Gradual Typing of Erlang Programs: A Wrangler Experience

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(paper co-authored with Daniel Luna)

Overview

This talk/paper:

- Aims to document and promote a different mode of Erlang program development:
  - one where most typos, interface abuses, type errors, etc. are *identified automatically* using static analyzers
  - one where *type information becomes part of the code* and *checked for definite violations* after program modifications
  - one where all the above are *optional*, can take place *gradually*, and can be *refined at any point* to the extent desired by the programmer

Practice and experience

- We have been practicing this development mode in large Erlang code bases:
  - **`dialyzer`**
  - **`typer`**
  - **`hipe`** (a very large part)
  - **`stdlib`** & **`kernel`** (many key modules)
- But wanted to also try it in code with which we were not familiar – hence this paper

Why Wrangler?

- Open source with many releases
- Developed by experts in typed FP
  - Expected it would be written in a type disciplined manner
  - Expected it would not contain (m)any type errors
  - Many higher-order functions – challenging for tools
- Authors of Wrangler aware of our tools

Step #1

Use Dialyzer

Wrangler 0.1

- Released January 2007
- 25 modules
- 35,000 lines of code
- Many modules are slight modifications or clones of Erlang/OTP ones – mainly of **`syntax_tools`**

Dialyzer on Wrangler 0.1

- Run as simply as

```
> cd distel-wrangler-0.1/wrangler
> dialyzer --src -c *.erl
```

- 67 warnings in less than 2 minutes
- about 50 of them due to abuse of **`file:open/2`**

  `file:open(Name,read)` vs. `file:open(Name,[read])`

- After fixing this and one similar interface abuse, 15 warnings remain
  - all genuine bugs

Can you spot the bug?

```
handle_call(Call, DefinedVars, State) ->
  ...
  case is_c_atom(Mod) andalso is_c_atom(Fun) of
    true ->
      M = atom_val(Mod),
      ...
      case {M_Loc, Call_Loc} of
        {{L1, C1}, {L2, C2}} ->
            if (L1 < L2) or
               ((L1==L2) and ((C2-C1) > length(M)))
      ...
```

```
refac_atom_info.erl:715:
   Guard test length(M::atom()) can never succeed
```

Can you spot the bug?

```
get_new_name(Sub, NewRegExp) ->
  Index = string:str(NewRegExp, "*"),
  case Index of
    0 -> NewRegExp;
    N ->
      Prefix = string:sub_string(NewRegExp, 1, N-1),
      case Sub of
        [] -> exit(error, "Cannot infer ...");
         _ -> Sub1 = hd(Sub),
              get_new_name(tl(Sub), Prefix++Sub1++...)
      end
  end.
```

```
refac_batch_rename_mod.erl:161:
   The call erlang:exit(’error’,string()) will fail
   since it differs in argument 1 from the success
   typing arguments (pid() | port(),string())
```

Can you spot the bug?

```
expand_files([File|Left], Ext, Acc)  ->
  case filelib:is_dir(File) of
    true ->
       ...
    false ->
       case filelib:is_regular(File) and
            filename:extension(File) == Ext of
         true -> expand_files(Left,  Ext, [File|Acc]);
         false -> expand_files(Left, Ext, [File])
       end
  end;
```

```
refac_util.erl:1322:
   The call erlang:and(bool(),[integer()]) will fail
   since it differs in argument position 2
   from the success typing arguments: (bool(),bool())
```

Wrangler 0.3

- Released January 2008 – one year after 0.1
- 25 modules
- 27,000 lines of code

Dialyzer on Wrangler 0.3

- Run as simply as

```
> cd distel-wrangler-0.3/wrangler/erl
> dialyzer --src -I ../hrl -c *.erl
```

- Analysis takes 50 secs – produces many warnings
- Many due to `file:open/2` and due to confusing `lists:concat/1` with `lists:append/1`
- After fixing these, 10 warnings remain
  - all genuine bugs
  - two of them are remains from Wrangler 0.1
  - not very surprising: they are in uncommon code paths

Step #2

Expose type information:
make it part of the code

Exposing type information

Can happen in either of the following ways:

- Add explicit type guards in key places in the code
  - Ensures the validity of the information
  - Has a runtime cost – typically small
  - Programs may not be prepared to handle failures
- Add type declarations and contracts
  - Documents functions and module interfaces
  - Incurs no runtime overhead
  - Can be used by dialyzer to detect contract violations

Turning @specs into -specs

Often Edoc **@spec** annotations

```
%% @spec batch_rename_mod(OldNamePattern::string(),
%%                        NewNamePattern::string(),
%%                        SearchPaths::[string()]) ->
%%        ok | {error, string()}
```

Can easily be turned into **-spec** declarations

```
   -spec batch_rename_mod(OldNamePattern::string(),
                          NewNamePattern::string(),
                          SearchPaths::[string()]) ->
          'ok' | {'error', string()}.
```

Turning @specs into -specs

In some other cases

```
%% @spec duplicated_code(FileName ::filename(),
%%                       MinLines ::integer(),
%%                       MinClones::integer()) -> term()
```

Type declarations are also required

```
-type filename() :: string().
-spec duplicated_code(FileName ::filename(),
                      MinLines ::integer(),
                      MinClones::integer()) -> term().
```

Turning @specs into -specs

- A problem with Edoc annotations is that often they are not in accordance with the code
  - Not surprising – they are comments after all!

- For example, to be correct, let alone precise, the previous case should read:

```
-type filename() :: string().
-spec duplicated_code(FileNames::[filename()],
                      MinLines ::[integer()],
                      MinClones::[integer()]) -> term().
```

How to turn `@specs` into `-specs`

Option 1: Convert `@specs` into `-specs` in one go

- Brave and quick
- Typically not a good idea: results in many Dialyzer warnings which may be hard to debug

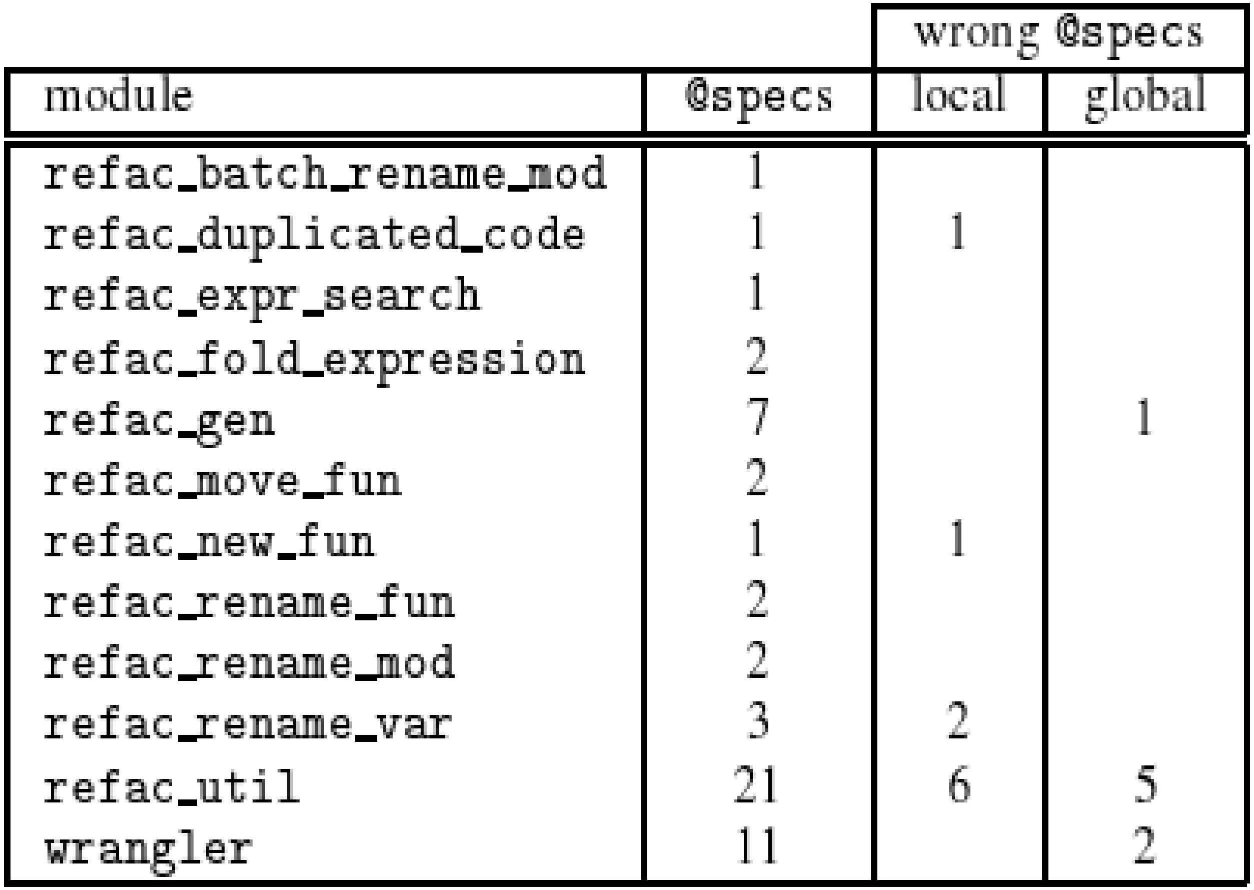
Experiment: 162 warnings on the code of Wrangler 0.3

Option 2: Convert `@specs` gradually and fix the erroneous ones using Dialyzer

- First locally (on a module-by-module basis)
- Then globally

→ **We strongly recommend Option 2**

Wrong @specs in Wrangler 0.3



		wrong @specs	
module	@specs	local	global
refac_batch_rename_mod	1		
refac_duplicated_code	1	1	
refac_expr_search	1		
refac_fold_expression	2		
refac_gen	7		1
refac_move_fun	2		
refac_new_fun	1	1	
refac_rename_fun	2		
refac_rename_mod	2		
refac_rename_var	3	2	
refac_util	21	6	5
wrangler	11		2

Table 2. Wrong @specs in Wrangler 0.3; blank entries denote 0

Step #3

Fix bugs exposed by `-spec` declarations

Step #4

Strengthen and factor **`-type`** declarations

Strengthening `-type` declarations

- Type declarations can be refined to the extent desired by the programmer

```
-type pos() :: any().
```

```
-type pos() :: tuple().
```

```
-type pos() :: {any(), any()}.
```

```
-type pos() :: {number(), number()}.
```

```
-type pos() :: {integer(), integer()}.
```

```
-type pos() :: {0..1000000, 0..200}.
```

Step #5

Strengthen underspecified **`-spec`** declarations

Strengthening underspecified -specs

Can take place semi-automatically using Dialyzer

```
> dialyzer -Wunderspecs --src -I ../hrl -c *.erl
```

```
refac_duplicated_code.erl:53:
   Type specification for duplicated_code/3 ::
    ([filename()],[integer()],[integer()]) -> term()
   is a supertype of the success typing:
    ([string()],[integer()],[integer()]) -> {'ok',string()}
```

Step #6

Add **`-spec`** declarations for all exported functions

Adding missing -specs

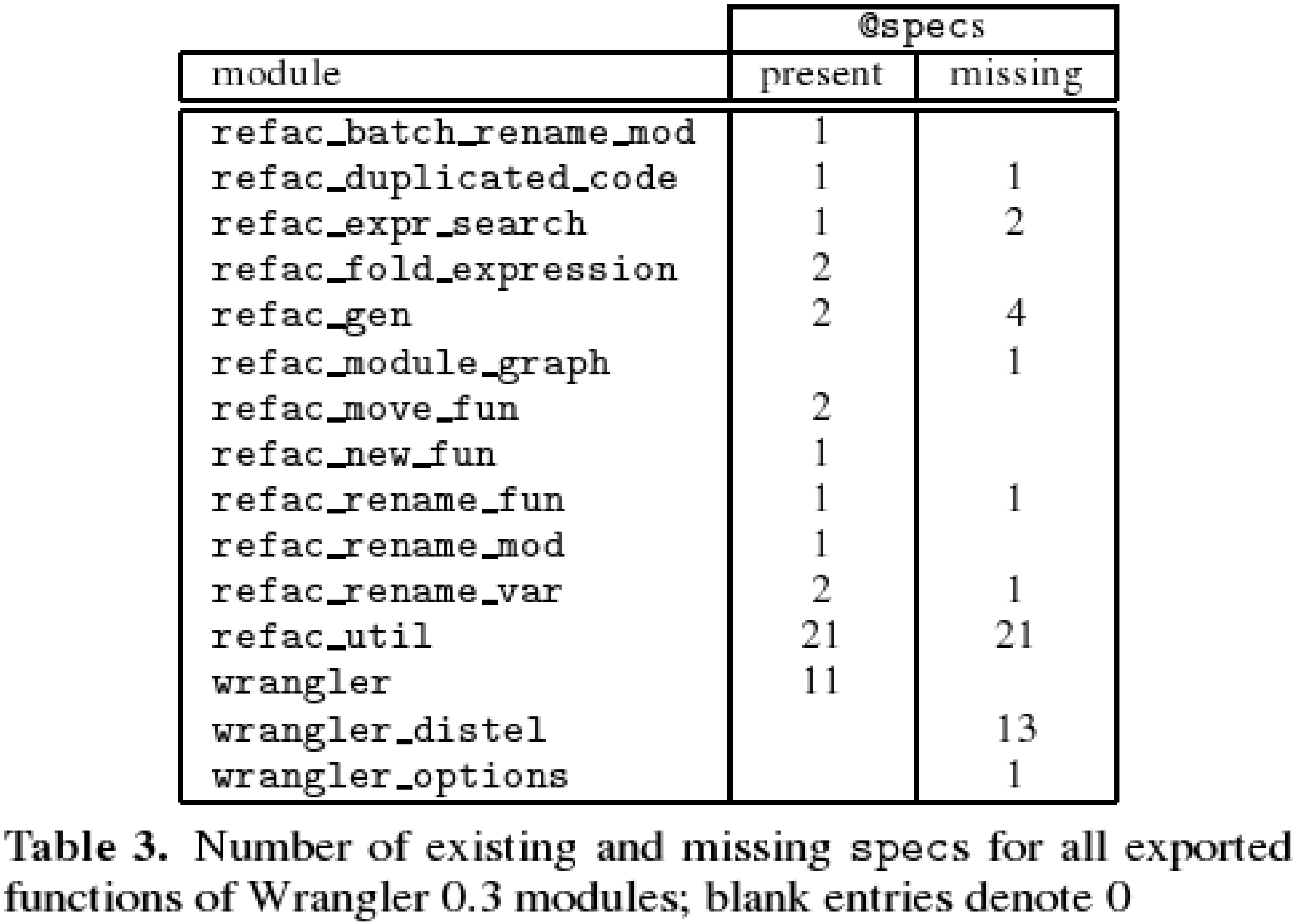
Can take place semi-automatically using Typer

```
> erlc +warn_missing_spec -I../hrl refac_rename_var.erl
./refac_rename_var.erl:166: Warning:
    missing specification for function pre_cond_check/4
```

```
> typer --show-exported -I../hrl refac_rename_var.erl

%% File: "refac_rename_var.erl"
%% ----------------------------
-spec pre_cond_check(tuple(),integer(),integer(),atom()) -> bool().
-spec rename(syntaxTree(),pos(),atom()) -> {syntaxTree(),bool()}.
-spec rename_var(filename(),...,[string()]) ->
              {'ok',string()} | {'error',string()}.
```

Missing @specs in Wrangler 0.3



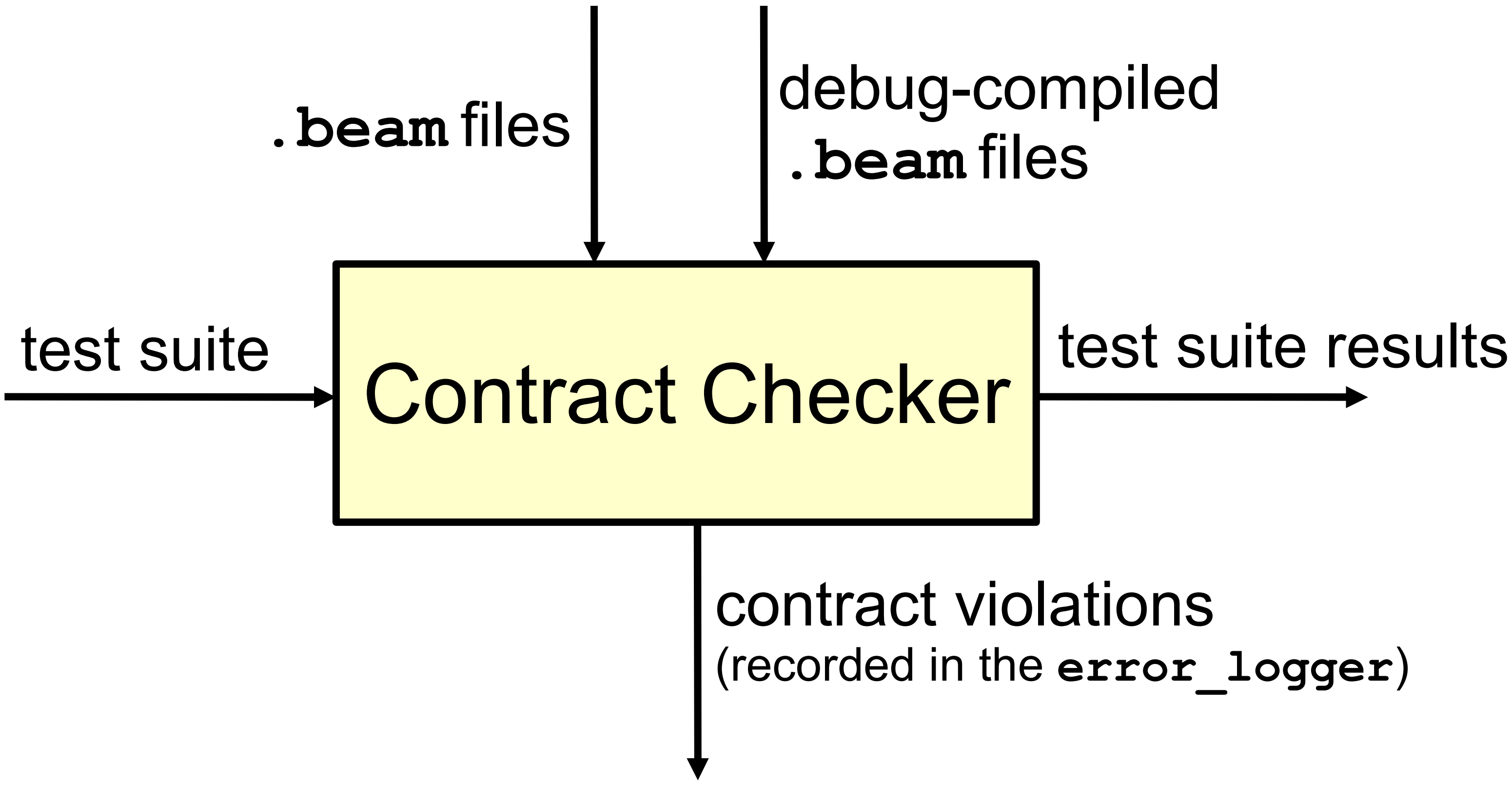
	@specs	
module	present	missing
refac_batch_rename_mod	1	
refac_duplicated_code	1	1
refac_expr_search	1	2
refac_fold_expression	2	
refac_gen	2	4
refac_module_graph		1
refac_move_fun	2	
refac_new_fun	1	
refac_rename_fun	1	1
refac_rename_mod	1	
refac_rename_var	2	1
refac_util	21	21
wrangler	11	
wrangler_distel		13
wrangler_options		1

Table 3. Number of existing and missing specs for all exported functions of Wrangler 0.3 modules; blank entries denote 0

Step #7

Test the validity of contracts using runtime monitoring

Testing for contract violations



Out of the 106 `-spec` declarations of Wrangler

- 55 were exercised by the test suite
- 4 of them were detected as erroneous

Concluding remarks

- Described a methodology for how to:
  - use static analysis for detecting definite type errors
  - add type information to existing Erlang applications
  - become confident about the validity of that information
- Showed both the benefits and common pitfalls of the approach on a non-trivial case study
- Type information is not a panacea but makes code more robust, easier to understand and maintain