OCaml

FROM IMPERATIVE TO FUNCTIONAL APIS

Marek Kubica @leonidasfromxiv

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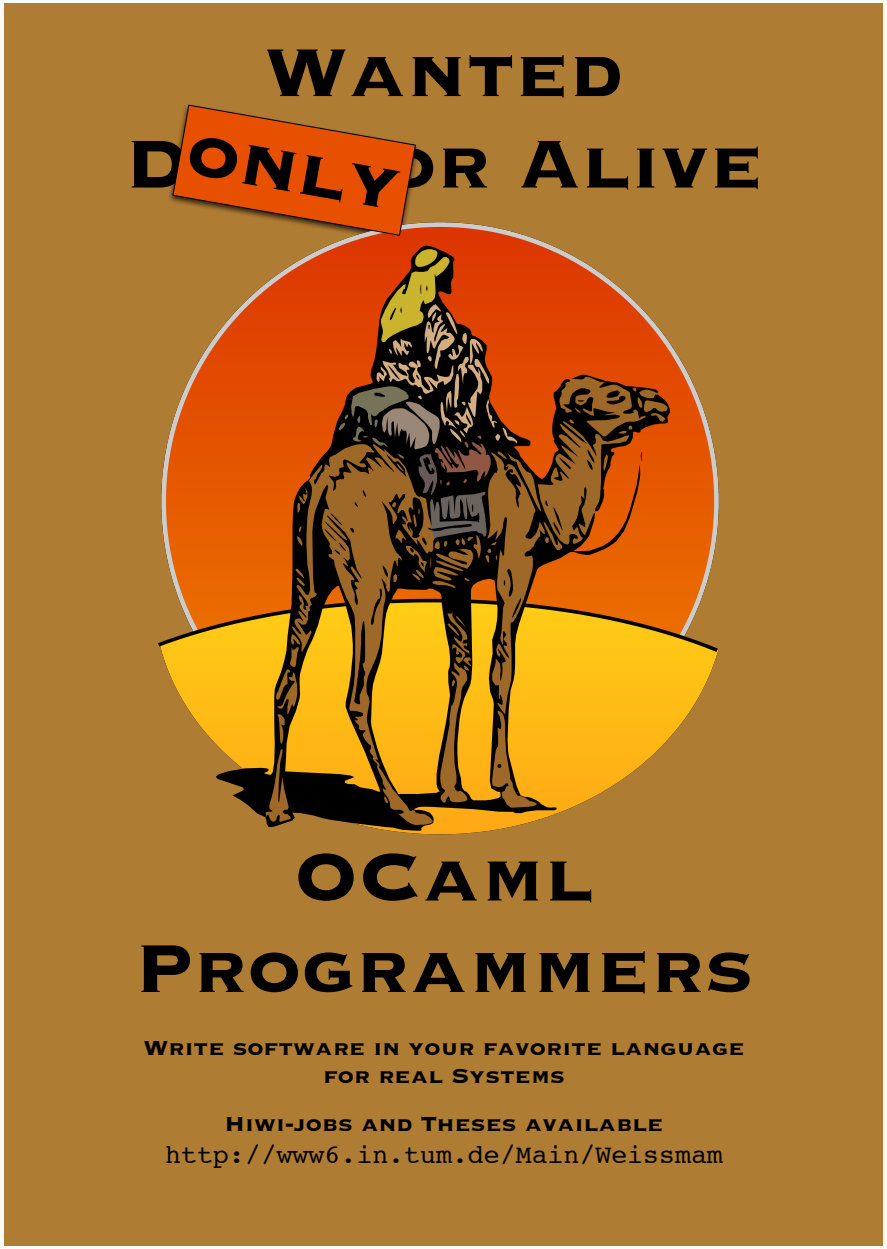
A WORD FOR THE SPONSORS

stλlefruits

- They sponsored me going to this conference
- Jan Stępień is holding a talk in the currying hall at 11:00
- … and a workshop at 14:00!
- Thanks, stylefruits!

WHO AM I?

- Marek Kubica
- Student at the TUM
- I do free software
- Dabbled in just about every language evar



SO, WHY?

- Data compression support in OCaml is… kinda meh
- Using OCaml foreign function interface to talk to libarchive
- Make it a bachelor thesis!
- Thought I might as well create a better API
- What *IS* a better API anyway?

SO, WHY?

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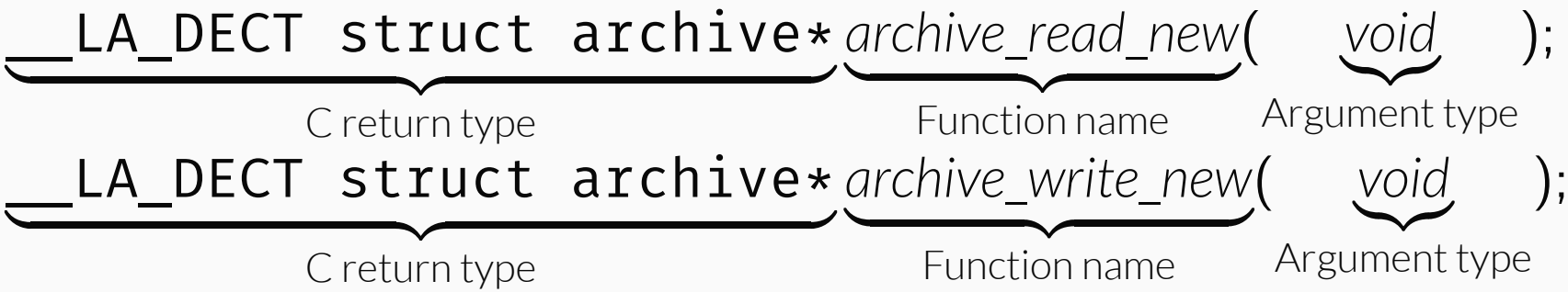
- What *IS* a better API anyway?

My goal for today

Show you that advanced static type features are not (only) academic.

STATIC TYPING THE C WAY

Let's check how C handles look like. How does libarchive handle this?



- Opaque pointer to some struct
- Write handles and read handles have the same type

So, what can we do with these handles?

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- Open them
- Configure them
- Read from them
- Write to them
- Close them

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Cool.

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Cool. But what if we screw up?

```
zsh: segmentation fault (core dumped)  ./errors
```

```
*** Error in ‘./errors’: double free or corruption (fasttop): 0x000000000077a010 ***
======= Backtrace: =========
/usr/lib/libc.so.6(+0x788ae)[0x7fa0c97cd8ae]
/usr/lib/libc.so.6(+0x79587)[0x7fa0c97ce587]
./errors[0x40057b]
/usr/lib/libc.so.6(__libc_start_main+0xf5)[0x7fa0c9776a15]
./errors[0x400479]
======= Memory map: ========
00400000-00401000 r-xp 00000000 fe:01 21244012                           /lambdacon/errors
00600000-00601000 rw-p 00000000 fe:01 21244012                           /lambdacon/errors
0077a000-0079b000 rw-p 00000000 00:00 0                                  [heap]
7fa0c953f000-7fa0c9554000 r-xp 00000000 fe:00 4213606                    /usr/lib/libgcc_s.so.1
7fa0c9554000-7fa0c9754000 ---p 00015000 fe:00 4213606                    /usr/lib/libgcc_s.so.1
7fa0c9754000-7fa0c9755000 rw-p 00015000 fe:00 4213606                    /usr/lib/libgcc_s.so.1
7fa0c9755000-7fa0c98f8000 r-xp 00000000 fe:00 4202529                    /usr/lib/libc-2.17.so
7fa0c98f8000-7fa0c9af8000 ---p 001a3000 fe:00 4202529                    /usr/lib/libc-2.17.so
7fa0c9af8000-7fa0c9afc000 r--p 001a3000 fe:00 4202529                    /usr/lib/libc-2.17.so
7fa0c9afc000-7fa0c9afe000 rw-p 001a7000 fe:00 4202529                    /usr/lib/libc-2.17.so
7fa0c9afe000-7fa0c9b02000 rw-p 00000000 00:00 0
7fa0c9b02000-7fa0c9b23000 r-xp 00000000 fe:00 4203728                    /usr/lib/ld-2.17.so
7fa0c9cfa000-7fa0c9cfd000 rw-p 00000000 00:00 0
7fa0c9d22000-7fa0c9d23000 rw-p 00000000 00:00 0
7fa0c9d23000-7fa0c9d24000 r--p 00021000 fe:00 4203728                    /usr/lib/ld-2.17.so
7fa0c9d24000-7fa0c9d25000 rw-p 00022000 fe:00 4203728                    /usr/lib/ld-2.17.so
7fa0c9d25000-7fa0c9d26000 rw-p 00000000 00:00 0
7fff44461000-7fff44482000 rw-p 00000000 00:00 0                          [stack]
7fff445fe000-7fff44600000 r-xp 00000000 00:00 0                          [vdso]
ffffffffff600000-ffffffffff601000 r-xp 00000000 00:00 0                  [vsyscall]
zsh: abort (core dumped)  ./errors foo
```

What actually happens: libarchive returns `ARCHIVE_FATAL`.

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Unless you trigger a bug in libarchive.

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Unless you trigger a bug in libarchive. Then it segfaults.

Lots of things can go wrong

- Reading from handle that is not open *
- Writing to a read handle
- Not setting the options correctly (compression formats)

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* this actually happened

Not to gripe on libarchive…

Public Service Announcement

libarchive is a rather well designed library. Mostly idiomatic C, so don't think this is a deliberately bad example. It is how things *are* in C land.

- This is an OK API for C.
- Fragile APIs are common in C.

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But can we do better?

Yes

Yes

(obviously)

FIX UP THE HANDLE TYPES

How to prevent writing to read handles and reading from write handles?

```
external read_new: unit -> archive = "ost_read_new"
external write_new: unit -> archive = "ost_write_new"
```

FIX UP THE HANDLE TYPES

How to prevent writing to read handles and reading from write handles?

```
external read_new: unit -> archive = "ost_read_new"
external write_new: unit -> archive = "ost_write_new"
```

Yup, create different handle types.

```
type r = archive
type w = (archive * write_buffer_ptr * written_ptr)
```

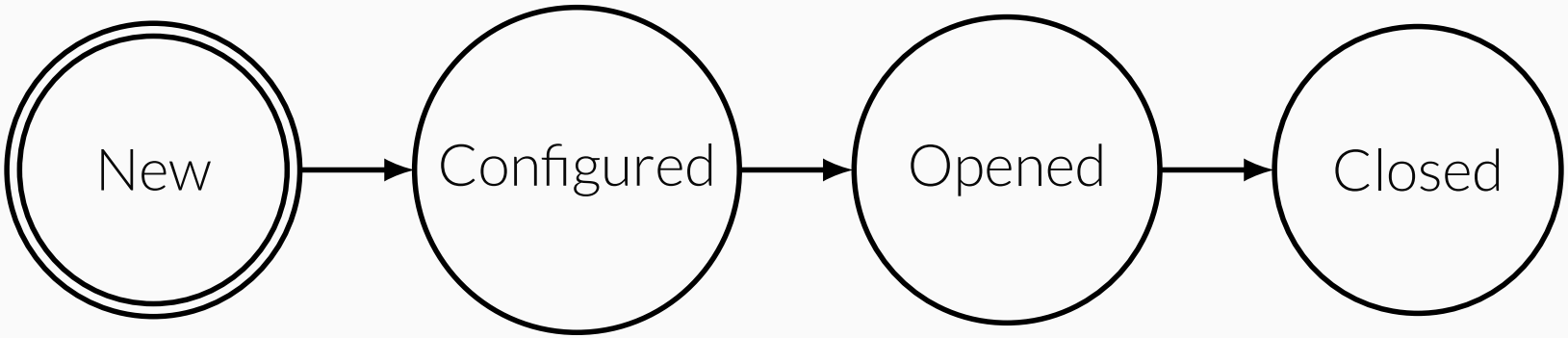
So now we have distinct types to represent handles.

ACHIEVEMENT UNLOCKED!

But of course you aren't attending the talk for this trivial epiphany.
We can do this easily in C as well! Let's do better.

OUR HANDLES HAVE STATES!

The handles always traverse some fixed states:



Couldn't we encode the state in the type somehow?

ADDING STATE INFORMATION IN THE TYPE

We can add state. OCaml has parametrized types *:

```
# [];;
- : 'a list = []
# [1];;
- : int list = [1]
# type 'a read_handle = ReadHandle of 'a;;
type 'a read_handle = ReadHandle of 'a
```

* if you haven't seen them, think of them kinda like generics

ASIDE: OPEN UNION TYPES

So, now we can parametrize types with other types.

We could create our own state types:

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But these can't be extended if someone wants to add a new state.

Plus, we're lazy. Let's use open union types aka polymorphic variants:

```
[`New] [`Configured] [`Opened] [`Closed]
```

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Foiled again!

The OCaml compiler is too smart, it knows that `[‘Opened]` `read_handle` is the same type as `[‘New] read_handle`. Therefore every function which takes the `[‘Opened]` handle accepts every other type of handle as well.

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We create a module and only say:

```
module Handle : sig
  type 'a r
  (* our signatures *)
  val new : unit -> [`New] r
end = struct
  type 'a r = read_handle
  (* our functions *)
  external new : unit -> [`Open] r = "ost_read_new"
end
```

ACHIEVEMENT UNLOCKED!

✓Writing read handles disallowed

✓Using the proper handle in an incorrect way disallowed

And now for something completely different!

HAVE YOU EVER SEEN THIS?

Ever used Python?

```
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
AttributeError: 'NoneType' object has no attribute 'foo'
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Ever seen C?

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zsh: segmentation fault (core dumped)  ./errors
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You know whose fault it is!

- `null`
- `None`
- `NULL`
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Everytime you return NULL as a placeholder value, ~~$DEITY kills a kitten~~ you have to check whether you weren't handed NULL in return.

Let’s kill the ~~Batman~~ Null pointer!

ATTEMPT ONE: EXCEPTIONS

- Common solution
- Ubiquitous (Java, Python, C++, Ruby, whathaveyou)
- Easy to understand
- OCaml does have exceptions

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- Common solution
- Ubiquitous (Java, Python, C++, Ruby, whathaveyou)
- Easy to understand
- OCaml does have exceptions
- Not typesafe, unless you consider checked exceptions
- Boring!

ATTEMPT TWO: OPTION TYPES

Observation: when we return NULL, we either return something meaningful or a marker that there was nothing to return.

We might even say:

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Therefore, everytime a function returns `'a option` we have to pattern match:

```
let optional x = Some x
match optional 42 with
   | Some x -> x
   | None -> 0
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```

If we forget:

ACHIEVEMENT UNLOCKED!

✓No more Null pointer failures on runtime!

Everything is fun and games until you need to specify a reason for failure.

What if we could add an error message?

```
type ('a, 'b) err = Success of 'a | Failure of 'b
```

Done!

But pattern matching on every function call sucks because it is tedious! Just look at this mess:

```
match firstfn 42 with
  | Success (x) -> (match secondfn x with
    | Success (y) -> (match thirdfn y with
      | Success (z) -> z
      | Failure (f3) -> "Failure at thirdfn")
    | Failure (f2) -> "Failure at secondfn")
  | Failure (f1) -> "Failure at fristfn"
```

Right. Maybe we can simplify…

In Haskell, **`option`** is called "Maybe monad" and **`error`** is called "Error monad".

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In Haskell, `option` is called "Maybe monad" and `error` is called "Error monad".

BAM, SCARY MONADS!

Haskell features an operator called `bind` aka `>>=` to chain operations on monads.

```
val bind: 'a ErrorMonad.t ->
  ('a -> 'b ErrorMonad.t) ->
  'b ErrorMonad.t
```

`bind` takes an error monad wrapping type `'a`, and a function which takes `'a` and returns an error monad wrapping `'b` and returns that value.

Basically an unwrapper function.

For the error monad, it looks like this:

```
let bind m f = match m with
  | Success(x) -> f x
  | Failure(f) -> Failure(f)
```

We can use it like this:

```
match (bind (bind (firstfn 42) secondfn) thirdfn)
with
  | Success (x) -> x
  | Failure (_) -> "Failure in chain"
```

The code got a lot easier!

ASIDE: OPERATOR TRICKS

OCaml allows custom operators as long as they follow naming rules.

```
let (»=) = bind
```

Using it is easy:

```
match (firstfn 42) »= secondfn »= thirdfn with
  | Success (x) -> x
  | Failure (_) -> "Failure in chain"
```

ACHIEVEMENT UNLOCKED!

✓No more Null pointer failures on runtime!

✓Easy and convenient to get reason of failure

HE WHO CONTROLS THE ERRORS, CONTROLS THE UNIVERSE

Sometimes, errors will happen

```
let divide a b =
  match b with
  | 0 -> Failure "division"
  | b -> Success (a / b)

let handle_user_input () =
  match divide 42 (read_int ()) with
  | Success res -> Printf.sprintf "Got %d" res
  | Failure "division_by_zero" -> "Divided by zero"
```

Can you spot the error?

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Can you spot the error?

```
divide : int -> int -> (int, string) err
```

We could define a type constructor for each error case:

```
type division_error = Division_by_zero | Overflow
```

This works in this case, but what if we want to reuse constructors?

```
type multiplication_error = Overflow
```

Does not compile. Each constructor can only be of *one* type.

POLYMORPHIC VARIANTS TO THE RESCUE, AGAIN

Polymorphic variant constructors can be composed into types:

```
type division_error = [
  | `Division_by_zero
  | `Overflow
  ]
```

Works like sets. OCaml does it automatically if functions return variants.

Let's fix the program

```
let divide a b =
  match b with
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let handle_user_input () =
  match divide 42 (read_int ()) with
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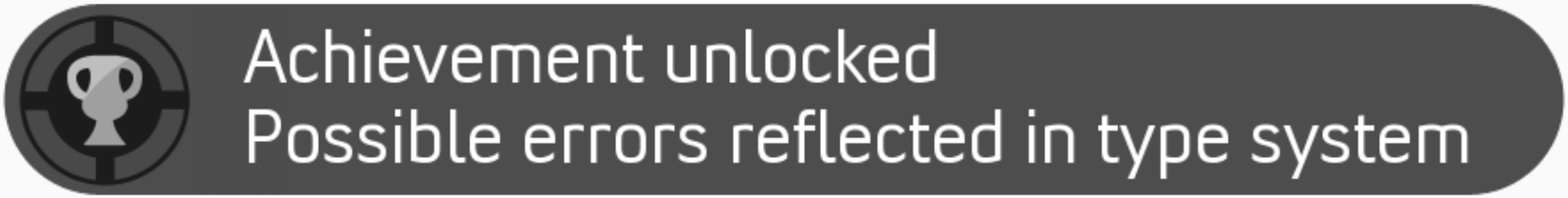
divide: int -> int -> (int, [> `Division ]) err
```

our error variant

ACHIEVEMENT UNLOCKED!



✓Possible errors can be seen in signatures

✓Type system can warn when errors not handled

HOW TO CONTINUE FROM HERE

There are many more tricks on how you can use the type system, to make illegal state unrepresentable, e.g. Generalized Algebraic Data Types (GADTs).

But take care: the API might turn out to be *too complicated*. Please, use common sense*.

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There are many more tricks on how you can use the type system, to make illegal state unrepresentable, e.g. Generalized Algebraic Data Types (GADTs).

But take care: the API might turn out to be *too complicated*. Please, use common sense*.

* if not applicable, emulate idioms from good APIs in your preferred programming language ☺

Marek Kubica

Check out my playthings:

- Leonidas-from-XIV on GitHub
- @leonidasfromxiv
- `https://xivilization.net/`