Typing the Wild in Erlang

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Erlang has no (static) types!

Icon made by Pixel-Perfect from www.flaticon.com

No types in a distributed language ⇒ distributed debugging!

```
...
spawn(DistantNode, mod, badfun, [42]).
...
```

A Practical Subtyping System For Erlang

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Typing Erlang

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December 12, 2002

TypEr: A Type Annotator of Erlang Code

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Experience from Developing the Dialyzer: A Static Analysis Tool Detecting Defects in Erlang Applicatior

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Practical Type Inference Based on Success Typings

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Detecting Software Defects in Telecom Applications Through Lightweight Static Analysis: A War Story

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Point Of No Local Return:

The Continuing Story Of Erlang Type Systems

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Our good friend Dialyzer

```
-spec zip(List1, List2) -> List3
    when List1 :: [A],
         List2 :: [B],
         List3 :: [{A, B}],
         A :: term(), B :: term().
```

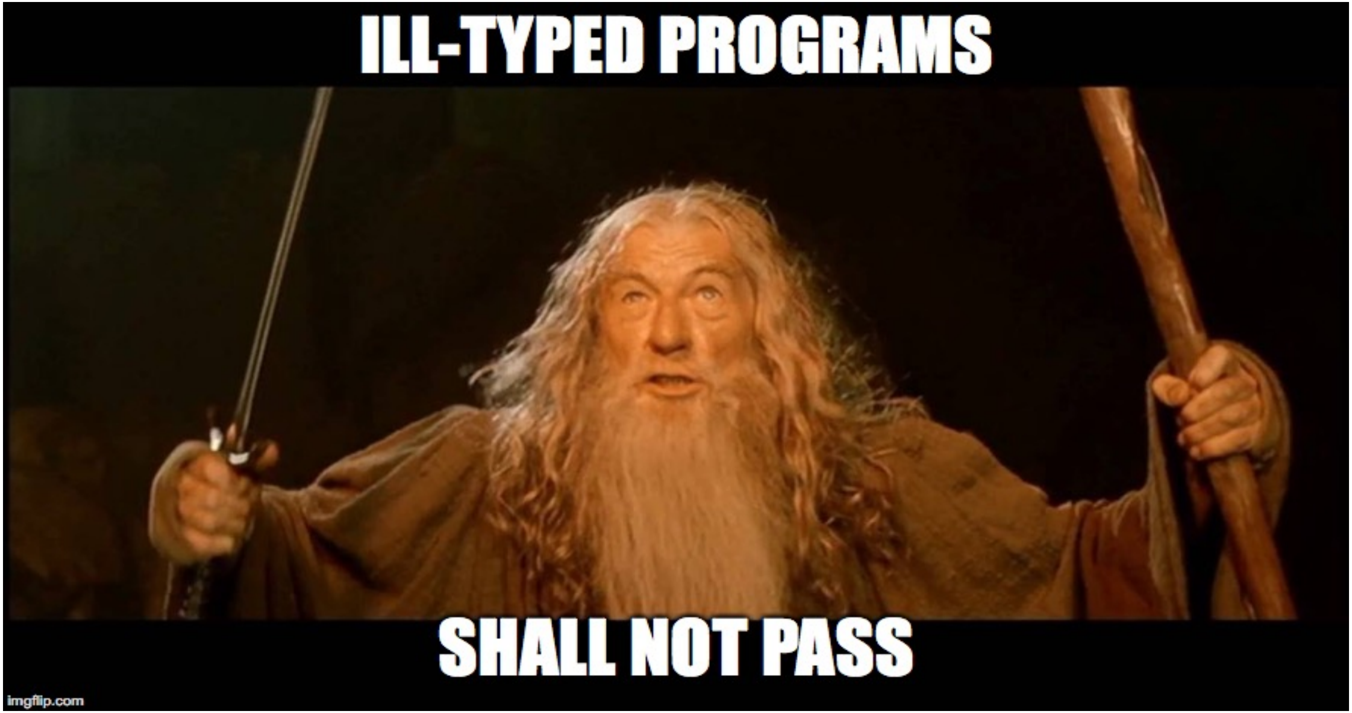
Dialyzer in action

```
$ dialyzer test.erl

  Checking ..
  Proceeding with analysis...
  done in 0m0.13s

done (passed successfully)
```

UH OH!

```
find() ->
    {ok,"s"} = lookup(0,[{0,4.2}]).
```

Goals of our type system



Hindley–Milner type system

- Has been very successful in typing

> “The difficulty is that with Hindley–Milner each type must involve a set of *constructors* distinct from those used in any other types, a convention not adhered to by Erlang programmers.”
> — Marlow and Wadler, 96

- Strong type inference properties

Hindley–Milner type system

- Has been very successful in typing

> “The difficulty is that with Hindley–Milner each type must involve a set of *constructors* distinct from those used in any other types, a convention not adhered to by Erlang programmers.”
> — Marlow and Wadler, 96

- Strong type inference properties

Algebraic Data Types (ADTs)

```
data Tree a = Nil
     | Node a (Tree a) (Tree a)
```

```
-type tree(A) :: nil
     | {node,A,tree(A),tree(A)}.
```

Type inference, an example

```
findNode(_,nil) ->
    false;
findNode(N,{node,N,Lt,Rt}) ->
    true;
findNode(N,{node,_,Lt,Rt}) ->
    findNode(N, Lt) or findNode(N,Rt).
```

```
findNode/2 ::
(A,tree(A)) → boolean()
```

Assigning types to constructors

```
-type cl() :: {response,integer()}
-type sr() :: {request,integer()}
```

response/1 :: integer() → cl()

request/1 :: integer() → sr()

Overloading constructors

- Contemporary implementations of Hindley-Milner restrict constructors to have a *unique* type

- In Erlang, restricting constructors to a unique type is practically impossible
  Example: `{ok,Value}`

Constructor overloading problem

```
-type cl(R) :: {'EXIT',pid(),R}
      | {response,integer()}
-type sr(R) :: {'EXIT',pid(),R}
      | {request,integer()}
```

```
EXIT/2 :: ?
```

Constructor overloading problem

```
-type cl(R) :: {'EXIT',pid(),R}
      | {response,integer()}
-type sr(R) :: {'EXIT',pid(),R}
      | {request,integer()}
```

EXIT/2 :: (pid(), R) → cl(R) ?

EXIT/2 :: (pid(), R) → sr(R) ?

Constructor overloading solution

```
-type cl(R) :: {'EXIT',pid(),R}
      | {response,integer()}
-type sr(R) :: {'EXIT',pid(),R}
      | {request,integer()}
```

```
EXIT/2 :: A ~ [cl(R),sr(R)]
    ⇒ (pid(),R) → A
```

Constructor overloading solution

```
-type cl(R) :: {'P… …d(),R}
      | {response,…
-type sr(R) :: {… …),R}
      | {request,in…
```

deferred unification constraint (duc)

```
EXIT/2 :: A ~ [cl(R),sr(R)]
    ⇒ (pid(),R) → A
```

Specializing type of a constructor

```
handle(ClientId,X)->
   case X of
     {request,N} ->
         ClientId ! N + 42;
     {'EXIT',_,R} ->
       log(R)
   end,
   handle(ClientId,X).
```

$$\texttt{handle} :: \texttt{Padd D} \Rightarrow (\texttt{D},\texttt{sr(B)}) \longrightarrow \texttt{C}$$

Specializing type of a constructor

```
EXIT/2 :: A ~ [~~cl(R)~~,sr(R)]
     ⇒ (pid(),R) → A
```

↓

```
EXIT/2 :: (pid(),R) → sr(R)
```

Lack of specializing information

```
getReason({'EXIT',_,R}) -> R.

foo() ->
    getReason({'EXIT',self(),true})
```

```
getReason/1 ::
A ~ [cl(R),sr(R)] ⇒ (A) → R
```

Lack of specializing information

```
getReason({'EXIT',_,R}) -> R.

foo() ->
    getReason({'EXIT',self(),true})
```

foo/0 :: (A,B) → C ~ [(pid(),B) → cl(B), (pid(),B) → sr(B)]; C ~ [cl(boolean()), sr(boolean())] ⇒ () → B

Extracting types from ducs

```
foo/0 ::
(A,B) → C ~ [(pid(),B) → cl(B),
(pid(),B) → sr(B)];
C ~ [cl(boolean()), sr(boolean())]
⇒ () → B
```

⬇

```
foo/0 :: C ~ [cl(B), sr(B)];
C ~ [cl(boolean()), sr(boolean())]
⇒ () → B
```

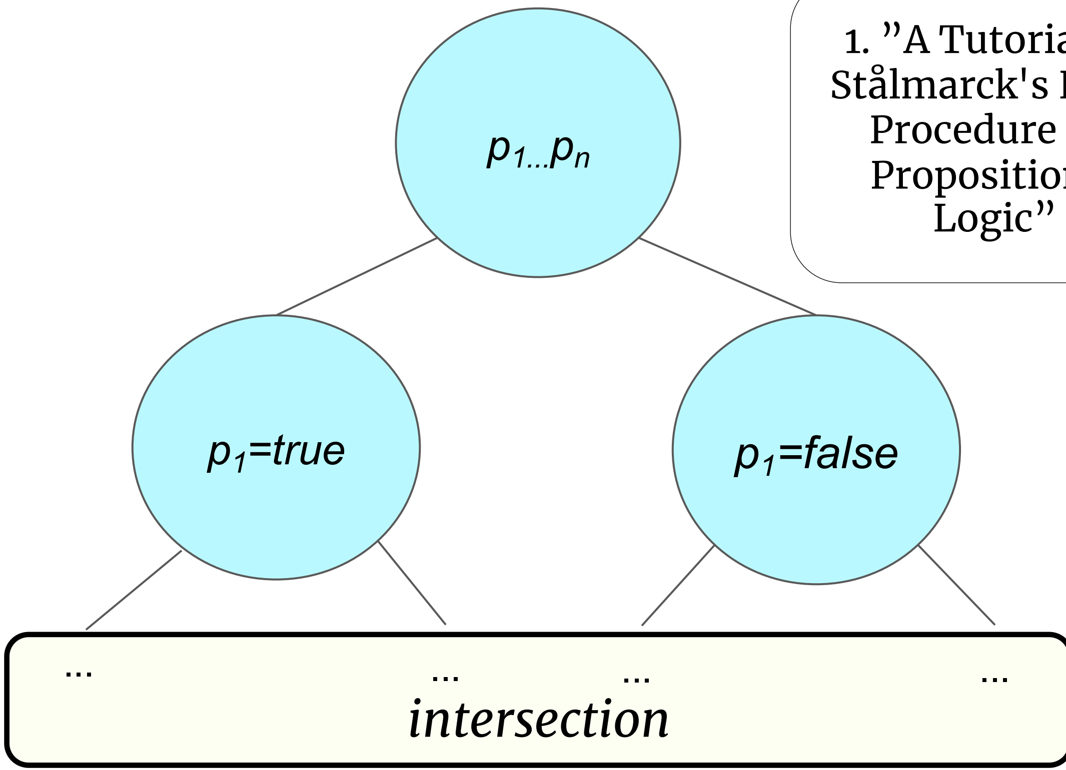
Extracting types from ducs

```
foo/0 ::
(A,B) → C ~ [(pid(),B) → cl(B),
(pid(),B) → sr(B)];
```

```
foo/0 :: () → boolean()
```

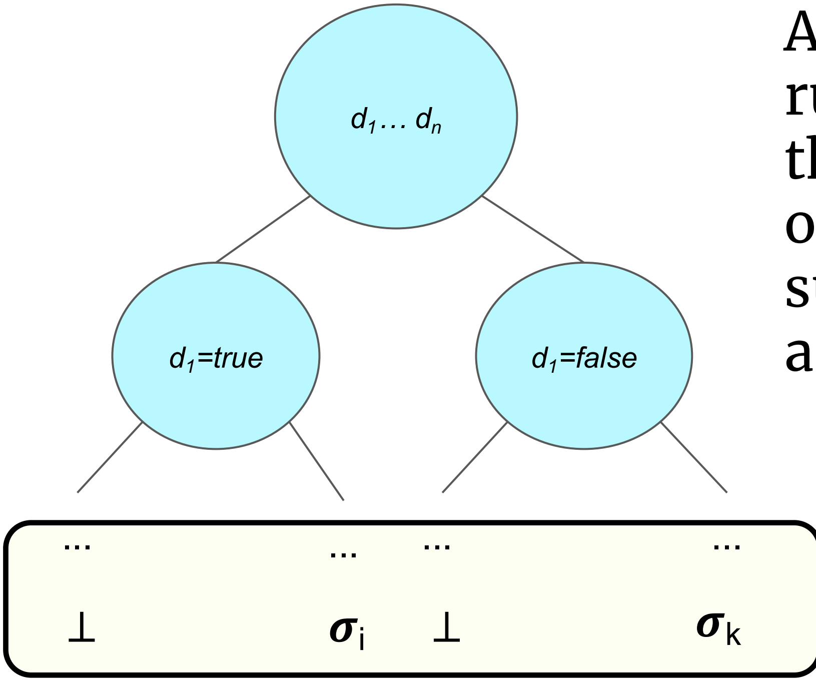
```
foo/0 :: C ~ [cl(B), sr(B)];
C ~ [cl(boolean()), sr(boolean())]
⇒ () → B
```

Stålmarck's Dilemma Rule [1]



1. "A Tutorial on Stålmarck's Proof Procedure for Propositional Logic"

Propositions as constraints!



Applying the Dilemma rule on ducs gives us that the intersection of all valid type substitutions must always hold

Typing Records

```
-record(person, {
    name :: string(),
    age  :: integer(),
    id
}).
```

⬇ *generates*

```
-type person(A) ::
    {person,string(),integer(),A}
```

Typing Records, an example

```
me() -> #person{
    name = ”Nachi”,
    age  = 26,
    id   = ”order66”
}

me/0 :: person(string())
```

Allowing flexible programming

Branches of different type? No problem!

...*provided* return value is not used

```
case X of
    {request,N} ->
        ClientId ! N + 42;
    {'EXIT',_,R} ->
        log(R)
end
```

Allowing flexible programming?!

- element(Position,Tuple)

```
element(2,{a,b,c}) = b
```

- is_tuple(Tuple)

```
is_tuple({}) = true
```

- spawn(Module,Function,Args)
- …

Simplifying by Partial Evaluation

Before

```
T = {F(X),G(X)},
  element(1,T).
```

After

```
T1 = F(X),
T2 = G(X),
   T1.
```

Results

- Type inference applied successfully to a few small libraries
    - OTP libraries: *orddict* and *orddsets* (~ 200 LOC)
    - An implementation of a distributed fault tolerant resource pool (~100 LOC)
- < 3 LOC added/modified in each case (mainly ADT definitions)

Vs Dialyzer

```
-type maybe(A) :: none | {ok,A}.

lookup(K,[])             -> none;
```

```
Type error:
Cannot unify [char()] with float()
```

```
find() ->
    {ok,"s"} = lookup(0,[{0,4.2}]).
```

Limitations!

- Can't do generic programming over constructors!

```
-type rbt(K,V) :: empty
   | {r,rbt(K,V),K,V,rbt(K,V)}
   | {b,rbt(K,V),K,V,rbt(K,V)}
to_list(empty, List) -> List;
to_list({_,L,Ks,Vs,R}, List) ->
  to_list(L, [{Ks,Vs}|to_list(R, List)]).
```

- PE helps only when at least *some* static information is available

Future Work

- Type inference for modules & error handling
- Typing concurrency by adding *effects*
- Better ways to integrate type inference and partial evaluation

```
foo(Z) →
    [{A,B}|[X|Xs]] = Z, element(2,X)
```

That’s all folks!

Type checker source at:
https://github.com/nachivpn/mt

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Typing Records (undefined values)

```
-record(person, {
    name :: [char()],
    age :: integer(),
    id
}).
```

```
me() -> #person{
    name = "Nachi",
    age = 26,
}
```

```
-type person(A) ::
    {person,[char()]
    ,integer(),A}
```

```
me/0 ::
person(undefined())
```

Typing Records (unification error)

```
-record(person, {
    name :: [char()],
    age :: integer(),
    id
}).
```

```
me() -> #person{
    name = "Nachi",
}.
```

```
-type person(A) ::
    {person,[char()]
    ,integer(),A}
```

```
Cannot unify undefined()
with integer()
```

Typing Records (update)

```
-record(person, {
    name :: [char()],
    age :: integer(),
    id
}).
```

```
updateId(Rec,ID) ->
    Rec#person{id=ID}.
```

```
-type person(A) ::
    {person,[char()]
    ,integer(),A}
```

```
updateId/2 ::
(person(A), B) →
person(B)
```

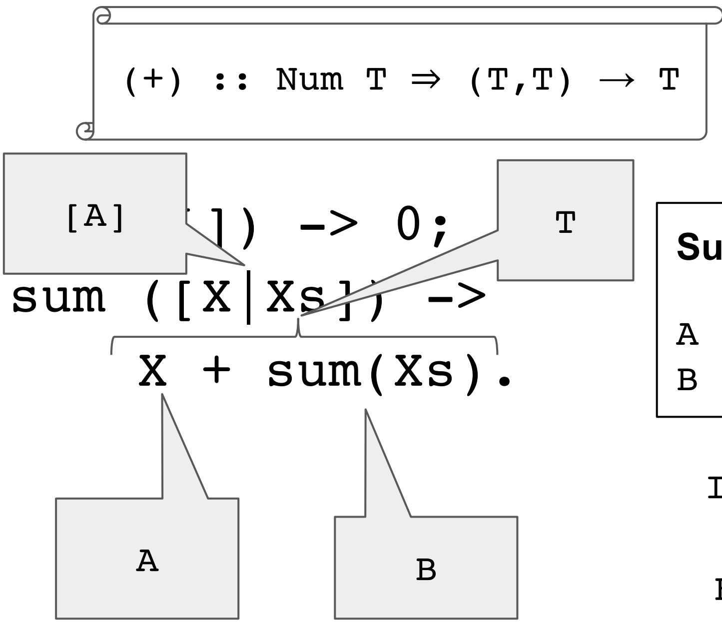
Type classes for some operators

```
(!) :: Padd A ⇒ (A,B) → B

unlink :: Port A ⇒ (A) → boolean()

...
```

Type inference walkthrough



Substitution

A = T
B = T

Predicates

{Num,T}

Intermediate: ([A]) → T

Final: Num T ⇒ ([T]) → T