A problem in concurrency [25]

Problem Definition

Santa Claus sleeps in his shop up at the North Pole, and can only be wakened by either all nine reindeer being back from their year long vacation on the beaches of some tropical island in the South Pacific, or by some elves who are having some difficulties making the toys. One elf's problem is never serious enough to wake up Santa (otherwise, he may **never** get any sleep), so, the elves visit Santa in a group of three. When three elves are having their problems solved, any other elves wishing to visit Santa must wait for those elves to return. If Santa wakes up to find three elves waiting at his shop's door, along with the last reindeer having come back from the tropics, Santa has decided that the elves can wait until after Christmas, because it is more important to get his sleigh ready as soon as possible. (It is assumed that the reindeer don't want to leave the tropics, and therefore they stay there until the last possible moment. They might not even come back, but since Santa is footing the bill for their year in paradise ... This could also explain the quickness in their delivering of presents, since the reindeer can't wait to get back to where it is warm.) The penalty for the last reindeer to arrive is that it must get Santa while the others wait in a warming hut before being harnessed to the sleigh.

A Solution

The solution that has worked best over the years, and also appears to be the simplest, is written using C statements and pseudo-code. (Constants are also used in case the number of reindeer were to change, or if the group size of "solution-seeking" elves is modified.) Basically, the reindeer arrive, update the count of how many have arrived, and the last one wakes up Santa. An elf, upon discovering a problem, attempts to modify the count for the number of elves with a problem and either: waits outside Santa's shop if he/she is the first or second such elf; knocks on the door and wakes up Santa if that elf is the third one; or waits in the elves' shop until the elves currently with Santa start coming back. (The code for this solution can be found in the Appendix.)

The solution with semaphores takes about 2 pages of C code [25]!

Smarter solutions to Santa's problem

Better with Erlang...yet, 43 LoC

```
-module(santa).
-author('ok@cs.otago.ac.nz'). % Richard A. O'Keefe
-export([start/0]).

worker(Secretary, Message) ->
    receive after random:uniform(1000) -> ok end,  % random delay
    Secretary ! self(),                            % send my PID to the secretary
    Gate_Keeper = receive X -> X end,              % await permission to enter
    io:put_chars(Message),                         % do my action
    Gate_Keeper ! {leave,self()},                  % tell the gate-keeper I'm done
    worker(Secretary, Message).                    % do it all again

secretary(Santa, Species, Count) ->
    secretary_loop(Count, [], {Santa,Species,Count}).

secretary_loop(0, Group, {Santa,Species,Count}) ->
    Santa ! {Species,Group},
    secretary(Santa, Species, Count);
secretary_loop(N, Group, State) ->
    receive PID ->
        secretary_loop(N-1, [PID|Group], State)
    end.

santa() ->
    {Species,Group} =
        receive                                    % first pick up a reindeer group
            {reindeer,G} -> {reindeer,G}           % if there is one, otherwise
        after 0 ->
                receive                            % wait for reindeer or elves,
                    {reindeer,G} -> {reindeer,G}
                  ; {elves,G}    -> {elves,G}
                end                                % whichever turns up first.
        end,
    case Species
      of reindeer -> io:put_chars("Ho, ho, ho!  Let's deliver toys!\n")
       ; elves    -> io:put_chars("Ho, ho, ho!  Let's meet in the study!\n")
    end,
    [PID ! self() || PID <- Group],        % tell them all to enter
    [receive {leave,PID} -> ok end         % wait for each of them to leave
        || PID <- Group],
    santa().

spawn_worker(Secretary, Before, I, After) ->
    Message = Before ++ integer_to_list(I) ++ After,
    spawn(fun () -> worker(Secretary, Message) end).

start() ->
    Santa = spawn(fun () -> santa() end),
    Robin = spawn(fun () -> secretary(Santa, reindeer, 9) end),
    Edna  = spawn(fun () -> secretary(Santa, elves,    3) end),
    [spawn_worker(Robin, "Reindeer ", I, " delivering toys.\n")
     || I <- lists:seq(1, 9)],
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%   as discussed by Simon Peyton Jones (with a Haskell solution using
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%   He quotes J.A.Trono "A new exercise in concurrency", SIGCSE 26:8-10, 199
  ...
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```

Even more straighforward

```
receive
        {reindeer, Pid1} and {reindeer, Pid2} and {reindeer, Pid3} and
        {reindeer, Pid4} and {reindeer, Pid5} and {reindeer, Pid6} and
        {reindeer, Pid7} and {reindeer, Pid8} and {reindeer, Pid9} ->
                io:format("Ho, ho, ho! Let's deliver presents!~n"),
                [Pid1, Pid2, Pid3, Pid4, Pid5, Pid6, Pid7, Pid8, Pid9];
        {elf, Pid1} and {elf, Pid2} and {elf, Pid3} ->
                io:format("Ho, ho, ho! Let's discuss R&D possibilities!~n"),
                [Pid1, Pid2, Pid3]
end
```

with JErlang [22]

A running example

```
def monitor() = Actor[Event, Unit] {                        // gets Event and (possibly) returns Unit
    receive { (self: ActorRef[Event]) => {
        case ( Fault(_, id1, _, ts1),
               Fix(_, id2, ts2) )                           // Acca/Pekko cannot handle multiple msgs
                  if id1 == id2 =>
            updateMaintenanceStats(ts1, ts2)
            Continue
        case ( Fault(mid, id1, descr, ts1),
               Fault(_, id2, _, ts2),
               Fix(_, id3, ts3) )
                  if id2 == id3 && ts2 - ts1 > T =>         // assume T > 0
            updateMaintenanceStats(ts2, ts3)
            log(s"...")
            self ! DelayedFault(mid, id1, descr, ts1)       // For later processing
            Continue
        case ( DelayedFault(_, id1, _, ts1),
               Fix(_, id2, ts2) )
                  if id1 == id2 =>
            updateMaintenanceStats(ts1, ts2)
            Continue
    }
  }
}
```

Matching join patterns

```
case ( Fault(_, id1, _, ts1),
       Fix(_, id2, ts2) )
                  if id1 == id2 => ...

case ( Fault(mid, id1, descr, ts1),
       Fault(_, id2, _, ts2),
       Fix(_, id3, ts3) )
         if id2 == id3 && ts2 - ts1 > T => ...
```

Let the mailbox of the monitor actor get

Fault(_, 1, _, 10:35)	Fault(_, 2, _, 10:40)	Fault(_, 3, _, 10:55)	Fix(_, 3, _, 11:00)	···

Exercise

Which are the matching sequences?

Choosing patterns

Choosing patterns

If more matchings are possible, how do we pick one?

Choosing patterns

If more matchings are possible, how do we pick one?
Usual solutions

- non-deterministic selection
- longest matching sequence

Fair join patterns [13, 14, 16]: take the "oldest" sequence

- using a length-biased lexicographic order on positions in the mailbox
- avoid leaving messages indefinitely in the mailbox

Choosing patterns

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Exercise

Find the fair join pattern for

```
case ( Fault(id1, ts1), Fix(id2) ) if id1 == id2 => ...
```

when the mailbox becomes

```
Fix(3)
```

Choosing patterns

If more matchings are possible, how do we pick one?
Usual solutions

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Fair join patterns [13, 14, 16]: take the "oldest" s

- using a length-biased lexicographic order on positi
- avoid leaving messages indefinitely in the mailbox

a single message doesn't match any patterns

so we've to wait for a new message

Note: messages arrive one at a time and search must be restarted each time!

Exercise

Find the fair join pattern for

```
case ( Fault(id1, ts1), Fix(id2) ) if id1 == id2 => ...
```

when the mailbox becomes

`Fix`(3)	`Fault`(1, 10:35)

Choosing patterns

If more matchings are possible, how do we pick one?
Usual solutions

- non-deterministic selection
- longest matching sequence

the next message doesn't satisfy the condition

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Exercise

Find the fair join pattern for

```
case ( Fault(id1, ts1), Fix(id2) ) if id1 == id2 => ...
```

when the mailbox becomes

`Fix`(3)	`Fault`(1, 10:35)	`Fault`(2, 10:36)

Choosing patterns

If more matchings are possible, how do we pick one?
Usual solutions

- non-deterministic selection
- longest matching sequence

the next message doesn't satisfy the condition

Fair join patterns [13, 14, 16]: take the "oldest" sequence

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Exercise

Find the fair join pattern for

```
case ( Fault(id1, ts1), Fix(id2) ) if id1 == id2 => ...
```

when the mailbox becomes

`Fix`(3)	`Fault`(1, 10:35)	`Fault`(2, 10:36)	`Fault`(3, 10:37)

Choosing patterns

If more matchings are possible, how do we pick one?
Usual solutions

- non-deterministic selection
- longest matching sequence

finally we've a match

Fair join patterns [13, 14, 16]: take the "oldest" sequence

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- avoid leaving messages indefinitely in the mailbox

Exercise

Find the fair join pattern for

```
case ( Fault(id1, ts1), Fix(id2) ) if id1 == id2 => ...
```

when the mailbox becomes

`Fix`(3)	`Fault`(1, 10:35)	`Fault`(2, 10:36)	`Fault`(3, 10:37)

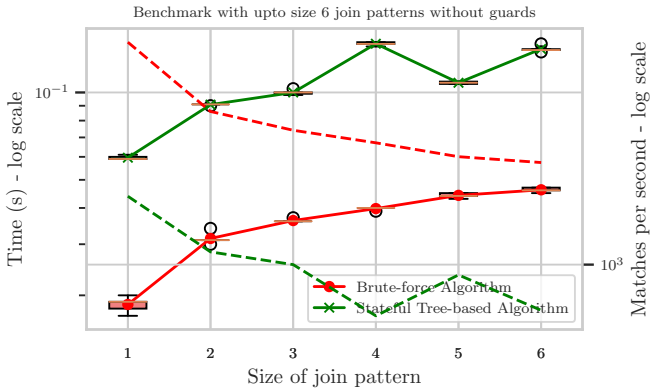
Go to Ayman's slides

Evaluating the JoinActor library

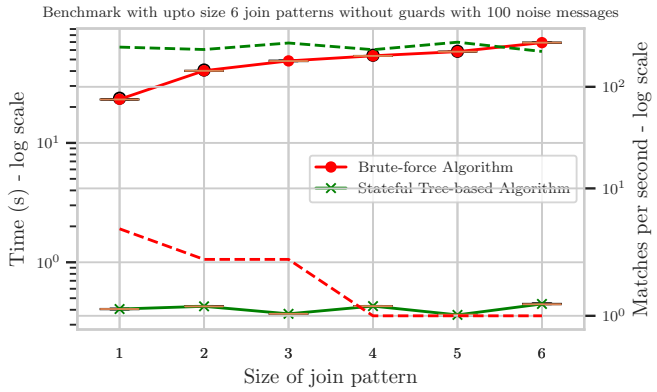
Evaluating the JoinActor library

- Benchmarking pattern size without guards

no noise



noise



Evaluating the JoinActor library

- Benchmarking pattern size without guards

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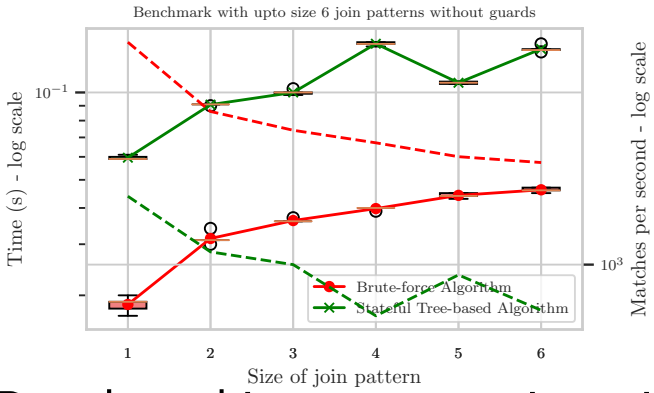
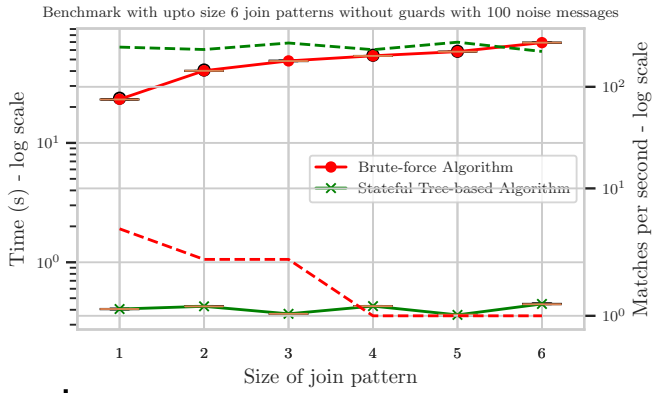
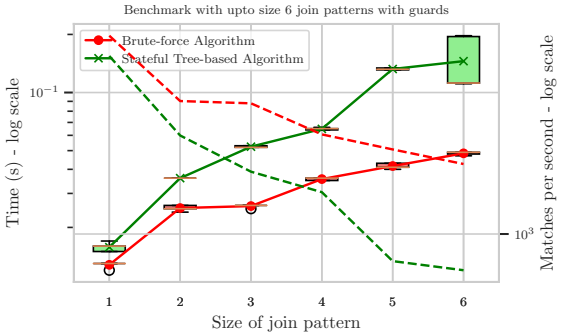


noise

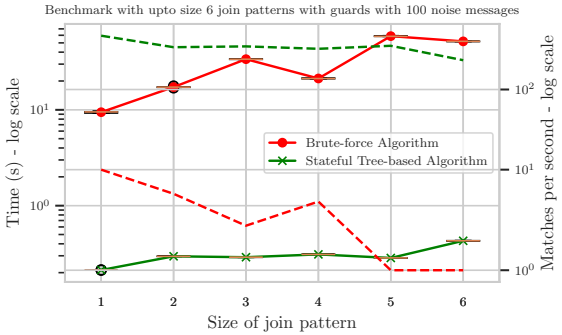


- Benchmarking pattern size with guards

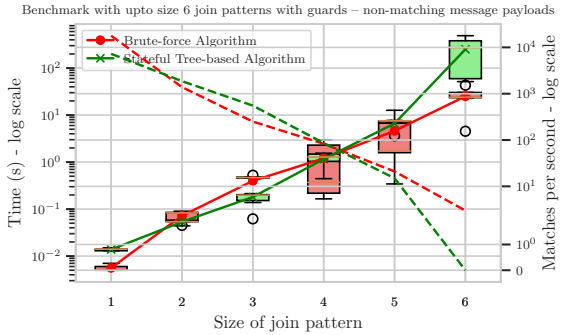
no noise



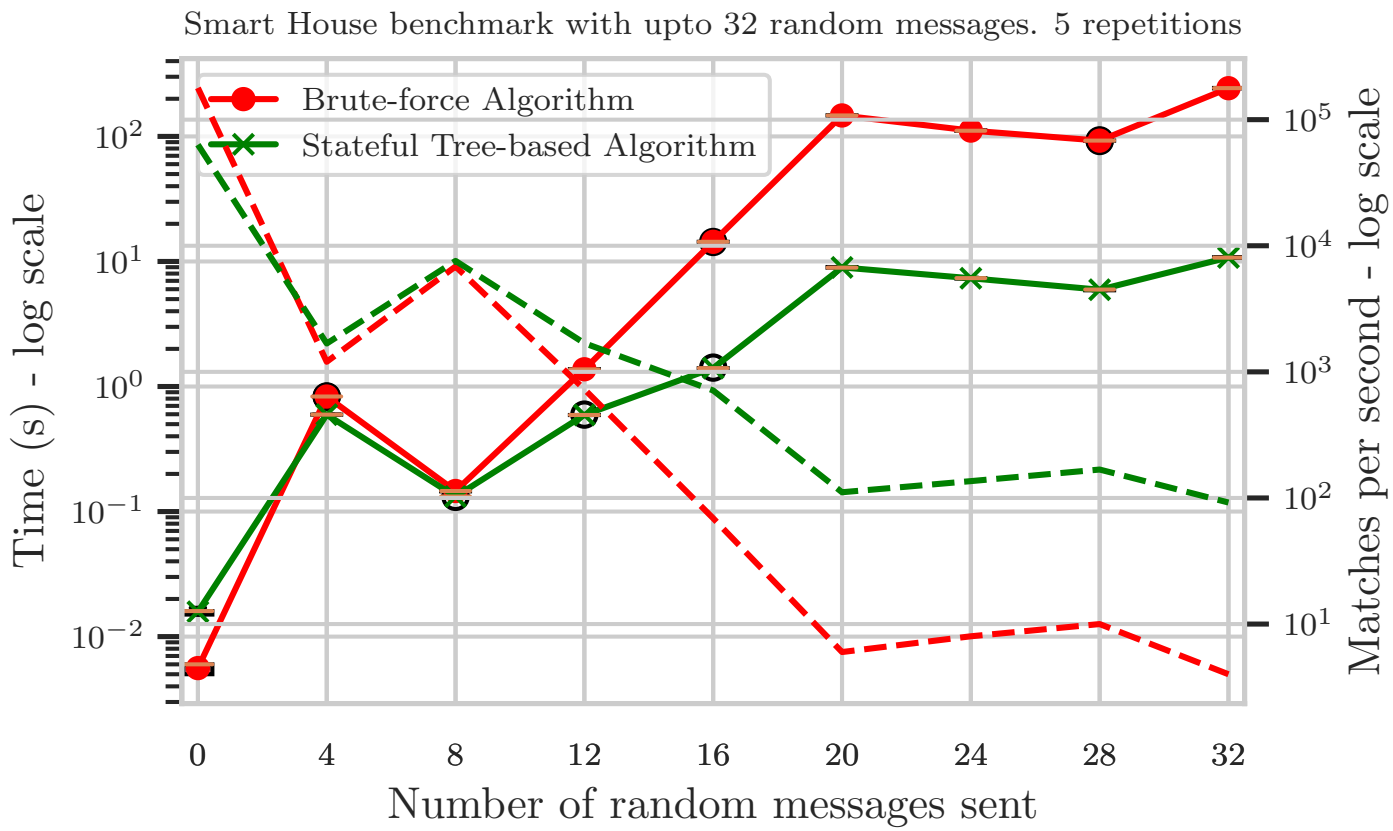
some matching noise



non-matching noise



A non-synthetic benchmark



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