Description

The Production cell has been introduced in [LL1995] as a case study to compare different formal methods with respect to their modelling and analysis features. It comes along with a specification of safety and progress properties, which the control software to be developed is expected to fulfill. The production cell sequentially processes plates, at an expected high throughput. The original (open) version of the production cell consists of two belts, a table, a robot with two arms, and a press. A crane has been artificially added, making the system self-contained and thus yielding a closed system. The closed systems differ by the number of plates circulating in the cell.

The Petri net has been first presented in [HD1995], and later published in [HDS1999]. At this time, we were not able to compute the complete marking graph for some versions of this model. Instead, partial order methods have been used to show liveness and for on-the-fly LTL model checking.

References


Scaling parameter

<table>
<thead>
<tr>
<th>Parameter name</th>
<th>Parameter description</th>
<th>Chosen parameter values</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N )</td>
<td>Initial number of plates in the production cell. For the open system, the initial number is zero. For the closed system, the number is fixed.</td>
<td>0, 1, 2, 3, 4, 5</td>
</tr>
</tbody>
</table>

Size of the model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number of places</th>
<th>Number of transitions</th>
<th>Number of arcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N = 0 )</td>
<td>198</td>
<td>176</td>
<td>730</td>
</tr>
<tr>
<td>( N = 1, 2, 3, 4, 5 )</td>
<td>231</td>
<td>202</td>
<td>846</td>
</tr>
</tbody>
</table>

Structural properties

- **free choice** — all (different) transitions with a shared input place have no other input place
- **marked graph** — every place has exactly one input transition and exactly one output transition
- **connected** — there is a undirected path between every two nodes (places or transitions)
- **strongly connected** — there is a directed path between every two nodes (places or transitions)
- **source place(s)** — one or more places have no input transitions
- **sink place(s)** — one or more places have no output transitions
- **source transition(s)** — one or more transitions have no input places
- **sink transition(s)** — one or more transitions have no output places
- **loop-free** — no transition has an input place that is also an output place
- **conservative** — for each transition, the number of input arcs equals the number of output arcs
- **subconservative** — for each transition, the number of input arcs equals or exceeds the number of output arcs

Behavioural properties

- **safe** — in every reachable marking, there is no more than one token on a place
- **deadlock** — there exists a reachable marking from which no transition can be fired
- **reversible** — from every reachable marking, there is a transition path going back to the initial marking
- **quasi-live** — for every transition \( t \), there exists a reachable marking in which \( t \) can fire

(a) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(b) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(c) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(d) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(e) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(f) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(g) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(h) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(i) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(j) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(k) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(l) stated by CÆSAR.BDD version 2.0 on all 6 instances (0, 1, 2, 3, 4, and 5).
(m) stated by CÆSAR.BDD version 2.0 to be false for \( N = 1 \) and true on the remaining 5 instance(s).
live — for every transition $t$, from every reachable marking, one can reach a marking in which $t$ can fire ..............? (p)

Size of the marking graphs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Number of reachable markings</th>
<th>Number of transition firings</th>
<th>Max. number of tokens per place</th>
<th>Max. number of tokens per marking</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N = 0$</td>
<td>2,776,936 ($^q$)</td>
<td>?</td>
<td>1</td>
<td>$\in [32, 198]$ ($^r$)</td>
</tr>
<tr>
<td>$N = 1$</td>
<td>25,632 ($^t$)</td>
<td>?</td>
<td>1</td>
<td>$\in [36, 231]$</td>
</tr>
<tr>
<td>$N = 2$</td>
<td>349,874 ($^u$)</td>
<td>?</td>
<td>1</td>
<td>$\in [36, 231]$</td>
</tr>
<tr>
<td>$N = 3$</td>
<td>1,465,206 ($^w$)</td>
<td>?</td>
<td>1</td>
<td>$\in [36, 231]$</td>
</tr>
<tr>
<td>$N = 4$</td>
<td>2,409,739 ($^v$)</td>
<td>?</td>
<td>1</td>
<td>$\in [36, 231]$</td>
</tr>
<tr>
<td>$N = 5$</td>
<td>1,657,242 ($^w$)</td>
<td>?</td>
<td>1</td>
<td>$\in [36, 231]$</td>
</tr>
</tbody>
</table>

Other properties

CPI (Covered by P-Invariants), CTI (Covered by T-Invariants). There are meaningful CTL/LTL properties available, documented in [HD1995].

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(p) true except for $N=1$.
(q) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.
(r) lower and upper bounds given by the number of initial tokens and the number of places.
(s) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.
(t) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.
(u) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.
(v) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.
(w) Computed by Marcie on 2013-12-14 – confirmed by CESAR.BDD version 2.0.