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This form is a summary description of the model entitled "Erlangen Mainframe V2" 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 represents the Erlangen mainframe [1] [2] [3] [4], a multiprocessor system designed to serve two purposes: (i) it maintains an important database and therefore has to process transactions submitted by many *users*, and (ii) it is used for program development and has to provide computing capacity to *programmers* for compiling and testing their programs. In addition, two interesting features are present:

- *Failures* may cause system downtimes, by making the mainframe become unavailable until it is repaired.
- Two types of *priorities* are built into the system. Database users need immediate reaction, so they *explicitly* have priority over the jobs issued by programmers. Failures cannot be preempted, which implies that they are neither buffered nor delayed; thus, they *implicitly* have the highest priority and take down the system immediately, until repair.

The description of the mainframe is highly modular and hierarchical (see Fig. 1). On the topmost level, the system is the parallel composition of three parts, the *Loads*, the *Queues*, and the *Processors*:

- *Loads*: There are three different arrival streams that put load on the system, namely the database *users*, the *programmers*, and *failures*. Each of these arrival streams produces events according to a given arrival rate. This rate however is not constant, but is instead modelled to vary according to a so-called Markov Modulated Poisson Process e. This means that each arrival stream has multiple phases (as in morning-afternoon-evening-night), and changing the phase comes with a change in arrival rate. The phase changes are governed by yet another rate, and happen synchronously across the streams; this is achieved by synchronising the three load processes, that otherwise run independently in parallel, on the phase change.
- *Queues*: The mediation between the events arriving from the loads and the processors is handled by three queues. The *user_queue* buffers the jobs generated by database users; the *prog_queue* buffers the jobs generated by programmers; the *fail_queue* reacts to failure events by triggering repairs. The priority mechanisms discussed above are implemented using clever synchronisations, ensuring that programmer jobs are only served if no user jobs are pending. Both types of jobs are, of course, processed only if the mainframe is not in a failure state.
- *Processors*: This part of the mainframe represents a multiprocessor consisting of four identical processors that run in parallel. The processors synchronise altogether on failures and repairs, meaning that failures affect the entire system, halting all processors, until repair. The various interactions between the components described above (which will be represented by *processes* in our models) are shown in Fig. 1. Transitions performed simultaneously by multiple processes are modelled using *synchronisation*. In Fig. 1, the black bullets denote synchronisations, annotated by the number of processes participating and by an associated *action* (e.g., *prog_job* or *get_prog_job*). Furthermore, white triangles indicate situations where there is competition between several processes (here, always those modelling the four processors) to participate as a process in such a synchronisation.

The Erlangen mainframe was originally described using the TIPP process algebra [1] [2] and, more recently, using the LNT language [4]. The present model corresponds to version V2 of [4] and is an Interactive Markov chain, in which transitions carry either an event or a stochastic rate.

We provide 20 different instances of the Erlangen mainframe version V2, by varying the number P of processors between 1 and 14. When P is greater than 9, the size of the corresponding PNML files gets too large and exceeds the limits stated by the MCC rules. To avoid this issue, we reduce the number of transitions by replacing certain processors by simpler versions that only accept high priority *user_job* requests, while rejecting lower priority *prog_job* requests. Each instance is denoted by a tuple (V, P, C), where V is equal either to a ("after") or to b ("before"), depending whether the interpreted Petri net

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was reduced or not by application of various optimizations, where C (with $C \leq P$) is the number of "complete" processors that handle both requests, while $P - C$ is the number of simplified processors in each instance.

All these instances were originally expressed in LNT, a modern language that can be translated to LOTOS automatically. Each generated LOTOS specification was then translated to an interpreted Petri net using the CADP toolbox. A P/T net was then 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.

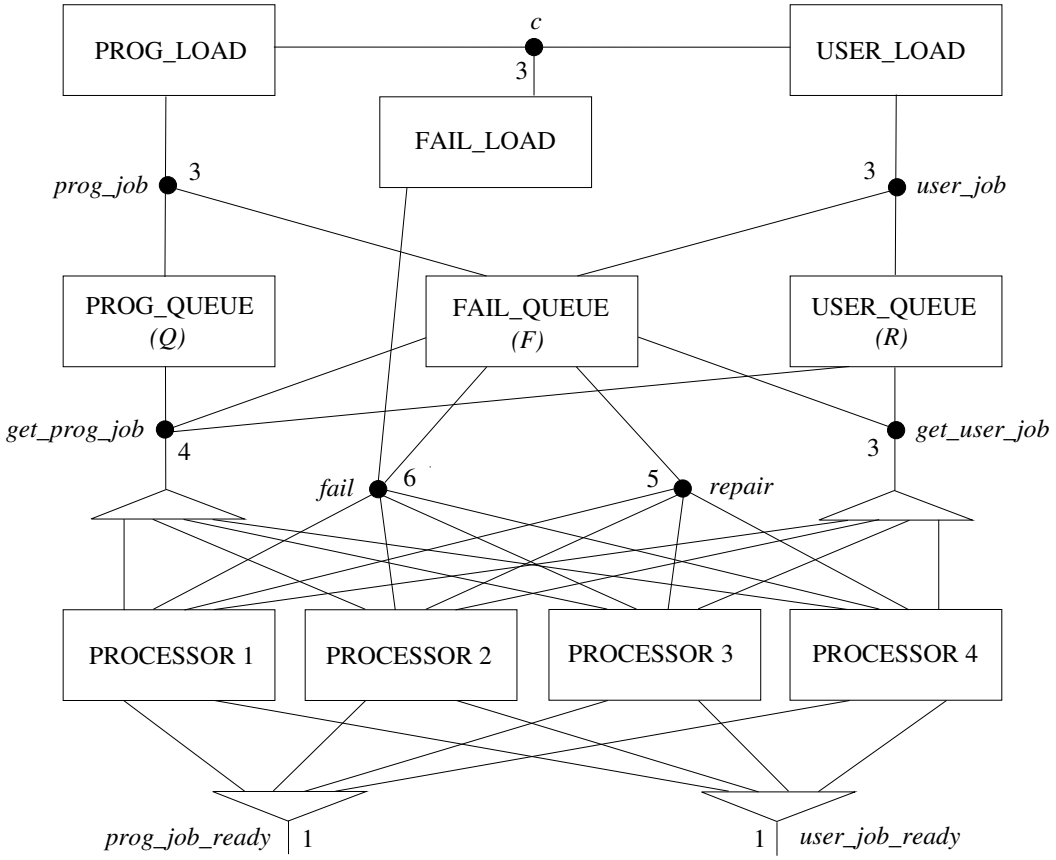

Figure 1: Representation of the original Erlangen mainframe (i.e., with $P = 4$ processors.)

References

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Scaling parameter

Parameter name	Parameter description	Chosen parameter values
(V, P, C)	V tells if the net was optimized or not; P is the total number of processors and C is the number of "complete" processors able to execute both types of jobs.	$\{a, b\} \times \{1...14\} \times \{1...9\}$

Size of the model

Parameter	Number of places	Number of transitions	Number of arcs	Number of units	HWB code
$V = a, P = 9, C = 9$	100	59159	1378263	17	2–16–55
$V = a, P = 10, C = 8$	102	78842	1994996	18	2–17–57
$V = a, P = 11, C = 6$	101	70091	1913335	19	2–18–58
$V = a, P = 12, C = 4$	100	62312	1825194	20	2–19–59
$V = a, P = 13, C = 2$	99	55397	1733021	21	2–20–60
$V = a, P = 14, C = 1$	101	73829	2458012	22	2–21–62
$V = b, P = 1, C = 1$	179	223	639	15	6–8–46
$V = b, P = 2, C = 2$	199	259	872	17	6–9–52
$V = b, P = 3, C = 3$	219	331	1585	19	6–10–58
$V = b, P = 4, C = 4$	239	511	3954	21	7–11–64
$V = b, P = 5, C = 5$	259	1015	11939	23	8–12–70
$V = b, P = 6, C = 6$	279	2491	38716	25	9–13–76
$V = b, P = 7, C = 7$	299	6883	127701	27	10–14–82
$V = b, P = 8, C = 8$	319	20023	420806	29	11–15–88
$V = b, P = 9, C = 9$	339	59407	1378759	31	12–16–94
$V = b, P = 10, C = 8$	345	79094	1995500	33	13–17–98
$V = b, P = 11, C = 6$	344	70343	1913839	35	14–18–101
$V = b, P = 12, C = 4$	343	62564	1825698	37	15–19–104
$V = b, P = 13, C = 2$	342	55649	1733525	39	16–20–107
$V = b, P = 14, C = 1$	348	74085	2458524	41	17–21–111

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]

[a] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[b] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[c] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[d] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[e] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[f] from place 1 one cannot reach place 0.
[g] place 0 is a source place.
[h] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[i] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
[j] stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).

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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)] ..... ✔

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* ..... ?
live — *for every transition t, from every reachable marking, one can reach a marking in which t can fire* ..... ?

(k) stated by CÆSAR.BDD version 3.7 to be true on 14 instance(s) out of 20, and false on the remaining 6 instance(s).
(l) stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
(m) stated by CÆSAR.BDD version 3.7 on all 20 instances (20 values of (V, P, C)).
(n) the definition of Nested-Unit Petri Nets (NUPN) is available from http://mcc.lip6.fr/nupn.php
(o) safe by construction – stated by the CÆSAR compiler.
(p) stated by CÆSAR.BDD version 3.7 to be false on 9 instance(s) out of 20, and unknown on the remaining 11 instance(s).
(q) stated by CÆSAR.BDD version 3.7 to be false on 9 instance(s) out of 20, and unknown on the remaining 11 instance(s).
(r) stated by CÆSAR.BDD version 3.7 to be false on 9 instance(s) out of 20, and unknown on the remaining 11 instance(s).

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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
$V = a, P = 9, C = 9$	1.58612e+09 [s]	?	1	16
$V = a, P = 10, C = 8$	2.84399e+09 [t]	?	1	17
$V = a, P = 11, C = 6$	3.06549e+09 [u]	?	1	18
$V = a, P = 12, C = 4$	3.30538e+09 [v]	?	1	19
$V = a, P = 13, C = 2$	3.56506e+09 [w]	?	1	20
$V = a, P = 14, C = 1$	6.40678e+09 [x]	?	1	21
$V = b, P = 1, C = 1$	1.02034e+09 [y]	?	1	8
$V = b, P = 2, C = 2$	1.52634e+10 [z]	?	1	9
$V = b, P = 3, C = 3$	2.40308e+11 [aa]	?	1	10
$V = b, P = 4, C = 4$	$\geq$ 2.47431e+12 [ab]	?	1 [ac]	11
$V = b, P = 5, C = 5$	$\geq$ 1.51247e+13 [ad]	?	1 [ae]	12
$V = b, P = 6, C = 6$	$\geq$ 1.11987e+14 [af]	?	1 [ag]	13
$V = b, P = 7, C = 7$	$\geq$ 3.54689e+14 [ah]	?	1 [ai]	14
$V = b, P = 8, C = 8$	$\geq$ 2.0783e+15 [aj]	?	1 [ak]	15
$V = b, P = 9, C = 9$	$\geq$ 4.61124e+15 [al]	?	1 [am]	16
$V = b, P = 10, C = 8$	$\geq$ 1.88172e+16 [an]	?	1 [ao]	17
$V = b, P = 11, C = 6$	$\geq$ 6.49117e+16 [ap]	?	1 [aq]	18
$V = b, P = 12, C = 4$	$\geq$ 2.12702e+17 [ar]	?	1 [as]	19
$V = b, P = 13, C = 2$	$\geq$ 1.65674e+18 [at]	?	1 [au]	20
$V = b, P = 14, C = 1$	$\geq$ 6.04621e+18 [av]	?	1 [aw]	21

[s] stated by CÆSAR.BDD version 3.7.
[t] stated by CÆSAR.BDD version 3.7.
[u] stated by CÆSAR.BDD version 3.7.
[v] stated by CÆSAR.BDD version 3.7.
[w] stated by CÆSAR.BDD version 3.7.
[x] stated by CÆSAR.BDD version 3.7.
[y] stated by CÆSAR.BDD version 3.7.
[z] stated by CÆSAR.BDD version 3.7.
[aa] stated by CÆSAR.BDD version 3.7.
[ab] stated by CÆSAR.BDD version 3.7.
[ac] stated by the CÆSAR compiler.
[ad] stated by CÆSAR.BDD version 3.7.
[ae] stated by the CÆSAR compiler.
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