This form is a summary description of the model entitled “Angiogenesis” 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

Angiogenesis, defined as the formation of new vessels from the existing ones, is a topic of great interest in all areas of human biology, particularly to scientists studying vascular development, vascular malformation and cancer biology. Angiogenesis is a complex process involving the activities of many growth factors and relative receptors, which trigger several signaling pathways resulting in different cellular responses. The Petri net was introduced in [1] and refined in [2].

In March 2020, Pierre Bouvier and Hubert Garavel provided a decomposition of the only one-safe instance of this model into a network of communicating automata. This network is expressed as a Nested-Unit Petri Net (NUPN) that can be found in the “toolspecific” section of the corresponding PNML file.

Graphical representation with parameter N. The gray coloured places are logic/fusion places.
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 tokens on places Akt, Enz, Gab1, KdStar, P3k, Pg, Pip2 and Pten</td>
<td>1, 5, 10, 15, 20, 25, 50</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>
<th>Number of units</th>
<th>HWB code</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N = 1 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>9</td>
<td>1–8–16</td>
</tr>
<tr>
<td>( N = 5 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
<tr>
<td>( N = 10 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
<tr>
<td>( N = 15 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
<tr>
<td>( N = 20 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
<tr>
<td>( N = 25 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
<tr>
<td>( N = 50 )</td>
<td>39</td>
<td>64</td>
<td>185</td>
<td>–</td>
<td>–39</td>
</tr>
</tbody>
</table>

Structural properties

ordinary — all arcs have multiplicity one  
(a) stated by CÆSAR.BDD version 3.3 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

simple free choice — all transitions sharing a common input place have no other input place  
(b) transitions “t0” and “k3” share a common input place “Gab1”, but only the former transition has input place “KdStar”.

extended free choice — all transitions sharing a common input place have the same input places  
(c) 57 transitions are not of a state machine, e.g., transition “t0”.

state machine — every transition has exactly one input place and exactly one output transition  
(d) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

marked graph — every place has exactly one input transition and exactly one output transition  
(e) from place “AktStar” one cannot reach place “Akt”.

connected — there is an undirected path between every two nodes (places or transitions)  
(f) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

strongly connected — there is a directed path between every two nodes (places or transitions)  
(g) place “AktStar” is a sink place.

source place(s) — one or more places have no input transitions  
(h) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

sink place(s) — one or more places have no output transitions  
(i) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

source transition(s) — one or more transitions have no input places  
(j) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

sink transition(s) — one or more transitions have no output places  
(k) stated by CÆSAR.BDD version 2.0 on all 7 instances (1, 5, 10, 15, 20, 25, and 50).

loop-free — no transition has an input place that is also an output place  
(l) 57 transitions are not conservative, e.g., transition “t0”.

conservative — for each transition, the number of input arcs equals the number of output arcs  
(m) 33 transitions are not subconservative, e.g., transition “t1”.
nested units — places are structured into hierarchically nested sequential units\(^{(n)}\)...?\(^{(o)}\)

Behavioural properties

safe — in every reachable marking, there is no more than one token on a place ...?\(^{(p)}\)
dead place(s) — one or more places have no token in any reachable marking ...?\(^{(q)}\)
dead transition(s) — one or more transitions cannot fire from any reachable marking ...?\(^{(r)}\)
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

<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 = 1)</td>
<td>110 (^{(u)})</td>
<td>288 (^{(v)})</td>
<td>(N (^{(w)}))</td>
<td>8 (^{(x)})</td>
</tr>
<tr>
<td>(N = 5)</td>
<td>(4.2735E+7 (^{(y)}))</td>
<td>(4.8687E+8 (^{(z)}))</td>
<td>(N (^{(aa)}))</td>
<td>40 (^{(ab)})</td>
</tr>
<tr>
<td>(N = 10)</td>
<td>(8.2265E+11 (^{(ac)}))</td>
<td>(1.5636E+13 (^{(ad)}))</td>
<td>(N (^{(ae)}))</td>
<td>(80 (^{(af)}))</td>
</tr>
<tr>
<td>(N = 15)</td>
<td>(11153896669107 (^{(bg)}))</td>
<td>?</td>
<td>(N (^{(ah)}))</td>
<td>(\geq 120)</td>
</tr>
<tr>
<td>(N = 20)</td>
<td>(351820947967344849 (^{(bh)}))</td>
<td>?</td>
<td>(N (^{(ai)}))</td>
<td>(\geq 160)</td>
</tr>
<tr>
<td>(N = 25)</td>
<td>(43090329340850957348 (^{(bi)}))</td>
<td>?</td>
<td>(N (^{(aj)}))</td>
<td>(\geq 200)</td>
</tr>
<tr>
<td>(N = 50)</td>
<td>?</td>
<td>?</td>
<td>(N (^{(ak)}))</td>
<td>?</td>
</tr>
</tbody>
</table>

\(^{(a)}\) the definition of Nested-Unit Petri Nets (NUPN) is available from [http://mcc.lip6.fr/nupn.php](http://mcc.lip6.fr/nupn.php)
\(^{(b)}\) stated by CÆSAR.BDD version 3.3 to be true on 1 instance(s) out of 7, and false on the remaining 6 instance(s).
\(^{(c)}\) stated by CÆSAR.BDD version 2.0 to be true on 1 instance(s) out of 7, and false on the remaining 6 instance(s).
\(^{(d)}\) stated by CÆSAR.BDD version 3.3 to be true on 1 instance(s) out of 7, and unknown on the remaining 6 instance(s).
\(^{(e)}\) Checked by Marcie on 2013-12-13; confirmed at MCC’2014 by Tapaal on 2 instances and by Lola on 5 instances.
\(^{(f)}\) has dead states.
\(^{(g)}\) has dead states.
\(^{(h)}\) given in [2] and computed by Marcie on 2013-12-13; confirmed at MCC’2014 by Marcie, PNMC, PNXDD, Stratagem, and Tapaal.
\(^{(i)}\) computed at MCC’2014 by Marcie.
\(^{(j)}\) computed at MCC’20214 by Marcie, PNMC, and Tapaal.
\(^{(k)}\) computed at MCC’2014 by Marcie, PNMC, and Tapaal.
\(^{(l)}\) exact value 42734935 given in [2] and computed by Marcie on 2013-12-13; confirmed at MCC’2014 by Marcie, PNMC, and PNXDD.
\(^{(m)}\) computed at MCC’2014 by Marcie.
\(^{(n)}\) confirmed at MCC’2014 by Marcie and PNMC.
\(^{(o)}\) computed at MCC’2014 by Marcie and PNMC.
\(^{(p)}\) computed at MCC’2014 by Marcie and PNMC.
\(^{(q)}\) exact value 8224558855495 computed by Marcie on 2013-12-13; confirmed at MCC’2014 by Marcie, PNMC, and PNXDD.
\(^{(r)}\) computed at MCC’2014 by Marcie.
\(^{(s)}\) confirmed at MCC’2014 by Marcie and PNMC.
\(^{(t)}\) computed at MCC’2014 by Marcie and PNMC.
\(^{(u)}\) computed by Marcie on 2013-12-13.
\(^{(v)}\) computed by Marcie on 2013-12-13.
\(^{(w)}\) computed by Marcie on 2013-12-13.
\(^{(x)}\) computed by Marcie on 2013-12-13.
\(^{(y)}\) computed by Marcie on 2013-12-13.