Evaluating Software Model Checking Tools

(It's a Dirty Job, But Someone's Got to Do It)

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- So we can't provide much guidance to users about
  - which FSV tool to apply, or even
  - whether FSV will be useful for their particular problems
- Evaluation also suggests improvements in tools, new research directions, etc.

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So, while analytical comparisons would be extremely useful, we need to do empirical evaluation.

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- Effective use of even a single tool on a system of realistic size and complexity is a major project
  - need significant expertise with the tool
- Would like to measure factors affecting ease of use, not just performance (time/memory)
  - but *sound* experiments with human subjects are difficult to design correctly and very expensive

A Case Study—Chiron GUI Development System

Client-server system

- Client comprises
  - application for which interface is being constructed
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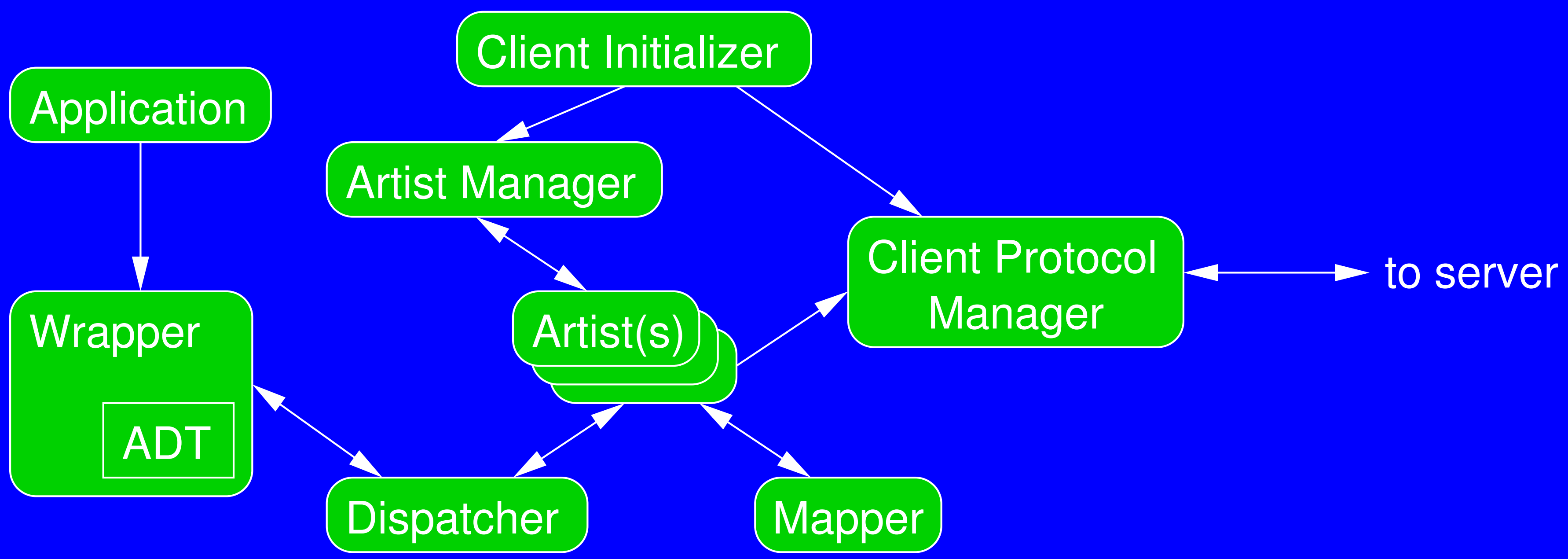
Architecture is highly concurrent and even a toy interface is more than 1000 lines of Ada

Runtime Architecture of a Chiron Client



The Tools

- SMV
  - symbolic (BDD-based) model checker
- SPIN
  - explicit state model checker
- INCA
  - generates a system of inequalities that must have integer solutions if the property is violated, and uses integer linear programming to check
- FLAVERS
  - uses data flow analysis techniques to propagate states of property automaton and various constraint automata through graph representing control flow

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- No formal spec
  - but extensive contact with Chiron developers
  - believe examples are realistic and reflect developers' understanding
- Sample properties:
  - Freedom from deadlock
  - If artist a_1 is registered for event e_1 and dispatcher receives e_1, it will not receive another event before passing e_1 to a_1.
  - Having received e_1, dispatcher does not notify artists of e_2.
  - Dispatcher does not notify an artist of an event the artist is not registered for.

Formalizing the Properties

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- formalizations need to be *consistent*
- would like to choose formalizations that lead to best tool performance
- used specification patterns system wherever possible (but don't know this leads to best tool performance)

A Property Example

If artist a_1 is registered for event e_1 and dispatcher receives e_1, it will not receive another event before passing e_1 to a_1.

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LTL:

```
[](((afternotifyartistse1 && isregistereda1e1) &&
    <>(notifyartistse1 || notifyartistse2)) -> (!(notifyartistse1 ||
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CTL:

```
AG((afternotifyartistse1 & isregistereda1e1) ->
    !E[!notifyclienteventa1e1 U (notifyartistse1 | notifyartistse2)])
```

Property Example, continued

INCA:

```
(defquery "p02a" "nofair" (omega-star-less (sequence
  (interval :initial t :open t
    :constraints
      '((>= "accept(a1;dispatcher.register_event;art1;e1)"
      (+ 1 "accept(a1;dispatcher.unregister_event;art1;e1)")))
    :ends-with '((rendezvous "adt_wrapper;dispatcher.notify_artists;e1;")))
  (interval
    :ends-with '((and
      (or (prefix "call") (prefix "accept"))
      (contains "adt_wrapper;dispatcher.notify_artists")))
    :forbid '((rendezvous "dispatcher;a1.notify_client_event;e1"))))))
```

Property Example, continued

FLAVERS:

{dispatcher_register_event_a1_e1, dispatcher_notify_artists_e2
dispatcher_unregister_event_a1_e1, artist1_notify_client_event_e1,
dispatcher_notify_artists_e1}

none

.*;
dispatcher_register_event_a1_e1;
[-dispatcher_unregister_event_a1_e1]*;
dispatcher_notify_artists_e1;
[-artist1_notify_client_event_e1]*;
[dispatcher_notify_artists_e1, dispatcher_notify_artists_e2];
.*

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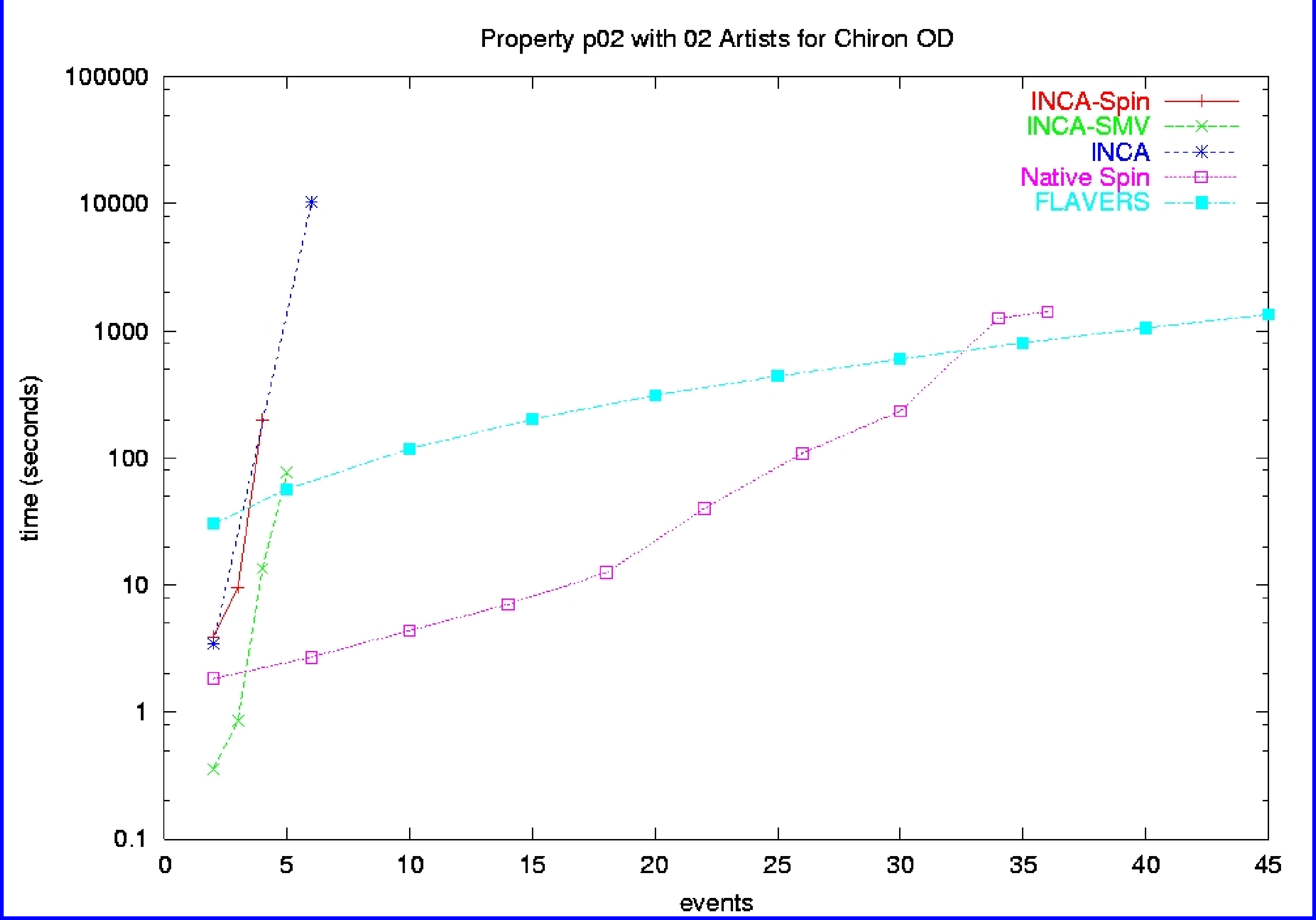
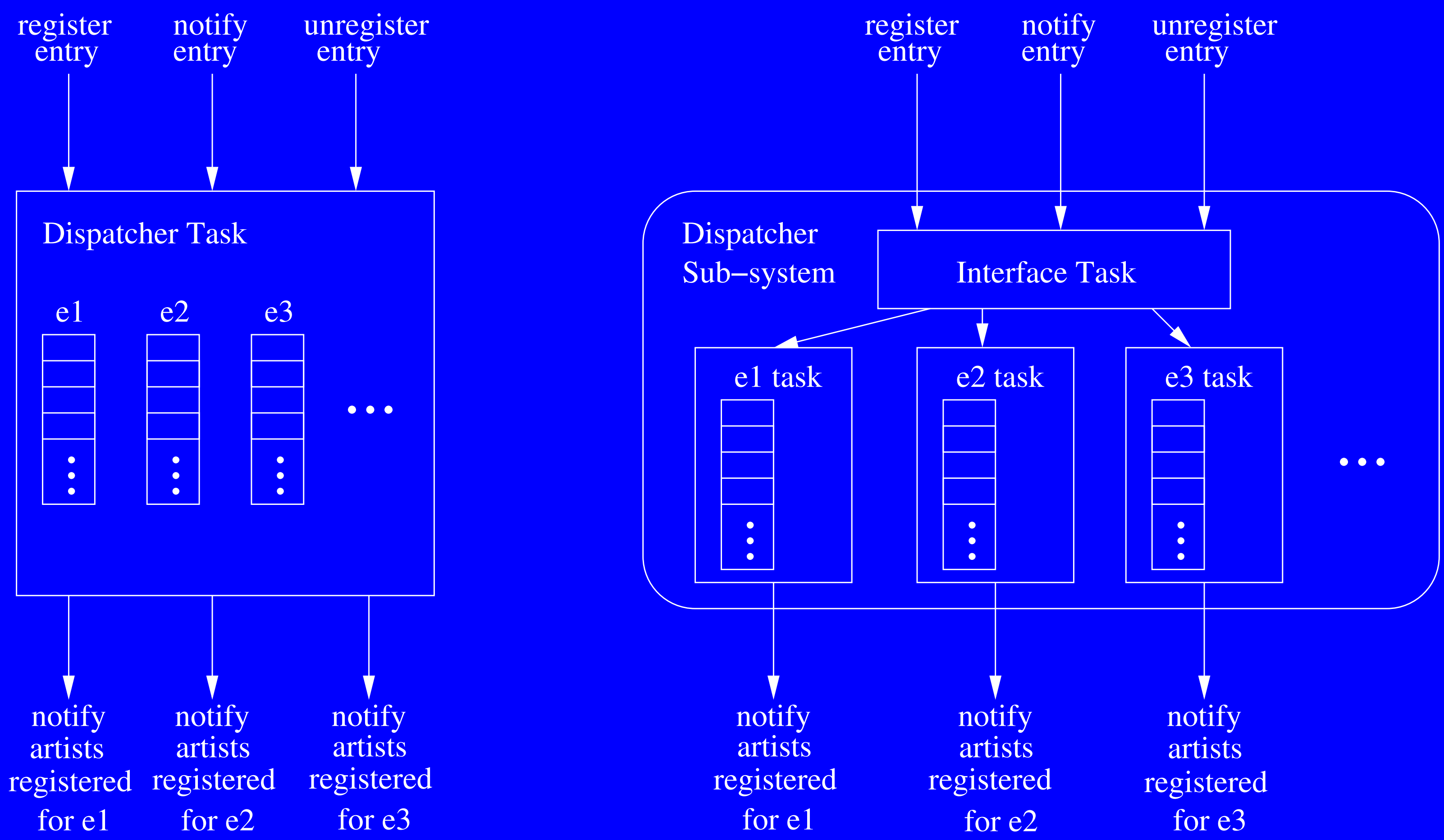
  - also converted one dynamic data structure of bounded size to a static one
- Used Corbett's translators [*TSE* 1996] to build SMV transition relation and Promela code
  - from FSAs built by INCA
  - extensive effort validating translators

Times

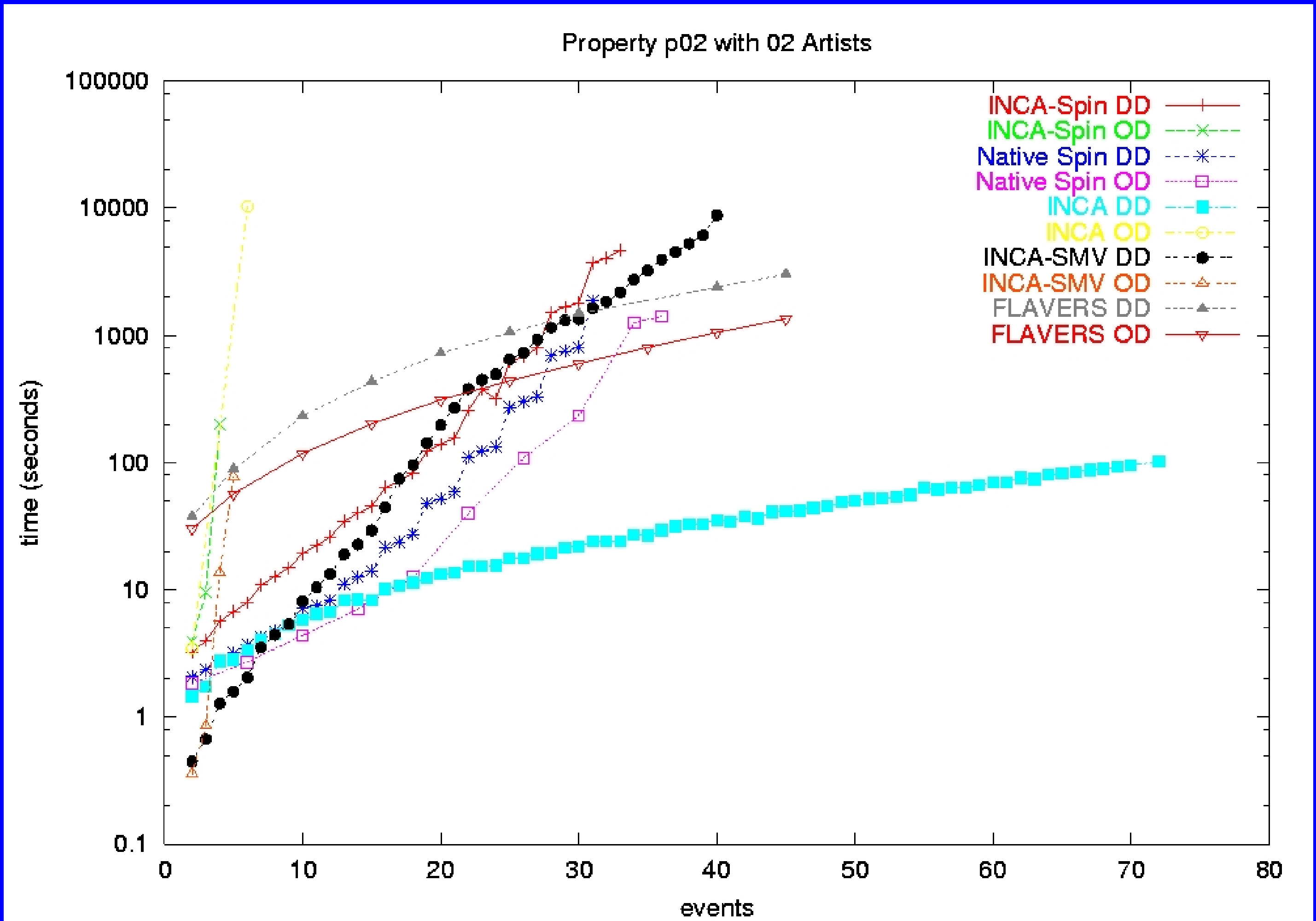


Property p02 with 02 Artists for Chiron OD
INCA-Spin
INCA-SMV
INCA
Native Spin
FLAVERS
time (seconds)
events
100000
10000
1000
100
10
1
0.1
0
5
10
15
20
25
30
35
40
45

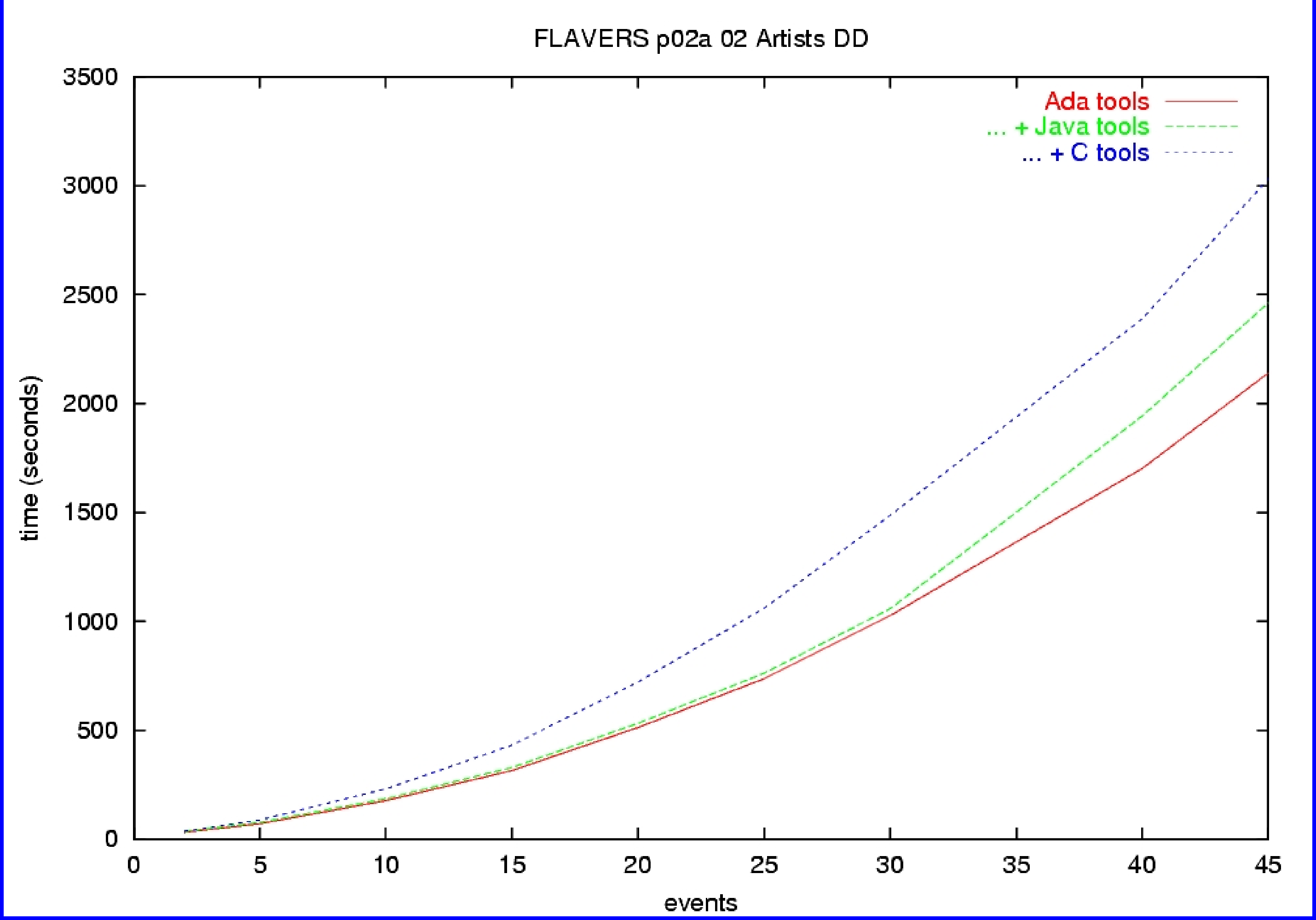
Decomposing the Dispatcher Task



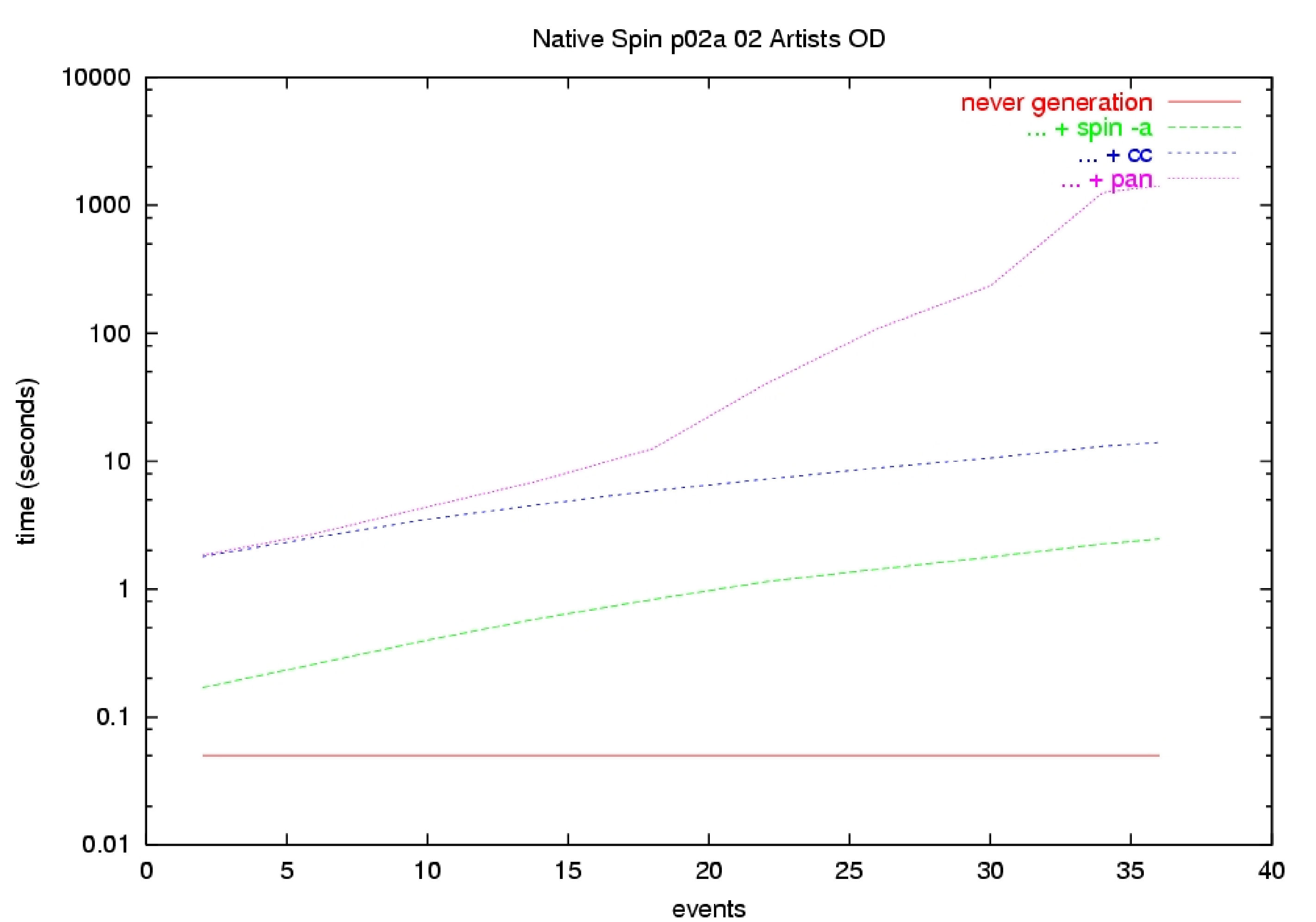
Times For Both Versions of Dispatcher



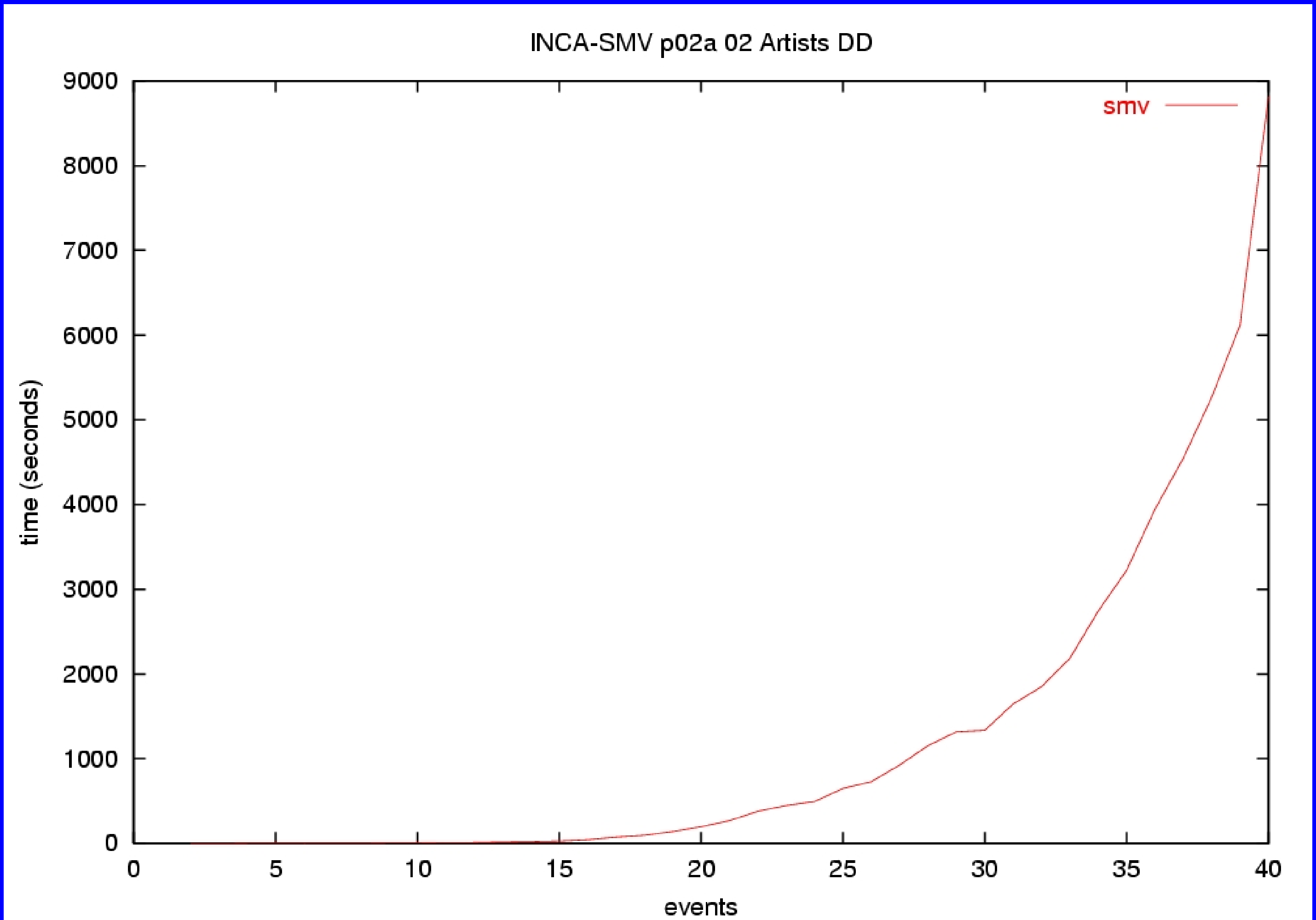
Components of FLAVERS Time



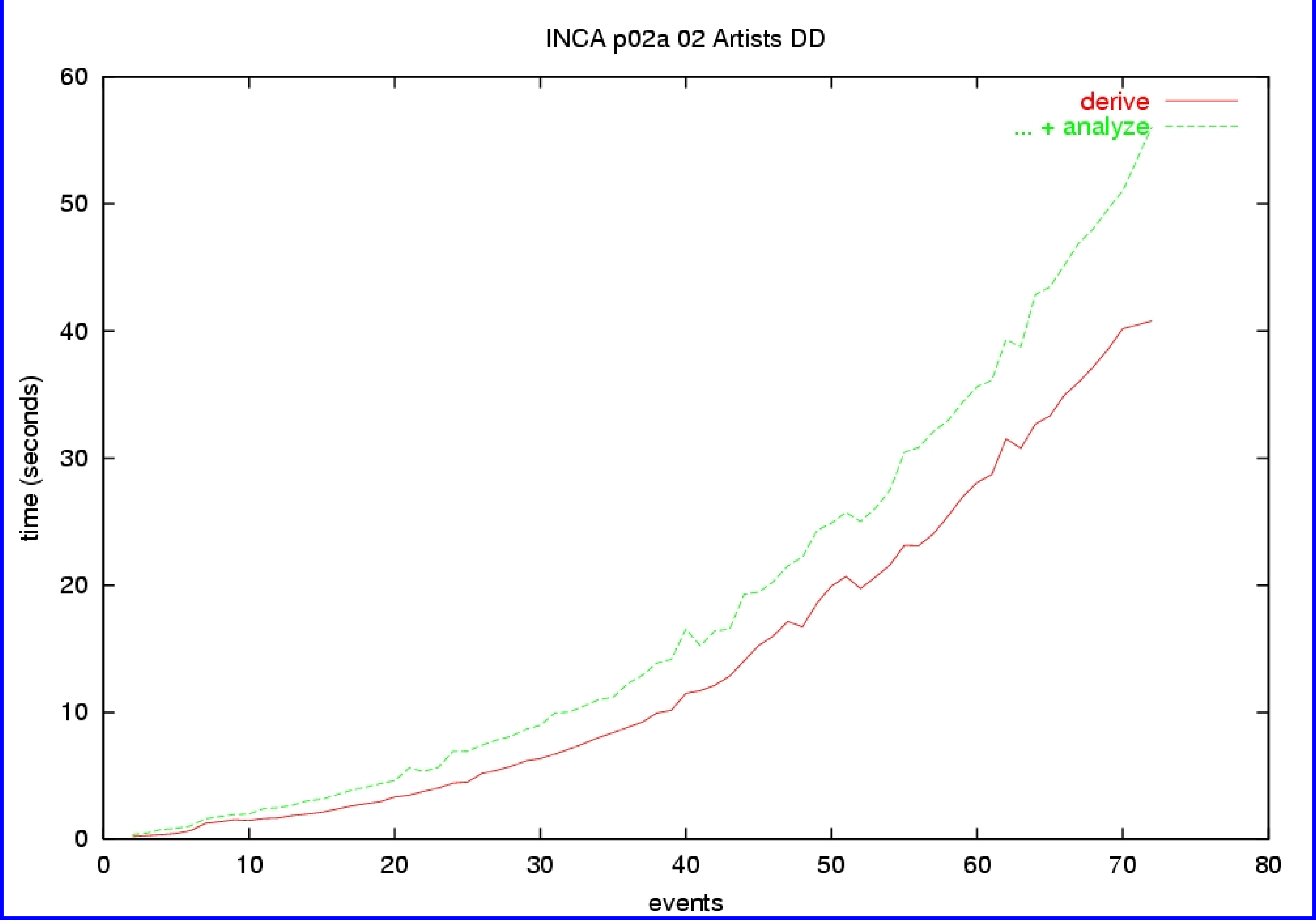
Components of SPIN Time



Components of SMV Time



Components of INCA Time



Some of the Things We Learned

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- Tools are very sensitive to details of model
  - substantial variation for all tools on "equivalent" systems
- Relatively little variation across properties
  - but algorithms and abstractions tailored to property can be helpful

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- Properties of interest were relatively complicated.