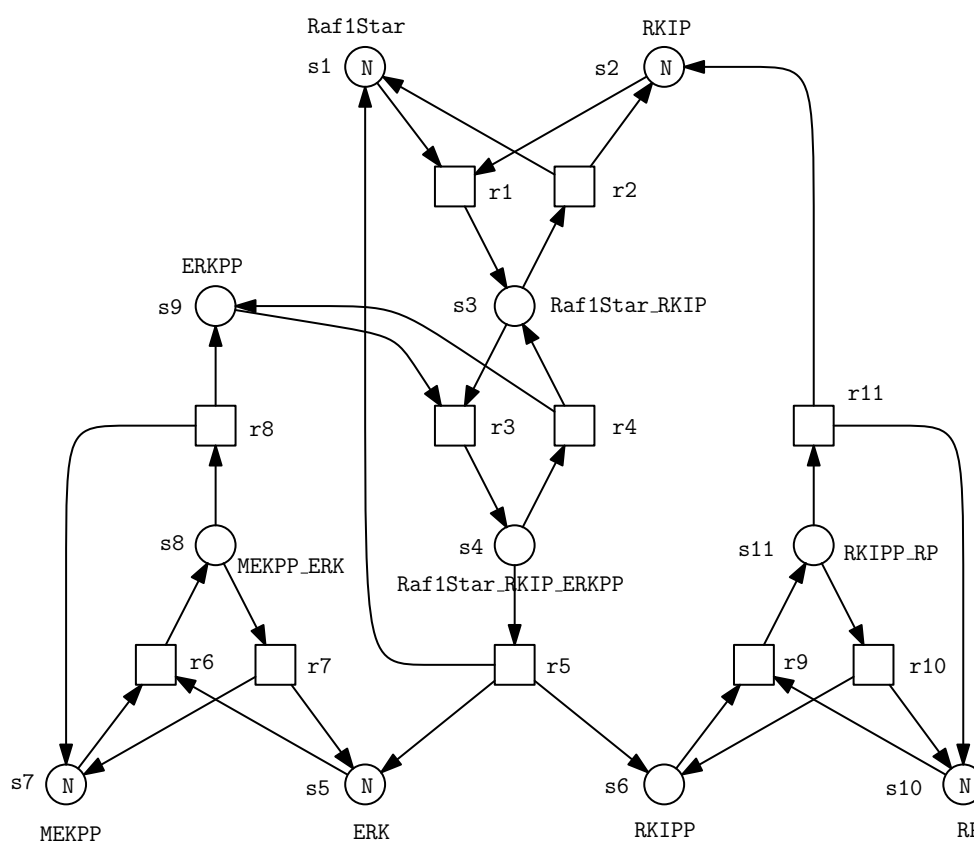


This form is a summary description of the model entitled “ERK” proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models are given together with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

Description

ERK is a short name for “RKIP/MEK-ERK signalling pathway”. The RKIP inhibited ERK pathway published in [CSK+03], discussed as qualitative and continuous Petri nets in [GH06], and as three related Petri net models in [HDG10].

In March 2020, Pierre Bowvier 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

References

- CSK+03** K.-H. Cho, S.-Y. Shin, H.-W. Kim, O. Wolkenhauer, B. McFerran and W. Kolch: Mathematical modeling of the influence of RKIP on the ERK signaling pathway; In CMSB 2003, LNCS 2602, Springer, pages 127–141, 2003.
- GH06** Gilbert, D. and Heiner, M.: From Petri nets to differential equations - an integrative approach for biochemical network analysis; In Proc. ICATPN 2006, LNCS 4024, Springer, pages 181–200, 2006.
- HDG10** M. Heiner, R. Donaldson and D. Gilbert: Petri Nets for Systems Biology; In Symbolic Systems Biology: Theory and Methods, (MS Iyengar, Ed.), Jones & Bartlett Learning, LCC, pages 61–97, 2010.

Scaling parameter

| Parameter name | Parameter description | Chosen parameter values |
|----------------|--|---------------------------------|
| N | initial number of tokens on places ERK, MEKPP, Raf1Star, RKIP and RP | 1, 10, 100, 1000, 10000, 100000 |

Size of the model

| Parameter | Number of places | Number of transitions | Number of arcs | Number of units | HWB code |
|--------------|------------------|-----------------------|----------------|-----------------|----------|
| $N = 1$ | 11 | 11 | 34 | 6 | 1-5-8 |
| $N = 10$ | 11 | 11 | 34 | - | --11 |
| $N = 100$ | 11 | 11 | 34 | - | --11 |
| $N = 1000$ | 11 | 11 | 34 | - | --11 |
| $N = 10000$ | 11 | 11 | 34 | - | --11 |
| $N = 100000$ | 11 | 11 | 34 | - | --11 |

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⁾ ? (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)

(a) there is an arc from place “Raf1Star_RKIP” (which has 2 outgoing transitions) to transition “r3” (which has 2 input places).
 (b) transitions “r3” and “r2” share a common input place “Raf1Star_RKIP”, but only the former transition has input place “ERKPP”.
 (c) 11 transitions are not of a state machine, e.g., transition “r1”.
 (d) stated by CÆSAR.BDD version 3.3 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (e) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (f) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (g) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (h) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (i) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (j) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (k) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).
 (l) 11 transitions are not conservative, e.g., transition “r1”.
 (m) 7 transitions are not subconservative, e.g., transition “r2”.
 (n) the definition of Nested-Unit Petri Nets (NUPN) is available from <http://mcc.lip6.fr/nupn.php>
 (o) stated by CÆSAR.BDD version 3.3 to be true on 1 instance(s) out of 6, and false on the remaining 5 instance(s).
 (p) stated by CÆSAR.BDD version 2.0 to be true for $N = 1$, and false on the remaining 5 instance(s).
 (q) stated by CÆSAR.BDD version 3.3 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).

- dead transition(s)** — *one or more transitions cannot fire from any reachable marking* ✗^(r)
deadlock — *there exists a reachable marking from which no transition can be fired* ✗^(s)
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* ✓

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 |
|----------------|--|------------------------------|---------------------------------|-----------------------------------|
| $N = 1$ | 13 ^(t) | 30 ^(u) | N ^(v) | $5 \cdot N$ ^(w) |
| $N = 10$ | 47 047 ^(x) | 372 372 ^(y) | N ^(z) | $5 \cdot N$ ^(aa) |
| $N = 100$ | 1.5914E+10 ^(ab) | 1.68445E+11 ^(ac) | N ^(ad) | $5 \cdot N$ ^(ae) |
| $N = 1\,000$ | 14 081 614 073 878 351 ^(af) | ? | N | $5 \cdot N$ |
| $N = 10\,000$ | ? | ? | N | $5 \cdot N$ |
| $N = 100\,000$ | ? | ? | N | $5 \cdot N$ |

^(r) stated by CÆSAR.BDD version 2.0 on all 6 instances (1, 10, 10², 10³, 10⁴, and 10⁵).

^(s) confirmed by CÆSAR.BDD version 2.0 to be false for $N = 1$, and unknown on the remaining 5 instance(s); confirmed at MCC'2014 by Lola on all 6 instances and Tapaal on 2 instances.

^(t) confirmed at MCC'2014 by Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

^(u) computed at MCC'2014 by Marcie.

^(v) confirmed at MCC'2014 by Marcie, PNMC, and Tapaal.

^(w) confirmed at MCC'2014 Marcie, PNMC, and Tapaal.

^(x) computed by Marcie on 2013-12-13; confirmed at MCC'2014 by Marcie, PNMC, PNXDD, Stratagem, and Tapaal.

^(y) computed at MCC'2014 by Marcie.

^(z) confirmed at MCC'2014 by Marcie, PNMC, and Tapaal.

^(aa) confirmed at MCC'2014 by Marcie, PNMC, and Tapaal.

^(ab) exact value 15 914 114 086 computed by Marcie on 2013-12-13; confirmed at MCC'2014 by Marcie and PNMC.

^(ac) computed at MCC'2014 by Marcie.

^(ad) confirmed at MCC'2014 by Marcie and PNMC.

^(ae) confirmed at MCC'2014 by Marcie and PNMC.

^(af) computed by Marcie on 2013-12-13.