Model Checking Contest

Report for 2012

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MCC 2012

Model Checking Contest @
Contents

- Objectives
- Evaluation procedure
- The models
- Participating tools
- Analysis of the results
- Concluding remarks
Contents

- Objectives
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Special thanks for those who helped to organize this MCC, in particular Nicolas Gibelin (Cluster), Lom Hillah (PNML), Emmanuel Paviot-Adet (models)
When it Comes to Deal with Large and Complex Systems...

Lots of questions are raised...

- To verify highly concurrent systems, should we use a symmetry-based or a partial order-based model checker?
- For models with large variable domains, should we use decision diagram-based, or a symmetry-based model checker?
- Can we combine structural reductions techniques with partial-order ones or symmetry-based ones?
- ...

A large variety of model checking techniques

- and their potential combination

A large variety of model categories

A challenge with large scale specifications

A need to evaluate in the fairest way current MC implementations
MCC is intended to:
- Exchange experience between tool programmers,
- Imagine some association of techniques, and thus better tools
- Stimulate development of tools
- Provide visibility to these tools

MCC can also be of great help for the PN community (and users):
- Define a common set of models for benchmarks
- Identify experimentally classes of problems (in models)
  - identify the techniques able to cope with a given class of problems...
- Improve communication between tools (and PNML ;-) )
- Provides raw data for comparison

This is the second edition
- We hope more editions for an enhanced analysis and evaluation of tools
Evaluation Procedure
What to be measured?

The «enemies» of model checking
- Memory consumption
- CPU consumption

«Examinations» to be processed
- State space generation
- Formula evaluation
  - Structural Formulas
  - Reachability Formulas
  - CTL formulas
  - LTL formulas

Another 2012 innovation
- Models to be proposed by the community («call for model»)
  - 7 models in 2011
  - 19 models in 2012 (including the 7 from 2011)
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Another 2012 innovation

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  - 7 models in 2011
  - 19 models in 2012 (including the 7 from 2011)

Special thanks for the community who provided interesting models

12 new models coming from 5 institutions

Univ. Evry Val d’Essone, France
Univ. Geneva, Switzerland
Univ. P. & M. Curie France
Univ. Paris 13, France
Univ. Rostock, Germany
**Evaluation procedure**

**Execution on a dedicated cluster (23 nodes)**
- PowerEdge R410 (6 ports gigabits) and 1.5To local disks
- 8GB memory (DDR3, 1333)
- Intel Xeon E5645@2.40GHz (6 cores, 12 threads)
- Cache L1=192kB, L2=1536kB, L3=12288kB

**Run = execution of a tool for one examination on one model/scale**
- A run is executed in a Virtual machine
- We process runs until one fails (to check how far a tool goes)

**A benchmark script launching all runs**
- With time confinement 3600 sec per run
- With memory confinement 4 GByte per run
- Time and memory measures
- CPU and Memory evolution
Evaluation Procedure

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2419 runs processed!
State Space : 639
Formulas : 1780
VM deployment : 6h!
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VM deployment : 6h!

Optimized technique compared to 2011
dispatch of runs all over the cluster
Difficulties

The Cluster
- Was delivered later than expected
  - Old nodes could not operate virtualization

The formulas
- Last year solution was not satisfactory
  - Based on invariants
  - Too «easy» formulas
  - One set per model

This year solution
- One set per run
- Two formats, XML and textual (update of the grammar)
  - But... ... a nightmare 😞

Other technical difficulties
- Fighting with qemu
- Change of structure for formulas
- Provide PNML form for submitted models
The Models
## Presentation of the Models

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<thead>
<tr>
<th>Model Name</th>
<th>model type</th>
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<th>dead-lock</th>
<th>free choice</th>
<th>state machine</th>
<th>event graph</th>
<th>reversible</th>
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</thead>
<tbody>
<tr>
<td>cs_repetitions</td>
<td>colored + P/T</td>
<td>✗</td>
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**Models from 2011**

- FMS
- Kanban
- MAPK
- Peterson
- Philosophers
- SharedMemory
- TokenRing

**Models proposed for 2012**

- cs_repetitions
- rwmutex
- echo
- eratosthenes
- galloc_res
- lamport_fmea
- neoelection
- philo_dyn
- planning
- railroad
- ring
- simple_lbs

Diversification of characteristics
Participating Tools
## The Submissions (order of arrival ;-)

<table>
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<tr>
<th>#</th>
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State space generation
- Decision Diagrams (any kind)
- Explicit representation of the state space
- Exploitation of the system symmetries
- Use of «topological» information (syphon, traps, invariant, etc)

Formula evaluation
- Abstractions (on the fly state elimination)
- Decision Diagrams (any kind)
- Explicit representation of the state space
- Use of a constraint solver (SAT, SMT)
- Use of structural reduction (Berthelet’s, Haddad’s, etc.)
- Use of Partial order techniques
Participating tools: Supported techniques

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- Use of structural reduction (Berthelot’s, Haddad’s, etc.)
- Use of Partial order techniques
- Also a combination of such techniques

State space
- ITS-Tool: Decision Diagrams + Symmetries
- PNXDD, ITS-Tool: Decision Diagrams + Topological

Formula evaluation
- Lola*: Explicit + Partial Orders + Topological
- Sara: Abstraction + SAT/SMT + Decision Diagrams
LoLa* and Sara did not participated in the State Space generation.
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Models

Helena

Max Value reached

participated
LoLa* and Sara did not participated in the State Space generation.

Models:
- ring
- planning
- rwmutex
- echo
- MAPK
- Kanban
- FMS
- lamport_fmea
- galloc_res
- cs_repetitions
- TokenRing
- SharedMemory
- Philosophers
- Peterson
- railroad
- eratosthenes
- simple_lbs
- neo-election
- philo_dyn

Participated
Max Value reached

ITS-Tools
LoLa* and Sara did not participated in the State Space generation

Marcie participated

Max Value reached
LoLa* and Sara did not participated in the State Space generation
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Models & examinations
Processed by Tools (State Space)

LoLa* and Sara did not participate in the State Space generation.

Models

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Three «killing models»

- cs-repetition
- planning
- neo-election

participated

Max Value reached

PNXDD
Only AlPiNa, Helena, LoLa* and Sara participated.
Only AlPiNa, Helena, LoLa* and Sara participated

%processed formulas participated
Max Value reached

Helena
Only AlPiNa, Helena, LoLa* and Sara participated

**Models**

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%processed formulas participated
Max Value reached

LoLa-binstore
Only AlPiNa, Helena, LoLa* and Sara participated

%processed formulas reached Max Value

Models & examinations

Processed by Tools (Reachability)
Only AlPiNa, Helena, LoLa\(^*\) and Sara participated

Max Value reached

% processed formulas participated

Sara
Only AlPiNa, Helena, LoLa* and Sara participated

% processed formulas participated
Max Value reached

Three «killing models»

Models

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lamport_fmea
galloc_res
cs_repetitions
TokenRing
SharedMemory
Philosophers
Peterson
railroad
eratosthenes
simple_lbs
neo-election
philo_dyn
cs-repetition planning ring
Only AlPiNa and Helena participated

%processed formulas participated
Max Value reached
Only AlPiNa and Helena participated.

Models:

- ring
- planning
- rwmutex
- echo
- MAPK
- Kanban
- FMS
- lamport_fmea
- galloc_res
- cs_repetitions
- TokenRing
- SharedMemory
- Philosophers
- Peterson
- railroad
- eratosthenes
- simple_lbs
- neo-election
- philo_dyn

Max Value reached

%processed formulas participated

Helena
Only ALPina and Helena participated

%processed formulas participated
Max Value reached

Models

- ring
- processing
- rwmutex
- echo
- MAPK
- Kanban
- FMS

Processed by Tools (Structural)

- Only ALPiNa and Helena participated
- Max Value reached
- %processed formulas participated
The «surprise model»

We had a bench of «big ones»
- From Paris and from Rostock

Unfortunately...
- Formula analysis ended last Sunday evening (about 23h00)

Due to the number of «small problems» to be solved...
- No possibility to operate this examination this year
Analysis of the Results
The execution itself was shorter than expected
- Around 6+8 hours (both examinations)

But outcomes were much bigger (see next slide)

State space analysis
- This is possible
- «comparison» is also possible

Formula evaluation
- This is more difficult
  - Some problems come from the original requirements
- Comparison impossible
  - All tools do not process the same subset of formulas
  - Most formulas were false

More work is needed on formulas for the next edition
No (more than last year) interest in a «race»

654 charts generated

- 358 for the state space examination
  - Comparison of CPU, elapsed time, Memory,
  - Evolution of memory and CPU
  - Radars

- 296 for the formulas examination (reachability and structural)
  - Comparison of CPU, elapsed time, Memory (no signification)
  - Radars

Identification (partial) of some «surprises» discovered when test were processed

- How tools scale up
  - P/T and colored

- Some observations on time and memory consumption
- Feed back with tools’ characteristics
Interesting Facts,
Initial cost of some techniques

Memory for state space generation (FMS)

Scaling parameter

Memory (MB)

AIPiNa  ITS–Tools  Marcie  PNXDD

24/06/2012, 11:26
Marcie (new tool) is doing quite well

CPU for state space generation (Philosophers)
Decision diagrams for Marcie

Memory for state space generation (SharedMemory)

Scaling parameter

Memory (MB)

AlPiNa
Crocodile
Helena
ITS-Tools
Marcie
PNXDD
Eratosthene $500 = 4,13 \times 10^{121}$ states
**Helena beats them all (philo_dyn 50 = 2.26x10^6 states)**

Memory for state space generation (philo--dyn)

![Graph showing memory usage for state space generation](image)

- **AlPiNa**
- **ITS-Tools**
- **Marcie**
- **Neco**
- **PNXDD**

Memory (MB) vs. Scaling parameter (log scale)
The tool going farer used a combination of techniques.
The tools that go farer also use a combination of techniques

Memory for state space generation (simple-lbs)

Scaling parameter

Memory (MB)

AlPiNa
ITS--Tools
Marcie
Neco
PNXDD
PNXDD, CPU/Memory over execution for cs–repetitions (25)
Marcie, CPU/Memory over execution for cs-repetitions (25)
AIPiNa, CPU/Memory over execution for cs-repetitions (25)
Clearly a CPU challenge
AlPiNa, CPU/Memory over execution for planning (fixed)
ITS–Tools, CPU/Memory over execution for planning (fixed)
Another CPU challenge
AIPiNa, CPU/Memory over execution for neo-election (2)
AIPiNa, CPU/Memory over execution for neo-election (3)

still CPU challenge
On formulas

It is impossible to really evaluate

- Charts have been generated but with no real meaning
- No execution chart (tracking bug)

On the number of evaluated reachability formulas

- LoLa-binstore is clearly better (LoLa-bloom has more fails)
- AlPiNa does not scale up well

On the number of evaluated structural formulas

- AlPiNa beats Helena (more formulas and less fails)

Let us note that sometimes tool diverge

- The vector of evaluated formula is not the same ;-

On the state space too

- Buts the notion of state (symbolic, explicit) may not be the same.
Concluding Remarks
Mitigated results for formulas
  - Lots of difficulties... and lessons learned
  - No much time left for analysis (and big data to go through)

MCC 2013 @ Petri Nets?
  - The team is ready to go
  - Need to provide more help to tools submitters
    - A way to execute a tool on the first instance of each model?

What to be proposed in MCC 2013 @ Petri Nets?
  - No more complex things (we must stabilize the procedure)
  - More memory (but 64bits VM then)
  - More models: models from 2012 and more?
  - A finer classification of properties
    - Bounds + Deadlocks + mixed
    - Satisfiable + Unsatisfiable
  - The «surprise model»
**Downloading Participating Tools**

- **AlPiNA - CUI, University of Geneva - Switzerland**
  - [http://cui.unige.ch/~buchs/Site/About_Me.html](http://cui.unige.ch/~buchs/Site/About_Me.html)

- **Crocodile - LIP6, Université P. & M. Curie - France**
  - [http://www.cosyverif.org](http://www.cosyverif.org) (as a part of the environment)

- **Helena - LIPN, Université Paris 13 - France**

- **ITS_Tools - LIP6, Université P. & M. Curie - France**
  - [http://ddd.lip6.fr](http://ddd.lip6.fr) and [http://www.cosyverif.org](http://www.cosyverif.org) (as a part of the environment)

- **LoLA Binstore - University of Rostock - Germany**
  - [http://www.informatik.uni-rostock.de/tpp/lola/](http://www.informatik.uni-rostock.de/tpp/lola/)

- **LoLA Bloom - University of Rostock - Germany**
  - [http://www.informatik.uni-rostock.de/tpp/lola/](http://www.informatik.uni-rostock.de/tpp/lola/)

- **Marcie - BTU-Cottbus - Germany**
  - [http://www-dssz.informatik.tu-cottbus.de/](http://www-dssz.informatik.tu-cottbus.de/)

- **Neco - IBISC, Université Evry val d’Essonne - France**
  - [www.ibisc.fr/~lfronc/](http://www.ibisc.fr/~lfronc/)

- **PNXDD - LIP6, Université P. & M. Curie - France**
  - [http://move.lip6.fr](http://move.lip6.fr) and [http://www.cosyverif.org](http://www.cosyverif.org) (as a part of the environment)

- **Sara - University of Rostock - Germany**
  - [http://www.informatik.uni-rostock.de/tpp/lola](http://www.informatik.uni-rostock.de/tpp/lola)