Embedding issues

- The stage-2 language is quite restricted
  - Can overload:
    - numeric literals, numeric operations, and string literals
  - Can’t overload:
    - If-then-else, Boolean literals, Eq/Ord type classes: we roll our own alternatives
    - Pattern-matching, general recursion, list comprehensions: we do without
- (Un)observable sharing
  - We have a combinator in the state monad
  - We recently decided to also use stable names + unsafePerformIO
- Haskell is still a great language for embedding
  - Static typing + type classes make distinguishing stages 1+2 easy
  - Can write code that is overloaded between the two stages
  - Type classes let us mimic the target language’s type system

Impact

- Gradually rolling it out across the group
- Most of our problems have been with Excel
  - Slow
  - Unreliable
  - Not designed as a compilation target
- Modellers appreciate the type-safety and abstraction
- Turn-around of changes can be an issue
  - No longer instantly visible in the sheet
- Lifecycle management is more complicated
  - Paradise library changes can break models (or fix them)
  - We have a runtime support library: requires a careful binary release process

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Why not GADTs?

- Trade-off between effort and safety
- The Excel backend plays fast and loose with types
- We annotate our terms with our own type information (at the value level)
  - Can run a typechecking pass
- So trade-off is between errors at Haskell compile time and at stage 1 runtime
  - Of course, we had to write our own typechecker