

Metaprogramming and symbolic execution for detecting runtime errors in Erlang programs

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The Erlang language

Erlang is a programming language with

- integration of **functional** and **concurrent** features
- concurrency model based on **asynchronous message-passing**
- dynamic typing
- hot code loading

These features make it appropriate for **distributed, fault-tolerant** applications (Facebook, WhatsApp)

Motivation (types)

Dynamically typed languages allow **rapid development**

Many errors **are not detected** until the program is run (or even later)

- a particular input
- a particular interleaving

In static languages, some errors would be caught **at compile time**

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Motivation (tools)

In the context of Erlang, **some tools mitigate these problems:**

- **Dialyzer:** Popular tool for performing type inference
- **SOTER:** Model checking and abstract interpretation
- etc.

But these tools are

- **not fully automatic** in some cases
- only **valid for one part** of the language (sequential or concurrent)

Erlang

Erlang subset

We consider sequential programs written in a **first-order subset of Erlang**

In Erlang, a module is a **sequence of function definitions**

$$\text{fun } (X_1, \dots, X_n) \rightarrow \text{expr end}$$

The function body *expr* includes

- literals (atoms, integers, float numbers)
- variables, list constructors, tuples
- let/case/try-catch expressions
- function applications and calls to built-in functions (BIFs)

Example program

```
-module(sum_list).  
-export([sum/1]).  
  
sum(L) ->  
  case L of  
    [] -> 0;  
    [H|T] -> H + sum(T)  
  end.
```

Note that this code

- compiles without warnings
- Dialyzer does not generate any warnings
- crashes when input is not a list of numbers

Our tool is able to

- list all potential runtime errors
- provide information about input types that cause them

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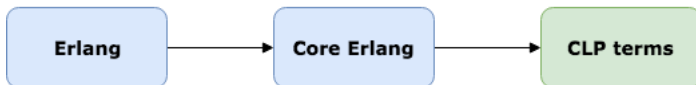
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Bounded Verification for Erlang programs

Erlang-to-CLP translation

CLP terms are obtained from Core Erlang programs



Translating from Core Erlang has **many benefits**:

- Syntactic sugar has been removed
- Pattern matching performed **only in case expressions**
- Automatic insertion of catch-all clauses

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fundef(lit(atom,'sum_list'),var('main',1),
  fun([var('@c0')],
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CLP interpreter

We define a CLP interpreter in terms of `tr/3`

```
tr(Bound, cf(IEnv, IExp), cf(FEnv, FExp))
```

- `Bound`: The current depth bound
- `cf(IEnv, IExp)`: A source configuration (env. and expression)
- `cf(FEnv, FExp)`: A target configuration (env. and expression)

`tr/3` defines a transition between source and target confs.

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Transition rules: An example

```

tr(Bound, cf(IEnv, IExp), cf(FEnv, FExp)) :-
    IExp = apply(FName/Arity, IExps),
    lookup_error_flag(IEnv, false),
    Bound > 0,
    Bound1 is Bound - 1,
    fun(FName/Arity, FParams, FBody),
    tr_list(Bound1, IEnv, IExps, EEnv, EExps),
    bind(FParams, EExps, AEnv),
    lookup_error_flag(EEnv, F1),
    update_error_flag(AEnv, F1, BEnv),
    tr(Bound1, cf(BEnv, FBody), cf(CEnv, FExp)),
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The run/4 predicate

```
run(FName/Arity,Bound,In,Out)
```

- FName/Arity: The function to be computed
- Bound: The **bound depth** to be explored
- In: The input parameters
- Out: The result value

Error detection with `run/4`

If an error is found, `Out` is bound to a term `error(Err)`

where `Err` represent the error type:

- `match_fail`: A pattern matching error
- `badarith`: Arithmetic function called with non-arithmetic args
- etc.

Error detection with run/4

```
?- run(FName/Arity, Bound, In, error(Err)).
```

When we run this query...

- No answers: Program is error-free up to Bound
- 1+ answers: **Error detected**, information about
 - error type
 - input type
 - constraints

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?- run(sum/1,20,In,error(Err)).
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We obtain some answers (**error detected**)

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In=[cons(lit(Type,_V),lit(list,nil))],  
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Error detection with run/4: An example

Let us introduce `int_list/2` to generate a *list of integers*:

```
?- int_list(L,100).
```

```
L=cons(lit(int,N1),cons(lit(int,N2),...))
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Reexecute `run/4` using `L` as input:

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Result: 0 answers (error-free program)

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Compared to Dialyzer

Similar

Dialyzer: Type inference based on success typings

Our tool: Type-related information on input values (depends on bound)

Different

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Our tool: Might provide this information if we include debugging info

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Compared to SOTER

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SOTER:

- Targets concurrent Erlang
- Based on abstract interpretation
- User provides abstractions

Our tool:

- Targets sequential Erlang (for now)
- Support for arithmetics operations using constraint solvers
- No user intervention is required

Conclusions

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We have presented our work on a [CLP interpreter for Erlang](#):

- 1 Erlang programs are translated to CLP terms
- 2 The CLP interpreter can run these programs on symbolic inputs
- 3 Error detection up to some bound can be performed

This way, we can perform [bounded verification for Erlang](#) programs

Future work

Extend the CLP interpreter to

- support higher-order constructs
- handle concurrent programs

We plan to apply specialization on the CLP interpreter (given an Erlang program and its symbolic input)

- May enable more efficient computation
- Can be used as input to other tools for analysis and verification (e.g., constraint-based analyzers or SMT solvers)

Thanks for your attention!