Add data into business process verification

(ab)using planning tools for BPM

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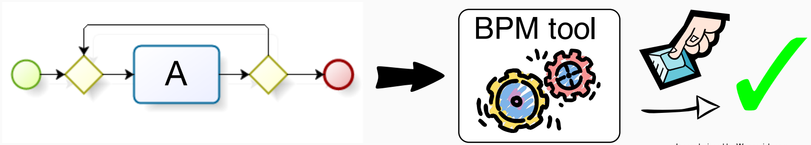
KRDB SOS-2020 11/9/2020

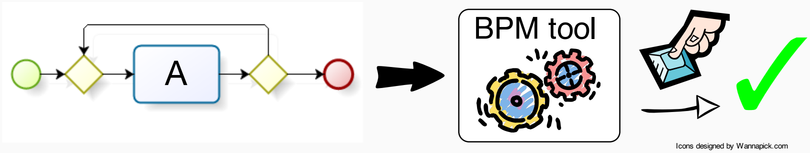
online slides available on stessaris.pages.scientificnet.org/talks/sos2020

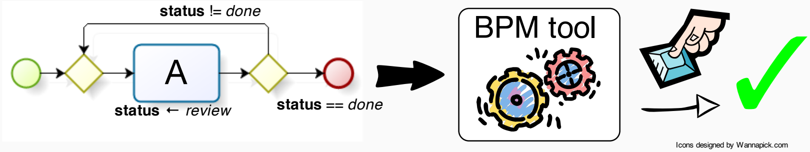
The problem with current tools



Icons designed by Wannapick.com

The problem with current tools





- Theory is there
    - why not available?
    - what can we do to bridge the gap?
- Scalability problem?

Our research

- Lots of *implementable* frameworks and methods
- Do available tools scale up?
- How do we verify that?

Reachability verification

- Interesting tasks can be reduced to reachability; e.g.
  - (proper) termination
  - dead transitions
  - trace repair/completion
  - . . .

E.g. Trace completion

- Assume model
- Given partial log
    - sequence of events + data updates
    - empty, partial, or complete
- Find complete sequence compatible with log

Classical planning

- Essentially reachability verification
- Plans/strategy as bonus
  - e.g. answer *what to do next* questions
- Strong community interested on scalability
  - International Planning Competition running since 1998

Planning and workflows

- Planning for workflows
  - *On the Disruptive Effectiveness of Automated Planning for LTLf-Based Trace Alignment* De Giacomo et al. AAAI 2017
  - *Automated Planning for Business Process Management* Marrella Journal on Data Semantics, June 2019
- Workflows for planning
  - *Planning via Petri Net Unfolding* Hickmott et al. IJCAI 2007

Focus of this work

- How we can exploit the available planning tools
- Which tools are best suited for workflow analysis
- Evaluate scalability

Putting tools to the test

- Focus on reachability; i.e. automated planning
- Select industrial-strength tools:
  - Answer Sets Programming: Clingo
  - Classical Planning: Fast Downward
  - Model checking: nuXmv
- Build a common ground among the tools
- Select appropriate experiments

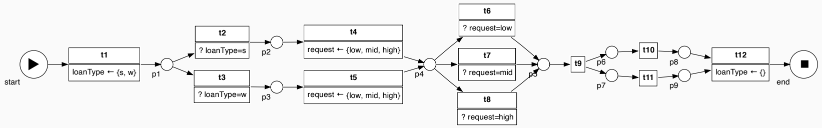
Data-aware Workflows: which one?

- Several proposed frameworks
- We selected a simple one
    - i.e. close to Classical Planning
- It's an initial step

DAta Workflow Nets (DAWNets)

- Workflow Nets
  - connected Petri Nets, with start and stop places
- Variables
  - domain
  - possibly unassigned
  - transitions assign values
- Transition guards
- based on *Soundness verification for conceptual workflow nets with data* Sidorova et al. Information Systems 2011/11

DAWNet example



DAWNets semantics

- Extends PN semantics
    - State: marking + vars
- Valid firing $t : s \rightsquigarrow s'$
    - s: token in each input place of t
    - s: guard is satisfied
    - s': tokens from in to out places
    - s': variables updated
- *Case*: sequence of valid firing

Restrictions

- Bounded networks (safeness)
    - *correct* algorithms to check it
- Finite domains

Different paradigms one task

- Different tools uses different languages
  - several ad hoc encodings in literature
- Common denominator: Labelled Transition Systems

DAWNets reachability as LTS

- Labels: transition names
- States: (M, ν) marking + variable assignment
- Initial state: token in start + unassigned variables
- Transition relation: (s, t, s') based on firing $t : s \rightsquigarrow s'$
- Goal states satisfying required properties
    - e.g. proper termination

PDDL Planners

- Reachability in LTS *is* a planning problem
- Actions schemata
    - pre/post conditions
- Initial conditions
- Final conditions
- Built-in frame axiom
- Operational semantics

PDDL in practice

- Planners are optimised for subsets of the language
- Fast Downward
    - grounding!
- Several heuristics, some depending on PDDL subset
- E.g. no object fluents
    - only boolean predicates
- Places: constants + *active* predicate
- Transitions: actions
- Variables: unary predicates

Planning using ASP

- Fluents
- *Causation rules* to define the LTS
  - head depends on both previous and current states

```
F if G ifcons H after M.

t:F :- t:G, not not t:H, (t-1):M.
```

- Variables, ASP style strong negation
  - grounding!
- Valid states are stable models wrt the rules
- Compact encoding
- Native domain constraints
- Inertia is not builtin

ASP planning in practice

- Language is not standardised
- Coala (based on Clingo)
    - Not optimised
- Places: unary predicate
- Transitions: actions
- Variables: unary predicates

Model checking

- Tools are based on TL over infinite traces (LTL)
    - looping on final states
- Variables over arbitrary domains or booleans
- TS defined using formulae over current and previous states
- Native constraints over domain
- Inertia is not builtin
    - no NMR to help with that

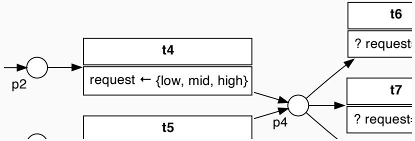
Model checking in practice

- nuXmv
- Places: boolean variables
- Transitions: variable over transition names
- Variables

Encodings

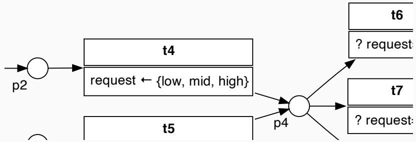
- More details in my early talk
- Leveraging trace equivalence
    - formally proven for each encoding
- Transferable models

PDDL encoding (Domain)



```
(:constants
  p2 p3 p1 p6 p7 p4 p5 p8 p9 start end - place
  high s low w mid - active_domain
)

(:predicates
  ;; Places
  (p_enabled ?p - place )
  (p_terminal ?p - place )
  ;; Variables
  (request ?v - active_domain )
  ;; Domains
  (t4_request_domain ?v - active_domain)
)
```



```
(:action t4
  :parameters ( ?request - active_domain )
  :precondition
    (and (p_enabled p2) (t4_request_domain ?request))
  :effect
    (and
      (p_enabled p4)
      (not (p_enabled p2))
      (forall (?v - active_domain) (not (request ?v)))
      (request ?request)))
```

PDDL encoding (Problem)

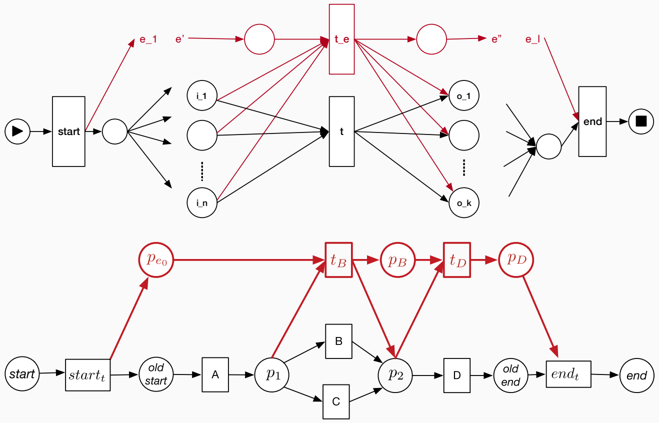
```
(:init
    (p_enabled start)
    (p_terminal end)
    (t4_request_domain low)
    (t4_request_domain mid)
    (t4_request_domain high)
)

(:goal
  (and
    (p_enabled end)
    (forall (?p - place)
      (or (p_terminal ?p) (not (p_enabled ?p))))))
```

Which experiments?

- Difficult to design general reachability experiments
- Focus on *Trace Completion*
- Several parameters via traces:
  - completeness degree
  - compliance
  - size

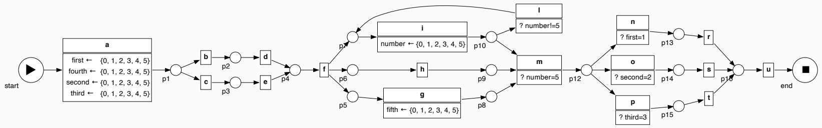
Trace Completion as Reachability



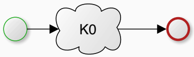
Synthetic models

- Synthetic base model
- Combination of copies of the base model
- 8 different traces per model (size 10-50+)
    - empty, 25%, 50%, 75%
    - also not compliant (4)

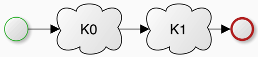
Base model


start
a
first ← {0, 1, 2, 3, 4, 5}
fourth ← {0, 1, 2, 3, 4, 5}
second ← {0, 1, 2, 3, 4, 5}
third ← {0, 1, 2, 3, 4, 5}
p1
b
c
p2
p3
d
e
p4
f
p7
p6
p5
i
number ← {0, 1, 2, 3, 4, 5}
h
g
fifth ← {0, 1, 2, 3, 4, 5}
p10
p9
p8
l
? number!=5
m
? number=5
p12
n
? first=1
o
? second=2
p
? third=3
p13
p14
p15
r
s
t
p16
u
end

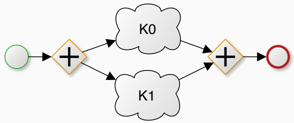
M1



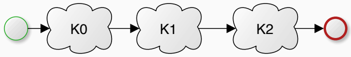
M2



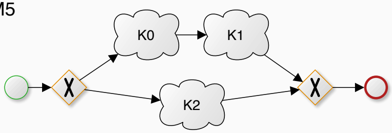
M3



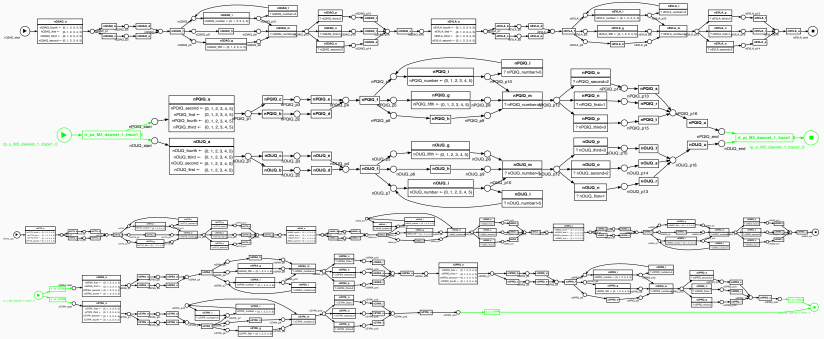
M4



M5



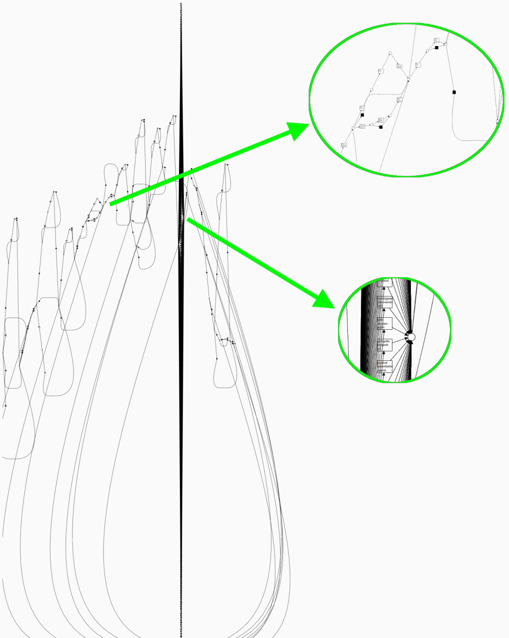
Models



Real life model

- BPI Challenge 2011 logs
  - *Real life log of a Dutch academic hospital*
- Model discovered using ProM Data-flow Discovery plugin
  - 355 transitions, 61 places, 710 edges, and 4 variables
- 9 random traces (size 3-500+)
  - empty, 25%, 50%, 75%
  - all compliant
- Also tested without data

Discovered model



Infrastructure

It's not reproducible if it only runs on your laptop

Jon Zelner

- Focus on reproducibility
- Leveraging Docker, and Kubernetes cluster
- More details on Use Containers for your Experiments!

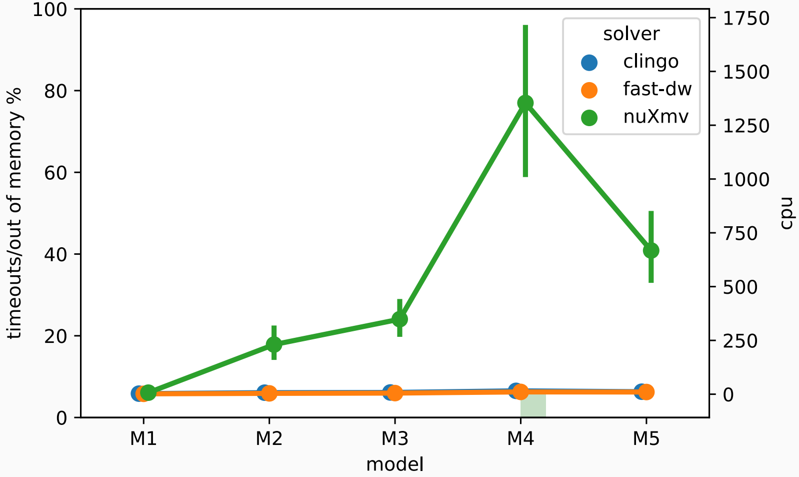
Have we a winner?

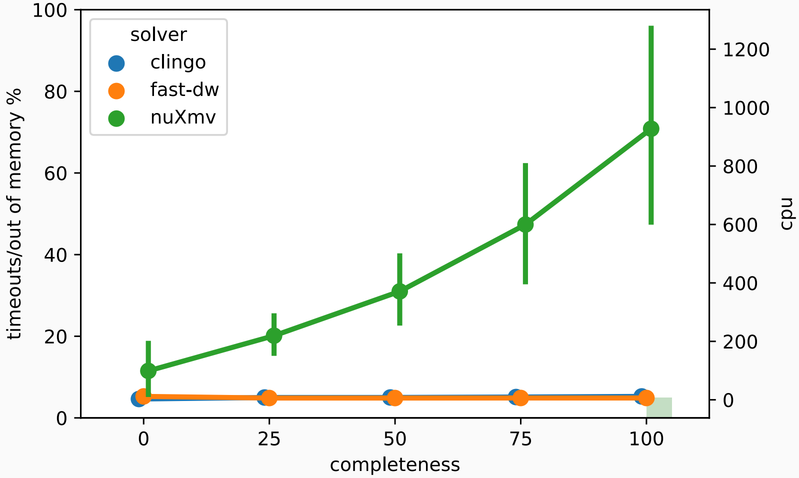
- Simple answer: **no**

Have we a winner?

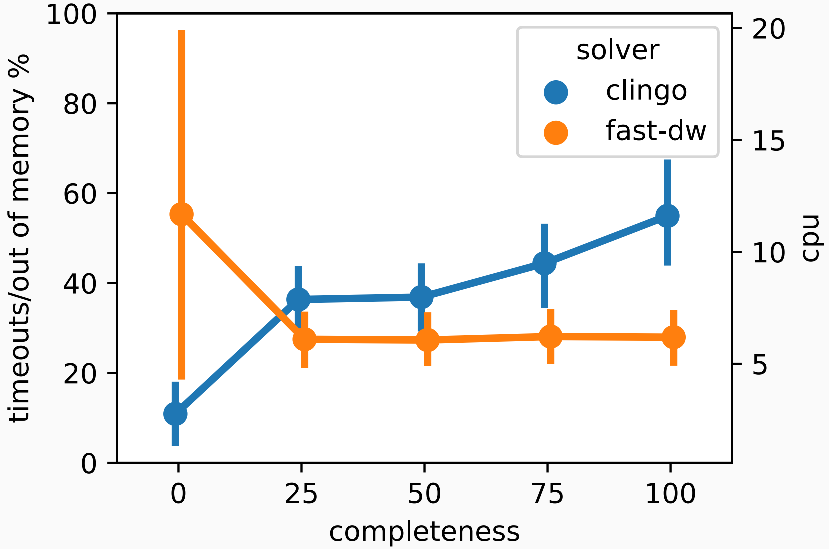
- Simple answer: **no**
- Actually, the picture is more complex... let's look at some *pictures*

Synthetic experiments

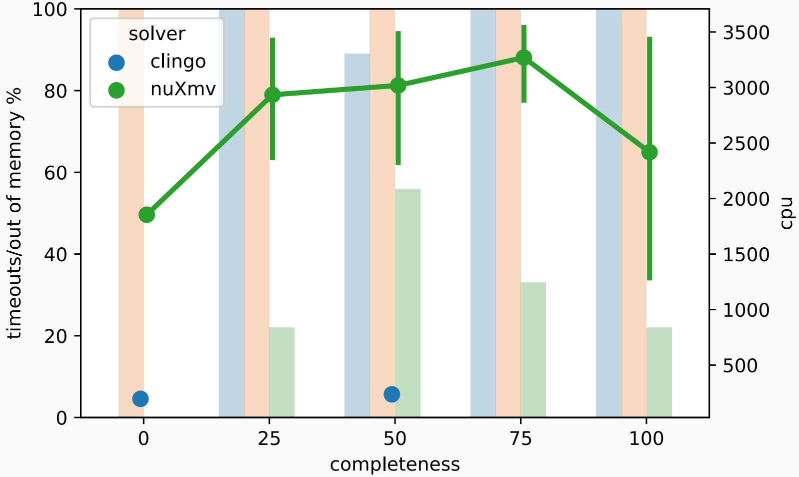



solver
clingo
fast-dw
nuXmv
timeouts/out of memory %
100
80
60
40
20
0
cpu
1200
1000
800
600
400
200
0
0
25
50
75
100
completeness

- Zooming into FD/clingo



Real life experiments



- What if we get rid of data?

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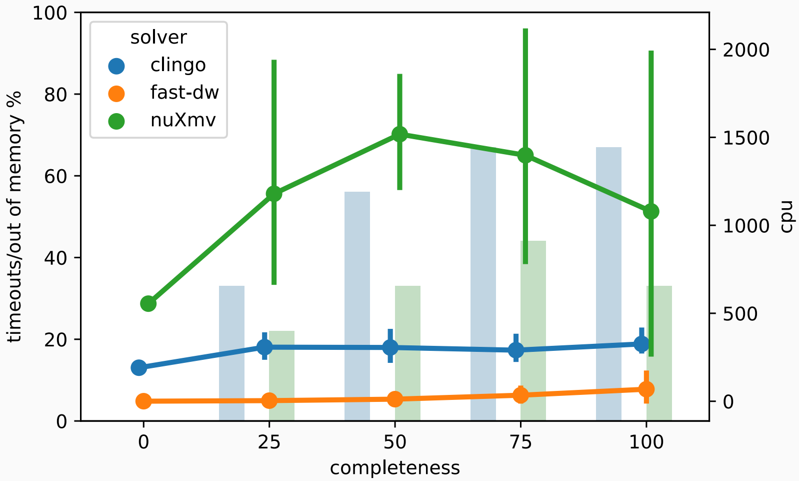

Ground or not to ground

- Grounding can be expensive!
- For *big* problems symbolic verification can be beneficial
- Room for hybrid methods?

Optimising encoding

- We didn't optimise encoding and heuristics
- Need collaboration with tool developers
    - E.g. direct encoding in SAS for FD

Conclusions

- Automated planning tools are effective
- Adding data makes the difference
- Hybrid systems can be a solution
- Now we can move to more complex languages

Thanks!

Questions?

References

- Solving reachability problems on data-aware workflows
    - code available
- Use Containers for your Experiments!
- Verification of workflow nets with data