Erlang Training and Consulting Ltd

Inviso/Onviso

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Stockholm, 13 Nov 2009

ProTest
property based testing

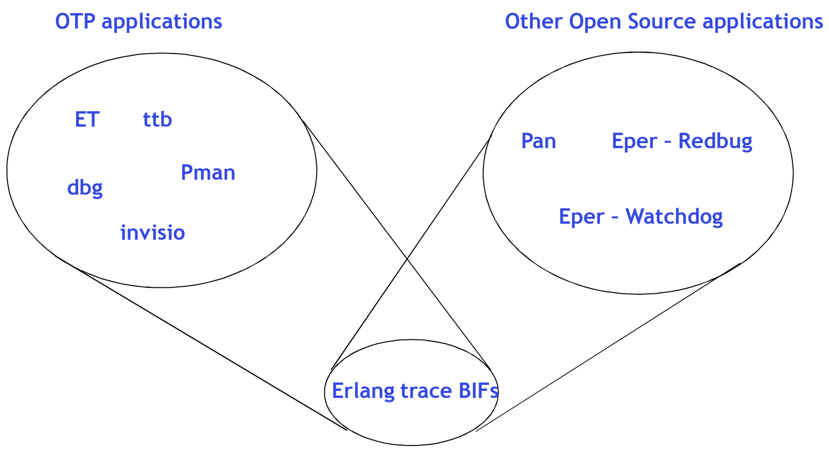
Agenda

Goal

The aim of the Protest Project is to develop and improve testing and tracing tools.

In this part of the project we would like to create a simple interfaced and safe tracing tool enable to use from a remote node. We chose to extend the existing Inviso application.

Tracing Tools available for Erlang



Erlang trace BIFs

All tracing solutions discussed are based on trace BIFs

Provides data for monitoring execution and memory usage

Events are sent as trace messages of the format

- {trace, Pid, Tag, Data1 [,Data2]}

Events include

- Message passing
- Gc and memory usage
- Process activity

At any one given time, only one process may receive trace events from another process

Erlang trace BIFs possible settings

Dynamically enabled. Filtering on pids: existing, new, all, pid()

Flags

- ‘send’, ’receive’ for message passing events
- ‘running’ for scheduling events: ‘in’ and ’out’ messages sent when a process is scheduled or preempted
- ‘exiting’ for scheduling exiting processes. Message tags: ‘in_exiting’, ‘out_exiting’, and ‘out_exited’.
- ‘procs’ for process-related events. Message tags: ‘spawn’, ‘exit’, ‘link’, ‘unlink’, ‘register’, ‘unregister’, ‘getting_linked’, ‘getting_unlinked’
- ‘call’ for function calls. Message tags: call, return_from It can be combined with arity, return_to and silent flags. In trace_pattern match_specifications can be defined.
- ‘set_on_ spawn’, ‘set_on_first_spawn’, ‘set_on_link’, ‘set_on_first_link’ sets the inheritance of the trace flags in the new processes
- ‘garbage_collection’. Message tags: ‘gc_start’, ‘gc_stop’.
- ‘timestamp’ and ‘cpu_timestamp’ for including timestamps to each trace message.

Dbg

The most popular debugging tool for Erlang (in Erlang OTP).

Text based debugger, suitable for text based terminals

Provides a friendly and simple interface to the trace and trace_pattern BIFs providing the same functionality:

- By setting trace flags for processes, ports and functions and manipulating the trace patterns even on multiple nodes

Suitable on large systems: Small impact on system performance, but traces can be set only one node at a time, and not remotely.

Not always safe, e.g. dbg:tracer(), dbg:p(all,m) can kill the running system

Advantages of inviso & dbg

Inviso

- Configurable output, can be sent to:
  - erlang interface
  - log file
  - text output in erlang shell
- Powerful tool for automatic tests:
  - custom profiling
  - property testing
  - white-box testing
- Strong support for usage in distributed systems

Dbg

- Light tool, very useful for ad-hoc tracing on newly found faults with simple interface
- Helper function (fun2ms) for generating match specifications

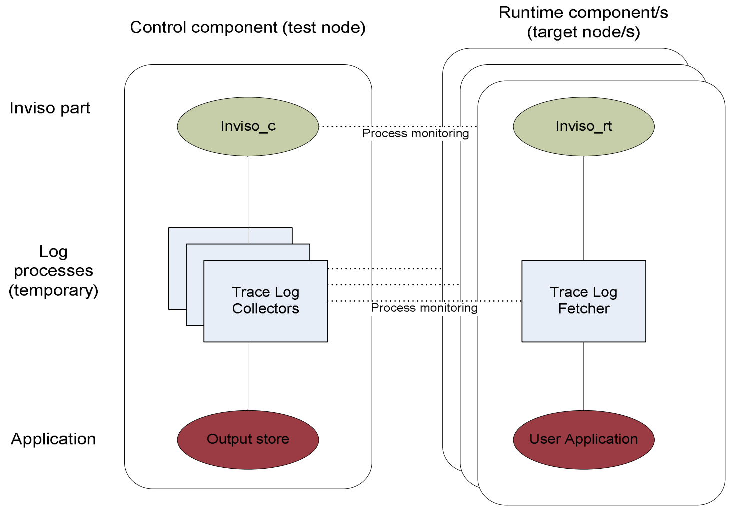
The inviso Tool

- The **inviso** tool is an erlang trace tool
- Provides an interface to the **trace** and **trace_pattern** BIFs
- Designed with distributed systems in mind
- Has small impact on system performance
- Suitable for use on large distributed systems
- Has more functionality than **dbg,** but too complex to be considered a simple debug tool like dbg

Can be used for:

- **Troubleshooting**: tracing and debugging
- automatic white-box testing
- system profiling
- property checking

The inviso Tool



The inviso Tool - Start-up requirements

An instance of RT is started on each node in the system being traced.

These can be controlled from one node, which may be part of the system or a separate, dedicated test node.

Only requirements are:

- the **runtime tools** application is started **on all traced nodes**
- test node can communicate with all the system nodes

The Inviso Tool – Trace

Trace information can be:

- Logged to file
- Passed as parameters to custom functions
- Displayed as text in the Erlang shell
- Sent to another Erlang nodes' runtime system (good for minimizing the performance impact on system under test)
  - This other node can be a **specialised debugging/testing node**

The inviso Tool – Performance

Good to design tests and traces to run in a **separate test node** beside the system, because:

- Easier to divide test from core functionality of the system
- Tests can have minimal impact on system operation, both configuration & performance wise

System protection under test

- Optional overload protection, vital for live systems. If a user defined function decides that a node is overloaded then tracing will be suspended on that node
- Essential in case overloading is caused by the tracing

The inviso Tool

Can be used for debugging if the fault is more subtle or harder to find and something more powerful than dbg is needed. Inviso is more suited to designed traces and tests.

The interface is powerful but too complex to be considered a simple ad-hoc debug tool like dbg, it would be a simple task to develop a wrapper to make this more usable for debugging

The Inviso Tool - Step by Step

Clearing the trace flags

[illegible]

```
    {test,remove_load_func,[[]]}}}]).
```

Match Specifications

```
[{[ping,'$1','$2'],
  [],
  [{return_trace}]}]
```

- A match specification consists of an Erlang Term.
- Describes a “programme” that tries to match.
- Compiled to something more efficient than a function.
- Powerful but complex to write and often unreadable.
- Match specifications can be generated from literal funs using dbg:fun2ms function.

Goal of the Onviso extension

◆ Provide an easy to use, remotely usable, safe, online tracing tool

◆ Include our extension to the Inviso application within the OTP release (planned meetings with Kenneth Lundin)

◆ Include possible extensions for property checking

Onviso - Extension of the Inviso

Easy to use API as a wrapper for the original Inviso

- Using only 2 function to set up tracing on multiple nodes and merge them
- Added short-cuts for common match specifications
- Command line interface

Onviso - Extension of the Inviso

Added extra functionality

- Retrieve the status of the recent traces and configurations allowing to run different merge functions on the same trace data
- Default choices are provided for merging (the simplest is to write every trace into a file) and overload protection
- The merge functionality can be used for property testing

Setting up a trace -starting the nodes

Start and initialise all nodes in the system: in this example the server and client nodes

```
> client:init('server@machine').
```

```
> server:start().
```

Start the Inviso node

Set the same cookie on every node:

```
> erlang:set_cookie(node(),inviso).
```

Setting up a trace – define the patterns

Onviso uses the following format to specify a pattern:

```
{Module, Function, Arguments, MatchSpecification}
```

Example patterns:

```
{client, get, '_', return}

{server, loop, '_', []}
```

Please note the difference between the original MS `([{'_',[],[{return_trace}]}])` and the `return` short-cut

Setting up a trace

Possible trace calls:

```
>onviso:trace(Patterns, Flags). %traces only the local node

>onviso:trace(Patterns, Nodes, Flags).

>onviso:trace(Patterns, Nodes, Flags, OverLoadProtection).
```

To set up the trace on the Inviso node for example:

```
> onviso:trace([{server, loop, '_', []},
                 {client, put, '_', []},
                {client, get, '_', return}],
               ['server@laptop','client@laptop'],
              {all,[call]}).
```

Stop a trace

Every trace call returns a trace reference identifier. This id can be used to stop or merge a trace.

```
>onviso:stop(Id).
```

The traces are collected to files and distributed back to the Inviso control node.

Merge a trace – default examples

```
> onviso:merge(Id, void, void, shell). %result in the shell
```

```
> onviso:merge(Id, void, void, file). %result in
 “outputId.txt”  file, other easy options {file, Name},
{file_prefix, Prefix}
```

Please note:

- You can merge the trace files more than once.
- Even if the target node is under constant use, the merged logs will always contain the same result as the first merge, because the tracing stopped then.

Merge a trace - custom function

```
> BeginFun = fun(_InitData) -> {ok, 0} end.

> WorkFun = fun(_Node, _Trace, _PidMapping,
Count) ->                                       {ok,
Count + 1}                              end.

> EndFun = fun(Count) ->                io:format("We
collected ~p traces.~n", [Count])            end.

> onviso:merge(1, BeginFun, WorkFun, EndFun).
```

Short-cuts -- predefined atoms

To make it easier to adapt the tool some simplification are built in the interface.

1. Predefined match specifications like 'return' and 'caller' for getting the return values

2. Atoms defining the output in predefined EndFuns during merge like 'shell', 'file', {'file', Name}, {'file_prefix', Name}

Predefined examples for most common merge functions

1. Predefined merge functions for basic profiling either to shell or file
2. Built in trace and merge with overload protection

Exercises

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Contents

Onviso commands one pager

0. Start up all the target and monitor nodes, set the cookies.
1. Start the trace by calling `onviso:trace/2-4` functions with
   - Pattern list: ex. `{client, get, '_', return}`
   - Node list: ex. `'client@laptop'` - optional
   - Flags: ex. `{all,[call]}` jskdhks
   - Overload protection
2. Merge or stop:

```
onviso:stop(Id)

onviso:merge(Id,BeginFun, WorkFun, EndFun)
```

Erlang trace BIFs possible settings

Dynamically enabled. Filtering on pids: existing, new, all, pid()

Flags

- 'send', 'receive' for message passing events
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- 'exiting' for scheduling exiting processes. Message tags: 'in_exiting', 'out_exiting', and 'out_exited'.
- 'procs' for process-related events. Message tags: 'spawn', 'exit', 'link', 'unlink', 'register', 'unregister', 'getting_linked', 'getting_unlinked'
- 'call' for function calls. Message tags: call, return_from It can be combined with arity, return_to and silent flags. In trace_pattern match_specifications can be defined.
- 'set_on_ spawn', 'set_on_first_spawn', 'set_on_link', 'set_on_first_link' sets the inheritance of the trace flags in the new processes
- 'garbage_collection'. Message tags: 'gc_start', 'gc_stop'.
- 'timestamp' and 'cpu_timestamp' for including timestamps to each trace message.

Match specfications

MatchExpression ::= [MatchFunction, ...]

MatchFunction ::= { MatchHead, MatchConditions, MatchBody }

Examples:

- Match an argument list of three where the first and third arguments are equal:

```
[{['$1', '_', '$1'],  [],   []}]
```

- Match all objects with arity > 1 and the first element is 'elem', return the 2. element.

```
  [{'$1',  [{'==', elem, {element, 1, '$1'}},{'>=',{size, '$1'},2}],

    [{element,2,'$1'}]}]
```

Contents

Client Server Setup

Start and initialise all nodes in the system: in this example the server and client nodes (Based on the client.erl, server.erl files and both containing the runtime application)

```
> client:init('server@laptop').
```

```
> server:start().
```

Start a separate monitoring inviso node (running inviso and onviso applications)

Set the same cookie on every node:

```
> erlang:set_cookie(node(),inviso).
```

Exercise 1.1

Start up the traces on the inviso node on the following functions:

server:loop,   client:get, client:put

a. Start tracing on the function calls
b. Start tracing on the return values of the function calls in the client
c. Start tracing on the message passing

When starting the trace, try to write first the Patterns, then the node list and the decide the flags.

NOTE: Don't forget to generate some traffic on the nodes, before merging/stopping.

For stop and merge use the default for all the traces:

```
onviso:merge(Id, void, void, shell).
```

Exercise 1.1 - Solution

a.
```
onviso:trace([{server, loop, '_', []},
              {client, put, '_', []},
             {client, get, '_', []}],
            ['server@laptop','client@laptop'],
           {all,[call]}).
```

b.
```
onviso:trace([{server, loop, '_', []},
              {client, put, '_', []},
             {client, get, '_', return}],
            ['server@laptop','client@laptop'],
           {all,[call]}).
```

c.
```
onviso:trace([{server, '_', '_', []},
            {client, '_', '_', []}],
            ['server@laptop','client@laptop'],
           {all,['send','receive']}).
```

Exercise 1.2

Use any of the previous traces, but instead of printing to the shell, try to write it to a file.

Try to set the filename in the next step.

Exercise 1.2 - Solution

NOTE: You don't need to run the trace again, you can simple reuse the Id from a previous trace.

For starting the trace for example:

```
   onviso:trace([{server, loop, '_', []},
                 {client, put, '_', []},
                {client, get, '_', []}],
               ['server@laptop','client@laptop'],
              {all,[call]}).
```

The solution for merge:

```
       onviso:merge(Id, void, void, file).
       onviso:merge(Id, void, void,
         {file_prefix,  “NewMerge” }) % or {file,” New.txt” })
```

Exercise 2

Set up a second client node.

Count how much messages were sent by the clients based on the traces.

Try to think different solutions.

Exercise 2 - Solution

Trace:

```
onviso:trace([{client, put, '_', []}],
                ['client1@laptop','client2@laptop'],
               {all,[call]}).
```

Merge:

```
> BeginFun = fun(_InitData) -> {ok,0} end.

> WorkFun = fun(_Node, _Trace, _PidMapping, Count) ->
{ok, Count + 1}                                          end.

> EndFun = fun(Count) -> io:format("The clients sent ~p messages.~n", [Count])
end.

> onviso:merge(1, BeginFun, WorkFun, EndFun).
```

Contents

Elevator Setup

Start the elevator node in the system: the elevator application (Based on the elevator files and containing the runtime application and gs)

Start a separate monitoring inviso node (running inviso and onviso applications)

Set the same cookie on every node:

```
> erlang:set_cookie(node(),inviso).
```

Exercise 3.1

Count how many floors the lifts travelled during the examined period.

(Going up 3 levels and coming down 2 results in 5 this case)

The elevators can be started by

```
util:start(Id::int(), Floors::int, Elevators::int())
```

Exercise 3.1 Solution

Trace:

onviso:trace([{elevator, closed, '_', [{[{'$1','_'},'_'],[{'=:=',move,'$1'}],[]}]}],['elevator@aniko-laptop'],{all,[call]}).

Merge:

```
> BeginFun = fun(_InitData) -> {ok,0} end.

> WorkFun = fun(_Node, _Trace, _PidMapping, Count) ->
{ok, Count + 1}                                          end.

> EndFun = fun(Count) -> io:format("The clients sent ~p messages.~n", [Count])
end.

> onviso:merge(1, BeginFun, WorkFun, EndFun).
```

Exercise 3.2

Count how many times stopped the n. elevator on the m. or higher floor.

Exercise 3.2 Solution

Trace:

onviso:trace([{elevator, closed, '_', [{[{'$1','$2'},{'$3','_'}],[{'=:=',at_floor,'$1'},{'>=','$2',M},{'=:=','$3',N}],[]}]}],['elevator@aniko-laptop'],{all,[call]}).

Merge:

```
> BeginFun = fun(_InitData) -> {ok,0} end.

> WorkFun = fun(_Node, _Trace, _PidMapping, Count) ->
{ok, Count + 1}                                              end.

> EndFun = fun(Count) -> io:format("The clients sent ~p messages.~n", [Count])
end.

> onviso:merge(1, BeginFun, WorkFun, EndFun).
```

Exercise 4

Try to set and use any of the above traces with the command line interface

The command line interface can be started by cli:start().