Model: DiscoveryGPU
Type: P/T Net
Origin: Academic

since
MCC 2018

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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	$\{6, ..., 15\} \times \{a, b\}$

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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* .... ✔

simple free choice — *all transitions sharing a common input place have no other input place* .... ✗ [a]

extended free choice — *all transitions sharing a common input place have the same input places* .... ✗ [b]

state machine — *every transition has exactly one input place and exactly one output place* .... ✗ [c]

marked graph — *every place has exactly one input transition and exactly one output transition* .... ✗ [d]

connected — *there is an undirected path between every two nodes (places or transitions)* .... ✔ [e]

strongly connected — *there is a directed path between every two nodes (places or transitions)* .... ✗ [f]

source place(s) — *one or more places have no input transitions* .... ✔ [g]

sink place(s) — *one or more places have no output transitions* .... ? [h]

source transition(s) — *one or more transitions have no input places* .... ✗ [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* .... ✗ [l]

subconservative — *for each transition, the number of input arcs equals or exceeds the number of output arcs* ...... ✗ [m]

nested units — *places are structured into hierarchically nested sequential units* [n] .... ✔

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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* .... ✔ [(o)]
dead place(s) — *one or more places have no token in any reachable marking* .... ✘ [(p)]
dead transition(s) — *one or more transitions cannot fire from any reachable marking* .... ✘ [(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 $N \times 2$ values of V).
[(q)] stated by CÆSAR.BDD version 2.7 on all 20 instances (10 values of $N \times 2$ 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.
(ao) stated by CÆSAR.BDD version 2.7.
(ap) stated by the CÆSAR compiler.
(aq) stated by CÆSAR.BDD version 2.7.
(ar) stated by CÆSAR.BDD version 2.7.
(as) stated by the CÆSAR compiler.
(at) stated by CÆSAR.BDD version 2.7.
(au) stated by CÆSAR.BDD version 2.7.
(av) stated by the CÆSAR compiler.

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