FUNCTIONAL PROGRAMMING AT SIMCORP

FLORIAN BIERMANN

FLORIAN.BIERMANN@SIMCORP.COM

2020-09-30

SimCorp

THE SPEAKER

FLORIAN BIERMANN

- **ITU alumn**
  - M.Sc. in Software Development (2014)
  - Ph.D. in Computer Science (2018)
    - “Data Parallel Spreadsheet Programming”
- **Developer at SimCorp since August 2018**
  - OTC Core
  - C# and OCaml, sometimes a bit of F# and Emacs Lisp
  - Financial contracts, derivatives, framework, application integration

SIMCORP

INVESTMENT MANAGEMENT SOLUTIONS PROVIDER

- Established in 1971
- EUR 382.6 million revenue
- 25 offices globally, main development in DK and UA
- 1900 employees (2020)
- 300+ SimCorp Dimension clients worldwide

SimCorp Dimension

Fully integrated front-to-back investment management solution, powered by an award-winning Investment Book of Record, **offered globally**

190+ clients

FINANCIAL CONTRACTS

WHAT DO WE DO – AND WHY?

- **Bond (loan)**
  - Pay amount up front (nominal)
  - Pay interest on nominal over time
  - Pay back nominal in the end
- **Option (financial instrument)**
  - Right to exercise an underlying contract.
  - E.g. take up loan on already agreed conditions.
  - In a period or at specific points in time.
- **Over-the-Counter (OTC)**
  - Highly customizable financial instruments
  - Not “centrally cleared”, bilateral agreement.

Like an insurance: if it rains in May, you may buy crops at $5 a pound.

Financial contracts have market value!

Cross-currency trades, interest swaps, Sell-buy-back, …

SimCorp

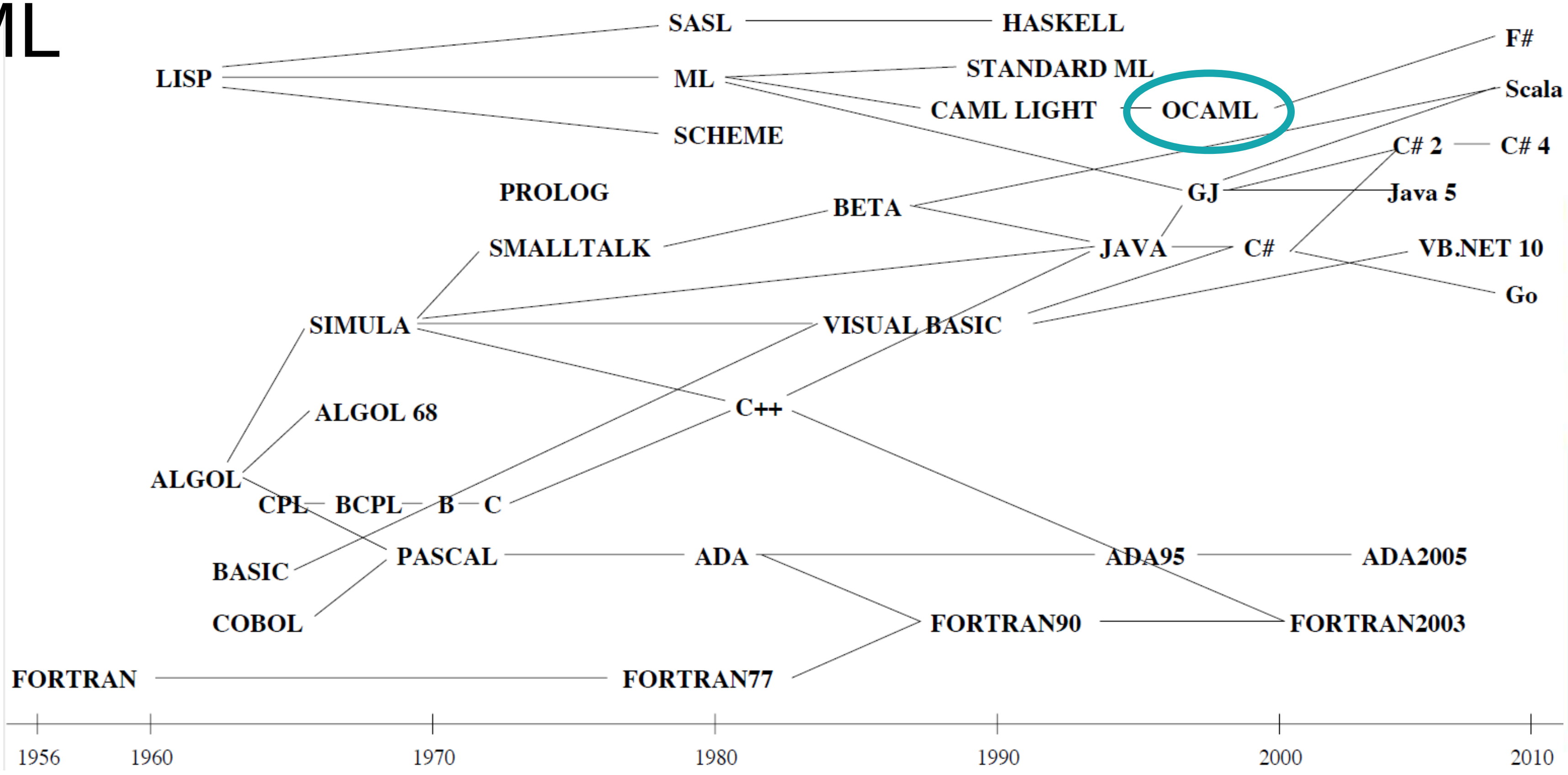
SIMCORP TECHNOLOGIES

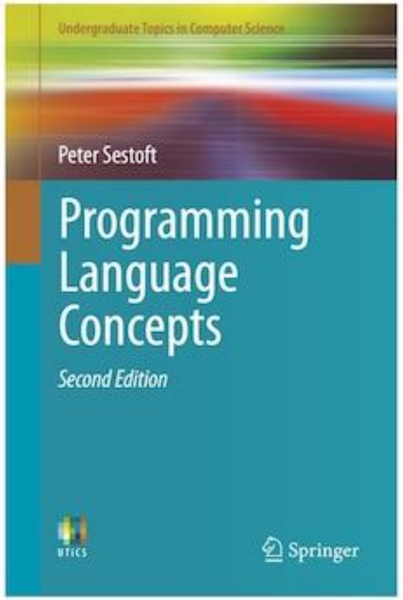
A SMALL SELECTION

WHAT THIS TALK IS NOT ABOUT

- Dyalog APL
  - Most code at SimCorp is APL code
  - In use since the 1970's
  - Dynamically typed, interpreted, declarative, array-oriented
- C#
  - Most new development on .NET
  - Threading, services, GUI
- F#
  - Some components of SimCorp Dimension
  - SimCorp internal static APL type checker

OCAML





- Multi-paradigm: functional, imperative, object-oriented
- Static types and type inference
- Strict evaluation
- Interactive top-level (REPL)

INDUCTIVE TYPES STRUCTURE PROGRAMS

```
type expr =
  | Cst of int
  | Add of expr * expr
  | Mul of expr * expr
  | Neg of expr
```

```
let rec eval : expr -> int = function
  | Cst i -> i
  | Add (e1, e2) -> eval e1 + eval e2
  | Mul (e1, e2) -> eval e1 * eval e2
  | Neg e -> -(eval e)
```

```
# let e1 = Add (Cst 1, Neg (Cst 1));;
val e1 : expr = Add (Cst 1, Neg (Cst 1))

# let e2 = Add (“one”, Cst 1);;
Error: This expression has type string but an expression was expected of
type expr

# eval e1;;
- : int = 0
```

Composing contracts: an adventure in financial engineering

Functional pearl

Simon Peyton Jones
Microsoft Research, Cambridge
simonpj@microsoft.com

Jean-Marc Eber
LexiFi Technologies, Paris
jeanmarc.eber@lexifi.com

Julian Seward
University of Glasgow
v-sewardj@microsoft.com

23rd August 2000

Abstract

Financial and insurance contracts do not sound like promising territory for functional programming and formal semantics, but in fact we have discovered that insights from pro-

At this point, any red-blooded functional programmer should start to foam at the mouth, yelling "build a combinator library". And indeed, that turns out to be not only possible, but tremendously beneficial.

The finance industry has an enormous vocabulary of jargon

FINANCIAL CONTRACTS MODELLING

- Two parties agree on an amortized loan.
- Pay 30000 DKK up front.
- Pay back over three years with interest.
- Decide when payments are due.

```
let amortized_loan =
  let principal = cst 30000. in
  let coupon = cst 11000. in
  all [ give (flow 2019-01-01 DKK principal);
        flow 2020-01-01 DKK coupon;
        flow 2021-01-01 DKK coupon;
        flow 2022-01-01 DKK coupon ]
```

A COMBINATOR LIBRARY FOR FINANCIAL CONTRACTS

OCAML DIALECT “LEXIFI OCAML”

```
type binop = Add | Sub | Mul | Div | Max

type obs =
   | Underlying of string
   | Const of float
   | Binop of obs * binop * obs
   | Fixed of date * obs

type contract =
   | One     of currency
   | Scale   of obs * contract
   | Acquire of date * contract
   | All     of contract list
   | Give    of contract
   | Either  of contract * contract
   | Anytime of date * date * contract * contract
```

Fix an underlying market rate to its value at some date.

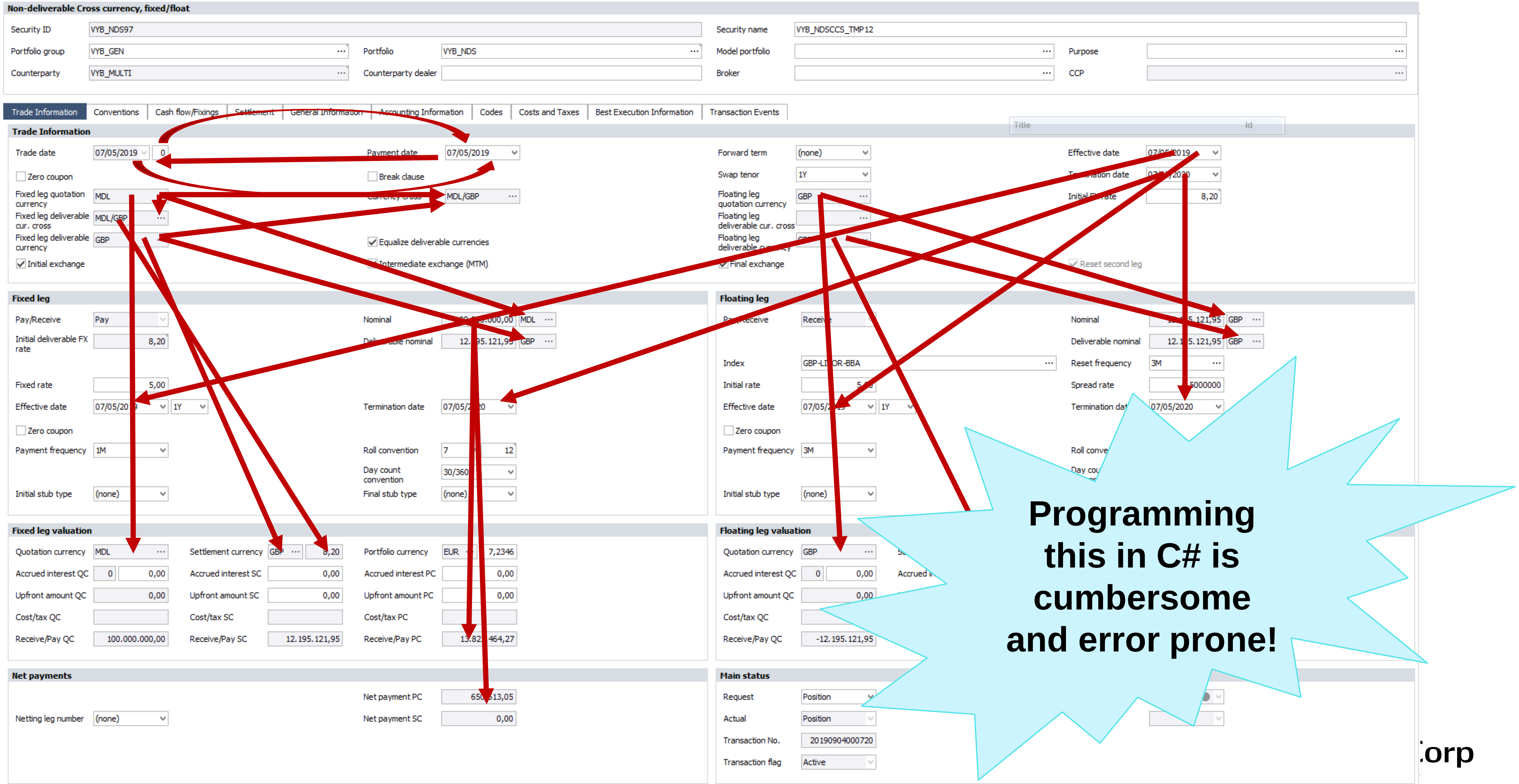
Exercise contract in between dates, or exercise other contract after.

```
let flow t cur obs =
  Acquire (t, Scale (obs, One cur))

let amortized_loan =
  let principal = Const 30000. in
  let coupon = Const 11000. in
  all [ Give (flow 2019-01-01 DKK principal);
        flow 2020-01-01 DKK coupon;
        flow 2021-01-01 DKK coupon;
        flow 2022-01-01 DKK coupon ]
```

Evaluates to a value of type `contract` that we can valuate.

SimCorp

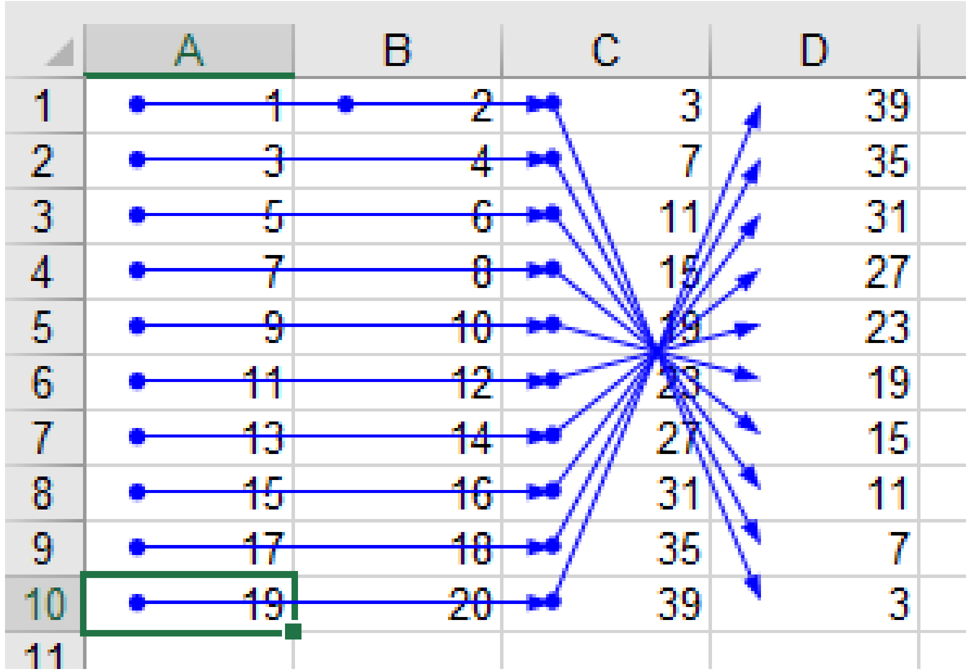
PROGRAMMING COMPLEX GUI LOGIC



LOOKS FAMILIAR?

SPREADSHEET-LIKE EVALUATION MODEL

- Fields depend on each other
  - When the user updates a field, all depending fields must be updated, too.
  - “Reactive programming”
  - “Self-adjusting computation”
- Free of side effects
  - From a programmer’s point of view!
- Programming challenge for domain experts
  - What happens if the user changes the number of settlement days to 5?
- **Solution: pure, type-safe, declarative programming**



	A	B	C	D
1	1	2	3	39
2	3	4	7	35
3	5	6	11	31
4	7	8	15	27
5	9	10	19	23
6	11	12	23	19
7	13	14	27	15
8	15	16	31	11
9	17	18	35	7
10	19	20	39	3
11				

SimCorp

Typelets — A Rule-Based Evaluation Model for Dynamic, Statically Typed User Interfaces

Martin Elsman[1] and Anders Schack-Nielsen[2]

[1] University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen, Denmark
mael@diku.dk
[2] SimCorp, Weidekampsgade 16, DK-2300 Copenhagen, Denmark
anders.schack-nielsen@simcorp.com

Abstract. We present the concept of *typelets*, a specification technique for dynamic graphical user interfaces (GUIs) based on types. The technique is implemented in a dialect of ML, called MLFi,[3] which supports dynamic types, for migrating type-level information into the object level, so-called type properties, allowing easy specification of, for instance, GUI control attributes, and type paths, which allows for type-safe access to type components at runtime. Through the use of Hindley-Milner style type-inference in MLFi, the features allow for type-level programming of user interfaces. The dynamic behavior of typelets are specified us-

RULES DESCRIBE BUSINESS LOGIC

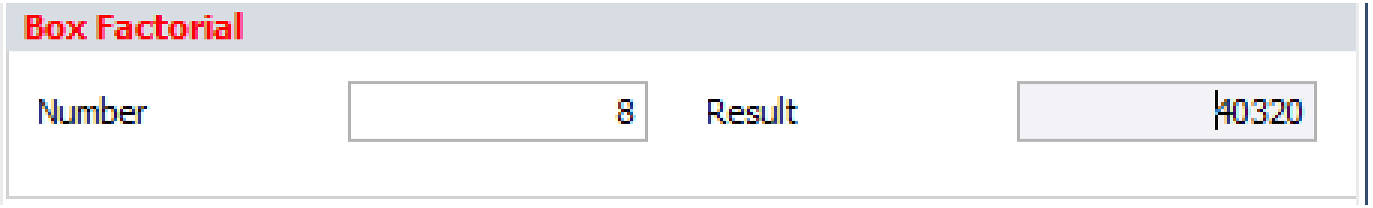
DECLARATIVELY COMPUTE FACTORIAL

```
type t = {
  number: int;
  result: (int [@t readonly])
}

let rule =
  let rec fact = function
    | 0 -> 1
    | n -> n * fact (n - 1)
  in
  Rule.update
    (Fields.value [%p number])
    (Fields.value [%p result])
    fact

let layout =
  let open Layout in
  box "Factorial"
      (lpick [%p number] % lpick [%p result])
```

Use record types to declare fields in the business logic.

Define “normal” OCaml function.

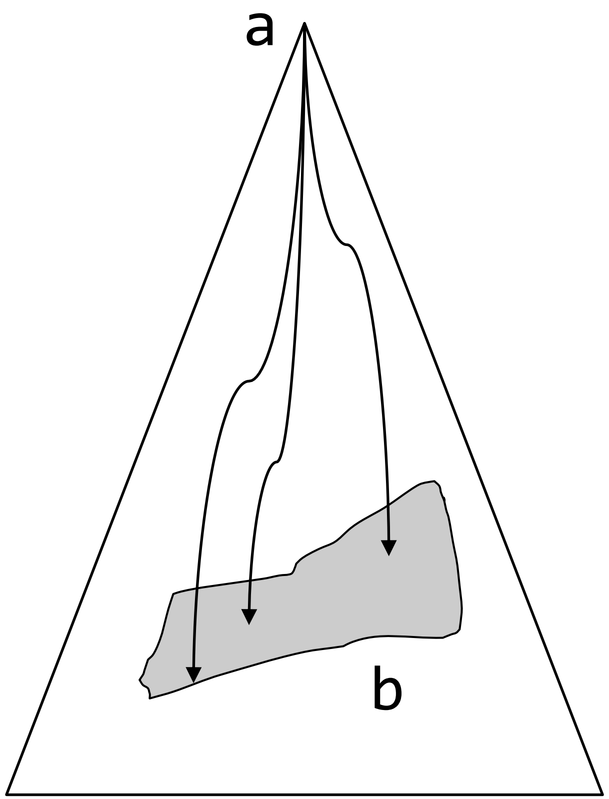
Use it as projection in “update” rule.



ACCESSING FIELDS THROUGH FIELD API

INTERNAL API FOR DEVELOPING BUSINESS LOGIC

```
module type FIELDS = sig
  type ('i, 'a) t (* 'i : type of the root *)
                  (* 'a : type of elements pointed to *)
  val const    : 'a ttype -> 'a -> ('i, 'a) t
  val value    : ('i, 'a) path -> ('i, 'a) t
  val enabled  : ('i, _) path -> ('i, bool) t
  val readonly : ('i, _) path -> ('i, bool) t
  val restrict : ('i, 'a) path -> ('i, 'a list) t
  val ( & )    : ('i, 'a) t -> ('i, 'b) t -> (‘i, 'a * 'b) t
end
```



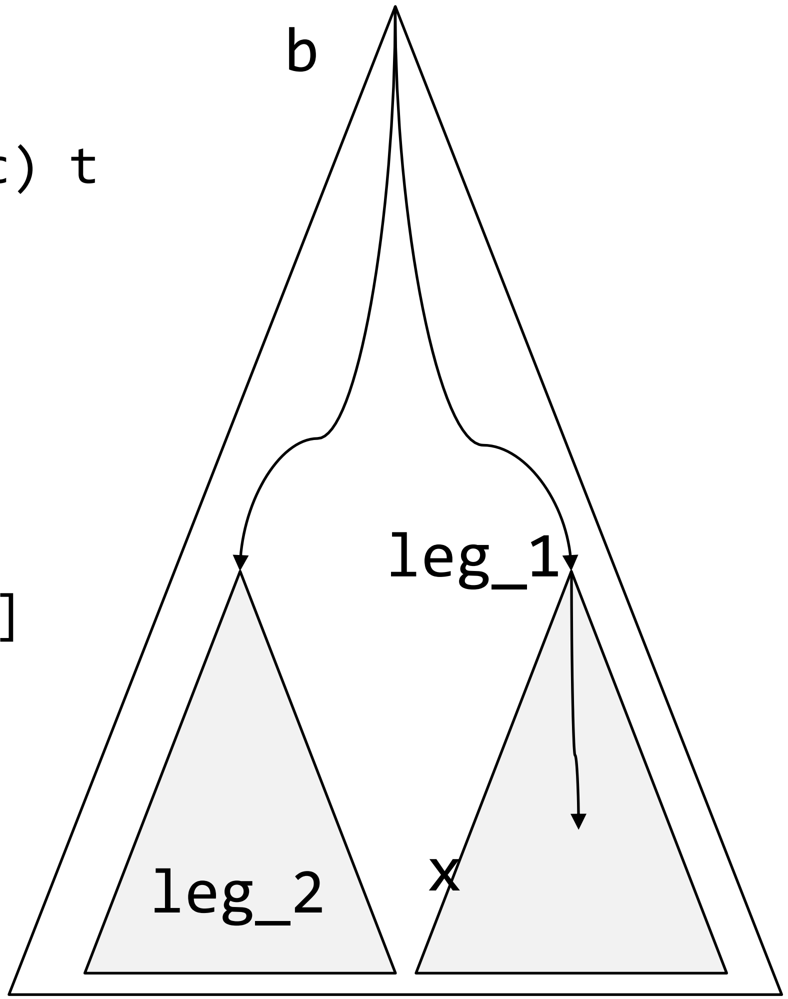

```
type vec2d = { x : float; y : float }
type vec3d = { x : vedc2; z : float }

let f = Fields.value [%p x.x] & Fields.value [%p x.y] & Fields.value [%p .z]
```

What is the type of `f`?

PATHS COMPOSE

ALLOWS TO DIFFERENTIATE BETWEEN REPLICATED STRUCTUES

```
module type PATHS = sig
  val subpath  : ('a, 'b) t -> ('b, 'c) t -> ('a, 'c) t
end


type a = { x : int; y : string }
type b = { leg_1 : a; leg_2 : a }

let x_leg_1 : (b, int) t = subpath [%p leg_1] [%p x]
```



CONSTRUCTING INSTRUMENTS THROUGH RULE API

INTERNAL API FOR DEVELOPING BUSINESS LOGIC

```
module type RULE = sig
  type 'i t
  type ('i,'a) fields = ('i,'a) Fields.t
  val update   : ('i,'a)fields -> ('i,'b)fields -> ('a -> 'b) -> 'i t
  val validate : ('i,'a)fields -> ('a -> string option) -> 'i t
  val button   : ('i,'a)fields -> ('i,'b)fields -> ('a -> 'b) -> ('i,unit)path -> 'i t
  val subpath  : ('i,'a)path -> 'a t -> 'i t
  val all      : 'i t list -> 'i t
  val iso      : ('i,'a)fields -> ('i,'b)fields -> ('a -> 'b) -> ('b -> 'a) -> 'i t
  ...
end
```

Check whether some property holds for given fields.

Lift rule of type `'a t` into context of `'i` if path from `'i` to `'a` exists.

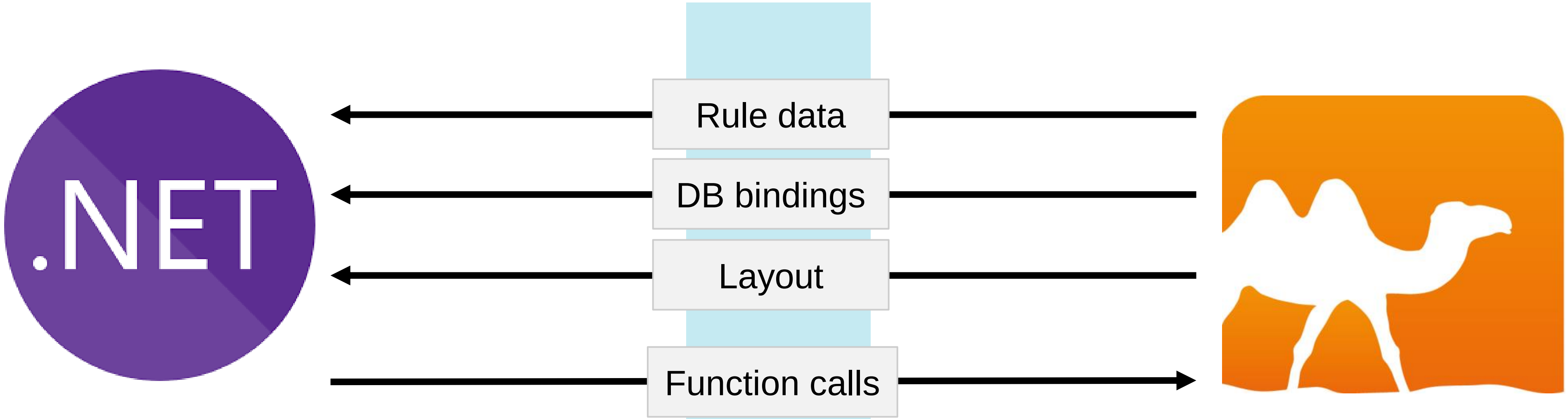
Isomorphism between two fields.

What does function `all : 'i t list -> 'i t` do?

SimCorp

RULE EXECUTION

INTERPETER IMPLEMENTED IN .NET – BUSINESS RULES IN OCAML



- Rule interpreter
- Ordering of rule execution
- GUI generation
- Database connection
- Input handling

OCaml-C#
Interop

LexiFi

- Business rules
- Mapping of database fields
- GUI Layout

github.com/LexiFi/csml

STOP: DEMO TIME!

MONADIC RULE API

SPLITTING RULES INTO SMALLER STEPS

- OCaml run-time is not reentrant
- Data base access & calls to APL are long-running and blocking.
- Solution: split rule computation into small chunks – compute step-wise.

Monadic type `'a m`!

```
module Rules : sig =
  val update_m : ('i,'a)fields -> ('i,'b)fields -> ('a -> 'b m) -> 'i t
  val update   : ('i,'a)fields -> ('i,'b)fields -> ('a -> 'b)   -> 'i t
end = struct
  let update src tgt f =
    update_m src tgt (fun x -> return (f x))
end
```

```
val return : 'a   -> 'a m
val abort  : unit -> 'a m
```

```
update_m
  (value [%p x])
  (value [%p w])
  (call_apl_1 >>= fun (_, y) ->
   return y >>=
   call_apl_2)
```

```
update_m
  (value [%p portfolio_ik])
  (value [%p currency_ik])
  (function
     | 0 -> abort ()
     | por_ik -> dbhandle >>= fun h ->
       match select1 h pCURIK (all [pPORIK =. por_ik]) with
         | [cur_ik] -> return cur_ik
         | _ -> abort ())
```


orp

EVALUATING RULES AFTER A USER CHANGE

TWO LOOPS TO RULE THE RULES

```
Value EvalRule(RuleComputation rc) {
  while (true) {
    if       (rc.IsValue) return rc.GetValue();
    else if (rc.IsAbort) return null;
    else if (rc.IsCSharpFunction) {
      rc = Invoke(rc.CSharpFunction, rc.GetValue());
    } else {
      rc = rc.Fun(rc.GetValue());
}}}
```

```
void EvalRules() {
  while (Rq.HasNext) {
    RuleInfo r = Rq.Pop();
    Value inp = Env.GetValue(r.Source);
    Value res = EvalRule(r.Run(inp));
    Env.SetValue(r.Target, res);
}}
```

Takes first step

`SetValue()` also updates `Rq`.

- Iterative algorithm on a queue of rules
- A rule is enqueued when one of its source fields is written to.
- Rules are evaluated step-wise to **enable interleaving**
  - Two clients:
  - One runs a C#-rule
  - The other runs an OCaml rule
  - Minimal mutual exclusion
- **Rule programmer does not really care.**

SimCorp

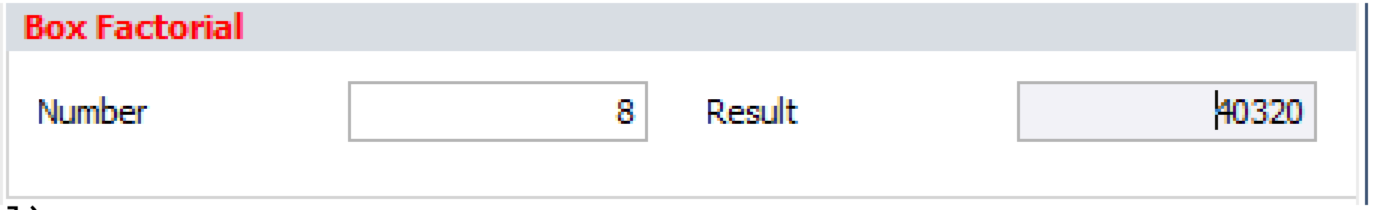
SEPARATION OF CONCERNS

GUI LAYOUT GENERATION VIA LAYOUT API

```
type base = Number | Button | CheckBox | TextBox | Date | DropDown

type ‘p t =
  | Pick    of access_path * string option * base
  | Hseq    of 'p t * ‘p t
  | Vseq    of 'p t * 'p t
  | Halign of halign * 'p t
  | Valign of valign * 'p t
  | Text    of string
  | NamedButton of string
  | Box     of string * ‘p t
```

```
type halign = Left | Center | Right
```

```
let layout =
  let open Layout in
  box "Factorial"
      (lpick [%p number] % lpick [%p result])
```



SimCorp

HOW WELL DOES THIS WORK IN PRACTICE?

HIGH RE-USE, FAST TIME-TO-MARKET

- Plug-in system using OCaml Functors:
  - A system to generate modules from other modules.
  - Highly composable, type safe, no run-time overhead.
  - Rule composition possible thanks to purity!
- Many business rules are generic!
  - E.g. business calendar functionality.
  - Financial instruments differ only in few places.
- Re-use factor for business rules is **~10**

- **274’845** lines of OCaml code
- **428’771** business rules in production
- **42’132** unique business rules
- Over **100** financial instruments

SUMMARY

FUNCTIONAL PROGRAMMING AT SIMCORP

- **Combinator library for modelling financial contracts**
  - Every-day business for us, revolutionary for the finance sector.
  - Domain experts model contracts.
- **Declarative business logic for type-safe GUI programmin**
  - Similar to constructing a spreadsheet.
  - Focus on *what*, not how.
- **Challenges ahead**
  - You gotta know your stuff:
    - Polymorphism, existential types, phantom types
    - Monads & API design
    - Compositionality & catamorphisms

Psst: functional programming in C#!

```
let rec flatten = function
  | [] -> []
  | xs :: xxs -> xs @ flatten xss
```


SimCorp

Thank you!

Florian.Biermann@SimCorp.com

SimCorp