Erlang Code Evolution Control

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Content

- Introduction
- The technique in detail
  - Type Analysis Phase
  - Test Case Generation Phase
  - Comparison Phase
- Recording the trace
- SecEr tool
- Conclusions & Future Work

Introduction

- In debugging programmers use breakpoints to observe the values of an expression during an execution
- Is this feature available in testing?
- It would be useful to focus the test cases on an specific point without code modifications

OUR PROPOSAL

- Introduce the ability to specify Points Of Interest (POI) in the context of testing
- A technique to compare two equivalent POIs in different versions of the same program for Erlang

Introduction

Old Version

```
main(X,Y) ->
  A = X + Y,
  D = X - Y,
  A * D.
```

New Version

```
main(X,Y) ->
  A = add(X,Y),
  D = sub(X,Y),
  A * D.

add(X,Y)->
  X + Y.

sub(X,Y) ->
  X - Y.
```

main(5,4)
OldVersionTrace: 1
NewVersionTrace: 1
Success

1.- Identify a POI and a set of input functions

2.- A test suite is automatically generated

Each test case contains:

- A call to an input function with specific arguments
- The sequence of values the POI is evaluated to (trace)

3.- Each test case is passed against the new version and both traces are compared

4.- A report of the success or failure of the test cases is provided

We have implemented our approach for Erlang in a tool named *SecEr*

Introduction

Old Version

```
main(X,Y) ->
  A = X + Y,
  D = X - Y,
  A * D.
```

New Version

```
main(X,Y) ->
  A = add(X,Y),
  D = sub(X,Y),
  A * D.

add(X,Y)->
  X + Y.

sub(Y,X) ->
  X - Y.
```

main(5,4)
OldVersionTrace: 1
NewVersionTrace: -1
Failure

1.- Identify a POI and a set of input functions

2.- A test suite is automatically generated

Each test case contains:

- A call to an input function with specific arguments
- The sequence of values the POI is evaluated to (trace)

3.- Each test case is passed against the new version and both traces are compared

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We have implemented our approach for Erlang in a tool named *SecEr*

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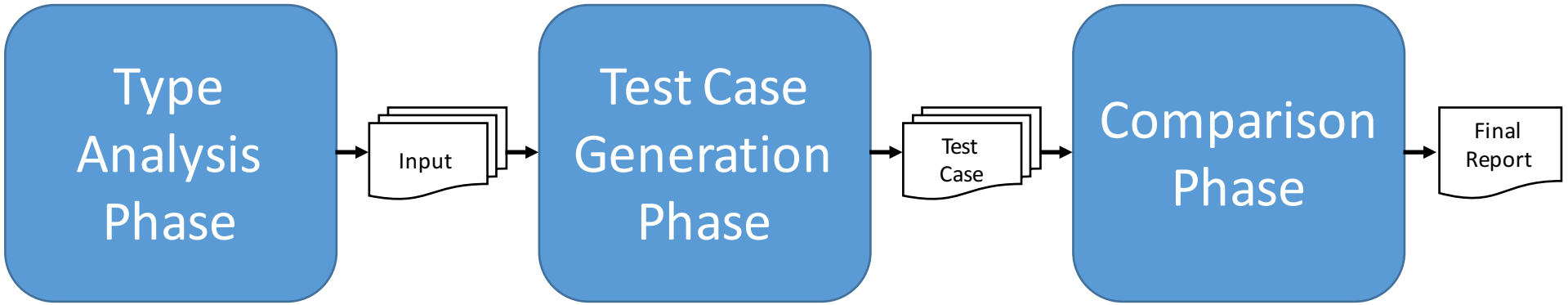
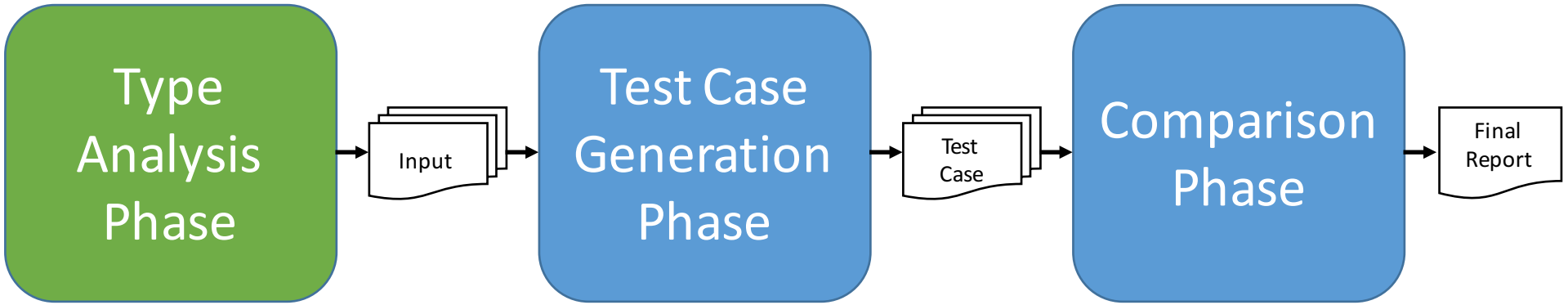
The technique in detail



The technique in detail



Type analysis phase

Type analysis phase


```
g(0,0)->…
g(1,1)->…
```
⇒ “-spec g(0|1, 0|1)->…”

1.- The infered types refer to the whole function ⇒ `g(0,1)`

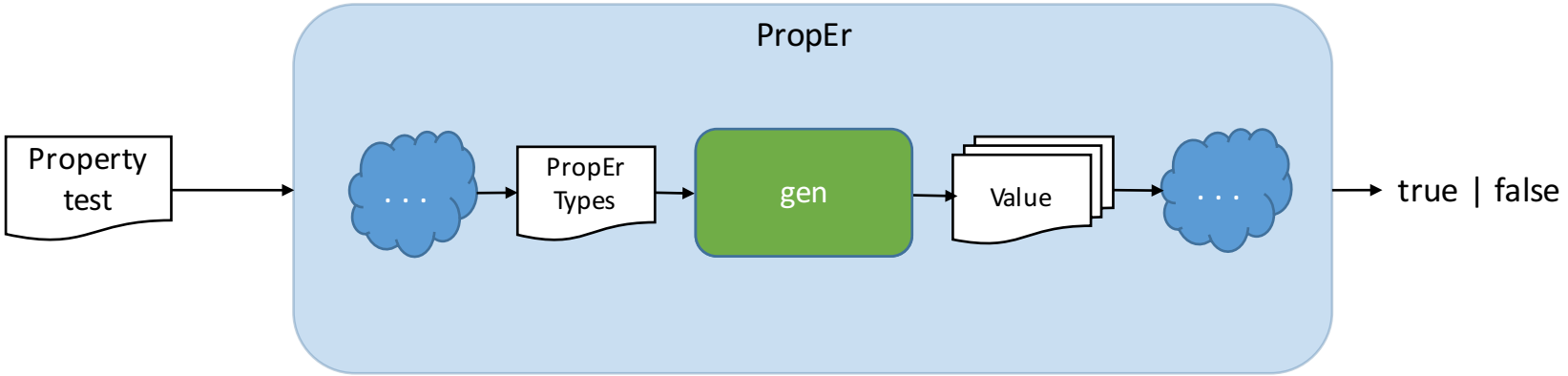
Solution: Consider each clause independently and refine the result to types per clause

`f(A,[A,B])` ⇒ “-spec f(1|2,[1|2|5|6])->…”

2.- The length of the list is unkwnown ⇒ `f(1,[1,2,5,6])`

3.- The repeated-variable restriction is ignored ⇒ `f(1,[2,5])`

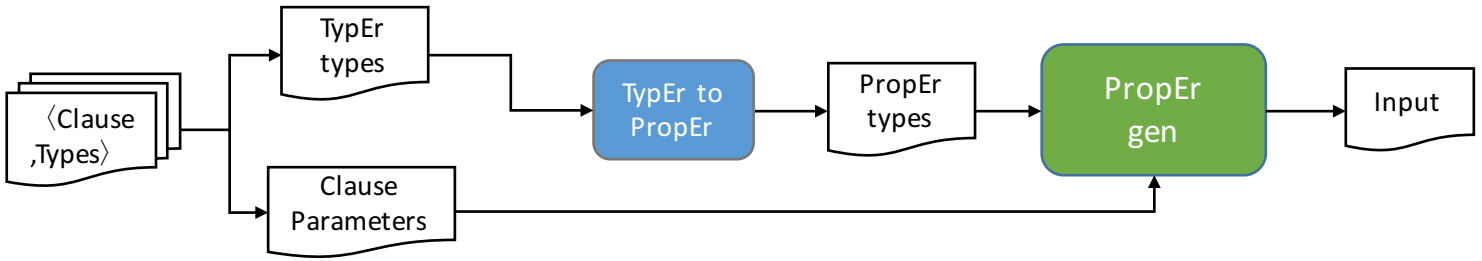
Type analysis phase




```
prop_identity() ->
    ?FORALL(X, any(), id(X) = X).

id(X) -> X.
```

Type analysis phase



`f(A,[A,B])`

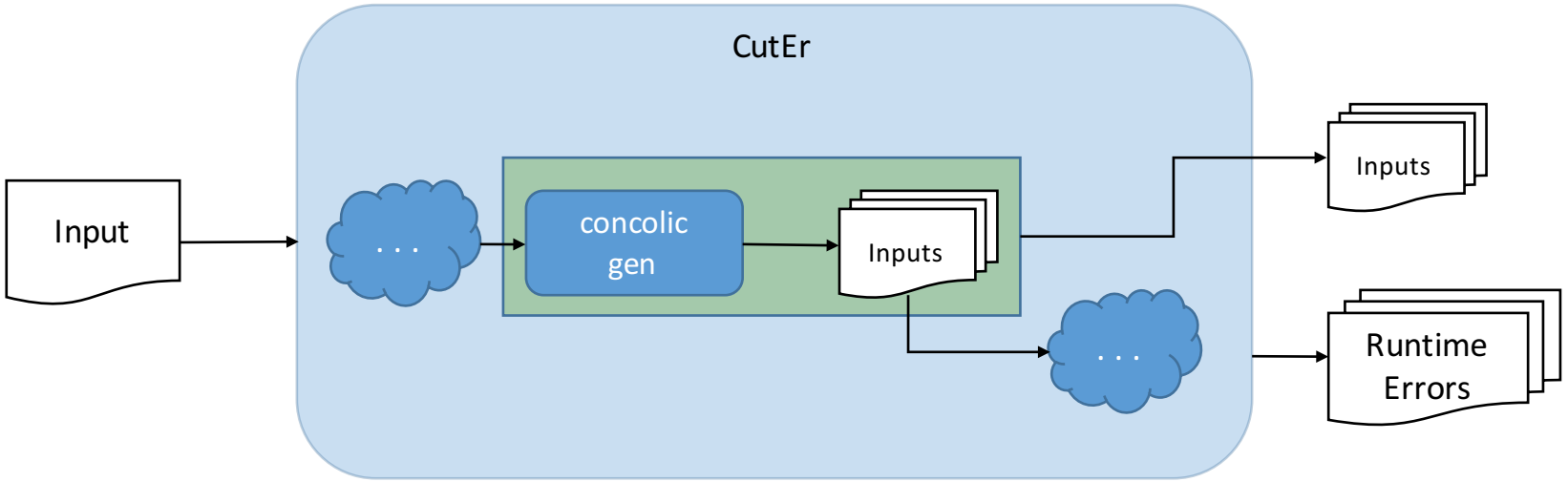
2.- The length of the list is unknown

Solution: Traverse the list parameters of the clause element by element

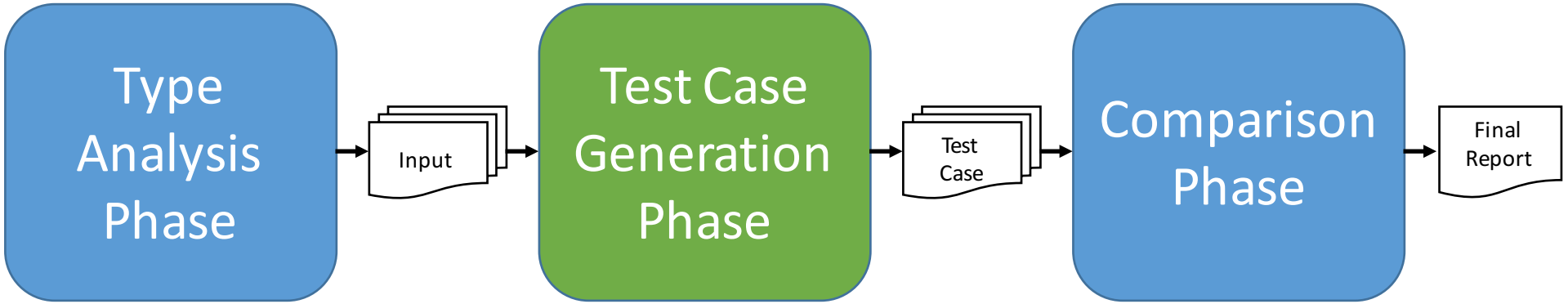
3.- Repeated variable relation is lost

Solution: Store the values of already treated variables

Type analysis phase



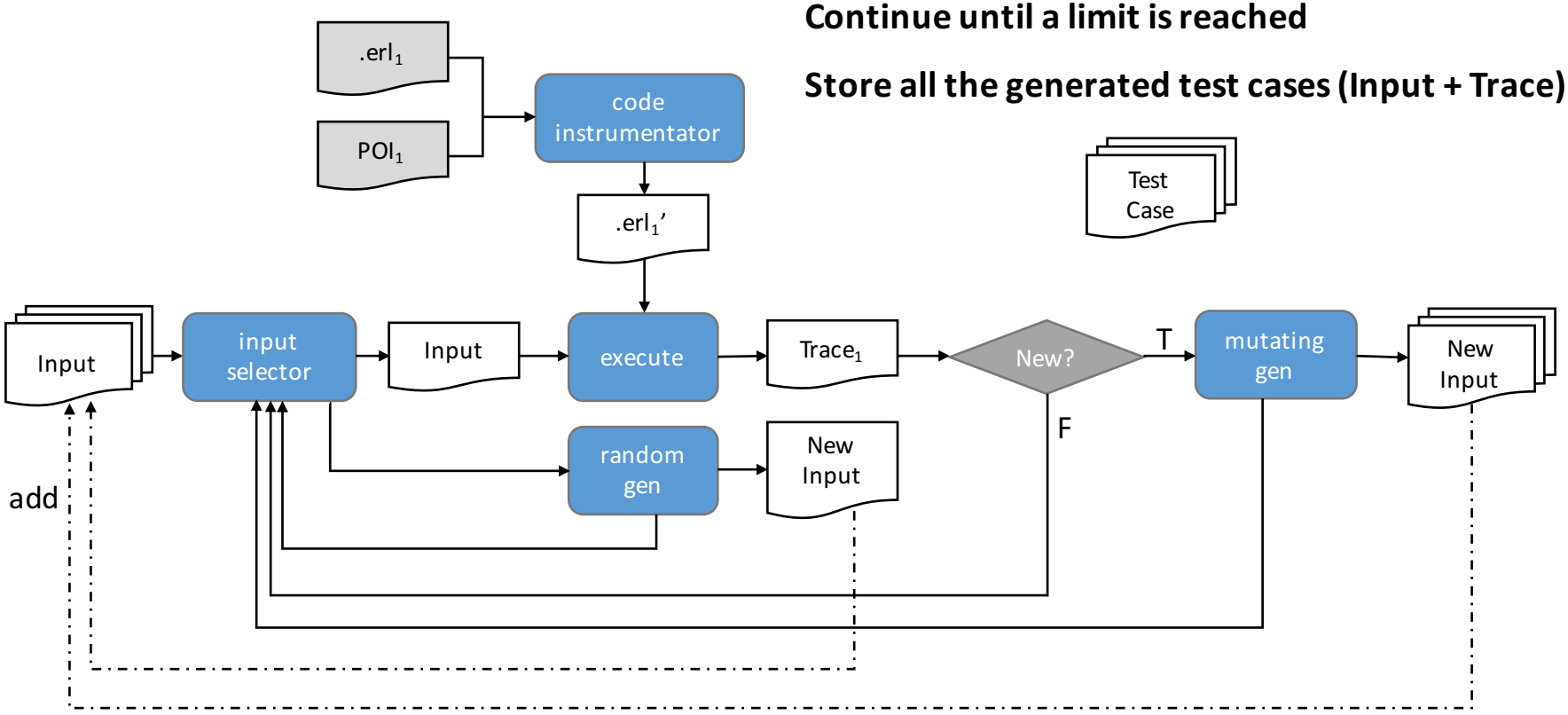
The technique in detail



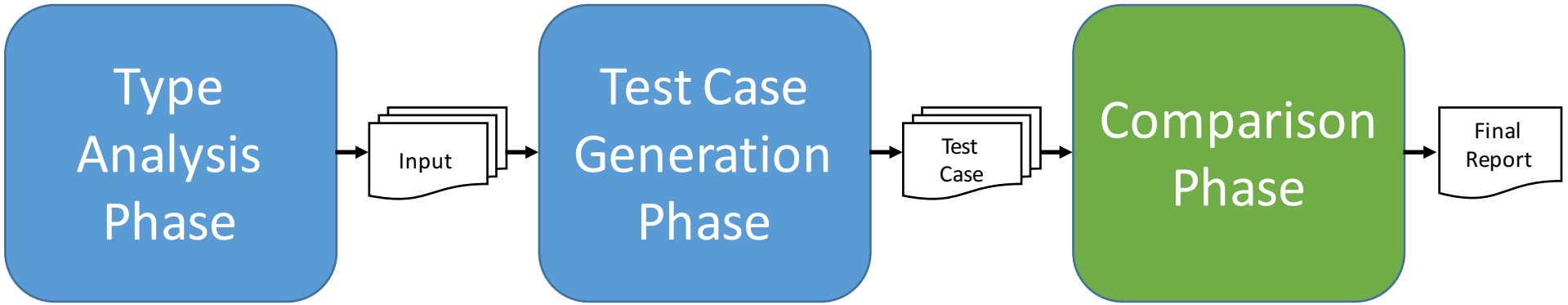
Test case generation phase

Continue until a limit is reached

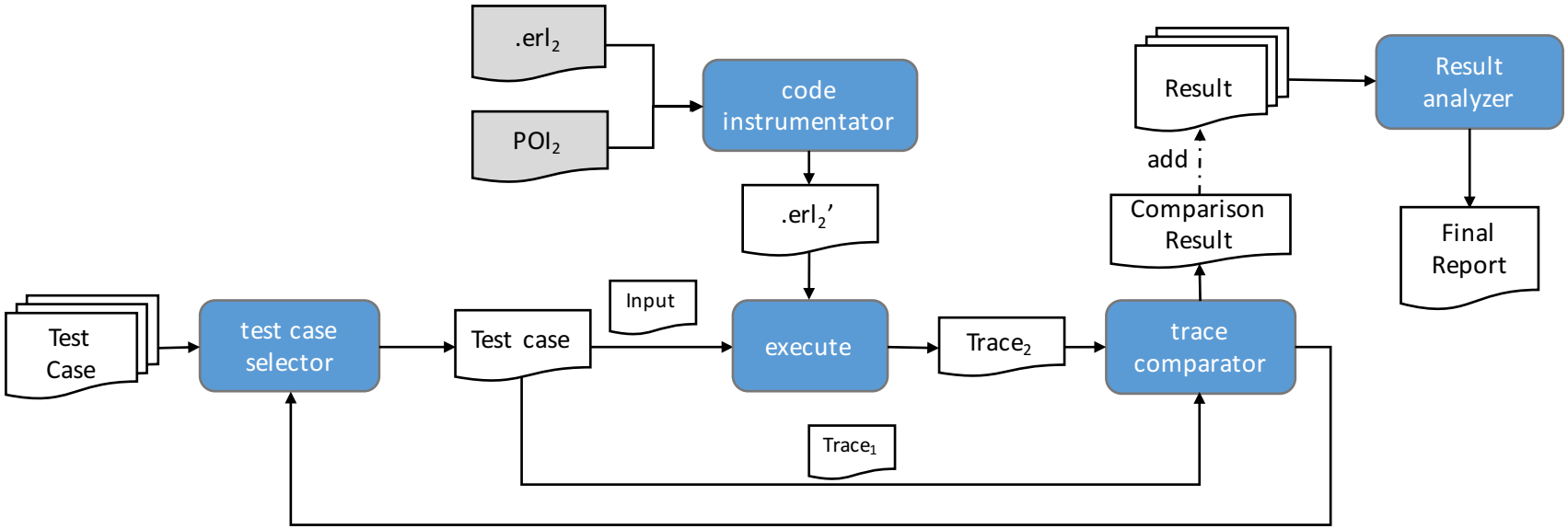
Store all the generated test cases (Input + Trace)



The technique in detail



Comparison phase



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Recording the trace

- There are several tools for tracing executions in Erlang
- None of them allows us to collect the trace of patterns
- Debuggers will not provide a value for a POI if it is inside an expression whose evaluation fails

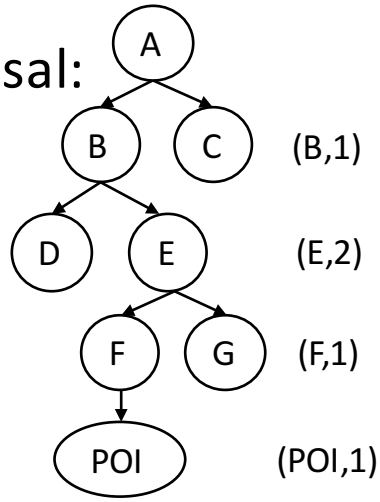
```
{1,B,3} = {1,2,4}
```

OUR PROPOSAL

- ➢ Collect the traces as a side effect when executing the code
  - ➢ Approach based on message passing to a tracing server
    - ➢ The code needs to be instrumented (4 STEPS)

Recording the trace (1 & 2)

1. Obtain and annotate the Abstract Syntax Tree of the program. Annotate each node with two lists of variables:
   - Variables being bound in its subtree
   - Variables that were already bound when reaching the node
2. Find the selected POI in the AST with a top-down traversal:
   - Store the current traversed path with tuples of the form (Node,ChildIndex)
   - The result is a path that yields directly to the POI



Recording the trace (3)

3. Analyze the location of the POI
   - Expressions: Add a send command to inform the tracing server
   - Patterns: Need special treatment

```
{1,B,3} = {1,2,4}
```

2

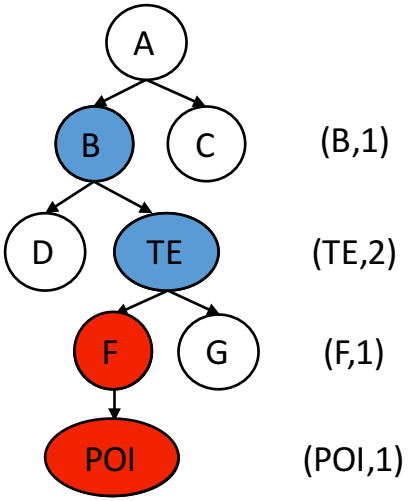
Target expressions

- Pattern-matching
- List comprehension
- Expressions with clauses:
  - if
  - case
  - functions
  - etc.

Recording the trace (3)

Divide the AST path into two sub-paths:

- PathBefore: Root -> deepest target expression
- PathAfter: First child of the target expression -> POI



PathBefore

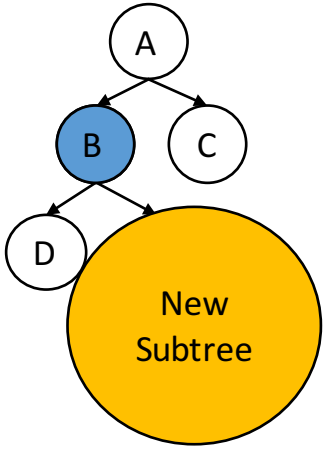
(B,1),(TE,2)

PathAfter

(F,1),(POI,1)

Recording the trace (4)

4. Perform the actual instrumentation
   - Traverse the PathBefore
   - Transform the code following a rule according to PathAfter
   - Traverse PathBefore backwards to update the AST



Five exclusive rules to instrument expressions

- LEFT_PM (pattern-matching)
- PAT_GEN_LC (list comprehensions)
- CLAUSE_PAT (pattern in expressions with clauses)
- CLAUSE_GUARD (guard in expressions with clauses)
- EXPR (expressions)

Recording the trace (4)

(LEFT_PM) `p = e → p = begin np = e, tracer!{add, npoi}, np end`

if `(p = e, _ ) = last(PathBefore)`

`∧ (_, pos(p)) = hd(PathAfter)`

where `(_, npoi, np) = pfv(p,PathAfter)`

`{1,B,3} = {1,2,4}`

```
p = begin {1,B,3}  = begin
          np = e  {1,POI,FV}  = {1,2,4},
tracer!{add, npoi} tracer  !  {add,POI},
                   np  {1,POI,FV}
                end  end
```

p = e

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SecEr tool

SecEr command:

```
$ ./secer -f FILE –li LINE – var VARIABLE [-oc OCCURRENCE]
          -f FILE –li LINE – var VARIABLE [-oc OCCURRENCE]
          [-funs INPUT_FUNCTIONS] –to TIMEOUT
```

Old_Version_POI

New_Version_POI

SecEr tool

happy0.erl

```
1  -spec main(pos_integer(),pos_integer()) ->
2   [pos_integer()].
3  main(N, M) ->
4   happy_list(N, M, []).
5
6  happy_list(_, N, L) when length(L) =:= N ->
7   lists:reverse(L);
8  happy_list(X, N, L) ->
9   Happy = is_happy(X),
10  if Happy ->
11    happy_list(X + 1, N, [X|L]);
12  true ->
13    happy_list(X + 1, N, L) end.
14
15 is_happy(1) -> true;
16 is_happy(4) -> false;
17 is_happy(N) when N > 0 ->
18  N_As_Digits =
19    [Y - 48 ||
20    Y <- integer_to_list(N)],
21  is_happy(
22    lists:foldl(
23      fun(X, Sum) ->
24        (X * X) + Sum
25      end,
26      0,
27      N_As_Digits));
28 is_happy(_) -> false.
```

happy1.erl

```
1  is_happy(X, XS) ->
2   if
3     X == 1 -> true;
4     X < 1 -> false;
5     true ->
6       case member(X, XS) of
7         true -> false;
8         false ->
9           is_happy(sum(map(fun(Z) -> Z*Z end,
10            [Y - 48 || Y <- integer_to_list(X)])),
11            [X|XS])
12      end
13  end.
14 happy(X, Top, XS) ->
15  if
16    length(XS) == Top -> sort(XS);
17    t
18      Happy = is_happy(X,[]),
19      Happy of
20        true -> happy(X + 1, Top, [X|XS]);
21        false -> happy(X + 1,Top, XS)
22      end
23  end.
24
25 -spec main(pos_integer(),pos_integer()) ->
26  [pos_integer()].
27 main(N, M) ->
28  happy(N, M, []).
```

```
$ ./secer -f happy0.erl –li 9 – var Happy -oc 1
          -f happy1.erl –li 18 – var Happy -oc 1
          -funs [main/2] –to 15
```

SecEr tool

```
$ ./secer -f happy0.erl -li 9  -var Happy -oc 1
          -f happy1.erl -li 18 -var Happy -oc 1
          -fun [main/2] -to 15

Function: main/2
----------------------------
Generated test cases: 320
Both versions of the program generate identical traces for the
point of interest
----------------------------
```

SecEr tool

```
1  -spec main(pos_integer(),pos_integer()) ->
2   [pos_integer()].
3  main(N, M) ->
4   happy_list(N, M, []).
5
6  happy_list(_, N, L) when length(L) =:= N ->
7   lists:reverse(L);
8  happy_list(X, N, L) ->
9    Happy = is_happy(X),
10   if Happy ->
11     happy_list(X + 1, N, [X|L]);
12   true ->
13     happy_list(X + 1, N, L) end.
14
15 is_happy(1) -> true;
16 is_happy(4) -> false;
17 is_happy(N) when N > 0 ->
18  N_As_Digits =
19    [Y - 48 ||
20    Y <- integer_to_list(N)],
21  is_happy(
22    lists:foldl(
23      fun(X, Sum) ->
24        (X * X) + Sum
25      end,
26      0,
27      N_As_Digits));
28 is_happy(_) -> false.
```

```
1  is_happy(X, XS) ->
2   if
3     X == 1 -> true;
4     X < 10 -> false;
5     true ->
6       case member(X, XS) of
7         true -> false;
8         false ->
9           is_happy(sum(map(fun(Z) -> Z*Z end,
10            [Y - 48 || Y <- integer_to_list(X)])),
11            [X|XS])
12      end
13  end.
14 happy(X, Top, XS) ->
15  if
16    length(XS) == Top -> sort(XS);
17    true ->
18      Happy = is_happy(X,[]),
19      case Happy of
20        true -> happy(X + 1, Top, [X|XS]);
21        false -> happy(X + 1,Top, XS)
22      end
23  end.
24
25 -spec main(pos_integer(),pos_integer()) ->
26  [pos_integer()].
27 main(N, M) ->
28  happy(N, M, []).
```

SecEr tool

```
$ ./secer -f happy0.erl -li 9  -var Happy -oc 1
          -f happy1.erl -li 18 -var Happy -oc 1
          -fun [main/2] -to 15

Function: main/2
----------------------------
Generated test cases: 251
Mismatching test cases: 22 (8.76%)
All mismatching results were saved at: ./results/main_2.txt
--- First error detected ---
Call: main(4,1)
happy0 trace (9,Happy,1): [false,false,false,true]

happy1 trace (18,Happy,1): [false,false,false,false,false,false,true]
```

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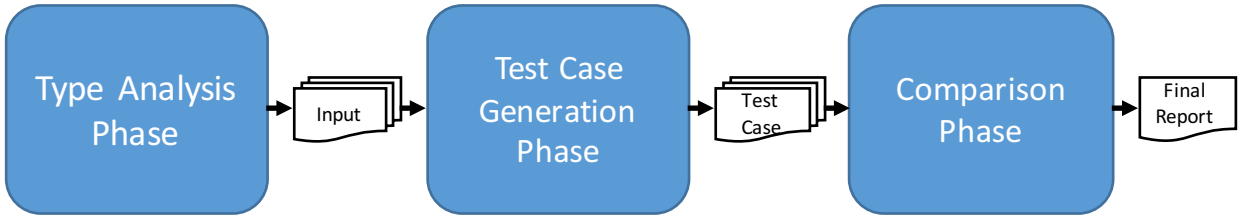
- Combination of Erlang existing tools and mutation to improve the result
- New approach to automatically check the behaviour preservation between versions



- New tracing process that allows for placing a POI in patterns, guards and expressions

```
{1,B,3} = {1,2,4}
```

```
{1,B,3} = begin
              {1,POI,FV} = {1,2,4},
              tracer ! POI,
              {1,POI,FV}
          end
```

Future Work

Future Work

- Adapt the approach to deal with indeterminism
- Increase the information stored in traces to report non-functional properties such as efficiency
- Allow for the specification of a list of POIs instead of a single POI
- Make the tool compatible with tests previously defined by the user

Thank you for your attention!!

Any question?