FUNCTIONAL PROGRAMMING AT SIMCORP

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THE SPEAKER

FLORIAN BIERMANN

- **ITU alumn**
  - M.Sc. in Software Development (2014)
  - Ph.D. on parallel, functional programming (2018)
    - “Data Parallel Spreadsheet Programming”
- **Developer at SimCorp since August 2018**
  - IBOR Agile Release Train
  - C# and Ocaml, sometimes a bit of F#
  - Financial contracts, derivatives, OTC

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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.

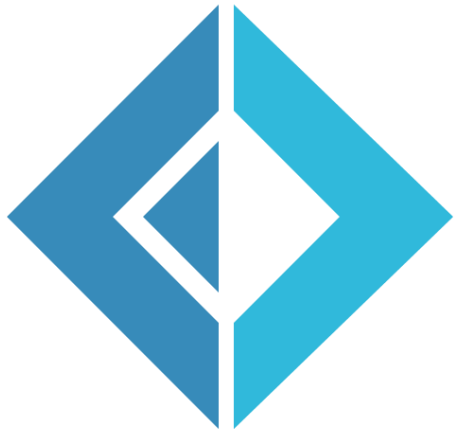
Like an insurance: if it rains in May, you may buy crops at $5 a pound.

Financial contracts have market value!

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

SIMCORP TECHNOLOGIES

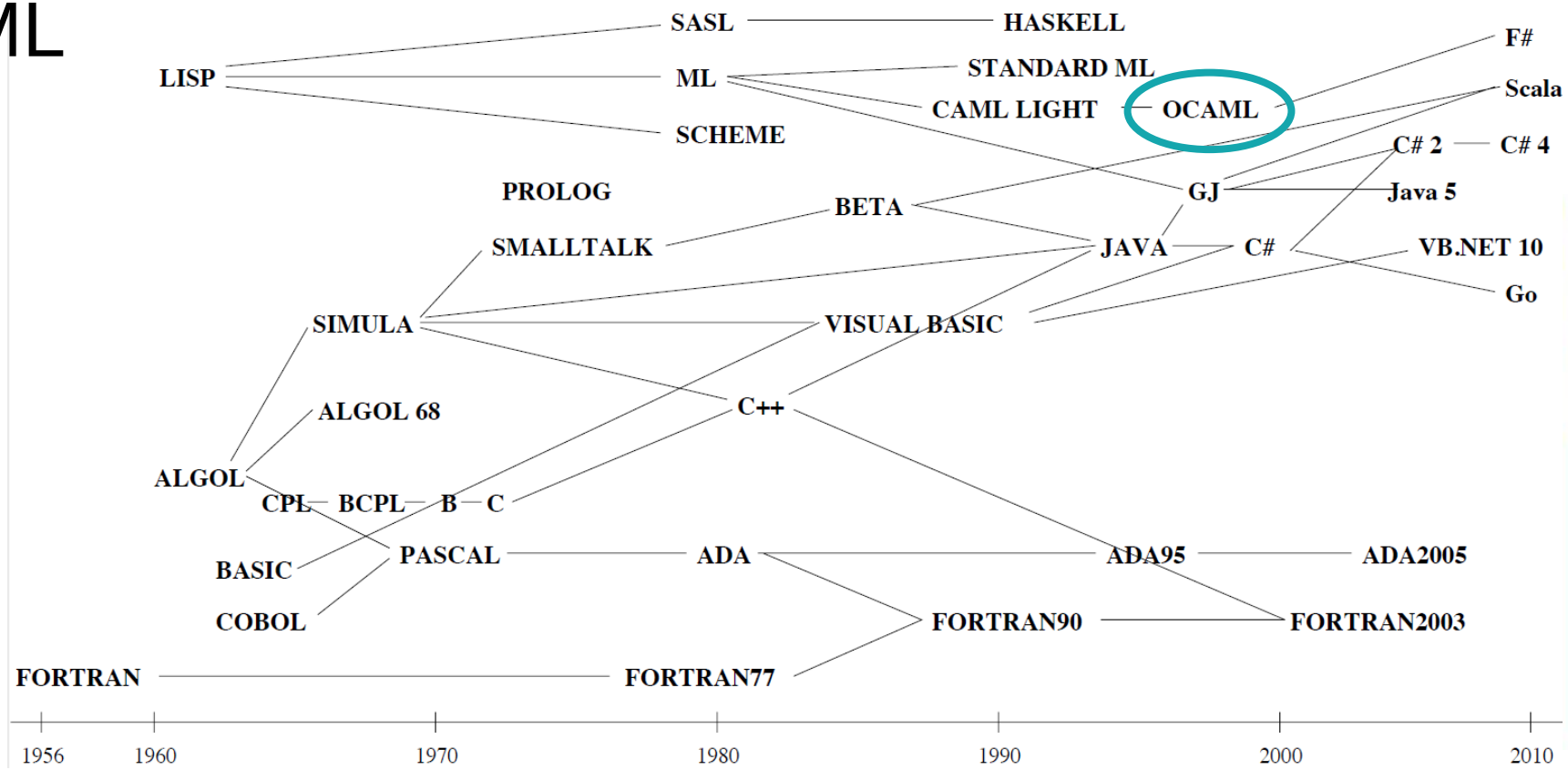
A SMALL SELECTION

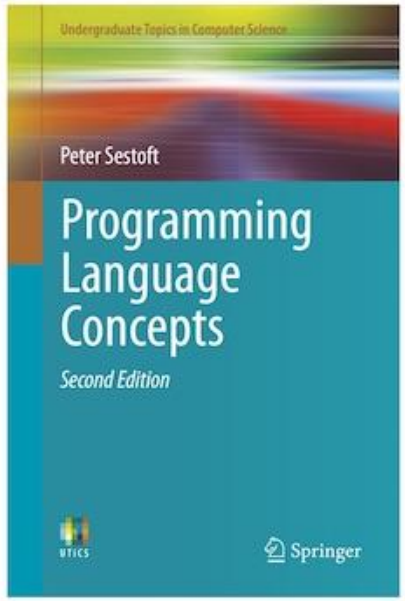


WHAT THIS TALK IS NOT ABOUT

- 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

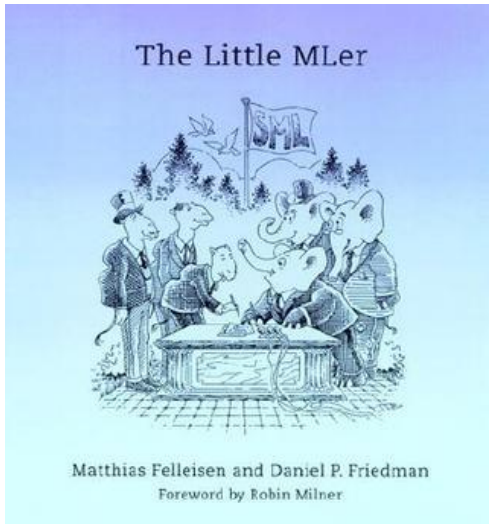




- Multi-paradigm: functional, imperative, object-oriented
- Static types and type inference
- Strict evaluation
- Interactive top-level (REPL)

OCAML TYPES ARE SAFE

```
type pizza =
  | Crust
  | Cheese  of pizza
  | Sausage of pizza
  | Anchovy of pizza
  | Onion   of pizza
```




```
Cheese (Sausage (Onion Crust))
Cheese (Anchovy (Onion Crust))
Crust (Sausage Crust)
```

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

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

type contract =
  | One     of currency
  | Scale   of observable * 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.

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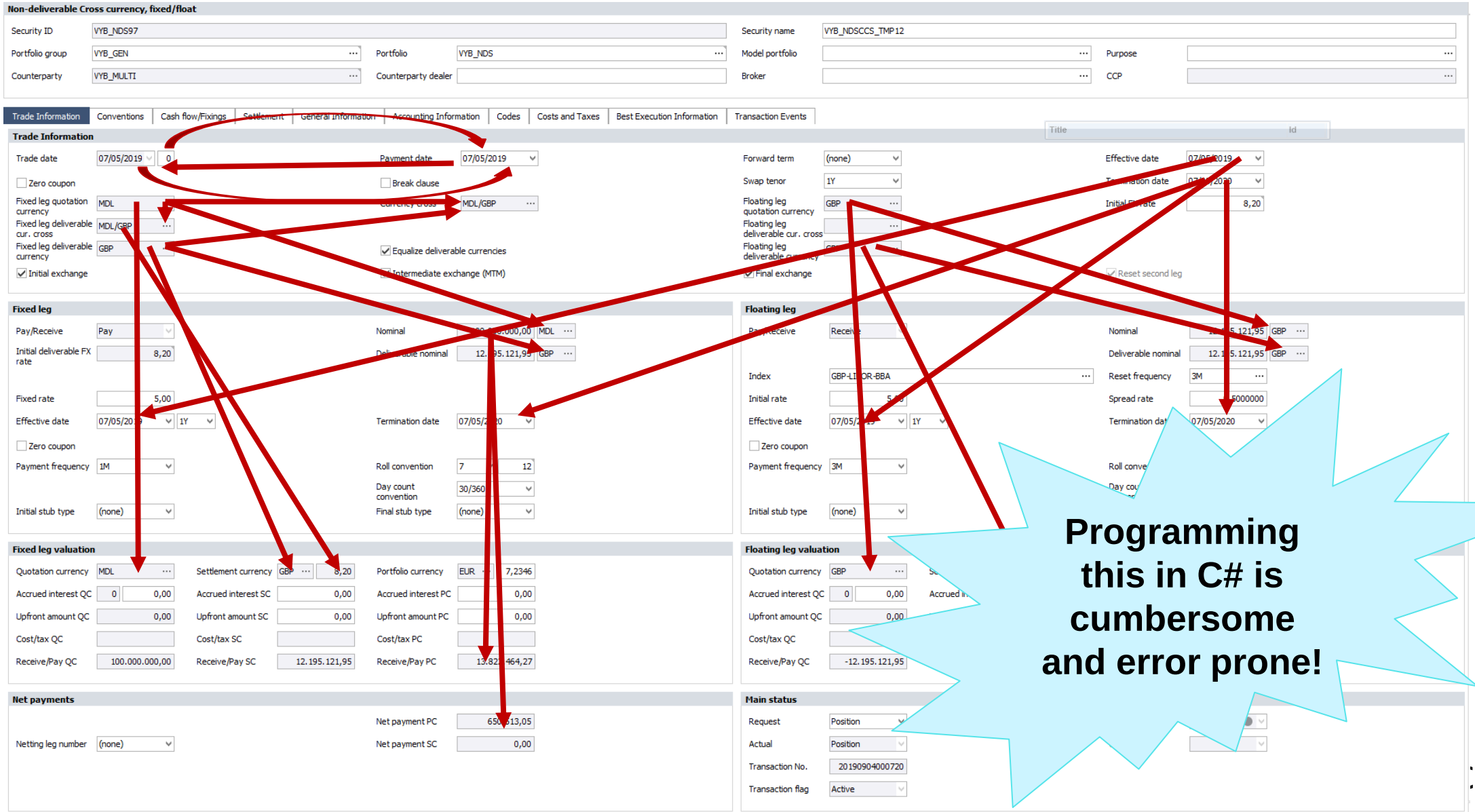
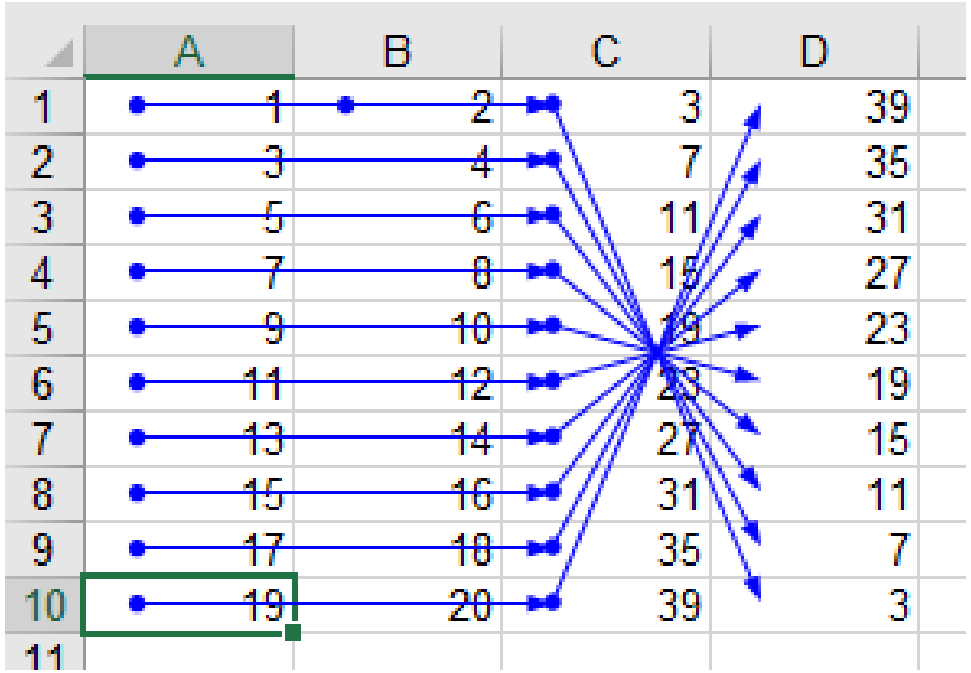
PROGRAMMING COMPLEX GUI LOGIC



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**



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

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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

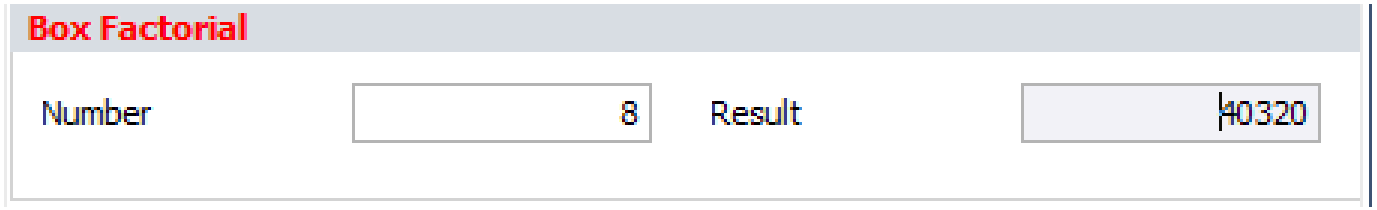
DECLARATIVELY COMPUTE FACTORIAL

```
type t = {
  number: int;
  result: int + [readonly]
}

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

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

Use record types to declare fields in the business logic.

Define “normal” OCaml function.

Use it as projection in “update” rule.



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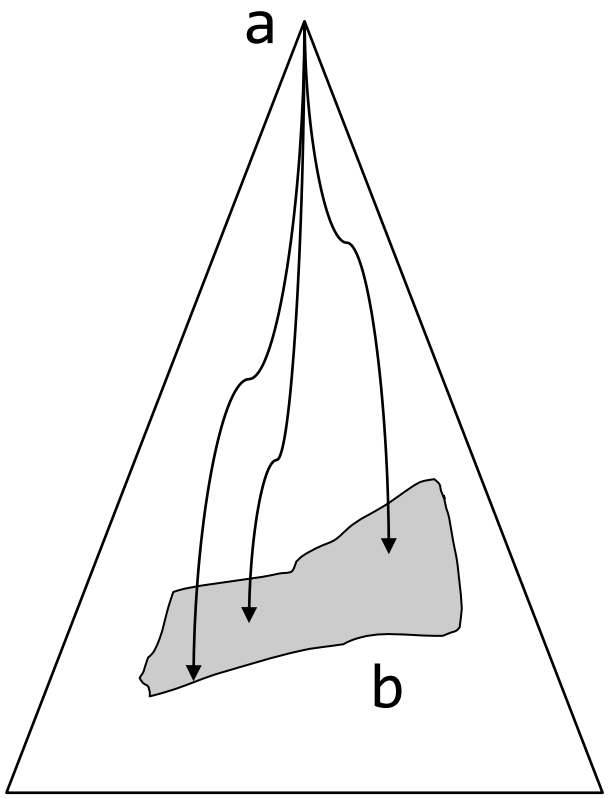
ACCESSING FIELDS THROUGH FIELD API

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 (.x.x) & Fields.value (.x.y) & Fields.value (.z)
```

What is the type of `f`?

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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)tpath -> '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
```

Isomorphism between two fields.

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

Check whether some property holds for given fields.

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

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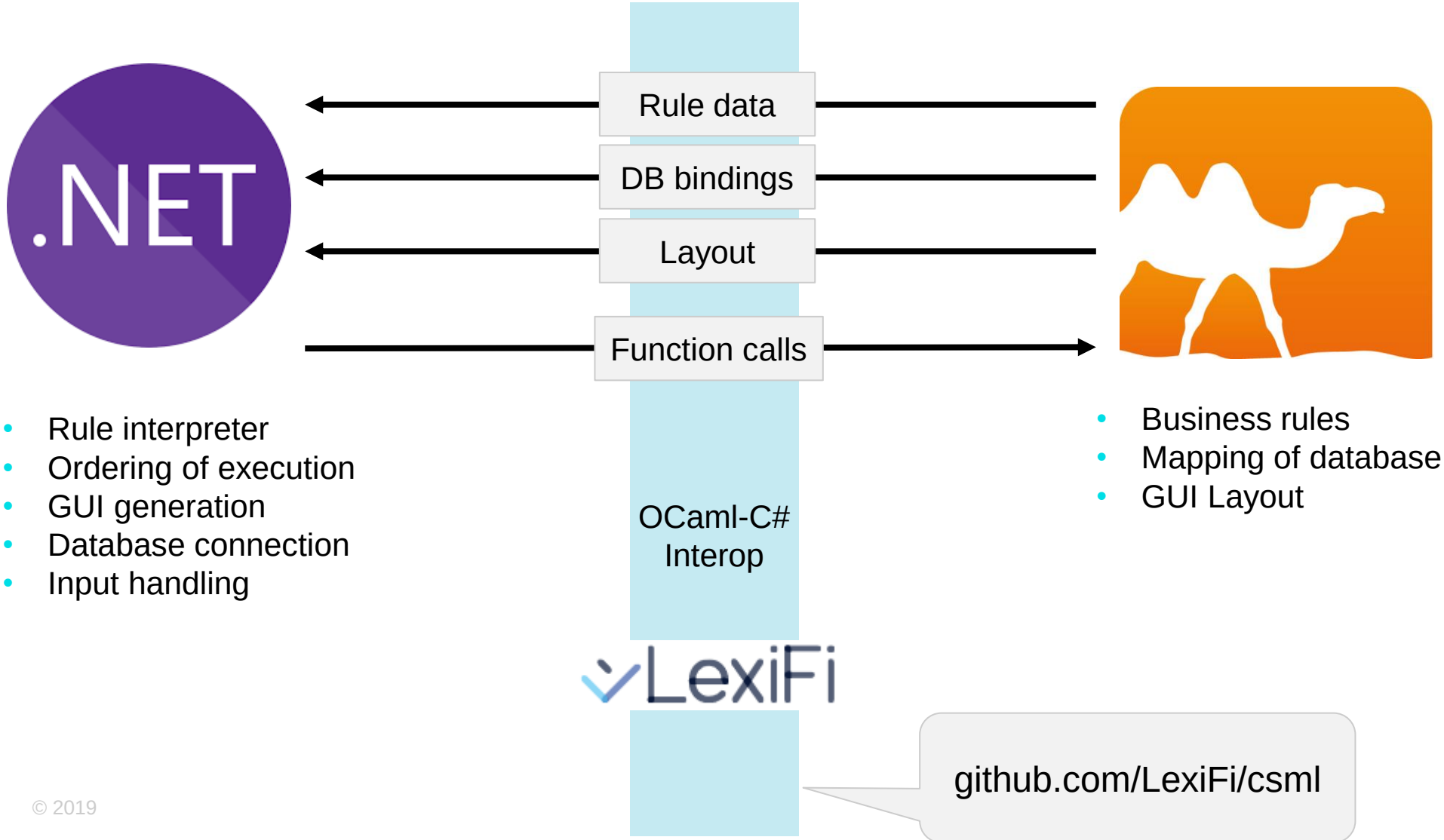
RULE EXECUTION

INTERPETER IMPLEMENTED IN .NET – BUSINESS RULES IN OCAML



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

- Business rules
- Mapping of database fields
- GUI Layout

MONADIC RULE API

SPLITTING RULES INTO SMALLER STEPS

- Lexifi OCaml run-time is not reentrant.
- Data base access & calls to APL are bottlenecks.
- Solution: split rule computation into small chunks.

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

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SEPARATION OF CONCERNS

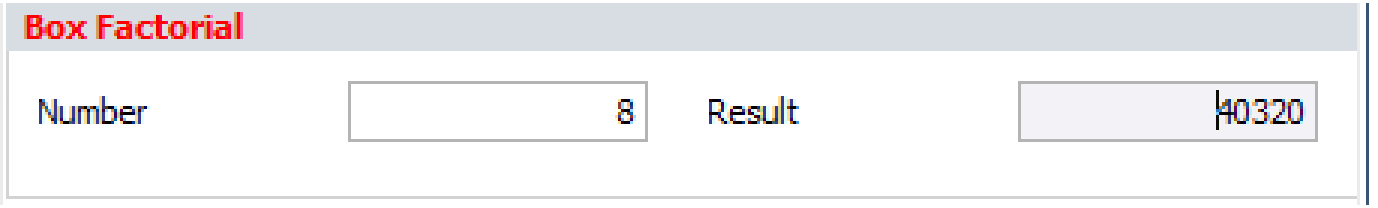
GUI LAYOUT GENERATION VIA LAYOUT API

```
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 (.number) % lpick (.result))
```



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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 programming**
  - 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

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

Thank you!

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