BEYOND THE BASICS OF LSP ADVANCED IDE SERVICES FOR OCAML

Xavier Van de Woestyne - @vdwxv - xvw.lol

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Tarides: Making Critical Systems Better

We help developers and companies build **robust**, **secure**, **high-performance** applications whilst maintaining crucial **reliability**.

BEYOND THE BASICS OF LSP
ADVANCED IDE SERVICES
FOR OCAML

And more ...

DUNE

OCaml

compiler
ecosystem
platform/tooling

SpaceOS

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*An ML language, a **strict Functional, Imperative**, with a powerful **type system** (ADTs, GADTs and row polymorphism), **Type inference**, Advanced **module system**, **OOP** with structural subtyping and **user defined effect** (as core language feature)*

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sorry for the **bazar** with my slides,
they're displaying my speaker notes!

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PLAN

What is a Language Server
A very naive editor Timeline

About Merlin
Basics workflow and features

About Lsp
Capabilities/Features and migration strategy

Implementation details about Some Advanced Features
Including a proof that Lambda Calculus can be concretely used as a functional programmer

Pro/Cons Lsp
and about VSCode integration

Conclusion and future work

BUT FIRST, WHY?

Discussions with other functional programming language users about their IDEs and their **expectations**, and also **present** our work :)

PLAN

About Merlin
Basics workflow and features

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Conclusion and future work

What is a Language Server
A very naive editor Timeline

And maybe find how to **solve some issues** with you

WHAT A GOOD IDE SHOULD BRING

Good support for code editing (hilighting/folding)

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Project discovery (Code Navigation)

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Tools orchestration and project management

Project discovery (Code Navigation)

Return valid information and mutations

NAIVE EDITOR TIMELINE

Configurable
TextBased
Editors

ACME

NAIVE EDITOR TIMELINE

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NAIVE EDITOR TIMELINE

ACME

Fully specialized
IDE

NAIVE EDITOR TIMELINE

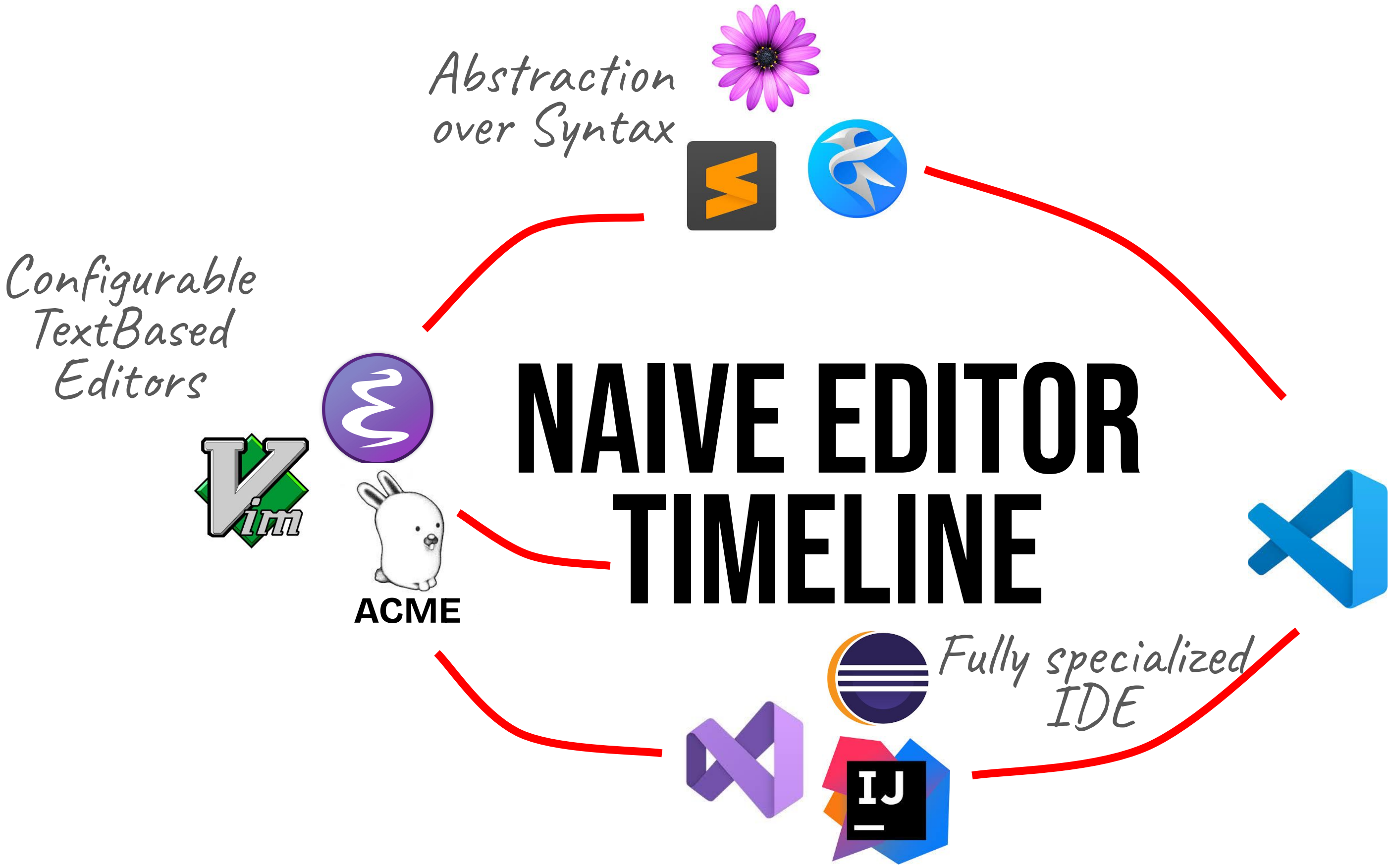
Configurable TextBased Editors

ACME

Abstraction over Syntax

Fully specialized IDE

NAIVE EDITOR TIMELINE




NAIVE EDITOR TIMELINE
Configurable TextBased Editors
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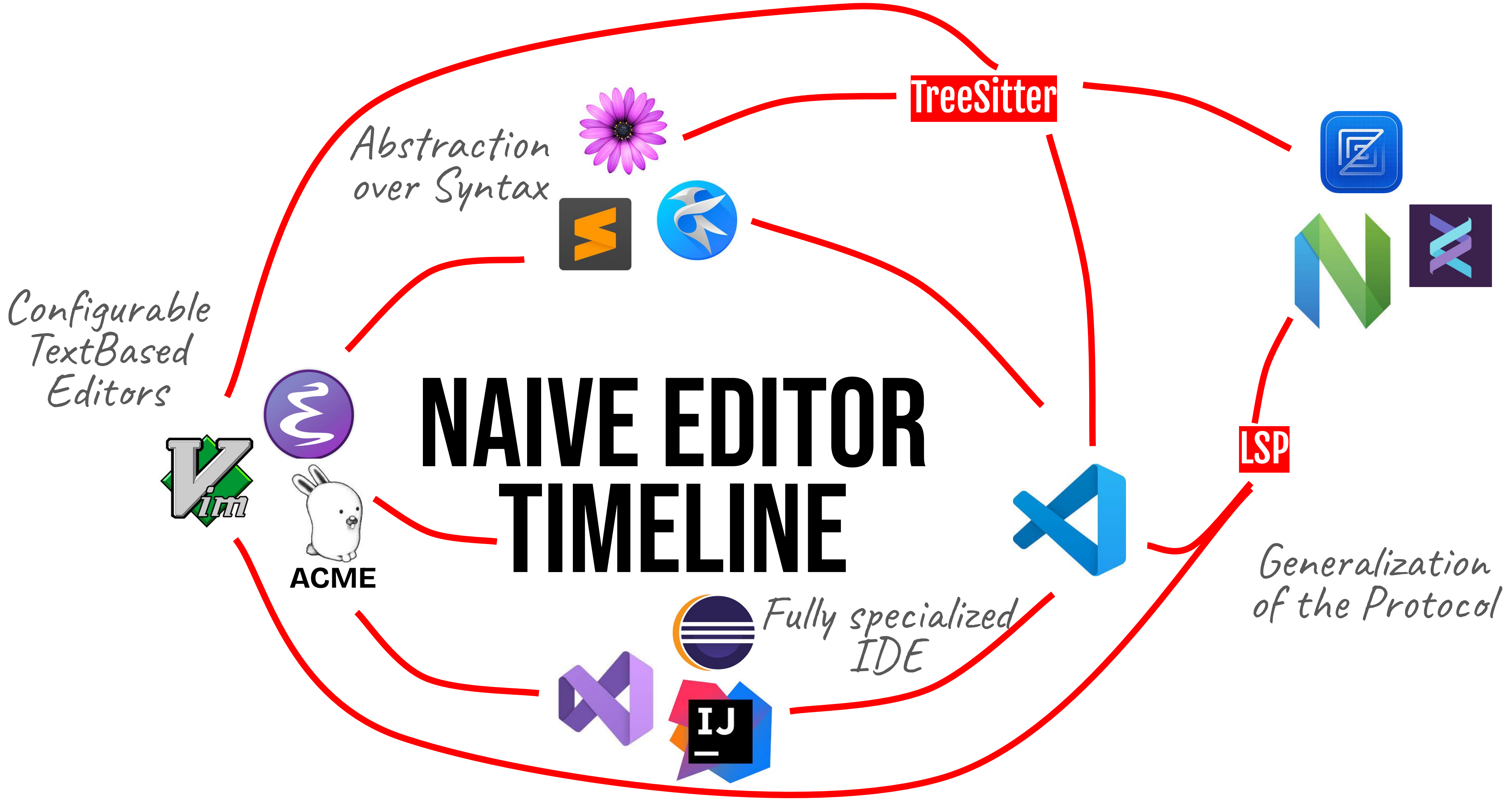
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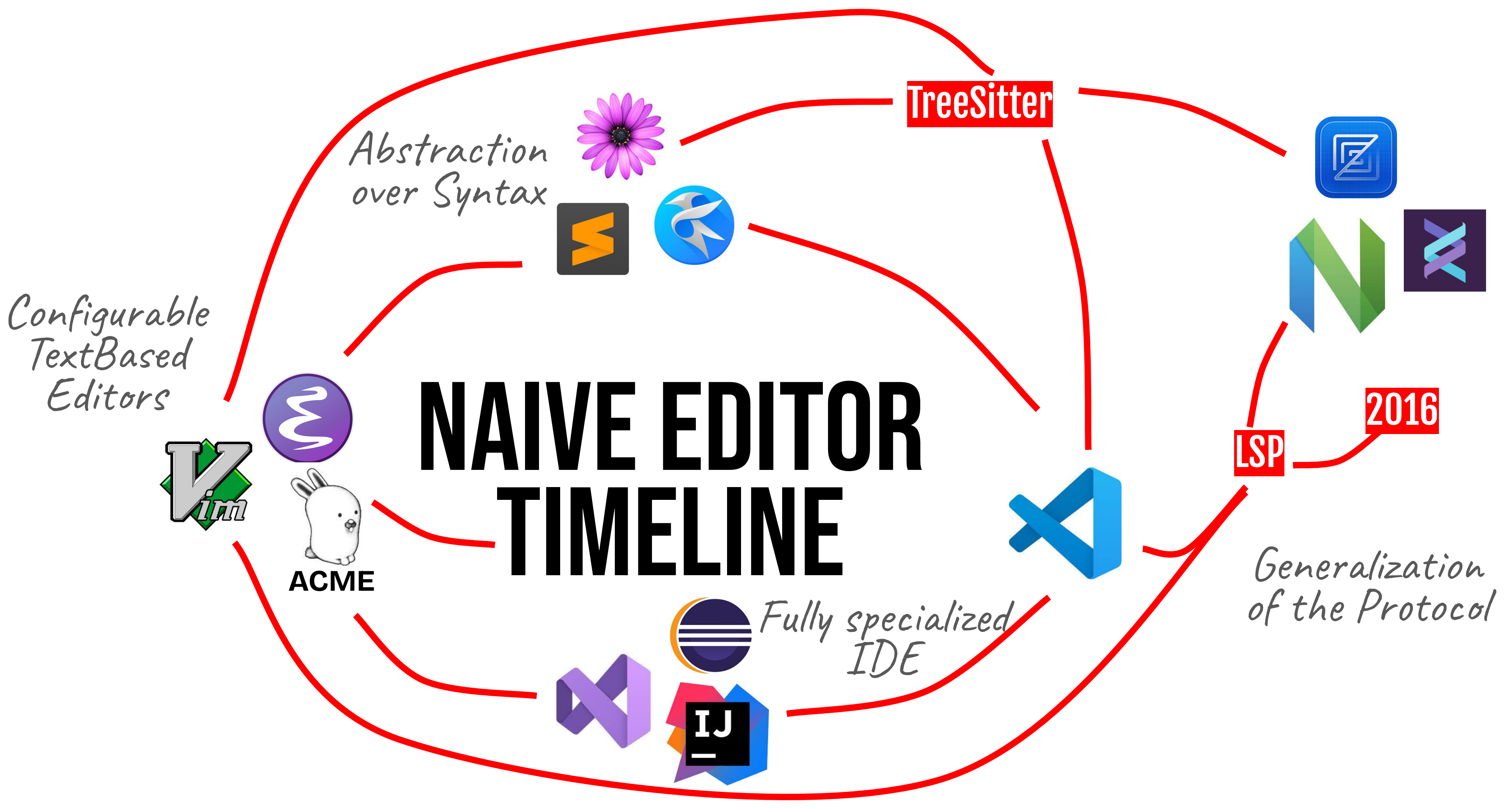
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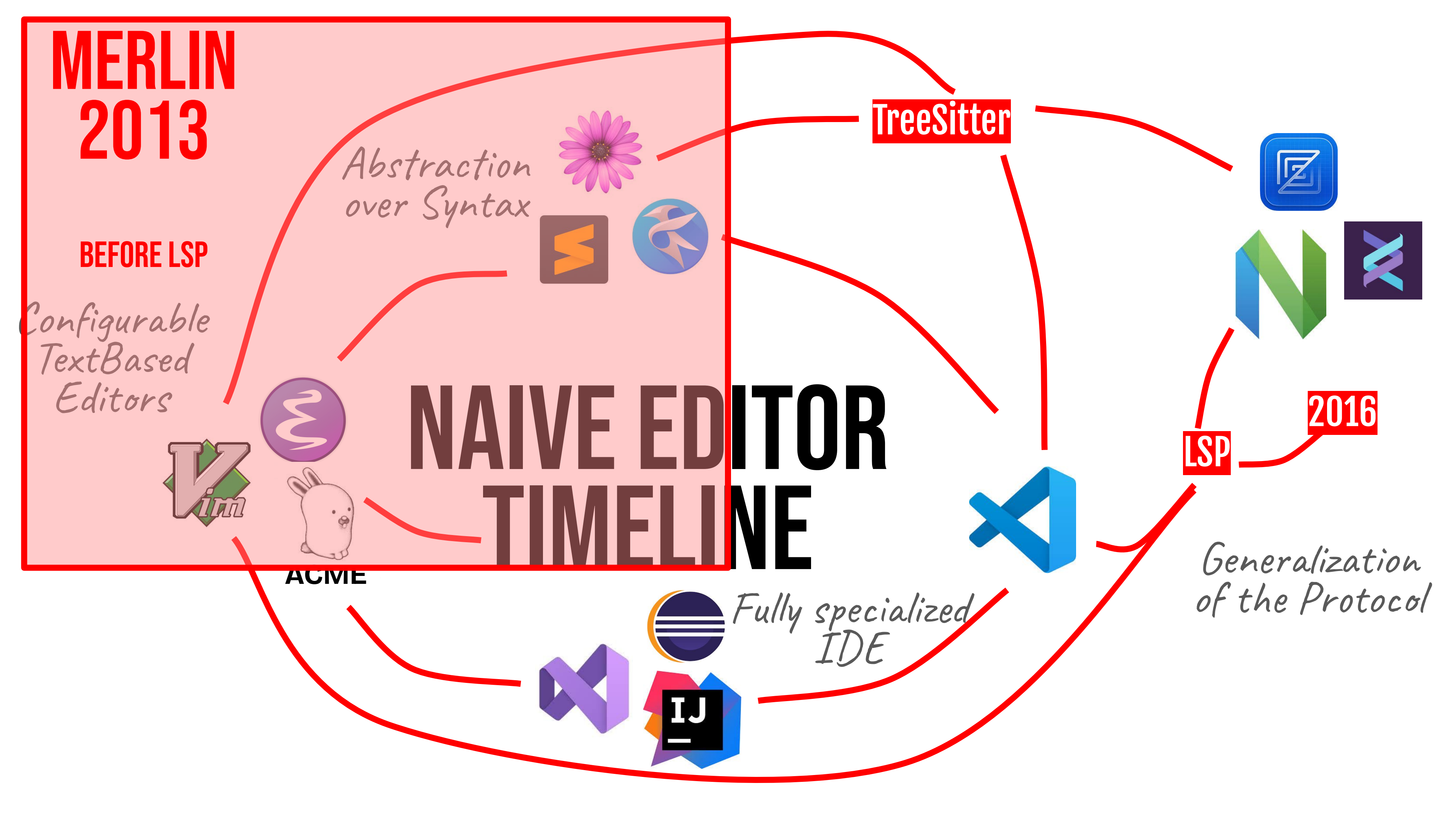
MERLIN
2013
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SO WHAT IS A LANGUAGE SERVER?

A daemon that receives text buffer
and user queries

SO WHAT IS A LANGUAGE SERVER?

GLOBAL ARCHITECTURE

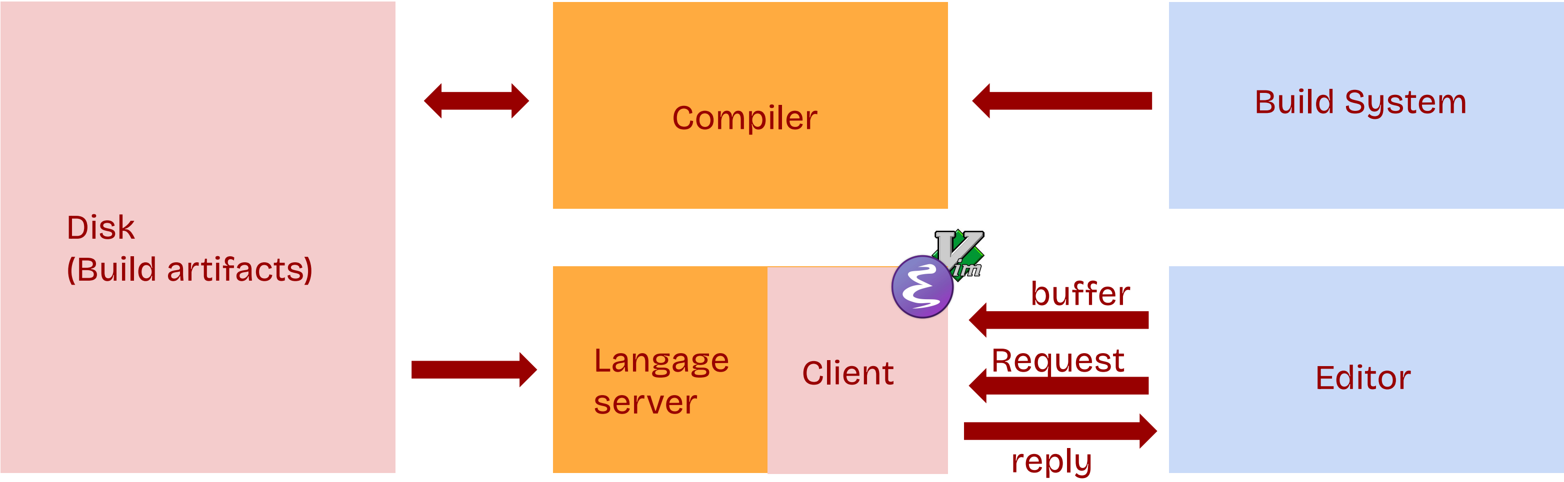
Documented in

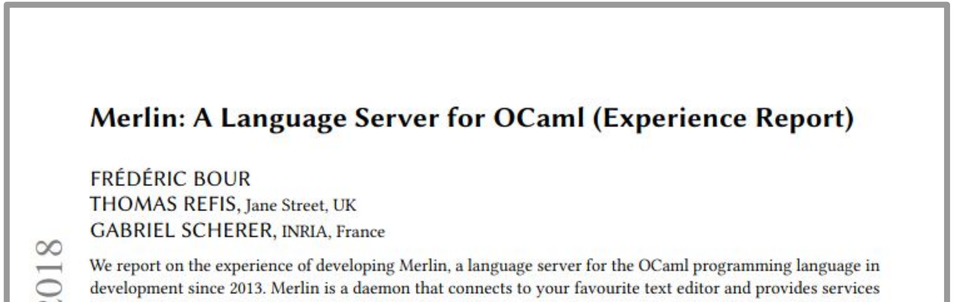
Merlin: A Language Server for OCaml (Experience Report)

FRÉDÉRIC BOUR
THOMAS REFIS, Jane Street, UK
GABRIEL SCHERER, INRIA, France

2018

We report on the experience of developing Merlin, a language server for the OCaml programming language in development since 2013. Merlin is a daemon that connects to your favourite text editor and provides services





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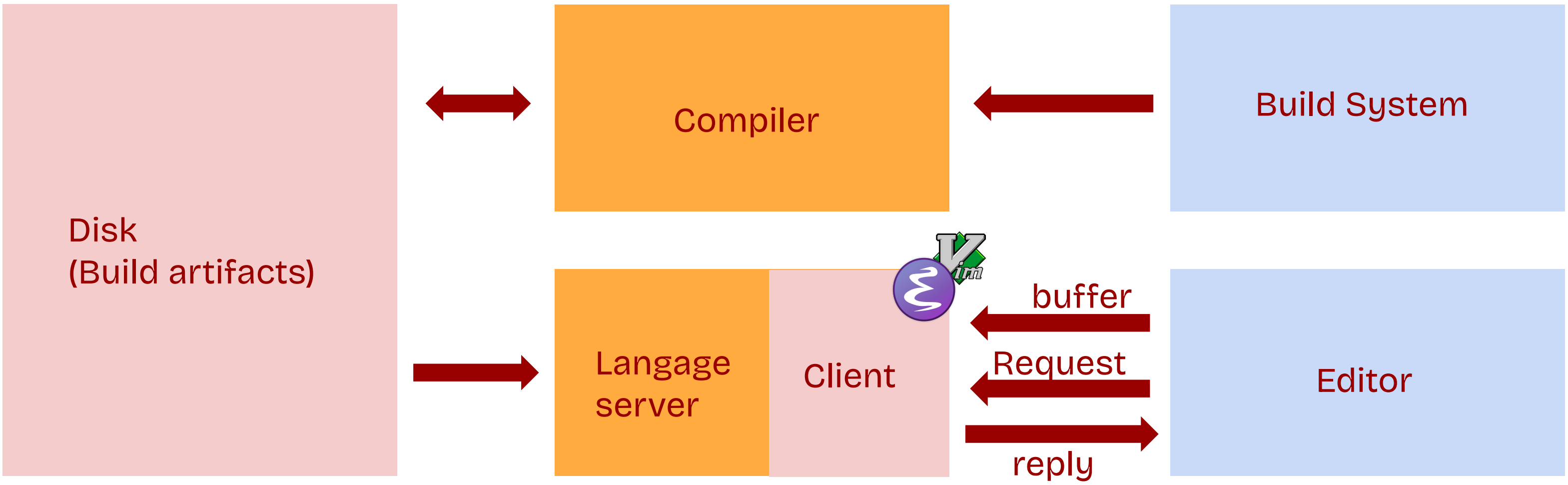
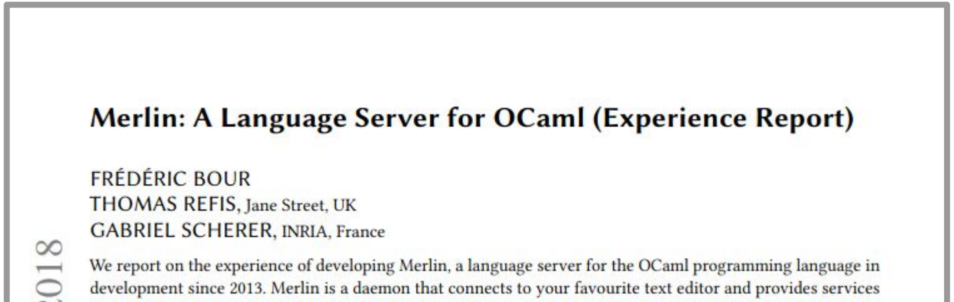


Include an
Incremental and Partial
language frontend
(Parser+ Typechecker)



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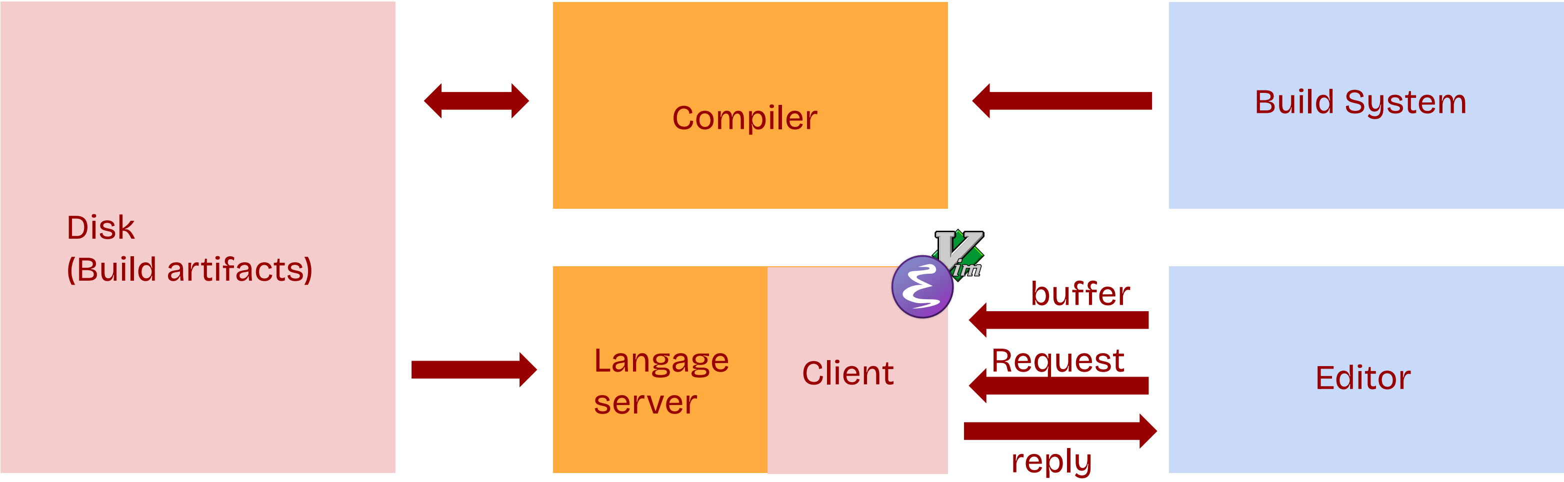
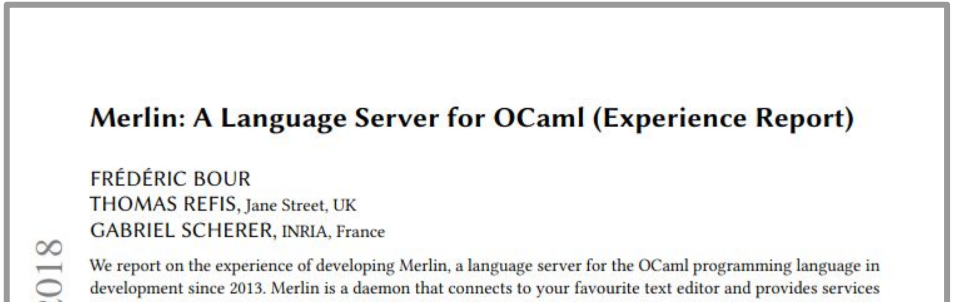


Include an **Incremental and Partial** language frontend (Parser+ Typechecker)

deal with **missing** or **wrong** part

only recomputed **changed part**



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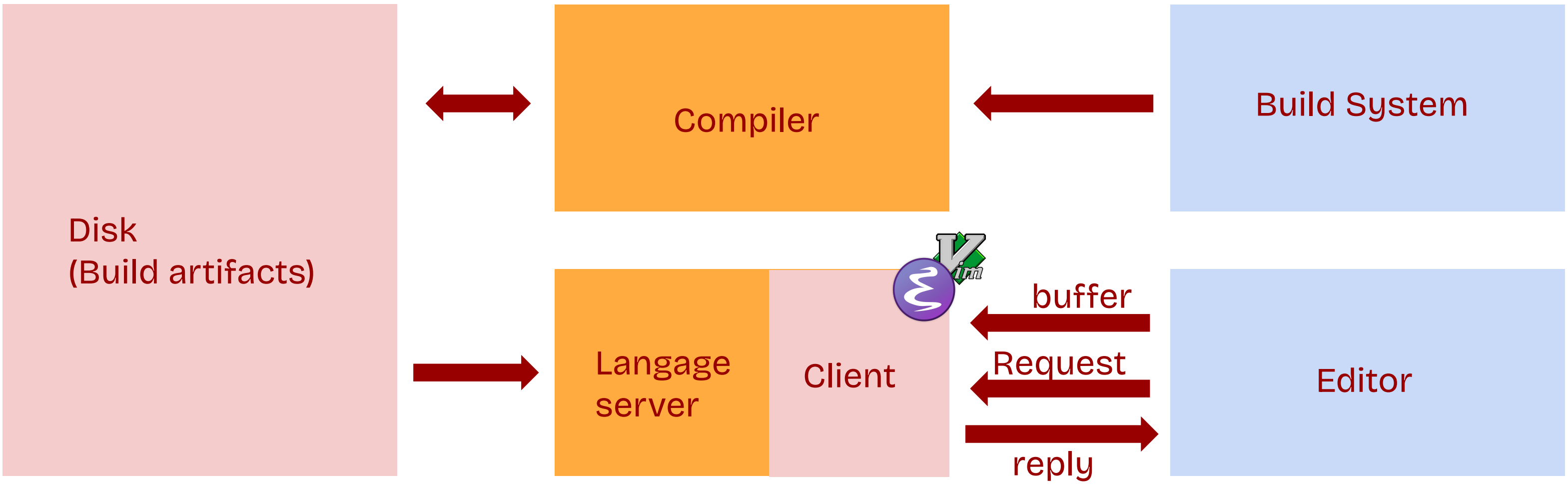
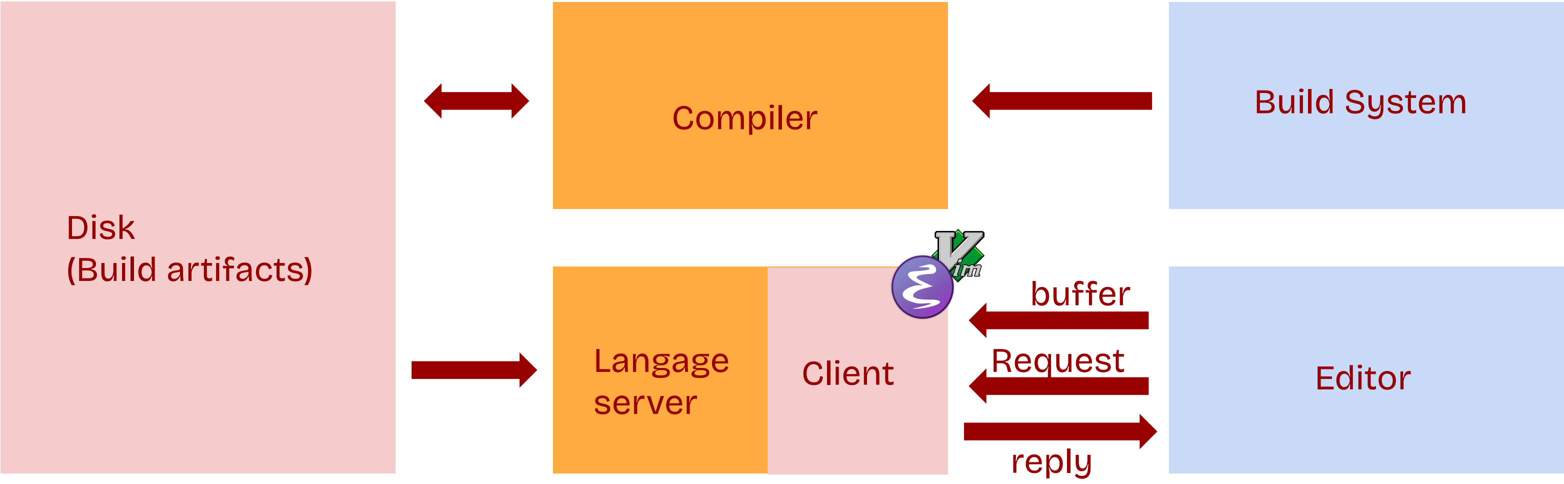


vendoring and **adapting** the existing OCaml toolchain

- making everything **pure** or **backtrackable**
- pure **lexer**
- pure **parser**
- **parsing error recovery** (faking data when it is missing)
- typechecking already has backtracking



purity unlock **memoization** for incrementality

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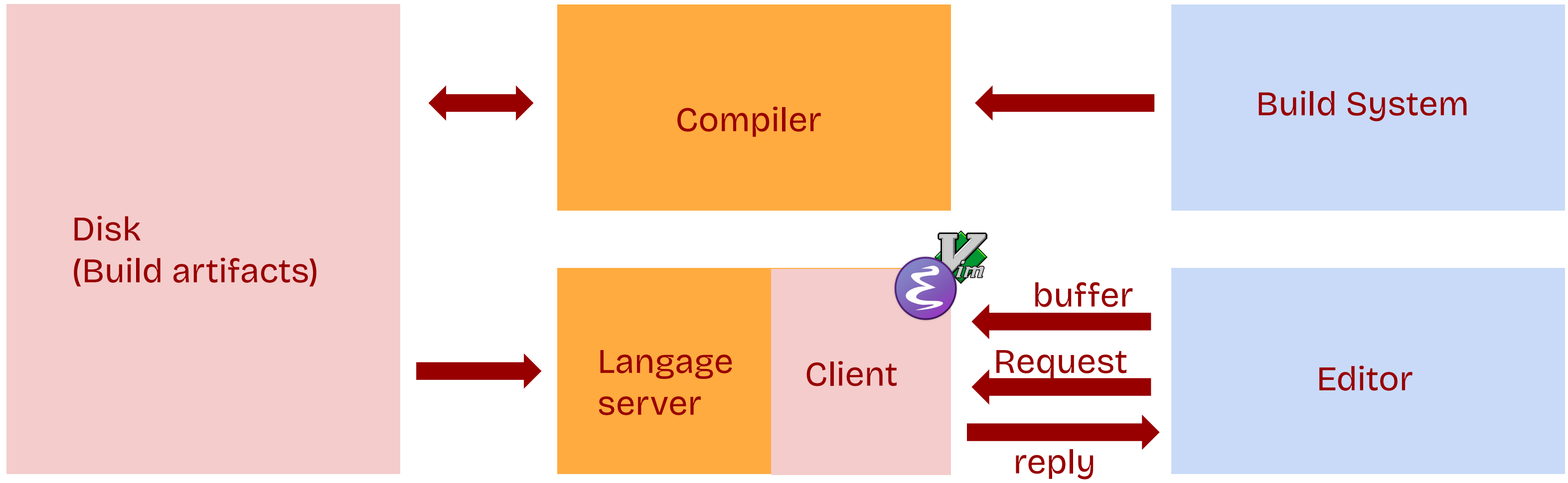

purity unlock **memoization** for incrementality

The paper also describes cool applications of static information about grammar (**error recovery, error messages, multi grammar**, **local GLR parser emulation**)

vendoring and **adapting** the existing OCaml toolchain

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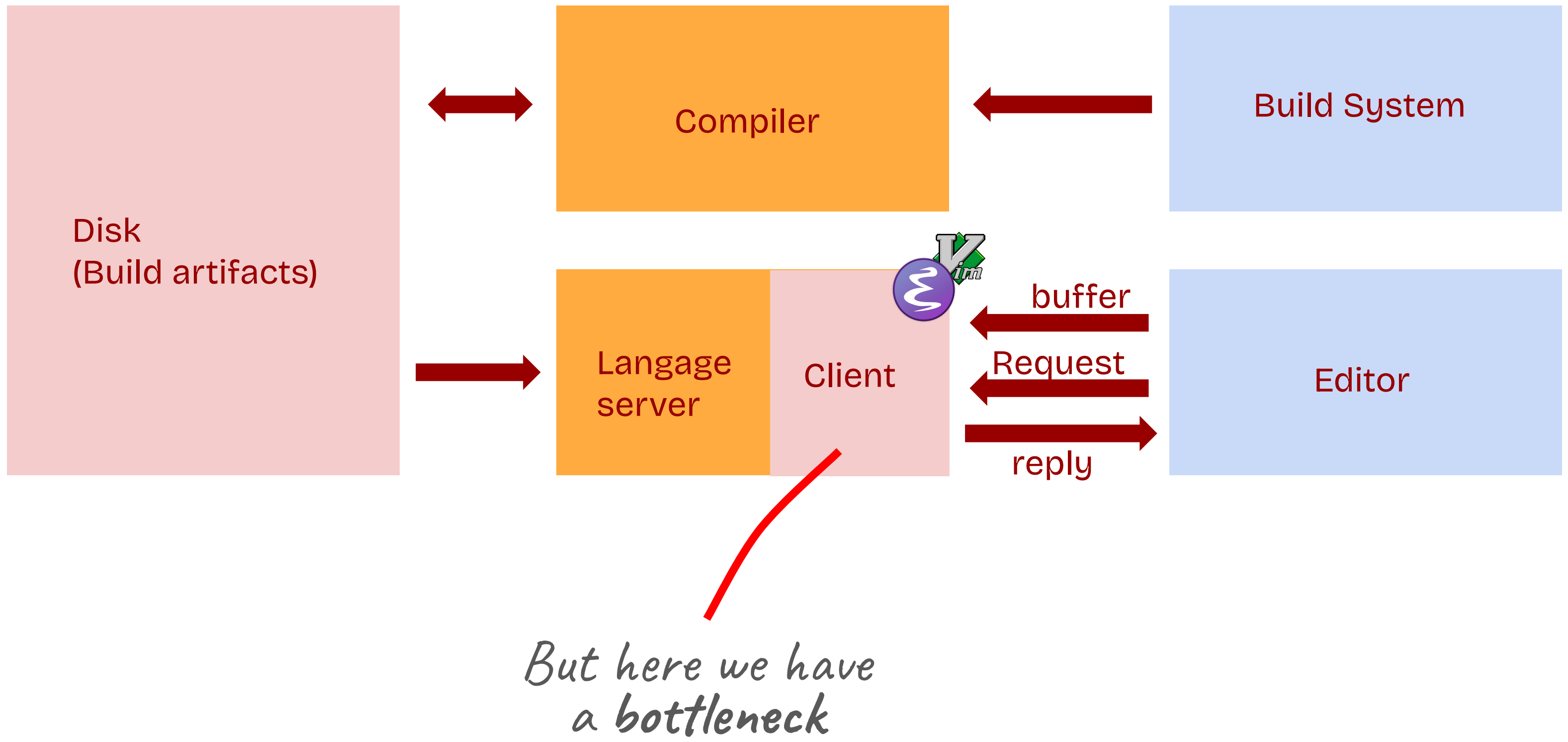
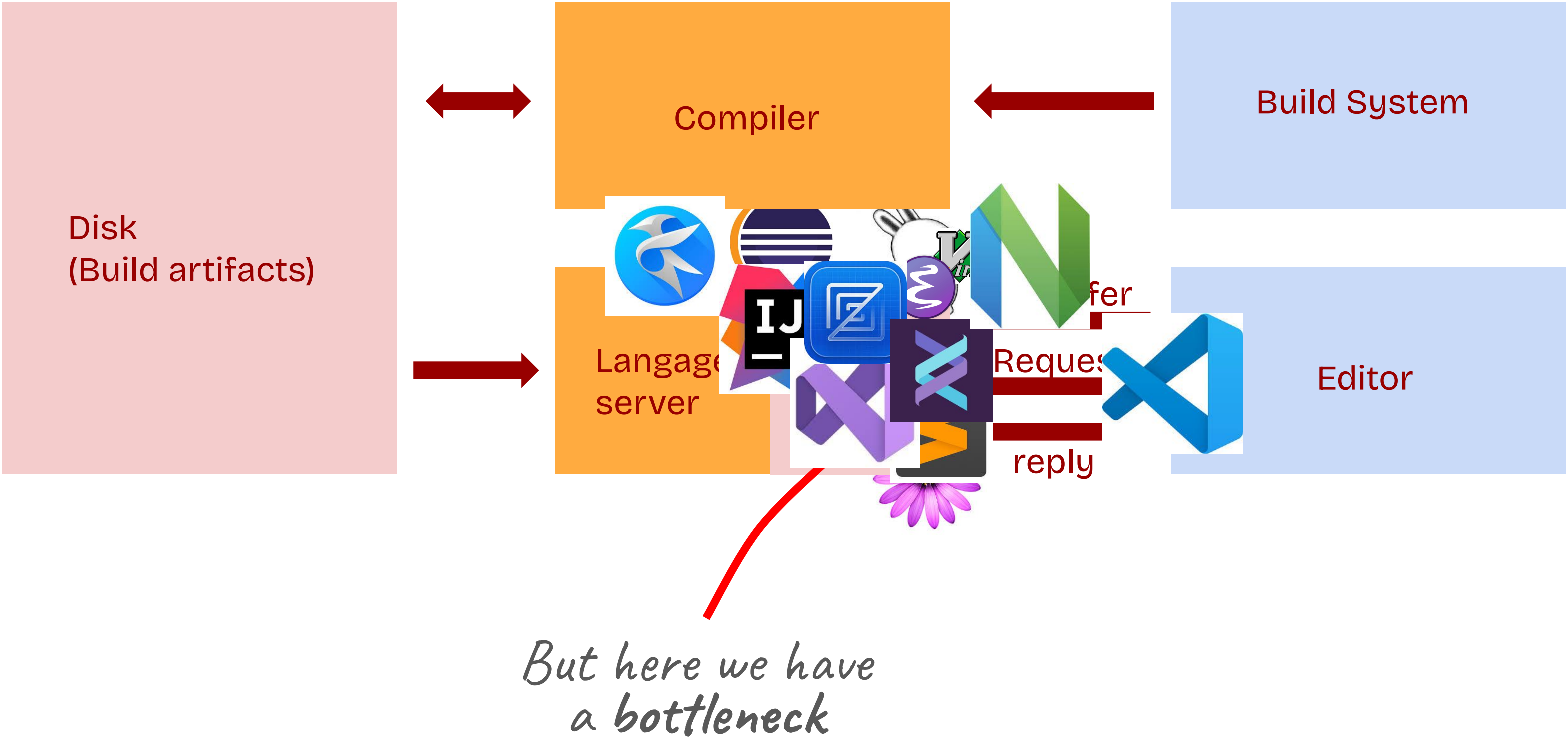

Compiler
Build System
Disk
(Build artifacts)
Langage
server
Client
buffer
Request
reply
Editor
But here we have
a bottleneck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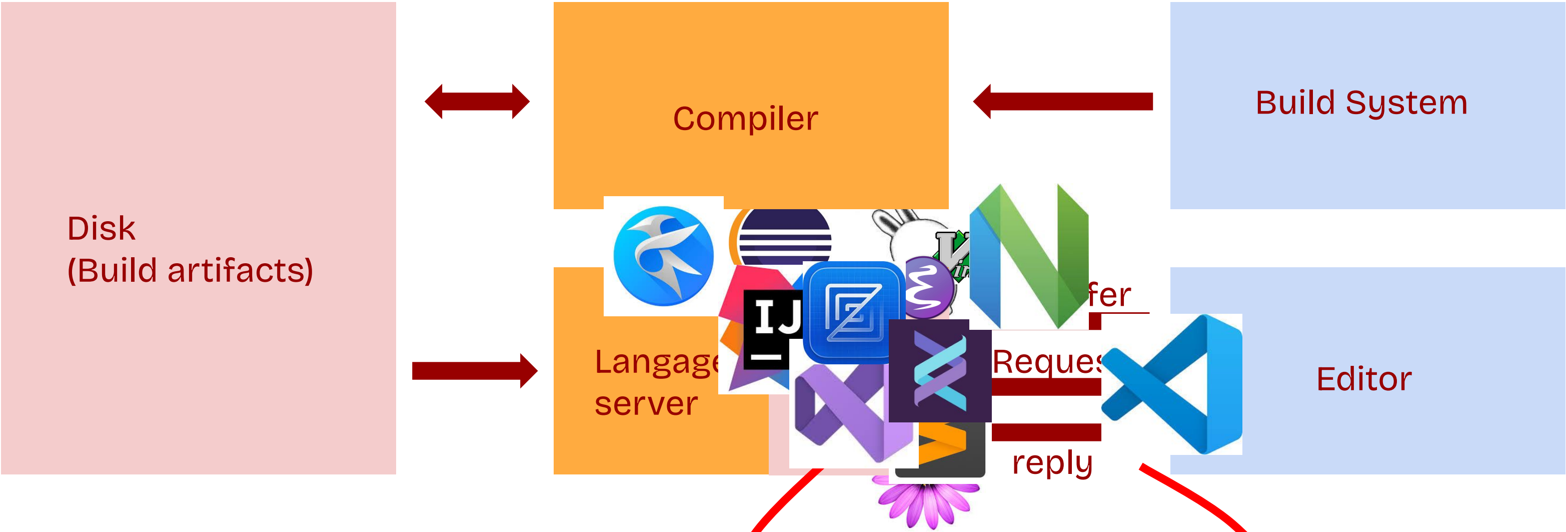
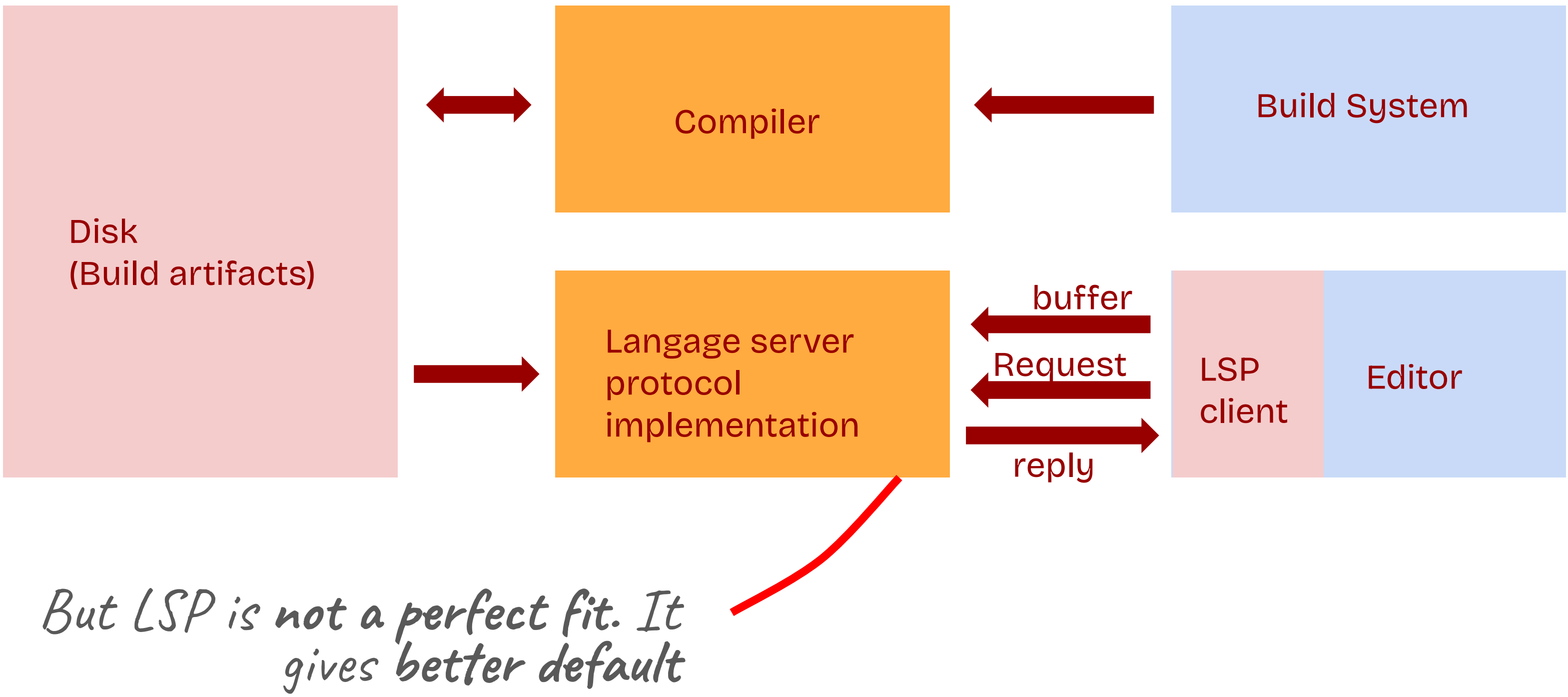


But here we have
a **bottleneck**

this is why LSP
since a lot of editors **are**
shipped with an LSP Client


Compiler
Build System
Disk
(Build artifacts)
Langage server
protocol
implementation
buffer
Request
reply
LSP
client
Editor
But LSP is not a perfect fit. It
gives better default

easy to extend
Syntax highlighting
by default

Syntax Highlighting
and code folding by
default

Hard to extend
**Complicated
protocol**

ACME

LSP

Syntax Highlighting, **auto-complete**, **jump-to-definition**, **hints** and **hovers**, **project manipulation**, **advanced search** (and a proper parallel client/server + capabilities notion)

and more feature but that assumes class-based and statement based languages.

easy to extend Syntax highlighting by default

Syntax Highlighting and code folding by default

Hard to extend ***Complicated protocol***

ACME

Let's observe some feature that diverges from the ones supported ***out of the box***

AN HUGE MIGRATION FROM MERLIN SERVER TO LSP

AN HUGE MIGRATION FROM MERLIN SERVER TO LSP

*Let's observe some feature that diverges from the ones supported **out of the box***

via **Code Action**

Contextual triggerable action on the document

via **Custom Request**

Lets the client implementing the reaction

AN HUGE MIGRATION FROM MERLIN SERVER TO LSP

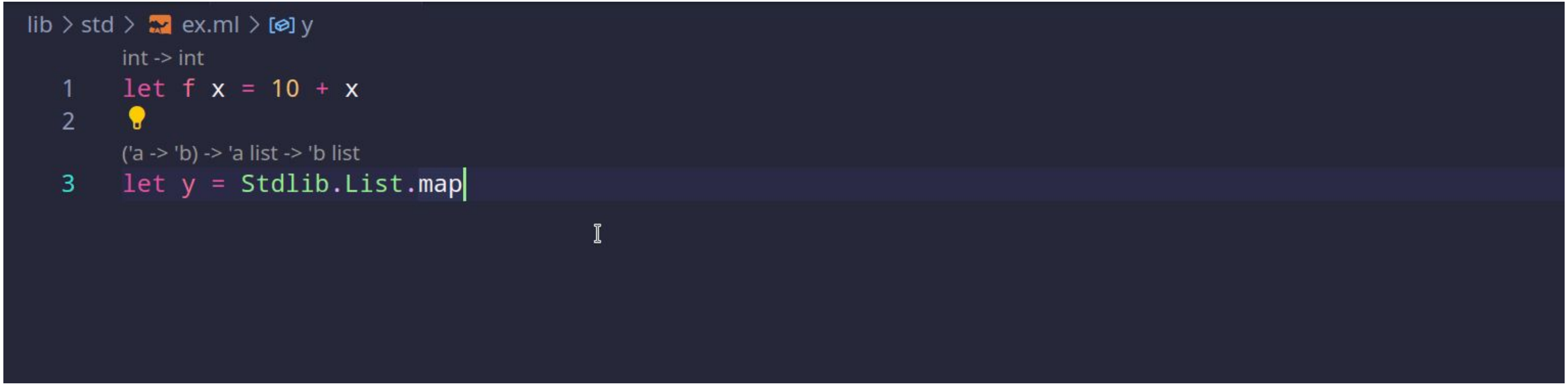
Let's observe some feature that diverges from the ones supported ***out of the box***

via ***Code Action***
Contextual triggerable action on the document

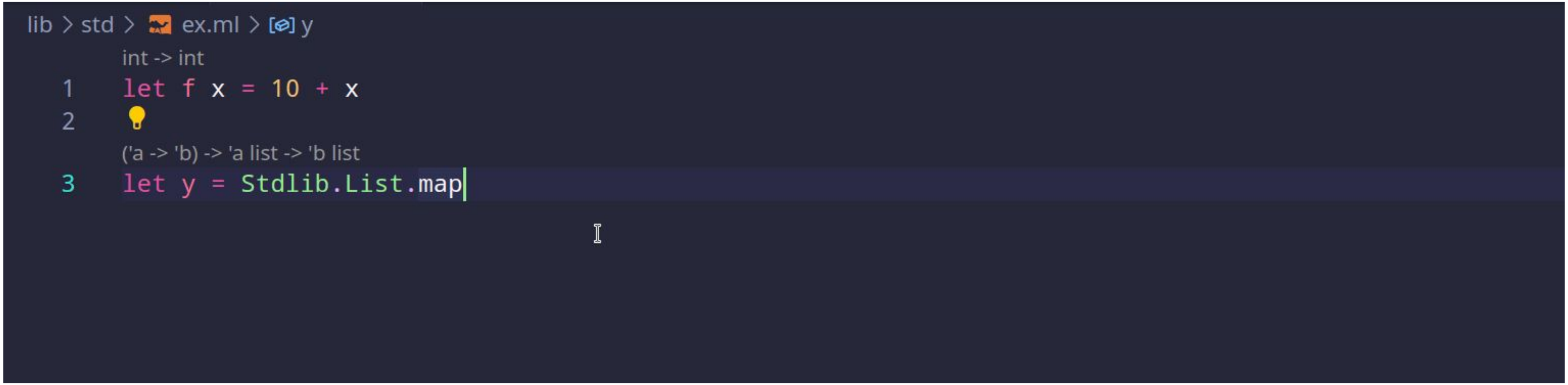
via ***Custom Request***
Lets the client implementing the reaction

that need ***SPECIFIC IMPLEMENTATION***
The comeback of our potential ***Bottleneck***

TYPES AND DOCUMENTATION



TYPES AND DOCUMENTATION



TYPES AND DOCUMENTATION

*Available via an **Hover Prodiver** and **Inlay Hints***

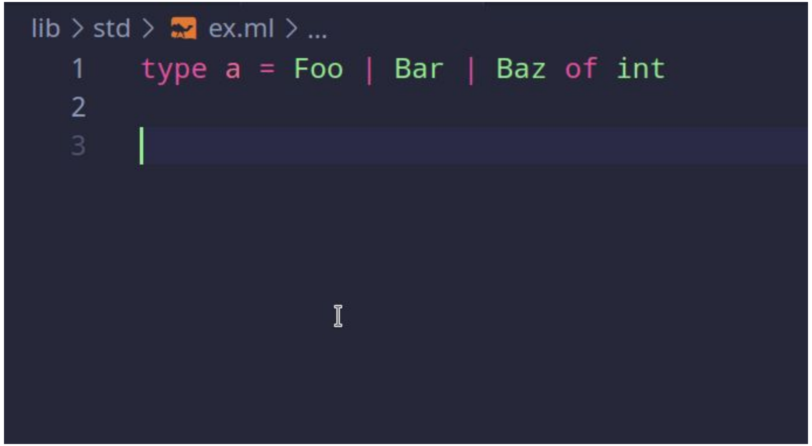
CASE ANALYSIS
AND CONSTRUCT EXPRESSION

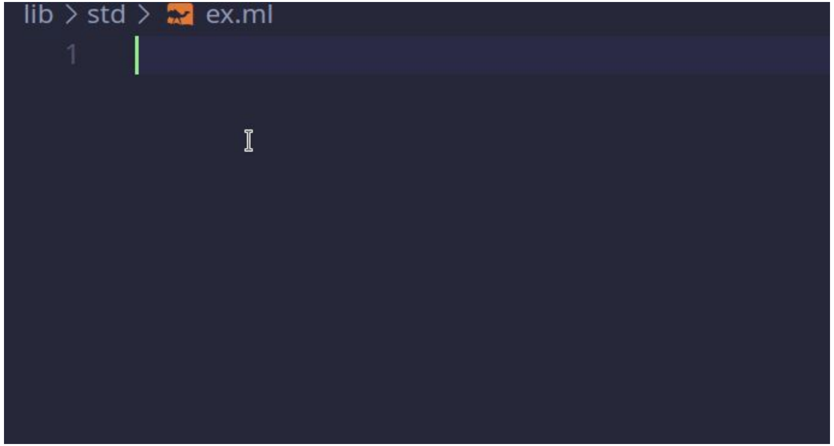
lib > std > ex.ml > ...

```
type a = Foo | Bar | Baz of int

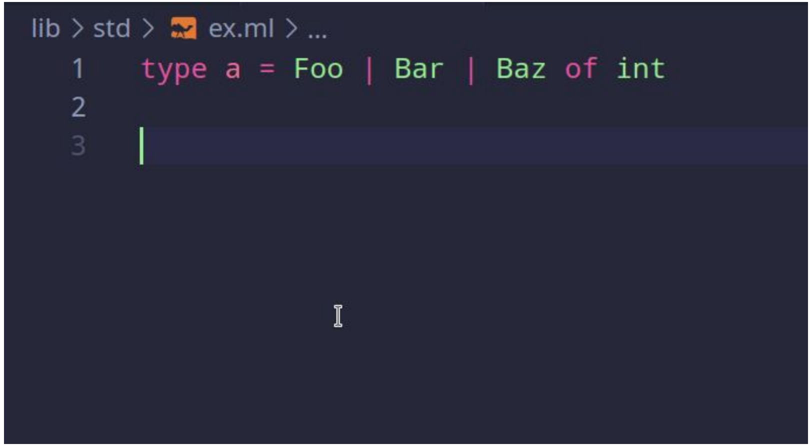
```

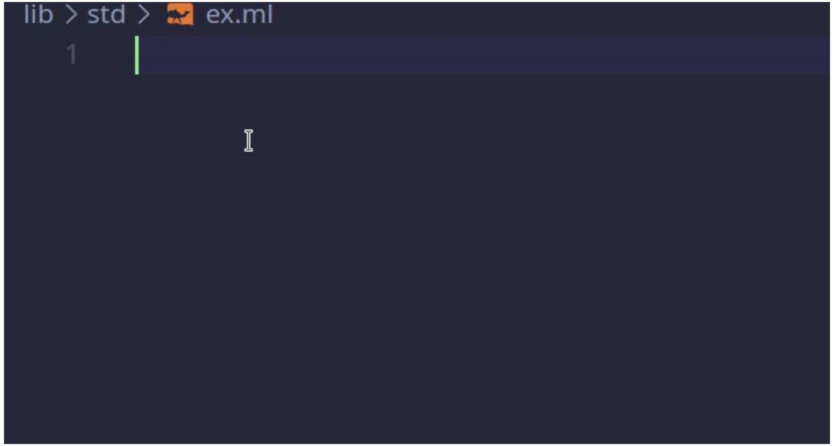
CASE ANALYSIS AND CONSTRUCT EXPRESSION





CASE ANALYSIS AND CONSTRUCT EXPRESSION





Available via ***Code Action*** *and* ***Completion***

CASE ANALYSIS AND CONSTRUCT EXPRESSION

OPEN REFACTORING

lib > std > ex.ml > ...

```
module Foo = struct
  let a = 10
  let b =11
  let c = 12

end


let x = Foo.a + Foo.b + Foo.c
```

OPEN REFACTORING

lib > std > ex.ml > ...

```
module Foo = struct
    int
    let a = 10
    int
    let b =11
    int
    let c = 12

end


int
let x = Foo.a + Foo.b + Foo.c
```

Available via a ***Code Action***

OPEN REFACTORING

SOURCE NAVIGATION

- Jump to the **prev** or **next** phrase (toplevel-definition)
- Switch from implementation to interface and vice-versa
- Jump to **fun/let/module/match**

SOURCE NAVIGATION

SOURCE NAVIGATION

- Jump to the **prev** or **next** phrase (toplevel-definition) — Available via a **Code Action**
- Switch from implementation to interface and vice-versa — Available via a **Code Action**
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Available via a ***Code Action***

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BUT

Highly pollutes the 'code-action' menu

No nesting/grouping in the protocol!

SOURCE NAVIGATION

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*Available via a **Code Action***

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Highly pollutes the 'code-action' menu

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*Moving to a **Custom Request***

SOURCE NAVIGATION

OUTLINES AND CODE STRUCTURE

Works well for outlines but not for document navigation

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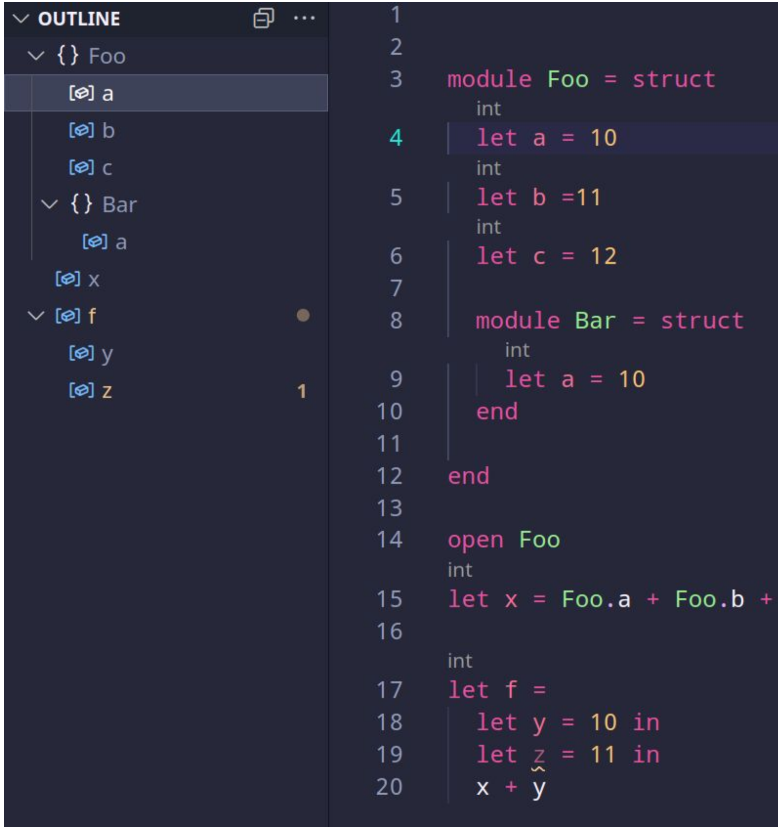
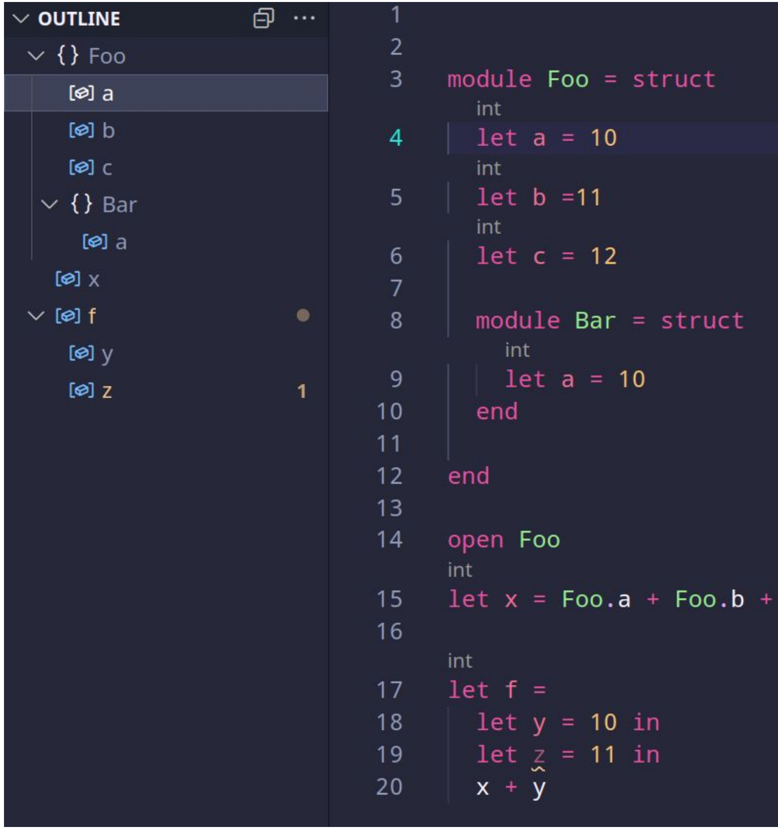
Works well for outlines but not for document navigation



OUTLINES AND CODE STRUCTURE

Assumes that **all languages are TypeScript-like** (in Outline Kind)

Works well for outlines but not for document navigation



OUTLINES AND CODE STRUCTURE

TYPE-ENCLOSING

TYPE-ENCLOSING

one of the **main feature** of
Merlin

```
type t =
 { result : int
 ; job_done : bool
 }
let f x =
 let init_value = x + 1 in
 let z =
   Stdlib.List.fold_left
     (fun acc x -> acc + int_of_string x)
     init_value
     [ "1"; "2"; "3"; "4" ]
 in
 { result = z; job_done = true }
let result = f 10
```

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one of the main feature of Merlin

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The "result" has type *t*

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but outside of the module it hard to guess what is really **t**

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```

so we want to **increase** the verbosity (in Emacs + Merlin we can re-call the feature to get the following definition)

but outside of the module it hard to guess what is really **t**

The "result" has type **t**

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An other useful feature is to **grow** and **shrink** the observable enclosing.

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An other useful feature is to **grow** and **shrink** the observable enclosing.

('acc -> 'b -> 'acc) -> 'acc -> 'b list -> 'acc

TYPE-ENCLOSING

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An other useful feature is to **grow** and **shrink** the observable enclosing.

[int -> string -> int] -> int -> string list -> int

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int

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TYPE-ENCLOSING

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An other useful feature is to ***grow*** *and* ***shrink*** *the observable enclosing.*

t : { result: int; job_done: bool }

TYPE-ENCLOSING

one of the ***main feature*** *of Merlin*

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type t =
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 ; job_done : bool
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let f x =
 let init_value = x + 1 in
 let z =
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     (fun acc x -> acc + int_of_string x)
     init_value
     [ "1"; "2"; "3"; "4" ]
 in
 { result = z; job_done = true }
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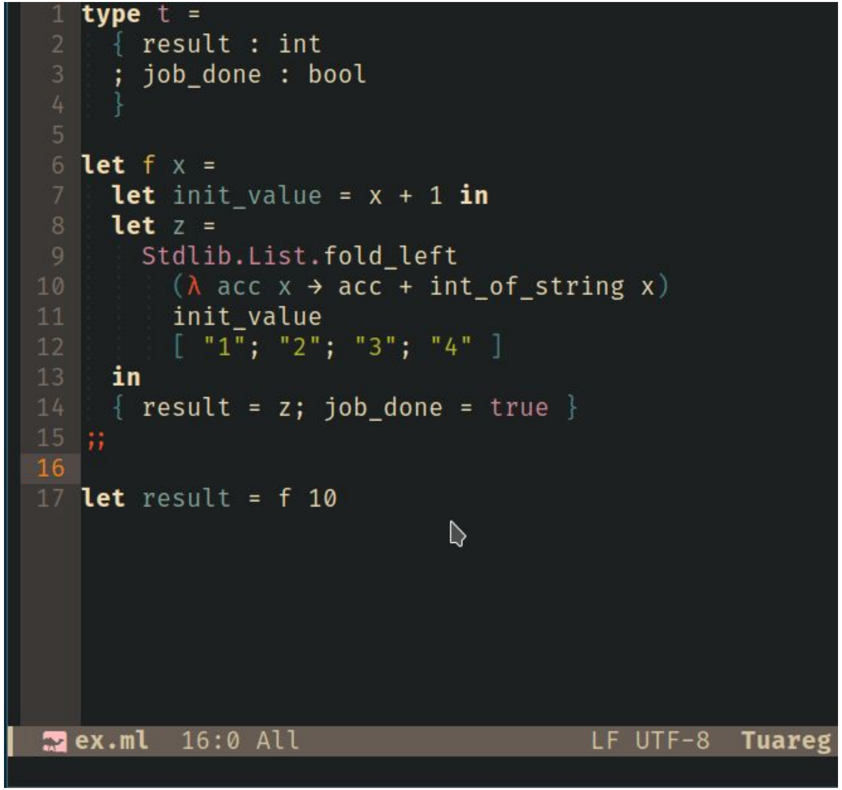

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Custom Request +
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ex.ml 16:0 All LF UTF-8 Tuareg

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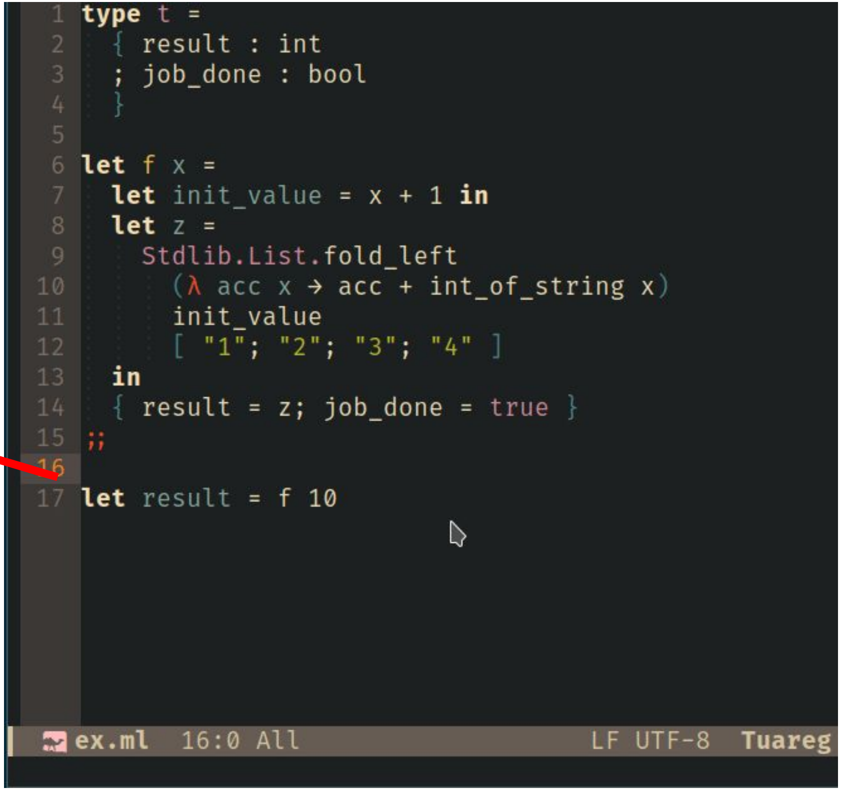
Can't really hook the ***Hover Provider***



LSP MAKES A LOT OF THINGS SIMPLER

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recentlu released!
OCaml-eglot

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IMPLEMENTATION DETAILS

Where the fun begins

PROJECT-WIDE OCCURRENCES

return every usage of the selected identifier
across all of the project's source files

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Hard to achieve in presence of powerful module system and separate compilation

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PROJECT-WIDE OCCURRENCES

Module Shapes for Modern Tooling

Ulysse Gérard, Thomas Refis, and Leo White

The ability to look up the definition of a variable is an essential feature of modern programming tooling. Beyond the simple code browsing action of jumping to that definition, it is a preliminary for more advanced tasks like fetching documentation or refactoring. The operation of finding a definition requires deep knowledge of a language's semantics to prevent finding erroneous positions in the presence of overlapping names, shadowed values, or complex features like module systems with includes and functor applications.

While imprecise results are tolerable for an *interactive* "jump to definition" use case, where the user can immediately assess the relevance of the definition the tool shows him

the source location of a declaration is therefore as simple as a lookup in the typing environment.

When trying to find the location of a definition however, there's no help to be had from the compiler. So a natural strategy that tools (e.g. merlin, rotor) can (and do) resort to is to *walk up* the typed AST, looking for the definition. On the example above, to find the definition of `N.x` we would first look for the module `N`, and then inspect its structure to find the definition of `x`.

We put an emphasis on walking "up", because, due to shadowing, the order in which the tree is visited matters. Consider a slight variation of the previous example where

OCaml's module system supports **aliases**, **includes**, and **(higher-order) functors**.

All of these make

finding any definition more complicated

EXAMPLE

LET'S FIND THE DEFINITION OF M.X

```
module type S = sig
 val x : int
end

module Identity (X : S) : S = X

module Simple = struct
 let x = 3
 let y = true
end
module Apply (Id : functor (_ : S) -> S)
             (X : S) = struct
 include Id (X)
end

module Alias = Simple
module M = Apply (Identity) (Alias)

let y = M.x
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Shapes are a new build artifcact that store that kind of path in the form of a small **typed lambda-calculus with products** associated with UID

A SIMPLIFIED REPRESENTATION

```
type t = desc * source_loc
and item = string * namespace (* val, type, module... *)
and var = ident
and desc =
| Leaf
| Var of var
| Abs of var * t
| App of t * t
| Struct of (item, t) Map.t
| Proj of t * item
```

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REPRESENTING OUR MODULE M

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   , Abs ("X", Var "X"), 3:0),
   Struct { ("x", value) -> Leaf, 5:23
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this calculus is **implicitly typed**
since its terms, which we call shapes, **are derived from OCaml's module terms which are typed-checked by the compiler.**

This implies that shapes **have a normal form in this calculus equipped with the usual reduction rules:**

$$\text{App}[\text{Abs}[x, \text{body}], \text{arg}] \ \beta > \text{body}[x \leftarrow \text{arg}]$$

$$\text{Proj}\ [[\ \text{Struct}\ \varphi\ ,\ \_\ ], e\ ]\ \pi > \varphi\ [e]$$

REDUCTION

Tricky to solve in presence of
separate compilation

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REDUCTION

An OCaml use case for strong call-by-need reduction

Gabriel Scherer (Partout, INRIA, France)
Nathanaëlle Courant (Cambium, INRIA, France)

2022

Shapes

The compiler artifact produces build artifacts that include, in particular, the "typed tree" of each source file. This is a good representation to use for programming tools (IDEs, code analyzers, etc.), but it is sometimes too complex. Consider the following OCaml program:

```
module Origin = struct let x = 1 end
module Second = struct let x = 2 let y = 2 end

module F(X) = struct
  include X
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```

A very smart idea using **Strong Call By Need Reduction**
usually useful for proof assistant

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Next step
Project Wide Renaming

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Available on last version

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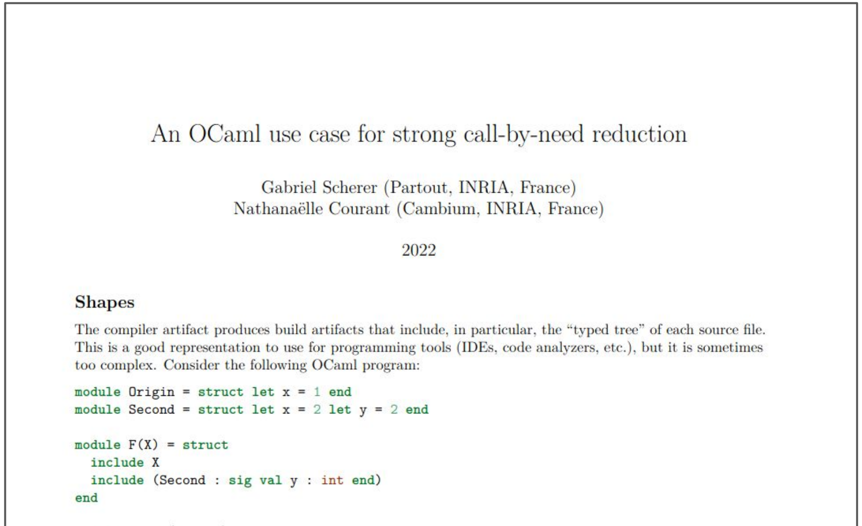

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SEARCH BY TYPES

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Discoverving a new code base can ***be complicated***

SEARCH BY TYPES

understanding architecture

Discoverving a new code base can **be complicated**

finding function and modules

SEARCH BY TYPES

We can use:
find-occurences
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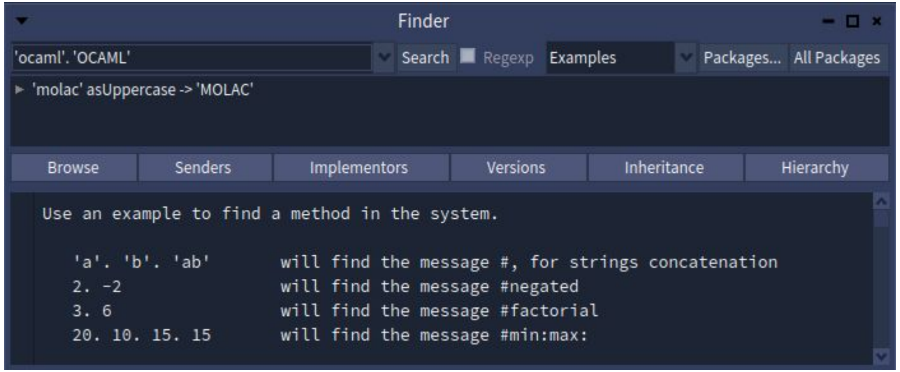
HOW TO FIND FUNCTION IN AN EXISTING CODEBASE

Finding by usage/example like in Pharo



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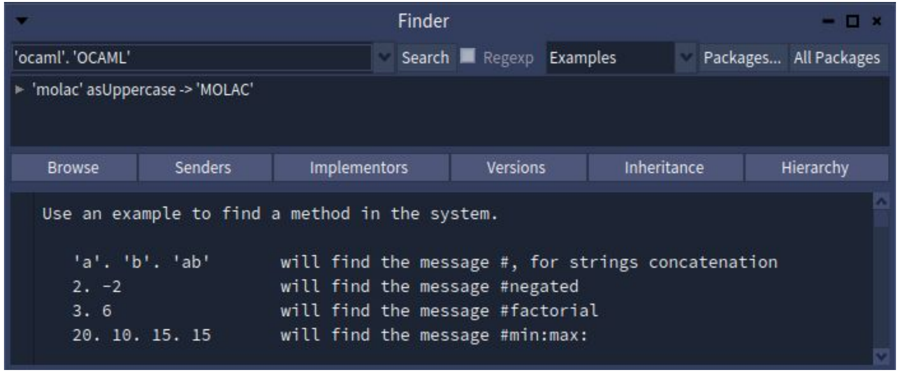

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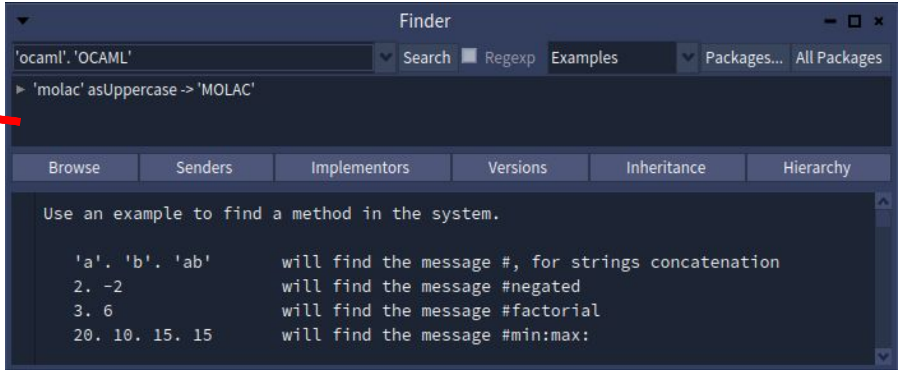
Finding by types like with Hoogle (Haskell)

Hard to implement at the editor level



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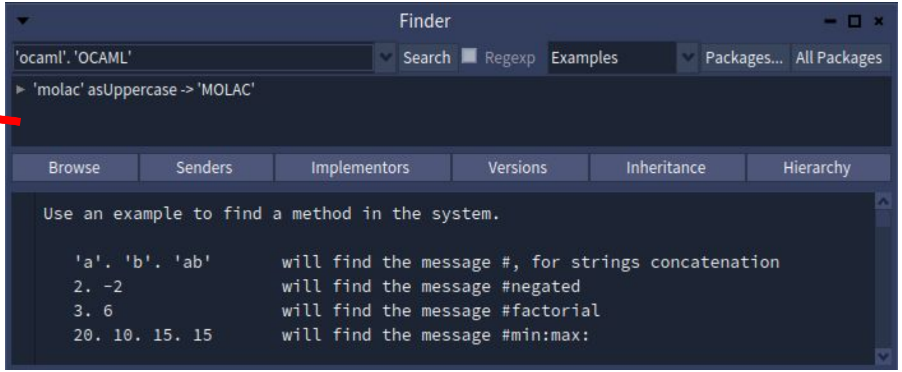

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In Type we trust !!!
(and it is a very good specification tool)

A VERY DESIRED FEATURE!

SINCE 2015

- ocaml-hoogle
- ocamlscope
- ocamlscope2
- ocp-index

Type-directed API search #459

Open **ghost** opened this issue on Oct 29, 2015 · 7 comments

ghost commented on Oct 29, 2015 ...

This is a feature request.

It would be really nice if Merlin could perform Coq-like type-directed searches, similar to what `SearchPattern` does in Coq.

The main use case I would have for this feature would be to query "which functions can produce a type M.t"? Or "which functions use this type M.t"? All that in the context of a large code base where the user needs a value of type `C.t` and he knows that function `f: A.t -> B.t -> C.t` exists, but then he wonders how to produce a `B.t` in order to give it to `f`, and then he finds out after much effort that a function `g: D.t -> B.t` exists, but then he has to find out how to obtain a `D.t`

and the not well documented search by polarity in Merlin

WHAT IS POLARITY SEARCH?

Every function can be declared as

type [-'a, +'b] t = 'a -> 'b

WHAT IS **POLARITY SEARCH**?

Every function can be declared as

```
type (-'a, +'b) t = 'a -> 'b
```

a is ***contravariant*** *b is* ***covariant***

WHAT IS POLARITY SEARCH?

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type [-'a, +'b] t = 'a -> 'b

a is **contravariant** b is **covariant**

WHAT IS POLARITY SEARCH?

flagging variances allows us to define a very small distance computation

Every function can be declared as
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a is **contravariant** b is **covariant**

WHAT IS POLARITY SEARCH?

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string -> int  -string +int
float -> int    +int -float
int -> int -> int    -int -int +int
```

minus for contravariant
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flagging variances allows us to
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Hard to use but a **proof that Merlin can fold definition**

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DURING THE TIME

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Type indexing in OCaml: search and find functions in a large ecosystem

Gabriel Radanne, Inria CASH/LIP
Laure Gonnord – Grenoble INP/LCIS & LIP/CASH

2021-2022

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Sometimes, we need a function so deeply that we have to go out and search for it. How do we find it ? Sometimes, we have a precise idea of the desired type : "this function has at least 2 parameters, a *bike* and a *date* and returns a boolean value". We will then search at some precise places (the directory containing the `Bike` module, for

DURING THE TIME

Sherlodoc

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Results for : 'a list → ('a → 'b) → 'b list

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because the complicated part is about indexation the full OCaml list of available packages

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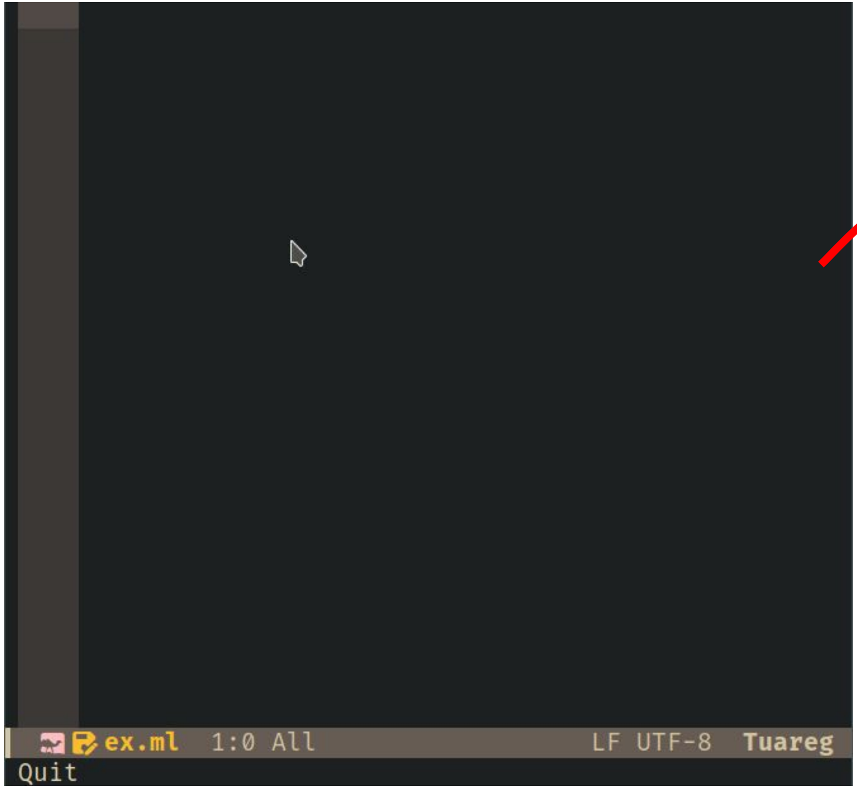
And adding some DX tool (constructible, doc etc)



future improvement:

- Better heuristics for tycon
- Support for modules, objects, labelled arguments and polymorphic variant (modulo isomorphism)
- Taking account of user-feedback

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Debug Adapter Protocol?
TreeSitter?

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Questions ?

BEYOND THE BASICS OF LSP ADVANCED IDE SERVICES FOR OCAML

Xavier Van de Woestyne - @vdwxv - xvw.lol