Typing Erlang

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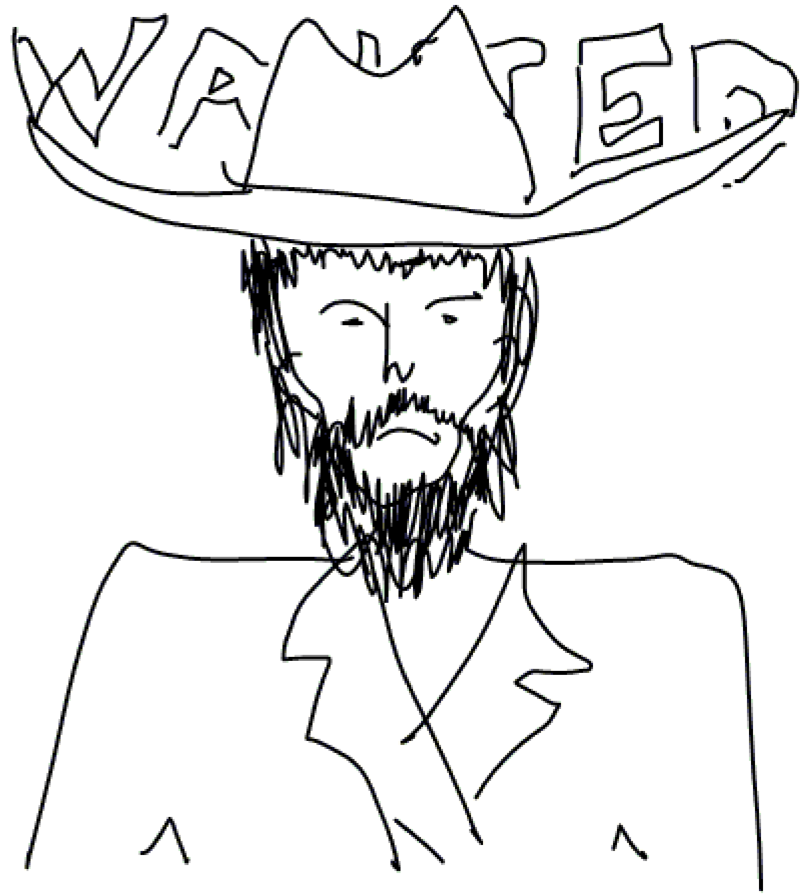
Wanted

- A type-checker for Erlang
- Usable on existing code without too much effort



Hasn’t it already been done?

- Marlow and Wadler, ICFP 1997
  - Type-inference for Erlang
  - No need for any programmer annotations
  - Discovered recursive datatypes automatically
  - Subtyping and ”lacks” predicates to handle multiple return types

```
lookup(Tree,Key) = Value | fail
lookup:: A lacks fail => tree(A) -> A | fail
```

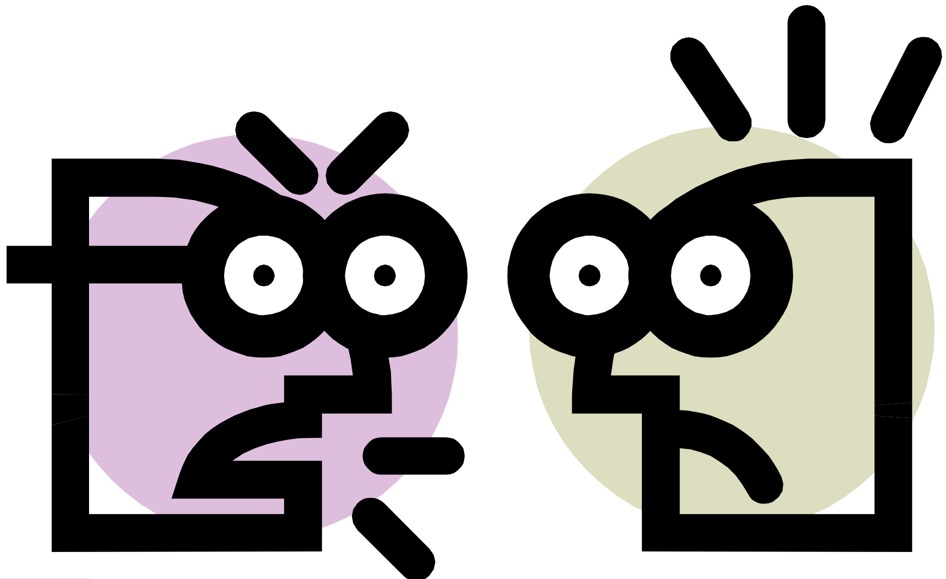
A must not include fail, to avoid confusion

But...

- The types inferred were large
- Type inference was slow
- Type errors were hard to understand

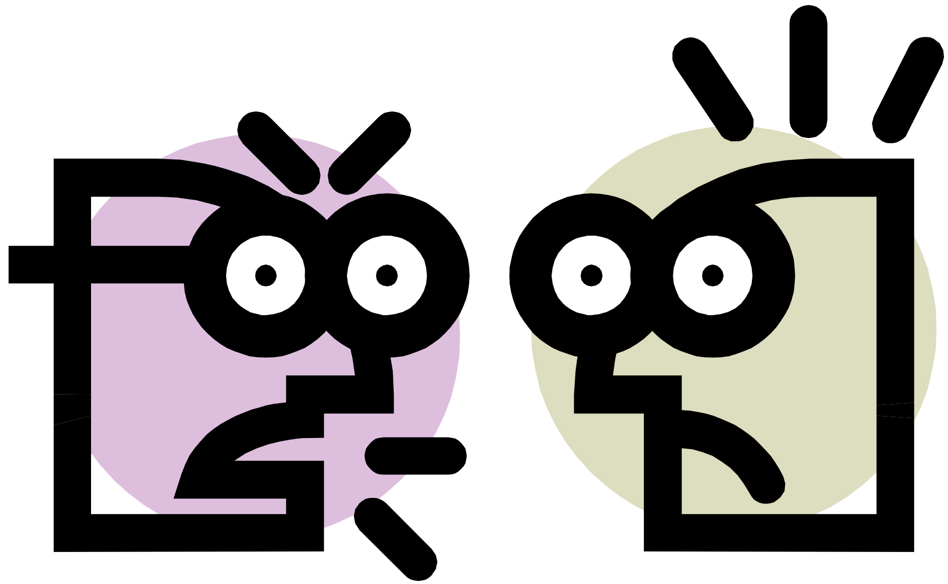
So no-one uses it!

An Analogy



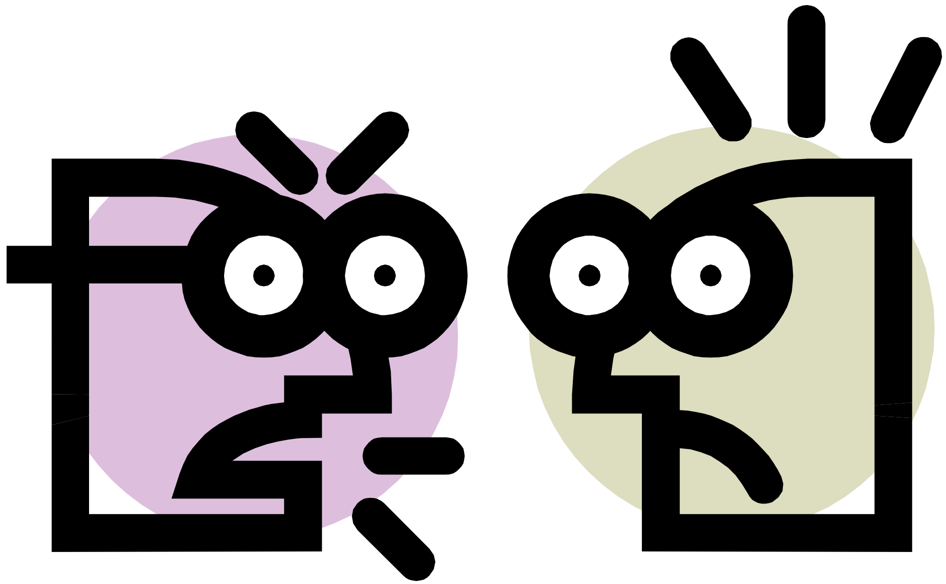
I'm not telling you anything about my code! Figure it out for yourself!

An Analogy



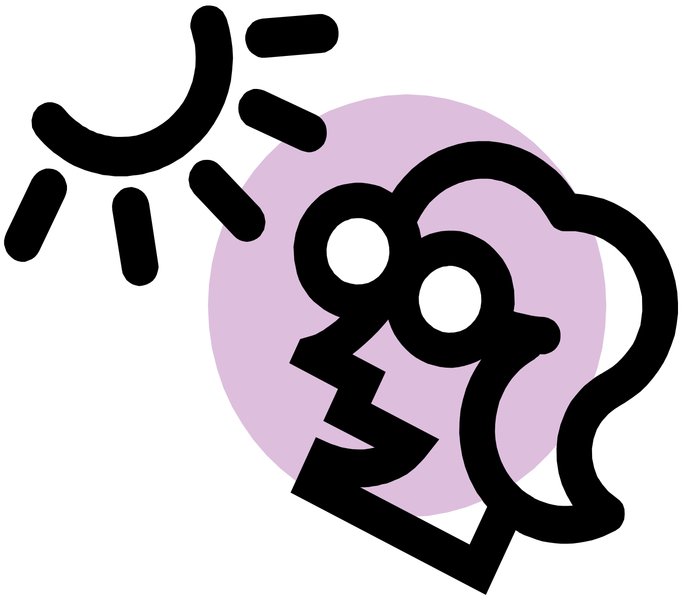
Your blurblewurble is boomziwacked

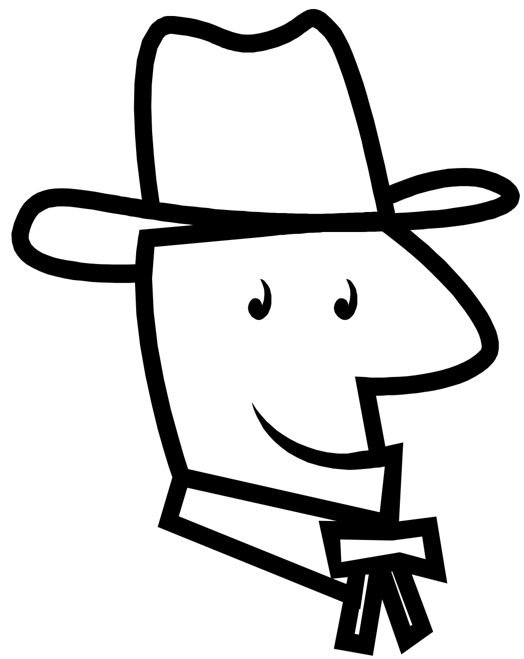
An Analogy



Why don’t you tell me what’s wrong in *my* terms?

An Alternative

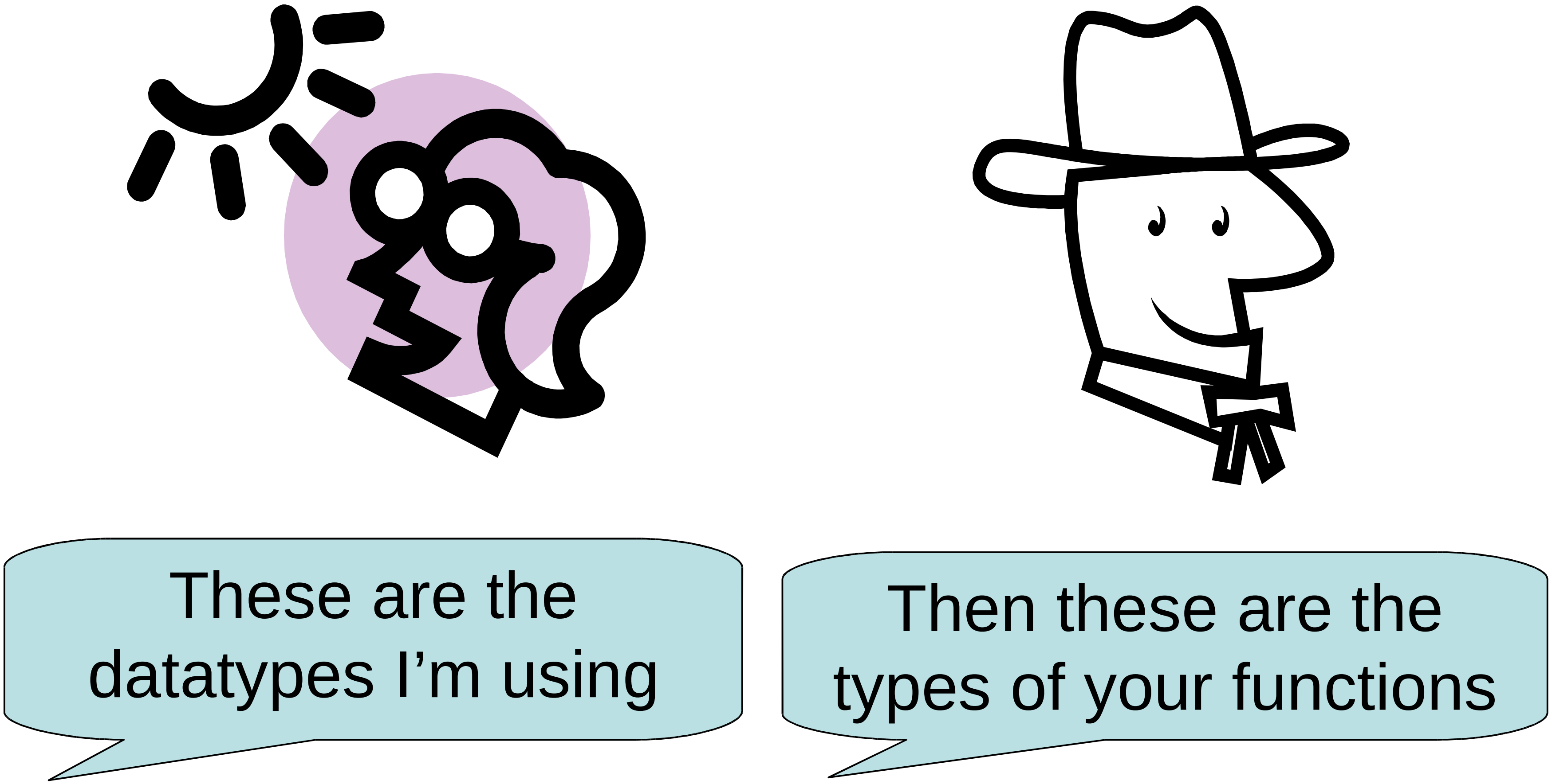




Here’s how my program works

I think you made a mistake just here

Hindley-Milner Typing (ML, Haskell...)



A reasonably small burden of annotations

An Indirect Benefit of Marlow and Wadler

- Multiple return types are now often avoided
  - Compare

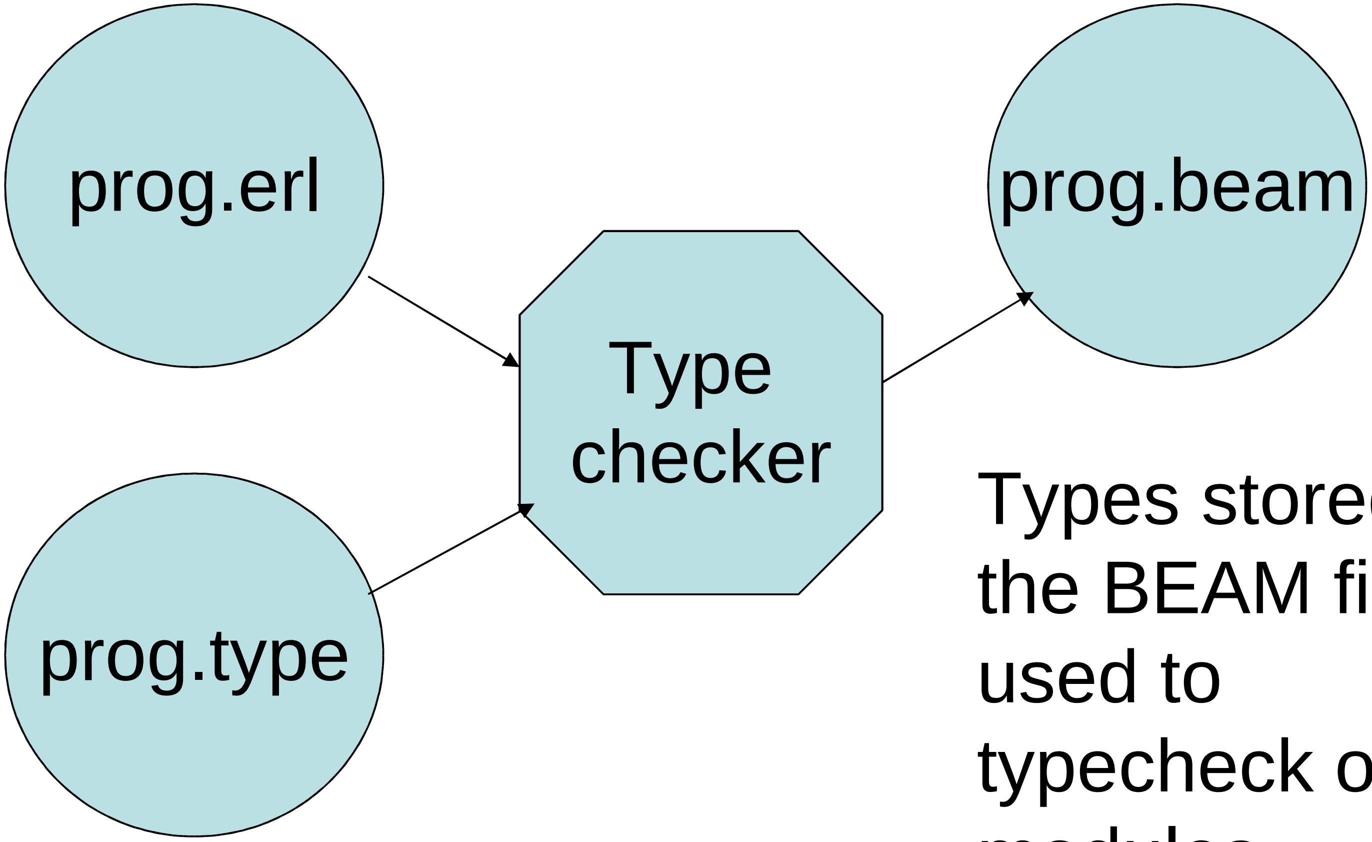
```
lookup(Tree,Key) = Value | fail
lookup:: A lacks fail => tree(A) -> A | fail
```

  - With

```
keysearch(Key, N, TupleList) ->
                    {value,tuple()} | false
```

- So the type-checking problem is now easier!

Plan for an Erlang typechecker



Types stored in the BEAM file used to typecheck other modules

Erlang Datatype Declarations

```
-data(maybe(A) = {value,A} | false).
```

- Atoms can be declared to belong to a new datatype
- So can tuples tagged with an atom at the front
- Atoms can be used with several arities

```
-data(as(A) = {a, A} | {a} | a).
```

A Problem

- Atoms can be used in more than one type!

```
-data(maybe(A) = {value,A} | false).
```

```
-data(bool() = true | false).
```

What is the type of false?

A Solution

- false is *overloaded* – must be resolved when a whole function is typechecked.
- Function types can be stated if necessary to resolve overloading.

```
-type(odd(integer()) -> bool()).
```

Inspiration from Haskell

- Function types are inferred *when possible*

- Stating function types enables a *more powerful* type system!

  - Type *checking* is easier than type *inference*

Lookup Revisited

- Functions like lookup have not disappeared altogether

Must be bool() to typecheck

```
lookup(Key,[ ]) -> false;
lookup(Key, [{Key,Value} | Rest]) -> Value;
lookup(Key,[ _ | Rest]) -> lookup(Key,Rest).
```

- Inferred type

```
lookup(K,[{K,bool()}]) -> bool()
```

Lookup with a Type Declaration

```
-type(lookup(K,[{K,V}]) -> V | bool()).
```

Easy to *check* these are in V | bool().

```
lookup(Key,[ ]) -> false;
lookup(Key, [{Key,Value} | Rest]) -> Value;
lookup(Key,[ _ | Rest]) -> lookup(Key,Rest).
```

- Cf. Bidirectional type checking

Refining Case Analysis

```
-type(default(V, V | bool()) -> V).
```

```
default(D,false) -> D;
default(D,V) -> V.
```

Here arg must be bool().

Here arg must be V

- Normally an argument has the *same* type in each case
- Cf. ”learning by testing” in languages with dependent types

Some Problems

- lists:keysearch(e,2,[{a,b,4},{d,e,5}]).
  - Returns {value,{d,e,5}}
  - The 2 specifies which tuple component is the key field.
  - Type of the key depends on the *value* 2!
- list_to_tuple([a,b,c]).
  - Returns {a,b,c}
  - The type of the result depends on the value of the argument

Some More Problems

- apply(lists,append,[[1,2],[3,4]]).
  - Returns [1,2,3,4]
  - The module and function name are *atoms*!
  - The argument list must have the right length.
  - The list elements may have different types!
- spawn(lists,append,[[1,2],[3,4]]).
  - Used to start every Erlang process!

OTP Behaviours

- gen_server:start_link({local, ch3}, ch3, [], [])
  - ch3 names a call-back module, which must export init, handle_call etc.
  - Callback functions invoked via apply must have types which make the gen_server well-typed.

Supervisors in OTP

Parameter module

```
start_link() ->
        supervisor:start_link(ch_sup, []).
init(_Args) ->
        {ok, {{one_for_one, 1, 60},
              [{ch3, {ch3, start_link, []}, permanent,
                 brutal_kill, worker, [ch3]}]}}.
```

Initial call to start the child

Applications in OTP

- Type checker needs to know the contents of the *application resource file*

```
{application, ch_app,
  [{description, "Channel allocator"},
   {vsn, "1"}, {modules, [ch_app, ch_sup, ch3]},
   {registered, [ch3]},
   {applications, [kernel, stdlib, sasl]},
   {mod, {ch_app,[]}} ]}.
```

Started by calling
ch_app:start(normal,[])

Dependent Types

- Types in Erlang depend on values (*dependent types*)
- Values aren’t known until run-time!
- Bad news for type checking!

Observation

```
start_link() ->
        supervisor:start_link(ch_sup, []).
init(_Args) ->
        {ok, {{one_for_one, 1, 60},
              [{ch3, {ch3, start_link, []}, permanent,
                 brutal_kill, worker, [ch3]}]}}.
```

- The initial call is usually constant

Observation

```
lists:keysearch(e,2,[{a,b,4},{d,e,5}]).
```

- The position of the key is usually constant

Observation

```
spawn(lists,append,[[1,2],[3,4]]).
```

- The module and function are often *not* constant – *but they are constants passed from elsewhere!*

How can you write a correct program,

if you don’t know the values of the ”dependent” parameters?

Our idea

- Combine *partial evaluation* and type inference

Partial Evaluation

```
power(0,X) -> 1;
power(N,X) when N>0 -> X * power(N-1,X).

        ... power(3,Y+Z) ...
```

Known (”static”)

Partial Evaluation

```
power(0,X) -> 1;
power(N,X) when N>0 -> X * power(N-1,X).

        ... power(3,Y+Z) ...
```

⇓

```
power3(X) -> X*power(2,X).

        ... power3(Y+Z) ...
```

Partial Evaluation

```
power(0,X) -> 1;
power(N,X) when N>0 -> X * power(N-1,X).

        ... power(3,Y+Z) ...
```

```
power3(X) -> X*power2(X).
power2(X) -> X*power(1,X).



        ... power3(Y+Z) ...
```

Partial Evaluation

```
power(0,X) -> 1;
power(N,X) when N>0 -> X * power(N-1,X).

        ... power(3,Y+Z) ...
```

```
power3(X) -> X*power2(X).
power2(X) -> X*power1(X).
power1(X) -> X*power(0,X).

        ... power3(Y+Z) ...
```

Partial Evaluation

```
power(0,X) -> 1;
power(N,X) when N>0 -> X * power(N-1,X).

        ... power(3,Y+Z) ...
```

```
power3(X) -> X*power2(X).
power2(X) -> X*power1(X).
power1(X) -> X*power0(X).
power0(X) -> 1.
        ... power3(Y+Z) ...
```

Our idea

- Combine *partial evaluation* and type inference
- Compute the ”dependent values” during type-inference
- Infer types from *specialised* versions of the code

Example

```
keysearch(Key, N, [H|T])
   when element(N, H) == Key -> {value, H};
keysearch(Key, N, [H|T]) -> keysearch(Key, N, T);
keysearch(Key, N, []) -> false.
```

- Specialise with N=2

```
keysearch2(Key, [H|T])
   when element2(H) == Key -> {value, H};
keysearch2(Key, [H|T]) -> keysearch2(Key, T);
keysearch2(Key, []) -> false.
```

What does a Partial Evaluator Compute?

- Conventionally – everything it *can*!
  - Everything depending only on known values
  - Code explosion!
  - *Not* input/output
- For type-checking – everything it *must*!
  - Only values which affect types
  - (Hopefully) small code expansion
  - *Including* reading application resource files, etc.

A Promising Approach

- Looks very promising for e.g. generic servers
- Demands *mixing* partial evaluation and type inference
  - E.g. length(tuple_to_list(T))

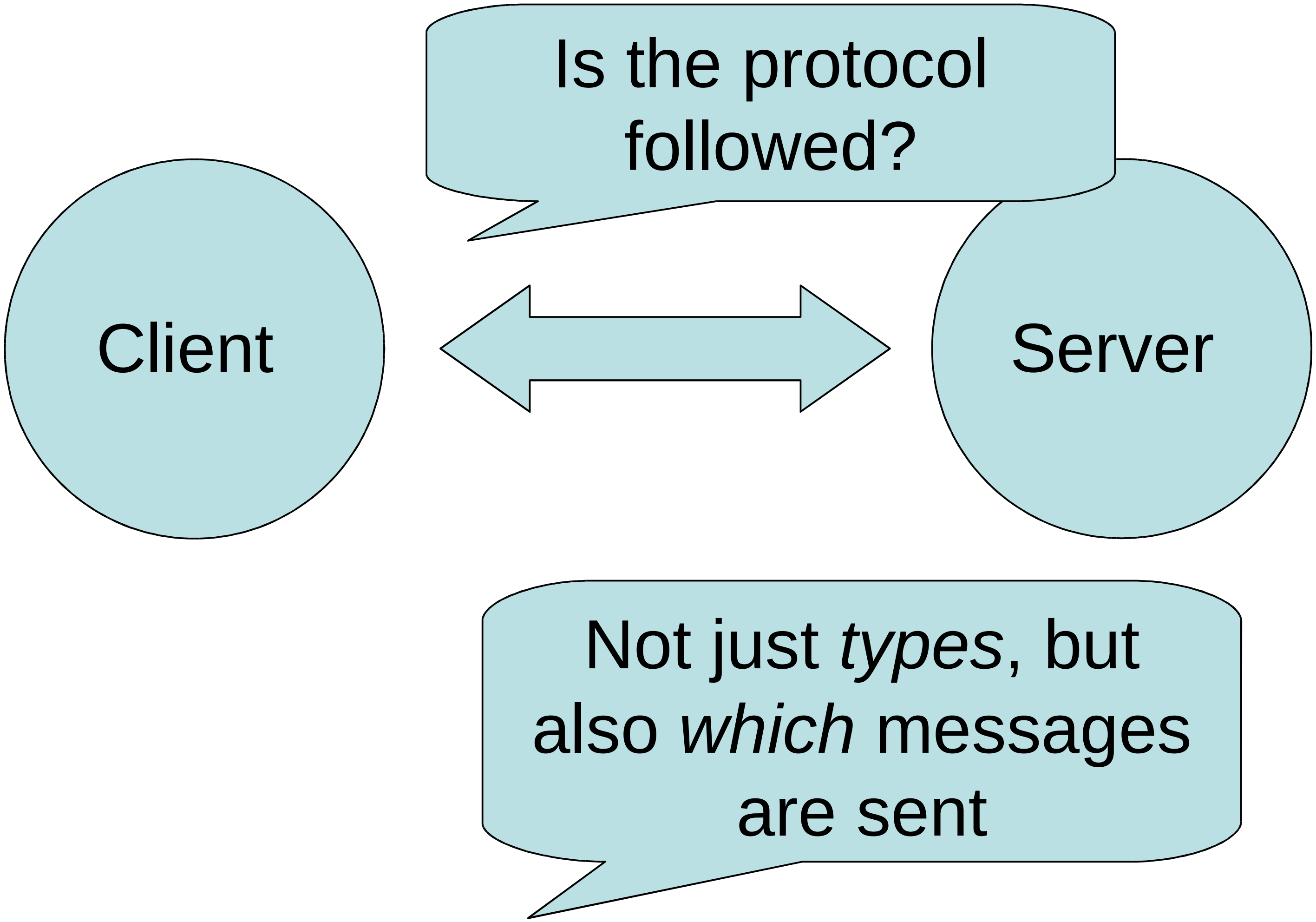
...known value [N,B]

Type of T {int(),bool()}...

...known result 2

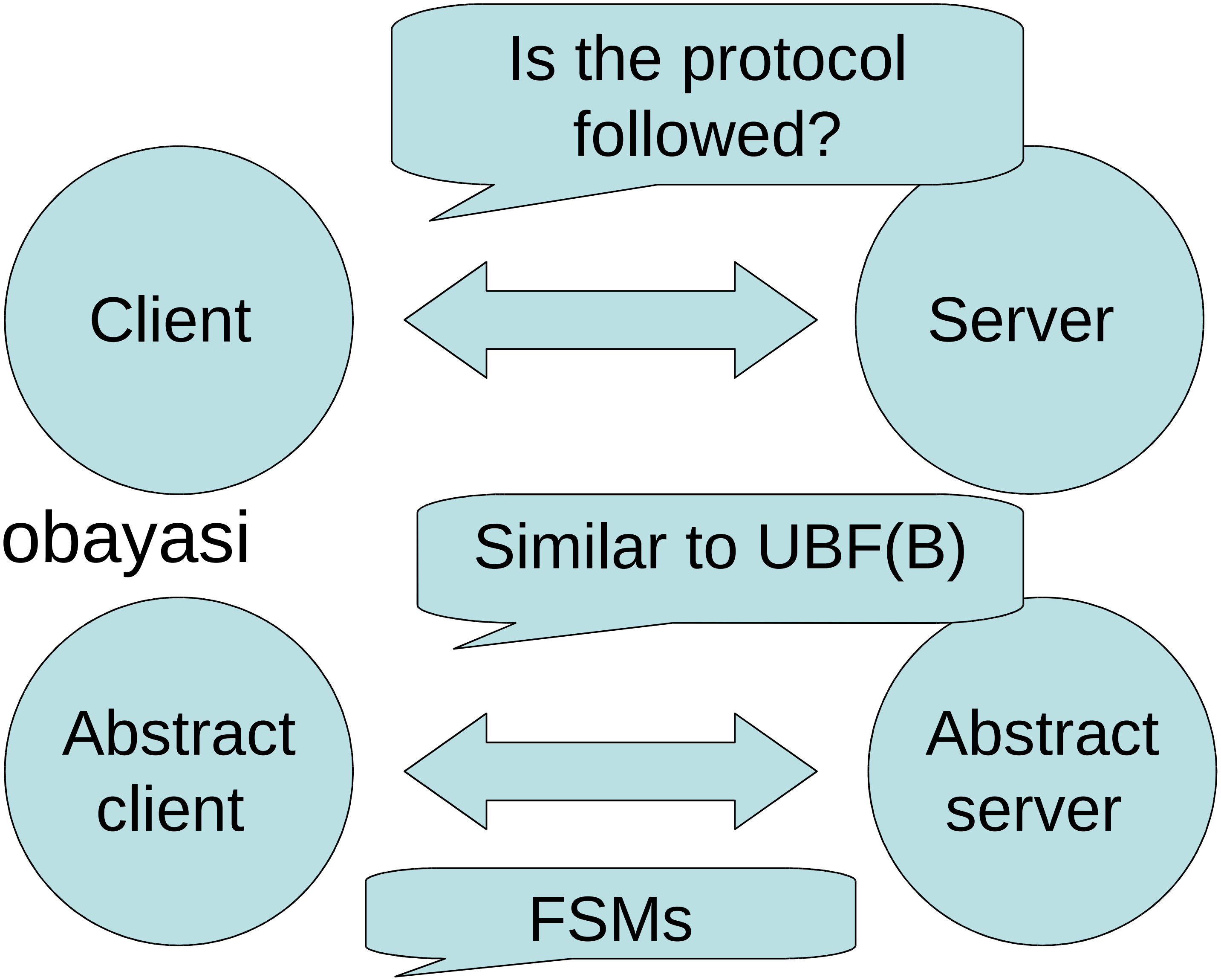
  - Just like *type specialisation* (Hughes 1996)

A Tough Nut: Concurrency



A Tough Nut: Concurrency

- Kobayasi



But...

- Servers which talk to many clients?
  - Many protocol instances to keep track of
- Clients which talk to many servers?
  - Can protocols be confused?
- Aliases for the same Pid?
  - Sending to one changes the state of the other
- Partial evaluation of concurrent programs?
  - Hitherto only *static* number of processes (Marinescu and Goldberg 1997)

Summary

- Typing Erlang is an exciting problem!
  - Draws on Hindley-Milner, bidirectional typing, partial evaluation, type specialisation, concurrency theory...
- Mixing values and types is a powerful idea
- Concurrency is a tough nut to crack
- Lots more work to do!