This form is a summary description of the model entitled "DiscoveryGPU" proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models are given together with property files (possibly, one per model instance) giving a set of properties to be checked on the model.

Description

This model describes the discovery protocol [1] used to dynamically detect the amount of thread workgroups that can be scheduled at the same time on a given GPU, for a given application. Each workgroup participate in a mutex-protected poll, which is closed once a workgroup is able to re-visit the poll. All workgroups that were able to participate in the poll are thus actually running in parallel on different hardware-level compute-units. As GPUs have non-preemptive scheduling, these discovered workgroups are able to safely participate in blocking synchronisation. This protocol is critical to enable safe inter-workgroup blocking synchronisation, which in turn can provide significant performance improvements in some applications.

The discovery protocol was formally specified using the LNT value-passing process calculus and analyzed using the verification tools available in the CADP toolbox. The collection of P/T nets was obtained from the LNT specifications of the protocol. Each LNT specification was translated automatically to LOTOS, and then to an interpreted Petri net using the CADP toolbox. Finally, a P/T net was obtained by stripping out all data-related information (variables, types, assignments, guards, etc.) from the interpreted Petri net, leading to a NUPN (Nested-Unit Petri Net) model translated to PNML using the CÆSAR.BDD tool.

Each instance of the model is parameterized by the number N of threads.

Each instance is also parameterized by its version V, which specifies how the NUPN has been produced from the LOTOS specification. V is either equal to "a" if the NUPN has been generated *after* applying all the structural and data-flow optimizations of the CÆSAR compiler for LOTOS, or to "b" if the NUPN has been generated *before* these optimizations.

References

[1] Tyler Sorensen, Alastair F. Donaldson, Mark Batty, Ganesh Gopalakrishnan, and Zvonimir Rakamaric. Portable Inter-workgroup Barrier Synchronisation for GPUs. In Proc. of the 31st Annual ACM SIGPLAN Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA'16), Amsterdam, The Netherlands, November 2016.

Scaling parameter

Parameter name	Parameter description	Chosen parameter values
(N, V)	N is the number of threads and V is the version defined above	$\{6, ..., 15\} \times \{a, b\}$

Model: DiscoveryGPU
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Hugues Evrard, Alastair Donaldson, and Tyler Sorensen
h.evrard@imperial.ac.uk

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Size of the model

Parameter	Number of places	Number of transitions	Number of arcs	Number of units	HWB code
$N = 06, V = a$	63	85	273	9	2–8–27
$N = 06, V = b$	184	194	503	15	7–8–44
$N = 07, V = a$	73	99	318	10	2–9–31
$N = 07, V = b$	212	224	582	17	8–9–50
$N = 08, V = a$	83	113	363	11	2–10–35
$N = 08, V = b$	240	254	661	19	9–10–56
$N = 09, V = a$	93	127	408	12	2–11–39
$N = 09, V = b$	268	284	740	21	10–11–62
$N = 10, V = a$	103	141	453	13	2–12–43
$N = 10, V = b$	296	314	819	23	11–12–68
$N = 11, V = a$	113	155	498	14	2–13–47
$N = 11, V = b$	324	344	898	25	12–13–74
$N = 12, V = a$	123	169	543	15	2–14–51
$N = 12, V = b$	352	374	977	27	13–14–80
$N = 13, V = a$	133	183	588	16	2–15–55
$N = 13, V = b$	380	404	1056	29	14–15–86
$N = 14, V = a$	143	197	633	17	2–16–59
$N = 14, V = b$	408	434	1135	31	15–16–92
$N = 15, V = a$	153	211	678	18	2–17–63
$N = 15, V = b$	436	464	1214	33	16–17–98

Structural properties

ordinary — *all arcs have multiplicity one* .... yes
simple free choice — *all transitions sharing a common input place have no other input place* .... no [a]
extended free choice — *all transitions sharing a common input place have the same input places* .... no [b]
state machine — *every transition has exactly one input place and exactly one output place* .... no [c]
marked graph — *every place has exactly one input transition and exactly one output transition* .... no [d]
connected — *there is an undirected path between every two nodes (places or transitions)* .... yes [e]
strongly connected — *there is a directed path between every two nodes (places or transitions)* .... no [f]
source place(s) — *one or more places have no input transitions* .... yes [g]
sink place(s) — *one or more places have no output transitions* .... ? [h]
source transition(s) — *one or more transitions have no input places* .... no [i]
sink transitions(s) — *one or more transitions have no output places* .... ? [j]
loop-free — *no transition has an input place that is also an output place* .... ? [k]
conservative — *for each transition, the number of input arcs equals the number of output arcs* .... no [l]
subconservative — *for each transition, the number of input arcs equals or exceeds the number of output arcs* ...... no [m]
nested units — *places are structured into hierarchically nested sequential units* [n] .... yes

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[a] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[b] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[c] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[d] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[e] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[f] from place 1 one cannot reach place 0.
[g] place 0 is a source place.
[h] stated by CÆSAR.BDD version 2.7 to be true on 10 instance(s) out of 20, and false on the remaining 10 instance(s).
[i] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[j] stated by CÆSAR.BDD version 2.7 to be true on 10 instance(s) out of 20, and false on the remaining 10 instance(s).
[k] stated by CÆSAR.BDD version 2.7 to be true on 10 instance(s) out of 20, and false on the remaining 10 instance(s).
[l] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[m] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[n] the definition of Nested-Unit Petri Nets (NUPN) is available from http://mcc.lip6.fr/nupn.php

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Behavioural properties

safe — *in every reachable marking, there is no more than one token on a place* ....yes [o]
dead place(s) — *one or more places have no token in any reachable marking* ....no [p]
dead transition(s) — *one or more transitions cannot fire from any reachable marking* ....no [q]
deadlock — *there exists a reachable marking from which no transition can be fired* ....? [r]
reversible — *from every reachable marking, there is a transition path going back to the initial marking* ....? [s]
live — *for every transition t, from every reachable marking, one can reach a marking in which t can fire* ....? [t]

Size of the marking graphs

Parameter	Number of reachable markings	Number of transition firings	Max. number of tokens per place	Max. number of tokens per marking
$N = 06, V = a$	1.77156e+06 [u]	?	1	8
$N = 06, V = b$	6.13871e+09 [v]	?	1	8
$N = 07, V = a$	1.94872e+07 [w]	?	1	9
$N = 07, V = b$	$\geq$ 1.59038e+11 [x]	?	1 [y]	9
$N = 08, V = a$	2.14359e+08 [z]	?	1	10
$N = 08, V = b$	$\geq$ 4.16622e+11 [aa]	?	1 [ab]	10
$N = 09, V = a$	2.35795e+09 [ac]	?	1	11
$N = 09, V = b$	$\geq$ 1.44163e+12 [ad]	?	1	11
$N = 10, V = a$	2.59374e+10 [ae]	?	1	12
$N = 10, V = b$	$\geq$ 5.47101e+12 [af]	?	1 [ag]	12
$N = 11, V = a$	2.85312e+11 [ah]	?	1	13
$N = 11, V = b$	$\geq$ 1.61943e+13 [ai]	?	1 [aj]	13
$N = 12, V = a$	3.13843e+12 [ak]	?	1	14
$N = 12, V = b$	$\geq$ 3.85496e+13 [al]	?	1 [am]	14
$N = 13, V = a$	3.45227e+13 [an]	?	1	15
$N = 13, V = b$	$\geq$ 7.55166e+13 [ao]	?	1 [ap]	15
$N = 14, V = a$	3.7975e+14 [aq]	?	1	16
$N = 14, V = b$	$\geq$ 1.23851e+14 [ar]	?	1 [as]	16
$N = 15, V = a$	4.17725e+15 [at]	?	1	17
$N = 15, V = b$	$\geq$ 4.73641e+14 [au]	?	1 [av]	17

[o] safe by construction – stated by the CÆSAR compiler.
[p] stated by CÆSAR.BDD version 3.3 on all 20 instances (10 values of N × 2 values of V).
[q] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of N × 2 values of V).
[r] stated by CÆSAR.BDD version 2.7 to be true on 11 instance(s) out of 20, and unknown on the remaining 9 instance(s).
[s] stated by CÆSAR.BDD version 2.7 to be false on 11 instance(s) out of 20, and unknown on the remaining 9 instance(s).
[t] stated by CÆSAR.BDD version 2.7 to be false on 11 instance(s) out of 20, and unknown on the remaining 9 instance(s).
[u] stated by CÆSAR.BDD version 2.7.
[v] stated by CÆSAR.BDD version 2.7.
[w] stated by CÆSAR.BDD version 2.7.
[x] stated by CÆSAR.BDD version 2.7.
[y] stated by the CÆSAR compiler.
[z] stated by CÆSAR.BDD version 2.7.
[aa] stated by CÆSAR.BDD version 2.7.
[ab] stated by the CÆSAR compiler.
[ac] stated by CÆSAR.BDD version 2.7.
[ad] stated by CÆSAR.BDD version 2.7.
[ae] stated by CÆSAR.BDD version 2.7.
[af] stated by CÆSAR.BDD version 2.7.
[ag] stated by the CÆSAR compiler.
[ah] stated by CÆSAR.BDD version 2.7.
[ai] stated by CÆSAR.BDD version 2.7.
[aj] stated by the CÆSAR compiler.
[ak] stated by CÆSAR.BDD version 2.7.
[al] stated by CÆSAR.BDD version 2.7.
[am] stated by the CÆSAR compiler.

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(an) stated by CÆSAR.BDD version 2.7.
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(au) stated by CÆSAR.BDD version 2.7.
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