Technical Manual of the `Ceylan-Traces` Layer

Organisation: Copyright (C) 2008-2018 Olivier Boudeville

Contact: about (dash) traces (at) esperide (dot) com

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Dedication: Users and maintainers of the `Traces` layer.

Abstract: The role of the Traces layer (part of the Ceylan project) is to provide trace services, so that the user can efficiently log, browse and search through detailed runtime messages that may be emitted concurrently (in parallel, and in a distributed way).

We present here a short overview of these services, to introduce them to newcomers. The next level of information is to read the corresponding source files, which are intensely commented and generally straightforward.

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General Information

This layer is in charge of providing Erlang programs with the means of emitting, collecting, storing and browsing *applicative traces* (i.e. logs).

For that, various components have been designed and implemented, such as trace aggregator, emitter, listener, supervisor, etc.

They collectively constitute the Traces layer, whose prerequisites are the WOOPER layer (for object-oriented primitives) and the Myriad layer (for many lower-level services).

The main purpose of this **Traces** layer is to provide adequate traces for distributed systems, and to ease their browsing. A few back-ends are available for that, from the direct reading of the (raw) trace files to considerably more user-friendly solutions, such as the generation of PDF reports or the use of a commercial tool named LogMX.

This layer defined a trace format of its own, supported by our Java-based parser for LogMX.

> **Note**
> In some cases, it may be convenient to have one's lower-level, debugging traces be directly output on the console.
> Then, once the basic bugs are fixed (ex: the program is not crashing anymore), the full power of this `Traces` layer can be best used, by switching these first, basic traces to the more advanced traces presented here.
> To output (basic) console traces, one may use the trace_utils module of the `Myriad` layer. For example:
> `trace_utils:debug_fmt("Hello world #~B",[2])`
> Then, to anticipate a bit, switching to the mainstream, more advanced traces discussed here is just a matter of replacing, for a trace type T (ex: `debug`), `trace_utils:T` with `?T`, like in:
> `?debug_fmt("Hello world #~B",[2])` (with no further change in the trace parameters).

Trace Emission

Typically the following include is needed so that an Erlang process can send traces:

```
-include("class_TraceEmitter.hrl").
```

Then sending-primitives can be used, such as:

```
?info("Hello world!")
```

or:

```
?info_fmt("The value ~B is the answer.",[MyValue])
```

Many API variations exist, to account for the various trace levels, contexts, etc.

The trace macros used above can be fully toggled at build-time, on a per-module basis (if disabled, they incur zero runtime overhead, and no source change is required).

Trace Levels

There are six built-in levels for trace channels, of increasing severity:

Trace Severity	**Mapped Level**
`debug`	6
`trace`	5
`info`	4
`warning`	3
`error`	2
`fatal`	1

There is also an addition trace severity, `void`, that designates traces that shall be muted in all cases.

Its purpose is to provide another means of muting/unmuting some traces, instead of commenting out/uncommenting said traces.

Trace Format

A set of traces is represented as an ordered stream of trace lines.

These traces are possibly exchanged over the network or stored in a file, whose extension is conventionally `.traces`.

For example the traces for a test named `my_foobar_test` are typically stored in a `my_foobar_test.traces` file, generated by the trace aggregator in the directory from which the corresponding test was launched.

Each trace line is a raw text (hence not a binary content) made of a series of predefined fields, separated by the pipe (`|`) character.

These fields are:

1. **technical identifier of the emitter**, as a string (ex: `<9097.51.0>` for the PID of a distributed Erlang process)
2. **name of the emitter** (ex: `"Instance tracker"`)
3. **dotted categorization of the emitter** (ex: `"Core.Tracker.Instances"`); here for example the emitter is an element of the service in charge of the instances, which itself belongs to the tracker services, which themselves belong to the core services
4. **application-level timestamp** (ex: operation count, relative tick, absolute timestep, or any complex, application-specific timestamp, etc.), possibly `none` or `undefined` if not applicable (ex: a simulation that would not be started yet)
5. **wall-clock timestamp**, in the `"Year/Month/Day Hour:Minute:Second"` format (ex: `"2016/6/10 15:43:31"`)
6. **emitter location**, as a string (ex: the name of the Erlang node, possibly including the name of the application use case, of the user and of the host; ex: `my_foobar_test_john@hurricane.org`)
7. **dotted categorization of the trace message** itself (ex: `MyApp.MyTopic.MyTheme`)
8. **severity of the trace message** (mapped to an integer level, as discussed above)
9. the **trace message** itself, an arbitrary text of arbitrary length, possibly containing any number of instances of the field delimiter

Example of trace line (end of lines added for readability):

```
<0.45.0>|I am a test emitter of traces|TraceEmitter.Test|none|
2016/6/13 14:21:16|traceManagement_run-paul@hurricane.foobar.org|
MyTest.SomeCategory|6|Hello debug world!
```

or:

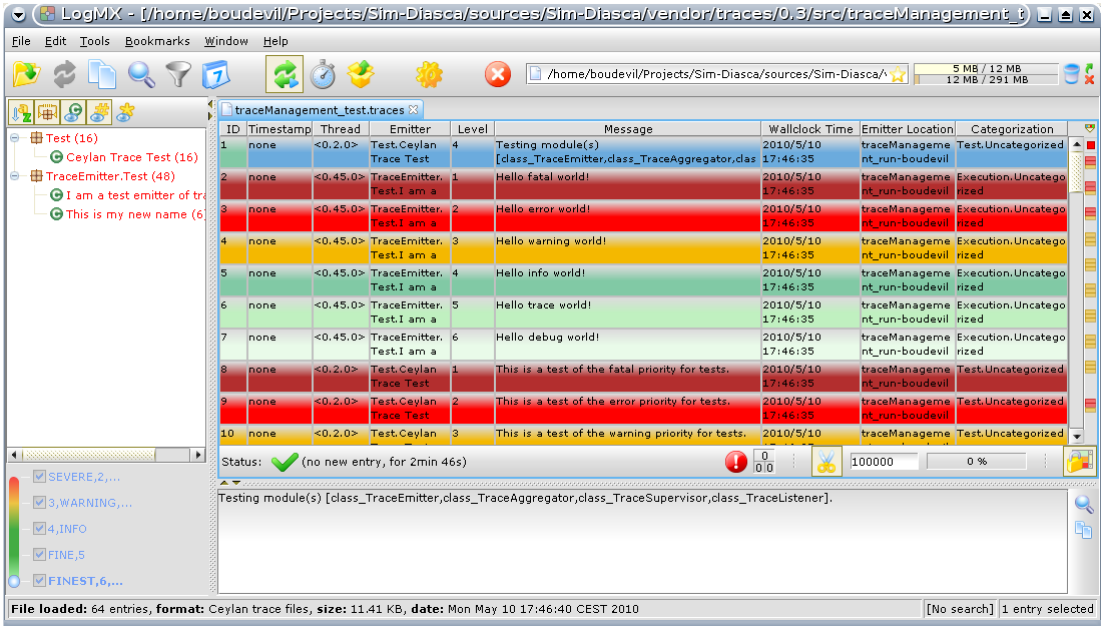
```
<9097.51.0>|Instance tracker|Core.Tracker.Instances|14875|
2016/6/10 15:43:31|My_application_case-john@hurricane.foobar.org|
Execution.Uncategorized|4|Creating a new root instance tracker
whose troubleshooting mode is enabled.
```

Trace Browsing

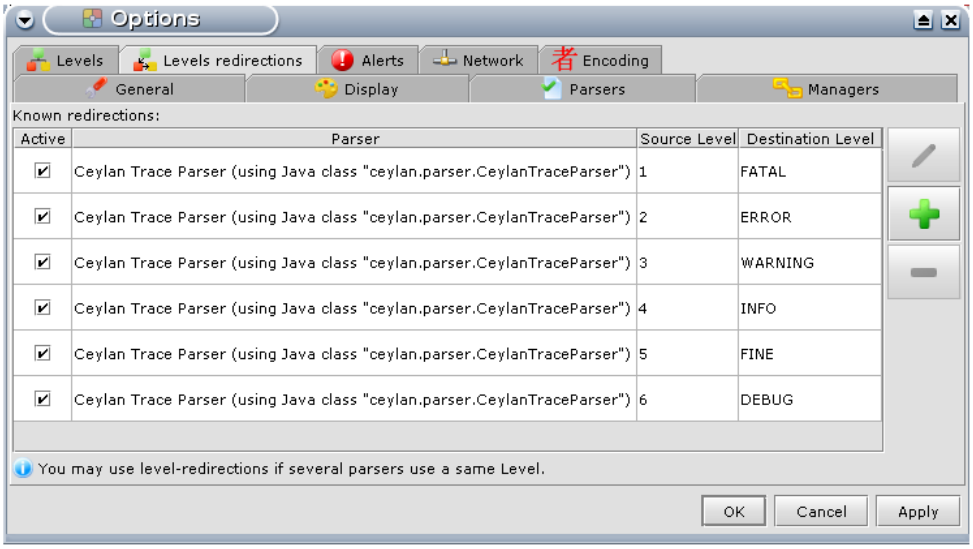
Traces may be browsed thanks to either of the following supervision solutions (see `class_TraceSupervisor.erl`):

- `text_traces`, itself available in two variations:
  - `text_only` if wanting to have traces be directly written to disk as pure, yet human-readable, text
  - `pdf`, if wanting to read finally the traces in a generated PDF file
- `log_mx_traces`, for LogMX-compliant traces (the default) and discussed below

Indeed the most usual tool that we use for trace browsing is LogMX, which we integrated:



We implemented a Java-based parser of our trace format for LogMX (see `CeylanTraceParser.java`):



Traces can be browsed with this tool:

- **live** (i.e. during the execution of the program), either from its start or upon connection to the running program whilst it is already running[1] (see `class_TraceListener.erl`)
- **post mortem** (i.e. after the program terminated for any reason, based on the trace file it left)

The trace supervision solution can be switched at compile time (see the `TraceType` defined in `traces/src/traces.hrl`); the `Traces` layer shall then be rebuilt.

[1] In which case the trace supervisor will receive transactionally a compressed version of all past traces then all new ones, hence with none possibly lost.

Trace Implementation

General Mode of Operation

All processes are able to emit traces, either by using standalone trace sending primitives (mostly for plain Erlang processes), or by inheriting from the `TraceEmitter` class, in the (general) case of WOOPER-based processes.

In the vast majority of cases, all these emitters send their traces to a single trace aggregator, in charge of collecting them and storing them on-disk, according to an adequate trace format.

This trace format can be parsed by various trace supervisors, the most popular being LogMX.

Various measures have been taken in order to reduce the overhead induced by the overall trace system.

Notably traces are sent in a "fire and forget", non-blocking manner (thanks to oneways, which are not specifically acknowledged). The number of messages exchanged is thus reduced, at the cost of a lesser synchronization of the traces (i.e. there is no strong guarantee that the traces will be ultimately recorded and displayed in the order of their emission in wallclock-time, as they will be directly and sequentially stored in their actual order of receiving by the trace aggregator[2], an order which itself depends on the potentially varied network latencies experienced from the potential multiple sources to the trace aggregator).

Trace Emitters

When sending a trace, an emitter relies on its `trace_timestamp` attribute, and sends a (binarised) string representation thereof (obtained thanks to the `~p` quantifier of `io:format/2`). This allows the trace subsystem to support all kinds of application-specific traces (ex: integers, floats, tuples, strings, etc.).

[2] For example, if both the trace aggregator and a process B are running on the same host, and if a process A, running on another host, emits a trace then sends a message to B so that B sends in turn a trace, then the trace from B *might* in some cases be received - and thus be listed - by the aggregator *before* the trace for A (it depends on the network congestion, relative scheduling of processes, etc.).

Ending Word

Have fun with Ceylan-Traces!