Update on EU project ProTest

ProTest
property based testing

University of Kent Computing · Erlang · QuviQ · Universidade da Coruña · IT University of Göteborg

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Some results from Q1 + Q2

- Testing Erlang Data Types with QuickCheck
- Refactoring with Wrangler
- Early fault detection with model-based testing
- Erlang Testing and Tools Survey

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Testing Erlang Data Types with QuickCheck

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Challenge

Erlang libraries supply a number of data types, but sometimes you want to design your own.

We presented a method that ensures full testing of an implementation of a home-made data type.

Full paper published at Erlang workshop 2008

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Testing

Implementation of data type for decimals

How to test this implementation?

```
decimal() ->
  ?LET(Tuple, {int(),nat()}, new(Tuple)).

prop_sum_comm() ->
  ?FORALL({D1,D2}, {decimal(),decimal()},
          sum(D1,D2) == sum(D2,D1)).
```

QuickCheck generates thousands of tests

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Testing

Which other properties do we add?

When do we have sufficiently many properties?

Use a Model

Erlang functions

Model operations

$$[\mathrm{sum}(D1,D2)] = [D1] + [D2]$$
$$[\mathrm{subs}(D1,D2)] = [D1] - [D2]$$
$$[\mathrm{mult}(D1,D2)] = [D1] * [D2]$$
$$[\mathrm{lt}(D1,D2)]_1 = [D1] < [D2]$$

.....

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Symbolic data

Use symbolic data structures instead of real data structures in test generation:

easier to analyze errors

```
decimal() ->
    ?LET(Tuple, {int(), nat()},
         {call, decimal, new, [Tuple]}).
```

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Symbolic data

Translate symbolic value to real value in property

```
prop_sum() ->
  ?FORALL({SD1,SD2},{decimal(),decimal()},
          begin
            D1 = eval(SD1),
            D2 = eval(SD2),
            model(sum(D1,D2)) ==
                model(D1) + model(D2)
          end).
```

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Testing model equivalence

We run QuickCheck....

```
> eqc:quickcheck(decimal_eqc:prop_sum()).
........Failed! After 9 tests.
{{call,decimal,new,[{2,1}]},
 {call,decimal,new,[{2,2}]}}
Shrinking..(2 times)
{{call,decimal,new,[{0,1}]},
 {call,decimal,new,[{0,2}]}}
false
```

Thus: 0.1 + 0.2 =/= 0.3 ??

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Testing model equivalence

Indeed!

Unavoidable rounding error according to IEEE 754-1985. Our model is incorrect.

We fix it!

```
> (0.1+0.2) == 0.3.
false
> (0.1+0.2) - 0.3.
5.55112e-17
```

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Testing model equivalence

Property prop_sum() passes thousands of test cases.

Similarly, we can add a property prop_mult().

But... although we will obtain 100% code coverage, we miss testing combinations of mult and sum!

Recursive generators

```
decimal() ->
   ?SIZED(Size, decimal(Size)).

decimal(0) ->
   {call, decimal, new, [{int(),nat()}]};
decimal(Size) ->
   Smaller = decimal(Size div 2),
   oneof([
      decimal(0),
      ?LETSHRINK([D1, D2], [Smaller, Smaller],
                 {call, decimal, sum, [D1, D2]}),
      ?LETSHRINK([D1, D2], [Smaller, Smaller],
                 {call, decimal, mult, [D1, D2]}
   ]).
```

Testing model equivalence

Add subs and divs to generator and test **same property** again:

```
> eqc:quickcheck(decimal_eqc:prop_sum()).
............Failed!
After 13 tests.
Shrinking....(4 times)
Reason:
{'EXIT',{{not_ok,{error,decimal_error}},
        [...]}}
{{call,decimal,divs,
   [{call,decimal,new,[{0,0}]},
    {call,decimal,new,[{0,0}]}]},
 {call,decimal,new,[{0,0}]}}
false
```

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Negative testing

We do want to test that division by zero results in an error... *in prop_divs, not in prop_sum*

```
prop_divs() ->
   ?FORALL({SD1, SD2}, {decimal(), decimal()},
      begin
         D1 = eval(SD1),
         D2 = eval(SD2),
         case catch (model(D1)/model(D2)) of
            {'EXIT',_} ->
                   is_error(divs(D1, D2));
            Value ->
               equiv(model(divs(D1, D2)),
                     Value)
         end
      end).
```

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Generate well defined values

We find the error in prop_divs and we do not want to generate decimals in which we divide by zero.

```
decimal() ->
   ?SIZED(Size, well_defined(decimal(Size))).

well_defined(G) ->
   ?SUCHTHAT(E, G, defined(E)).

defined(E) ->
   case catch {ok, eval(E)} of
      {ok, _}      -> true;
      {'EXIT', _} -> false
   end.
```

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Conclusion

Method:

1. Choose a model
2. Write symbolic (recursive) generators
3. Write one property for each operation, consider expected failing cases
4. Use a well-defined trick to avoid errors in generation

When following the proposed method, one has a guarantee that the data structure is fully tested.

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Refactoring with Wrangler

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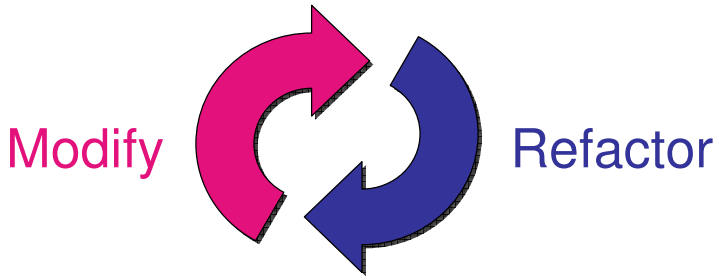
Refactoring

Refactoring means changing the design or structure of a program … without changing its behaviour.



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Generalisation and renaming

```
-module (test).
-export([f/1]).

add_one ([H|T]) ->
  [H+1 | add_one(T)];

add_one ([]) -> [].

f(X) -> add_one(X).
```

```
-module (test).
-export([f/1]).

add_int (N, [H|T]) ->
 [H+N | add_int(N,T)];

add_int (N,[]) -> [].

f(X) -> add_int(1, X).
```

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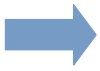
Generalisation

```
-export([printList/1]).

printList([H|T]) ->
  io:format("~p\n",[H]),
  printList(T);
printList([]) -> true.

printList([1,2,3])
```



```
-export([printList/2]).

printList(F,[H|T]) ->
  F(H),
  printList(F, T);
printList(F,[]) -> true.

printList(
  fun(H) ->
    io:format("~p\n", [H])
  end,
  [1,2,3]).
```

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Refactoring tool support

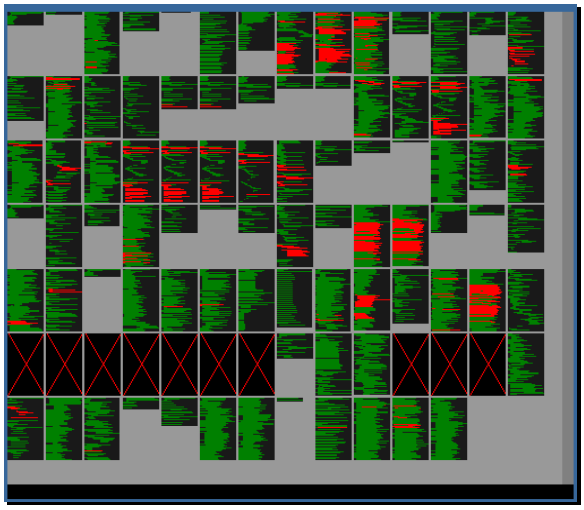
Bureaucratic and diffuse.

Tedious and error prone.

Semantics: scopes, types, modules, …

Undo/redo

Enhanced creativity



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Wrangler

Embedded in Emacs and Eclipse.

Structural, data type and module refactorings.

AAST-based analysis and transformation.

Works with multiple modules.

Supports undo of refactorings

Preserves layout and comments as much as possible.

Respects aspects of the macro system.

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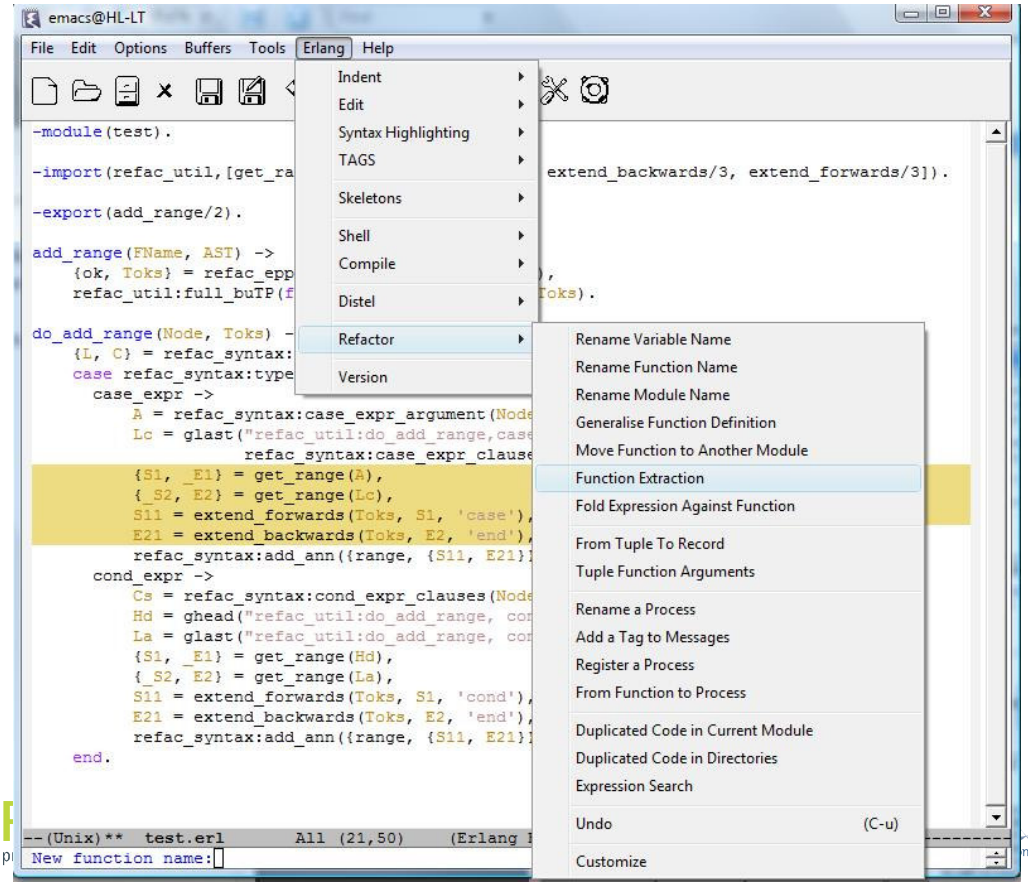

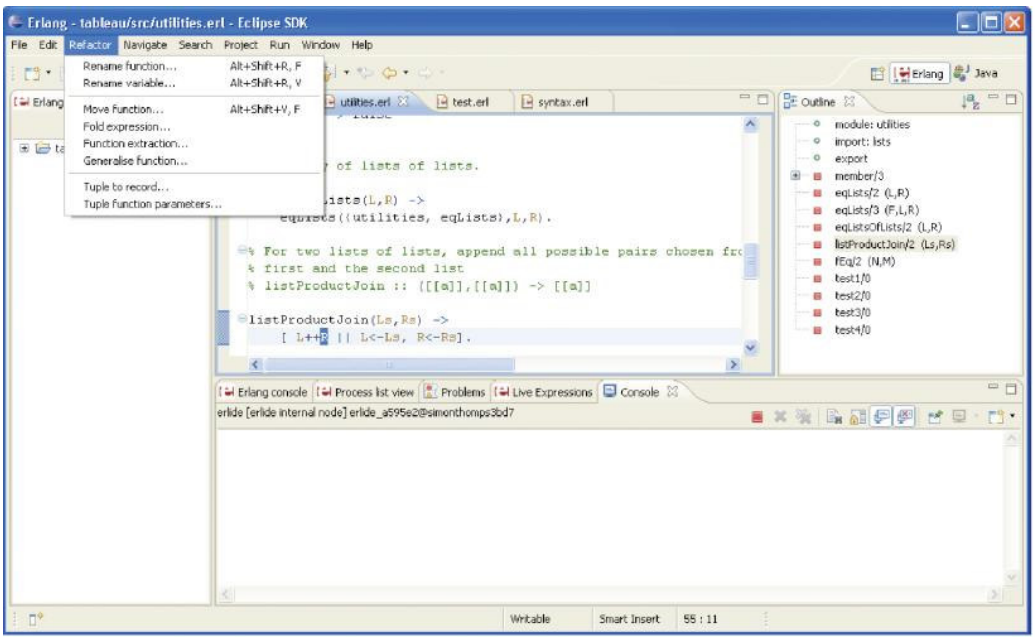

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Refactorings in Wrangler

- Renaming variable, function, module, process
- Function generalisation
- Move function
- Function extraction
- Fold against defn.
- Tuple function arguments
- Register a process
- From function to process
- Add a tag to messages

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Duplicate Code Detection

Especially for Erlang/OTP programs.

Report syntactically well-formed code fragments that are identical after consistent renaming of variables …

… ignoring differences in literals and layout.

Integrated with the refactoring environment.

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Code Inspection Support

- Variable use/binding information.
- Caller functions.
- Caller/callee modules.
- Case/if/receive expressions nested more than a specified level.
- Long function/modules.
- Non tail-recursive servers.
- Non-flushed unknown messages
- . . .

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Ongoing and Future work

- Continue the integration of Wrangler with Eclipse + Erlide
- More refactorings are being added including introduce macros, from module to process, etc.
- To investigate the use of trace information to help the refactoring process, especially process-related refactorings.

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http://www.cs.kent.ac.uk/projects/forse/

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Protest Survey on Erlang Testing Tools

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Research Method

- Published an online survey
- Advertised it by email:
  - Erlang Questions, approx. 1000 users
  - Erlang Training and Consulting Newsletter list, approx. 1000 users
  - Smaller Erlang related mailing lists
    - Trapexit User Group, 500 users
    - ProTest Mailing List, 50 users
    - London / Stockholm Erlang User Groups, 100 users
- 200 direct emails to relevant contacts at ETC
  - Merged with the main survey after the results were similar
- 40-45% of total(200) responses were from developers

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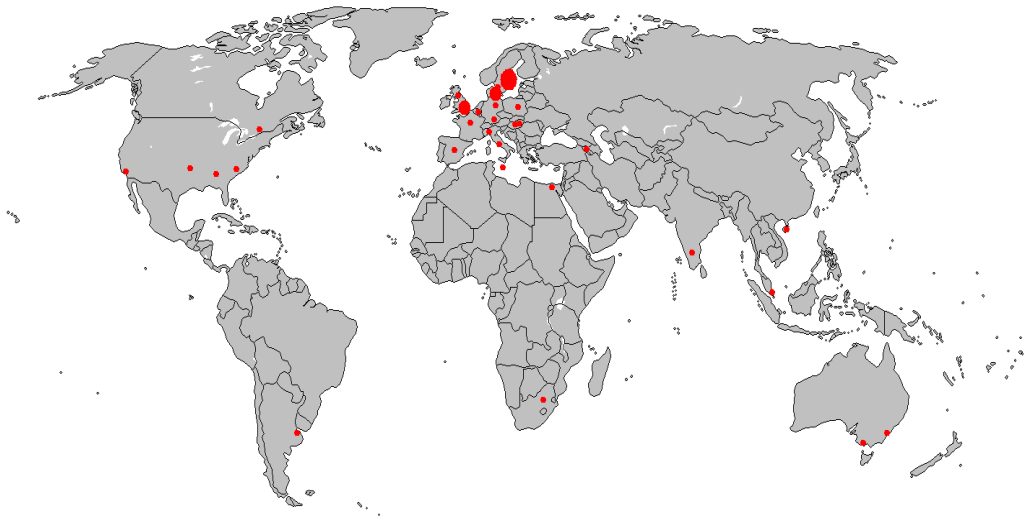
Geographical Diversion



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Survey Structure

We asked 20 questions about

- The Erlang development environment
- Usage and Knowledge of existing tools and open source applications
- Submitter's job role and Erlang background
- Identify common processes to improve tools support

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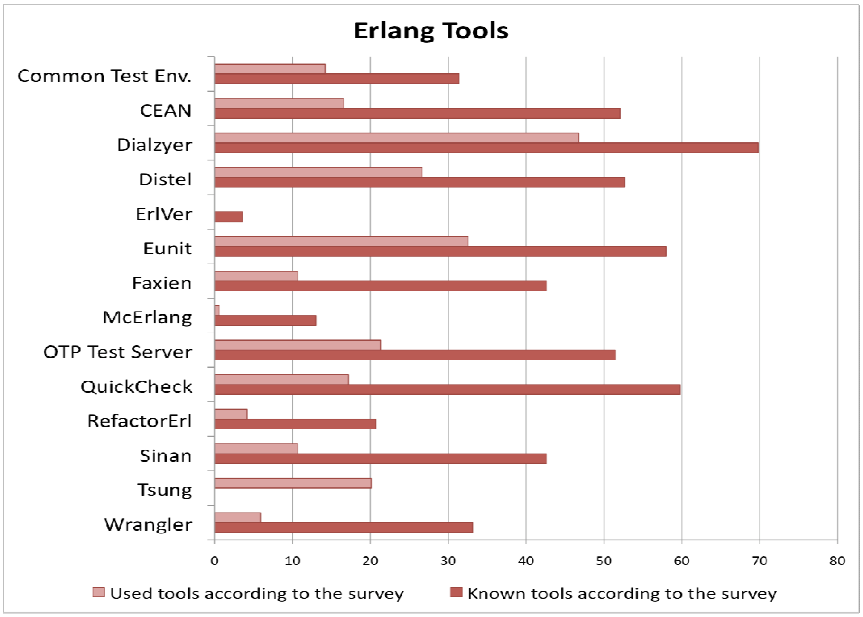
Erlang Tools Knowledge / Usage



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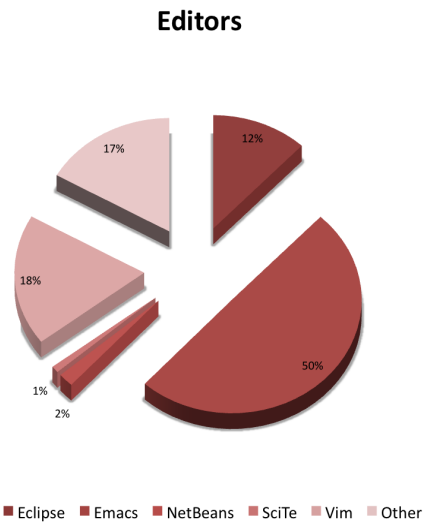
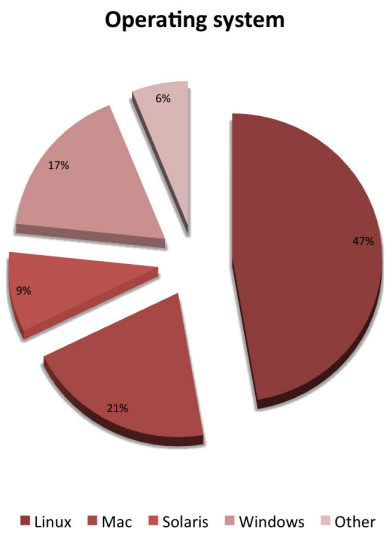
Editors and Operating Systems





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Problems Identified by the Survey

- Weaknesses of most Erlang tools and projects were found to be
  - Lack of documentation
  - Lack of examples and tutorials
  - Incomplete and untested tools
- Design issues included
  - Badly layered software
  - Not extensible and not structured
- Doubts about sustainability & support
- Hard to install and use
  - Especially for non Erlang users
  - Extensive manual configuration required

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Missing Functionality

- No tools for stub generation
- Testing tools lack high quality results display
  - Web interface or dashbord
- Load testers are not available for all requirements
  - Especially state based protocols
- Continous integration
  - Hooks towards version control systems
  - Integrated into a general framework
- A complete framework that integrates different tools

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Conclusion

What are the key factors for building a successful Erlang tool?

- Reliable software
- User friendliness
- Good documentation
- Support
- Well promoted!!

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Further Reading

Paper from the ACM SIGPLAN Erlang Workshop and Complete Survey Results are available at

www.protest-project.eu/publications.html

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Questions?

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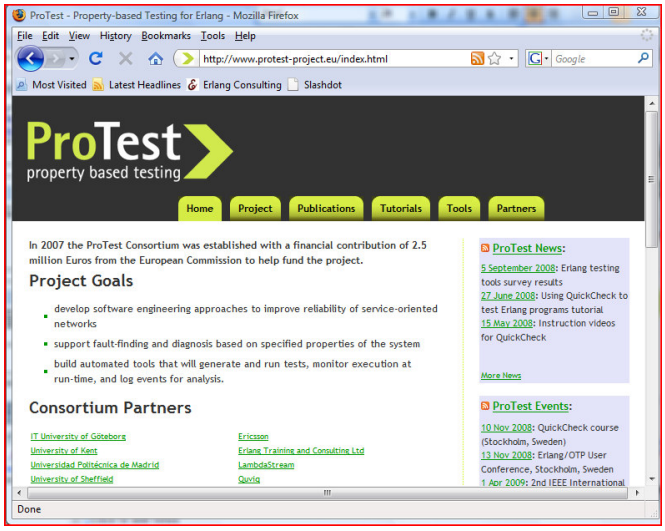

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