Centrum voor Wiskunde en Informatica

DivSPIN

A SPIN-compatible Distributed Model Checker

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ParaDiSe Parallel & Distributed Systems Laboratory

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Grenoble

DiVinE & SPIN

SPIN

Reverse-Engineered SPIN

Reverse-Engineered SPIN: NIPS

Reverse-Engineered SPIN: NIPS

Never Implement Promela Semantics (again)

Verification Scenario

State space too large for exhaustive sequential verification

- Distributed Model Checking to the rescue!

Obstacles:

- Possibility to reuse already developed model?
- Available hardware? (Cluster, GRID, . . .)
  Maintenance?
- Complex software dependencies:
  MPI, Java runtime, libraries, compiler(?), . . .
  in non-conflicting versions!

Outline

DivSPIN Goals

In a nutshell:

> "Provide distributed model checking tool with extremely low access barrier which is attractive to large user base of sequential model checking tools."

Effortless trial use

- Always up-to-date
- No installation
- No software dependency hell
- No expensive hardware to buy and maintain

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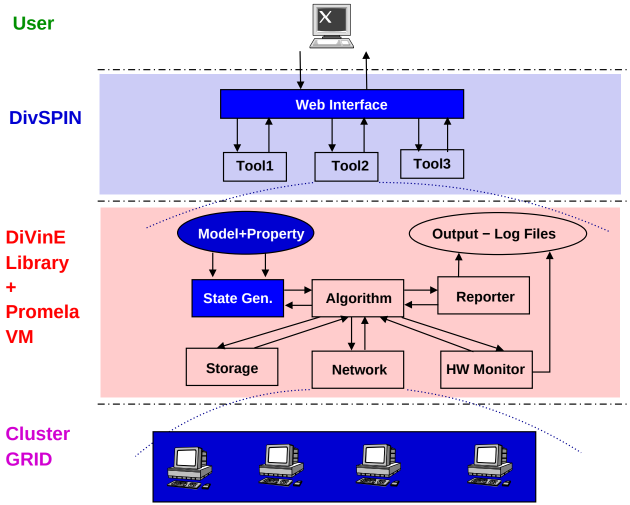
DivSPIN Overview



Cluster

Parsecs Cluster at RWTH

26 nodes, each:

- 2x Intel Pentium 500MHz
- 512MB RAM
- 100MBit switched Ethernet

* Dramatization

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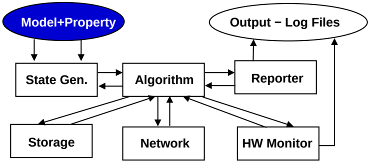
TUM

CWI

Modelling Language: Promela

```
chan ch = [1] of {int};

proctype P (x) {
  do
  :: ch!x;
  od
}
proctype Q (x) {
  do
  :: ch?x;
  :: break;
  od
}
```

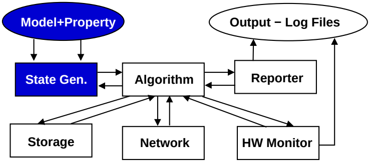


- Non-determinism
- Concurrency
- Synchronisation
- Priorities
- Extensions possible (clocks, heap, . . .)

Only basic data types (integers, records)

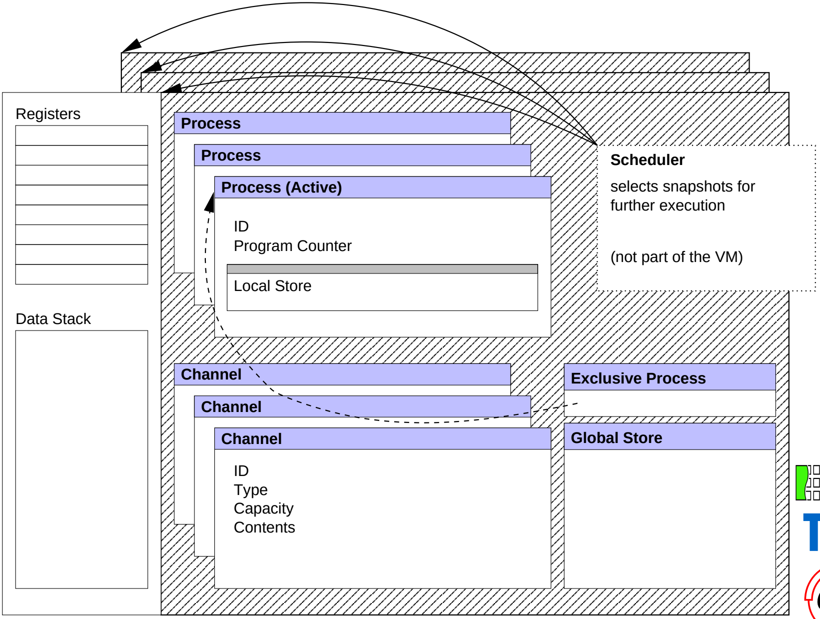
NIPS VM Design

- SPIN not very accessible (to distributed settings, anyway)
- Complete formal specification from scratch [WeberSchürmans05]



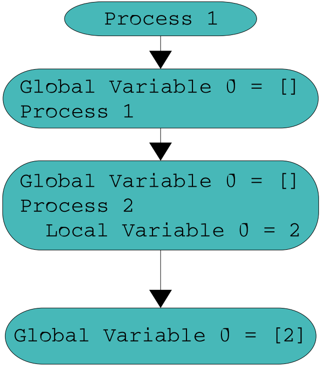
- Generally: least effort for compiler & VM implementor
- RISC-like instruction set
- Observable & unobservable steps in the language
- States: binary objects, directly manipulated by VM
- Performance: comparable to SPIN
- Well suited for embedding (unlike SPIN . . .)

NIPS VM Design



NIPS Example

```
chan c = [1] of {int}

proctype send (int x) {
  c!x
}
init { run send(2) }
```

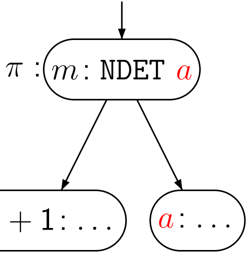



```
         GLOBSZ   2
         LDC      -31
         CHNEW    1        1
         STVA     G        2u       0
         STEP     N        0
         LJMP     P_init

P_send:  LDVA     G        2u       0
         TOP      r0
         CHFREE
         NEXZ
         PUSH     r0
         CHADD
         PUSH     r0
         LDVA     L        4        0
         CHSETO   0
         STEP     T        0

P_init:  LDC      -31
         LDC      2
         LRUN     4        1        P_send
         NEXZ
         STEP     T        0
```

Interesting Instructions

- NDET a

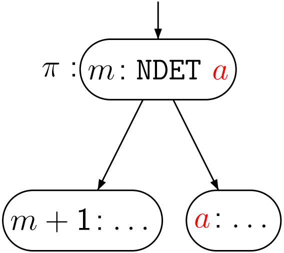
Explicit notion of non-determinism



Interesting Instructions

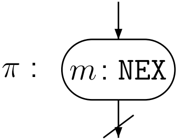
- NDET a

Explicit notion of non-determinism



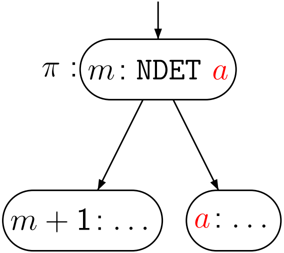
- NEX

Aborts process execution



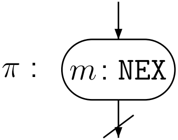
Interesting Instructions

- NDET a



Explicit notion of non-determinism

- NEX



Aborts process execution

- STEP M'

Finish multiple internal steps

$$\Gamma[M] \xrightarrow{\pi}_{step} \Gamma'[M']$$

NIPS VM Implementation

- $\approx$ 5kLOC of C code (including everything)
- State size: order of tens of bytes,
  within few bytes of SPIN's states
- No fancy optimizations yet
- Performance: comparable to SPIN
- Well suited for embedding (unlike SPIN ...)

Largest example so far: LUNAR Routing Protocol
10M states generated, $\approx$ 6 GB memory
Memory filled in less than two minutes
(AMD Athlon 64 3500+)

Benchmarking against SPIN

- Breadth-first state space generation (no POR)
- SPIN: generating C, compiled
- VM: compiling to bytecode, interpreted
- AMD Athlon64 3500+ (sequential)

	era(34)	leader(6,12)	ptrsn_N(3)	pftp
Total states				
SPIN	713,817	382,151	45,927	1,275,180
SPIN+Opt	342,082	106,449	25,371	219,167
NIPS	347,012	382,465	51,118	1,378,184
NIPS+PR	2,914	6,241	853	301,603
State-space generation time (seconds)				
Spin+Opt	26.441	0.12	0.085	0.770
NIPS+PR	0.177	0.176	0.012	4.996

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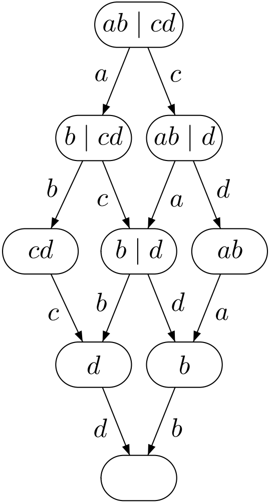
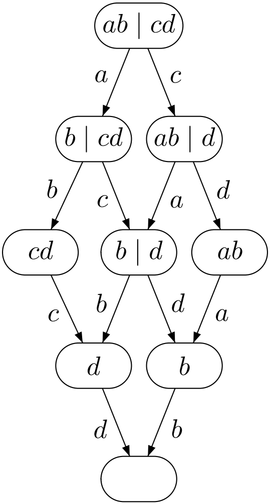
Path Reduction vs. POR

Full Transition
System

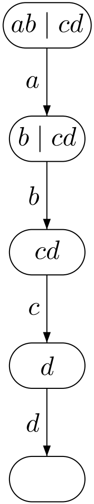


Path Reduction vs. POR

Full Transition System

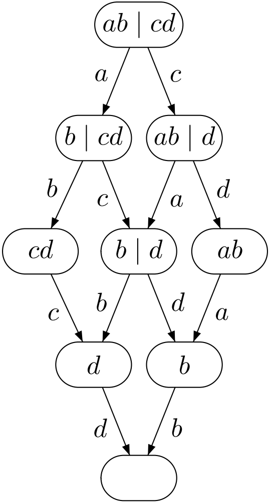


Partial Order Reduction

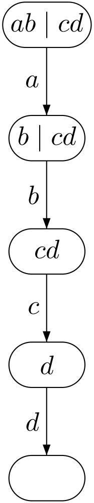


Path Reduction vs. POR

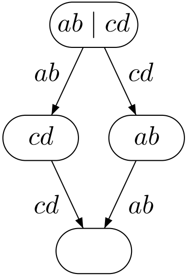
Full Transition System



Partial Order Reduction



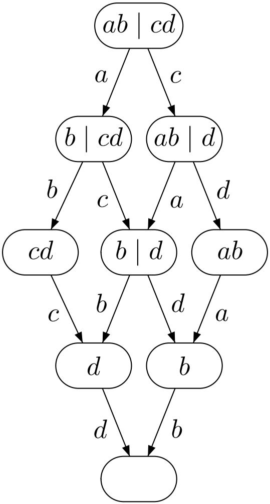
Path Reduction



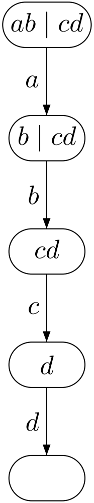
- Static
- Preserves branching structure

Path Reduction vs. POR

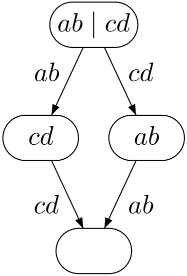
Full Transition System



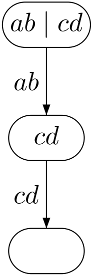
Partial Order Reduction



Path Reduction



PR+POR



- Static
- Preserves branching structure

Path Reduction

(path compression, [Yorav&Grumberg 2004]):
Collapse sequences of steps that cannot influence the value of a temporal logic specification

- Based on static program analysis.
- Identifies program locations which *may affect* the value of the specification.
- Preserves $\mathsf{CTL}^*_{-\mathbf{X}}$.
- Presented as applied to a simple high-level concurrent language (static processes, synchronous communication).

Assumption:
Specification is a formula over program variables.

Path Reduction for NIPS

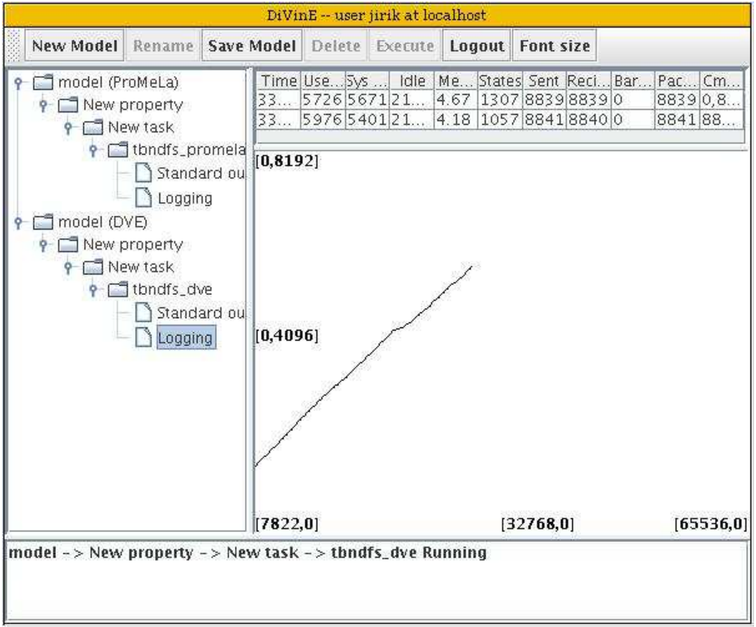
Versus [Y&G 2004]:

- Adapted to
  - Dynamic creation of channels and processes
  - Asynchronous communication
  - Global variables $\mapsto$ informal communication channels.
- Two phases:
  - *Transformation* of the NIPS program: preserves the model's semantics and just alters the transition system.
  - *Transition-system construction*: delegated to the (unmodified) NIPS virtual machine.

Less involved framework (almost too simple...)
Explicit notion of steps, program transformation
Hard work: delegate to VM

VM Todo List

- How to present counter examples?
  Currently: in terms of VM states
  Need clean reflective interface to VM
- How to integrate reduction techniques?
  (Partial Order Reduction, τ-confluence)


DiVinE -- user jirik at localhost
New Model
Rename
Save Model
Delete
Execute
Logout
Font size
model (ProMeLa)
New property
New task
tbndfs_promela
Standard ou
Logging
model (DVE)
New property
New task
tbndfs_dve
Standard ou
Logging
Time
Use...
Sys ...
Idle
Me...
States
Sent
Reci...
Bar...
Pac...
Cm...
33... 5726 5671 21... 4.67 1307 8839 8839 0 8839 0,8...
33... 5976 5401 21... 4.18 1057 8841 8840 0 8841 88...
[0,8192]
[0,4096]
[7822,0]
[32768,0]
[65536,0]
model -> New property -> New task -> tbndfs_dve Running

Extensions: Work In Progress

- More frontends (NTIF, ATMEL instruction set, ...)
- Formalizing VM in ACL2 theorem prover
- State compression
- More (semi-)static analyses (compatible with distributed settings)
  - Dead Variables ($\approx$ 10% reduction) [Y&G 2004] $\Longrightarrow$ Symmetry Reduction
  - ...

Conclusion

DivSPIN goals

- Ready-to-use distributed model checker
- Tap large user base

- Building on DiVinE framework
- Utilizing Promela as modelling language
- State-space generation:
  NIPS virtual machine
  Building block!