**Description**

**Abstract**

Remove trace instructions from bytecode and it will improve performance, 10% faster. Instead of trace instruction, we add event information for each instruction. In other words, we unified trace instructions with the following instructions.

**Background**

TracePoint and old set_trace_func method need to know which point they need to kick hooks at. trace VM instruction is inserted to represent such hook points and kicks hooks if needed. It is easy to introduce hook points into bytecode. However, this technique introduces some overhead on "no-hooks" situations (and I believe 99% of workloads does not need hooks, especially on production environment).

For example, compiled code of the following method has several trace instructions.

```ruby
def foo x
  _y = x
end
```

Disasm output is here:

```text
== disasm: #<ISeq:foo@<compiled>>=======================================
local table (size: 2, argc: 1 [opts: 0, rest: -1, post: 0, block: -1, kw: -1@-1, kwrest: -1])
0000 trace    8                    (   1)
0002 trace    1
0004 getlocal  x, 0
0007 dup
0008 setlocal  _y, 0
0011 trace    16                  (   2)
0013 leave
```

You can see 3 trace instructions on 0000, 0002 and 0011. They means hook points for :call, :line and :return events. It enables to support TracePoint, but introduces 3 dispatches for useless instructions.

We can remove trace instructions with the trace_instruction: true compile option, but we can't turn on TracePoint for such compiled ISeqs.

**Proposal**

Remove trace instruction and introduce event flags as information for each instructions.

With same code above, we can get the following disasm code.

```text
== disasm: #<ISeq:foo@<compiled>>=======================================
local table (size: 2, argc: 1 [opts: 0, rest: -1, post: 0, block: -1, kw: -1@-1, kwrest: -1])
08/24/2022
```
0000 shows [LiCa], it means :line and :call events.
0007 shows [Re] which represents a :return event.

It is too heavy if we check these event flags on each instruction dispatch.
So we introduce new instructions: trace_ prefix instructions such as trace_getlocal and so on.
All normal instructions have corresponding trace_ prefix instructions (generated by the VM generator automatically).

If we need to enable TracePoint (or set_trace_func), then rewrite all of instruction sequences (ISeqs) in the heap from normal
instructions to trace prefix instructions dynamically. trace_ prefix instructions check flags for an executing instruction and kick hooks if
needed.

- **Good:**
  - a. Low overhead for normal execution because we don't need to dispatch useless trace instructions.
  - b. We don't have trace instructions, so that it is easy to turn on tail call optimization flags.
  - c. We can enable/disable traces on small units.

- **Bad:**
  - a. Big overhead to turn on/off TracePoint because we need to modify all of existing ISeqs.
  - b. Introducing a few incomatibilities for tracing.

For (Bad-a) I believe nobody turn on and trun off tracepoints many times, so that turning on/off overhead is not so big impact.

For (Good-c), I need to explain more.
Current TracePoint enables all of hooks for all methods, ISeqs. With this technique, however, we can select enable/disable the hooks
in more small units, like files, classes, methods or a line. For example, we can enable the hooks only method named foo. Now we
have no interface to specify it, but we can design later.

**Evaluation**

```ruby
require 'benchmark'

def foo n
end

N = 100_000_000
Benchmark.bm(10){|x|
  x.report('trace off'){
    N.times{
      foo(10)
      foo(10)
      foo(10)
    }
  }
  x.report('trace on'){
    TracePoint.new{}.enable
    N.times{
      foo(10)
      foo(10)
      foo(10)
    }
  }
}

Current trunk:

<table>
<thead>
<tr>
<th></th>
<th>user</th>
<th>system</th>
<th>total</th>
<th>real</th>
</tr>
</thead>
<tbody>
<tr>
<td>trace off</td>
<td>9.090678</td>
<td>0.000000</td>
<td>9.090678 ( 9.083007)</td>
<td></td>
</tr>
<tr>
<td>trace on</td>
<td>108.217320</td>
<td>0.005524</td>
<td>108.222844 (108.201941)</td>
<td></td>
</tr>
</tbody>
</table>

modifed:

<table>
<thead>
<tr>
<th></th>
<th>user</th>
<th>system</th>
<th>total</th>
<th>real</th>
</tr>
</thead>
<tbody>
<tr>
<td>trace off</td>
<td>6.647247</td>
<td>0.000000</td>
<td>6.647247 ( 6.641530)</td>
<td></td>
</tr>
</tbody>
</table>
```

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Compatibility issues

With this change, we introduced a few incompatibilities:

- Line numbers on :return/`return` events show the last executed lines, instead of end lines (without return statement).
- begin block doesn’t show :line events.

Related issues:
Related to Ruby master - Bug #14582: Unable to use `method__entry` and `metho...

Open

Associated revisions

Revision 665ba24b - 11/14/2017 12:56 PM - ko1 (Koichi Sasada)
remove trace instruction. [Feature #14104]

- tool/instruction.rb: create trace_ prefix instructions.
- compile.c (ADD_TRACE): do not add trace instructions but add TRACE link elements. TRACE elements will be unified with a next instruction as instruction information.
- vm_trace.c (update_global_event_hook): modify all ISeqs when hooks are enabled.
- iseq.c (rb_iseq_trace_set): added to toggle trace_ instructions.
- vm_insnhelper.c (vm_trace): added. This function is a body of trace_ prefix instructions.
- vm_insnhelper.h (JUMP): save PC to a control frame.
- insns.def (trace): removed.
- vm_exec.h (INSN_ENTRY_SIG): add debug output (disabled).

Revision 60763 - 11/14/2017 12:58 PM - ko1 (Koichi Sasada)
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Revision 61313 - 12/18/2017 02:44 AM - mame (Yusuke Endoh)
iseq.c (finish_iseq_build): fix coverage leakage [Bug #14191]

Before this change, coverage.so had failed to measure some multiple-line code fragments. This is because removing trace instructions (#14104) changed TracePoint's lineno (new lineno), and coverage counter array was based on old lineno.
This change initializes coverage counter array based on new lineno.

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compile.c: add a RUBY_EVENT_COVERAGE_LINE event for line coverage

2.5's line coverage measurement was about two times slower than 2.4 because of two reasons; (1) vm_trace uses rb_iseq_event_flags (which takes O(n) currently where n is the length of iseq) to get an event type, and (2) RUBY_EVENT_LINE uses setjmp to call an event hook.

This change adds a special event for line coverage, RUBY_EVENT_COVERAGE_LINE, and adds tracecoverage instructions where the event occurs in iseq. tracecoverage instruction calls an event hook without vm_trace. And, RUBY_EVENT_COVERAGE_LINE is an internal event which does not use setjmp.

This change also cancels lineno change due to the deletion of trace instructions [Feature #14104]. So fixes [Bug #14191].

Revision 61350 - 12/20/2017 04:24 AM - mame (Yusuke Endoh)

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Revision 919fa894 - 12/23/2017 11:00 AM - ko1 (Koichi Sasada)
revert line number spec of *return events.

- compile.c (rb_iseq_compile_node): line number spec of :return, :b_return and :end events of 'TracePoint' is changed for [Feature #14104].
  
  Quoted from [Feature #14104]:
  
  Line numbers on :return/:b_return events show the last executed lines, instead of end lines (without return statement).
  Note that :end event also affected.

  However, "buybug", a well-known ruby debugger depends on previous behavior so that I reverted this specification.

- test/ruby/test_settracefunc.rb: catch up this fix.

Revision 61424 - 12/23/2017 11:00 AM - ko1 (Koichi Sasada)
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**Revision bd80fc53 - 06/05/2018 09:19 PM - normal**

test/dtrace: enable Tracepoint for function calls

Since [Feature #14104], "trace" instructions are no longer emitted by default, so we must enable them explicitly for function tracing to work.

[ruby-core:85965]

git-svn-id: svn+ssh://ci.ruby-lang.org/ruby/trunk@63580 b2dd03c8-39d4-4d8f-98ff-823fe69b080e

**Revision 63580 - 06/05/2018 09:19 PM - normalperson (Eric Wong)**

test/dtrace: enable Tracepoint for function calls

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[ruby-core:85965]

**Revision 63580 - 06/05/2018 09:19 PM - normal**

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[ruby-core:85965]

**Revision 100bf275 - 08/22/2018 11:09 AM - mame (Yusuke Endoh)**

calculate.c: remove tracecoverage instruction for line coverage

Line coverage was based on special instruction "tracecoverage". Now, instead, it uses the mechanism of trace hook [Feature #14104].

[ruby-core:85965]

git-svn-id: svn+ssh://ci.ruby-lang.org/ruby/trunk@64509 b2dd03c8-39d4-4d8f-98ff-823fe69b080e

**Revision 64509 - 08/22/2018 11:09 AM - mame (Yusuke Endoh)**

calculate.c: remove tracecoverage instruction for line coverage

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**Revision 64509 - 08/22/2018 11:09 AM - mame (Yusuke Endoh)**

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Line coverage was based on special instruction "tracecoverage". Now, instead, it uses the mechanism of trace hook [Feature #14104].

**Revision 6c9a7050 - 10/20/2018 10:45 AM - mame (Yusuke Endoh)**

Remove tracecoverage instructions

The instructions were used only for branch coverage. Instead, it now uses a trace framework [Feature #14104].

[ruby-core:85965]

git-svn-id: svn+ssh://ci.ruby-lang.org/ruby/trunk@65225 b2dd03c8-39d4-4d8f-98ff-823fe69b080e
Revision 65225 - 10/20/2018 10:45 AM - mame (Yusuke Endoh)
Remove tracecoverage instructions
The instructions were used only for branch coverage.
Instead, it now uses a trace framework [Feature #14104].

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History

#1 - 11/14/2017 09:08 AM - shevegen (Robert A. Heiler)
<table>
<thead>
<tr>
<th>user</th>
<th>system</th>
<th>total</th>
<th>real</th>
</tr>
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<td>108.222844</td>
</tr>
</tbody>
</table>

#2 - 11/14/2017 10:11 AM - ko1 (Koichi Sasada)
- Description updated

#3 - 11/14/2017 11:44 AM - ko1 (Koichi Sasada)
Here is a result of benchmark result with
ruby ~ruby/src/trunk/benchmark/driver.rb -e ruby_2_4::~/ruby/install/ruby_2_4/bin/ruby -e trunk_oct::~/ruby/install/trunk_r60079/bin/ruby -e trunk::~/ruby/install/trunk/bin/ruby -e modified::~/ruby/install/gitruby/bin/ruby -v -r 5
https://gist.github.com/anonymous/64b7e73e5972befc33a9acde09612f90

#4 - 11/14/2017 12:58 PM - ko1 (Koichi Sasada)
- Status changed from Open to Closed

Applied in changeset trunk|r60763.

remove trace instruction. [Feature #14104]
- tool/instruction.rb: create trace_ prefix instructions.
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#5 - 11/14/2017 04:40 PM - vmakarov (Vladimir Makarov)
ko1 (Koichi Sasada) wrote:
Abstract

Remove trace instructions from bytecode and it will improve performance, 10% faster. Instead of trace instruction, we add event information for each instruction. In other words, we unified trace instructions with the following instructions.

Hi, Koichi. I am very glad that you addressed this issue. The current implementation of tracing is just wasting CPU time. I thought about this too but my approach would be a different because I thought that I had to maintain the full compatibility of trace behaviour.

So I considered to remove and insert trace insns when the tracing is off or on. It requires to change branch offset, catch table offsets, and line tables. To speed up this, I would keep the log of pairs (place in iseq code, catch table, or line table), and log of pairs (, ).

I also thought that such general log mechanism would be useful in possible speculative iseq optimizations on MRI insns level.

But if the full trace behaviour compatibility is not so important, your solution is much much simpler and practically has the same code locality as you keep codes of trace and usual insns in disjoint parts of the interpreter switch-stmt.

I think rebuilding iseq is not a problem. Sorry if I missed the code change but I don't see a check of version of loaded iseq on compatibility. So what will happen if somebody tries to load the old iseq with trace insns into a new version of MRI?

#6 - 11/27/2017 05:59 AM - ko1 (Koichi Sasada)

vmakarov (Vladimir Makarov) wrote:

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I also thought that such general log mechanism would be useful in possible speculative iseq optimizations on MRI insns level.

I completely agree your approach is more compatible and flexible for other optimization techniques. But it is some tough work to implement it because PC info are located variety of places. I also believe (sometime) we need to implement similar technique you explained.

But if the full trace behaviour compatibility is not so important, your solution is much much simpler and practically has the same code locality as you keep codes of trace and usual insns in disjoint parts of the interpreter switch-stmt.

Yes, simplicity is the reason why I use this technique. Only few days I needed to make.

I think rebuilding iseq is not a problem. Sorry if I missed the code change but I don't see a check of version of loaded iseq on compatibility. So what will happen if somebody tries to load the old iseq with trace insns into a new version of MRI?

We don't guarantee the cross-version dump/load compatibility (this is why we embed version info into dumped results). So I believe there are no problem on this change.

#7 - 06/09/2022 05:36 AM - mame (Yusuke Endoh)

- Related to Bug #14582: Unable to use `method__entry` and `method_return` tracing probes since 2.5 added