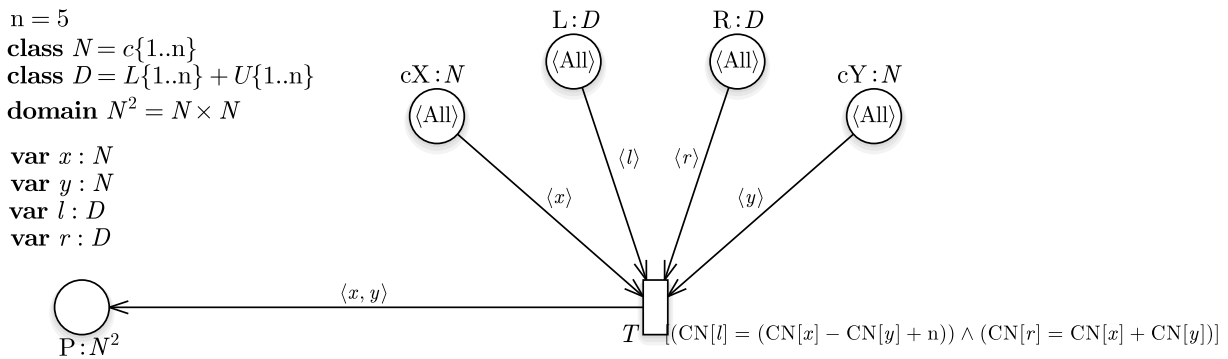


*This form is a summary description of the model entitled “NQueens” proposed for the Model Checking Contest @ Petri Nets. Models can be given in several instances parameterized by scaling parameters. Colored nets can be accompanied by one or many equivalent, unfolded P/T nets. Models are given together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

## Description

The model represents the classical  $n$ -queens problem. The Petri net represents a  $n \times n$  chessboard where the player must position  $n$  queens so that no two queens threaten each other. The model works by positioning one queen at a time, until either a valid solution is found (i.e. all  $n$  queens are placed), or some constraint is violated. Place  $P$  represents the chessboard. Places  $cX$  and  $cY$  represent the constraints of having at most one queen for each row/column. Places  $L$  and  $R$  represent the constraints of having at most one queen for each left/right diagonals. Transition  $T$  models the process of putting a new queen piece to the chessboard in position  $x, y$ . The number of solutions is found by counting all reachable states where  $\sum_{i=1}^n \sum_{j=1}^n cX_i = 0 \wedge cY_i = 0$ .

In March 2020, Pierre Bouvier and Hubert Garavel provided a decomposition of three instances of this model into networks of communicating automata. Each network is expressed as a Nested-Unit Petri Net (NUPN) that can be found, for each instance, in the “toolspecific” section of the corresponding PNML file. In April 2021, Pierre Bouvier decomposed all the remaining instances of this model.



Graphical representation for  $n = 5$  in the colored version of the model

## Scaling parameter

Parameter name	Parameter description	Chosen parameter values
$n$	The size of the chessboard.	5, 8, 10, 15, 20, 25, 30

## Size of the model

Parameter	Number of places	Number of transitions	Number of arcs	Number of units	HWB code
$n$	$n^2 + 6n$	$n^2$	$5n^2$	?	1-?-?
$n = 5$	55	25	125	32	1-31-41
$n = 8$	112	64	320	49	1-48-72
$n = 10$	160	100	500	61	1-60-96
$n = 12$	216	144	720	73	1-72-106
$n = 15$	315	225	1125	91	1-90-133
$n = 20$	520	400	2000	121	1-120-198
$n = 25$	775	625	3125	151	1-150-248
$n = 30$	1080	900	4500	181	1-180-298

## Structural properties

<b>ordinary</b> — all arcs have multiplicity one .....	✓
<b>simple free choice</b> — all transitions sharing a common input place have no other input place .....	✗ (a)
<b>extended free choice</b> — all transitions sharing a common input place have the same input places .....	✗ (b)
<b>state machine</b> — every transition has exactly one input place and exactly one output place .....	✗ (c)
<b>marked graph</b> — every place has exactly one input transition and exactly one output transition .....	✗ (d)
<b>connected</b> — there is an undirected path between every two nodes (places or transitions) .....	✗ (e)
<b>strongly connected</b> — there is a directed path between every two nodes (places or transitions) .....	✗ (f)
<b>source place(s)</b> — one or more places have no input transitions .....	✓ (g)
<b>sink place(s)</b> — one or more places have no output transitions .....	✓ (h)
<b>source transition(s)</b> — one or more transitions have no input places .....	✗ (i)
<b>sink transitions(s)</b> — one or more transitions have no output places .....	✗ (j)
<b>loop-free</b> — no transition has an input place that is also an output place .....	✓ (k)
<b>conservative</b> — for each transition, the number of input arcs equals the number of output arcs .....	✗ (l)
<b>subconservative</b> — for each transition, the number of input arcs equals or exceeds the number of output arcs .....	✓ (m)
<b>nested units</b> — places are structured into hierarchically nested sequential units <sup>(n)</sup> .....	✓

## Behavioural properties

<b>safe</b> — in every reachable marking, there is no more than one token on a place .....	✓ (o)
<b>dead place(s)</b> — one or more places have no token in any reachable marking .....	? (p)
<b>dead transition(s)</b> — one or more transitions cannot fire from any reachable marking .....	? (q)
<b>deadlock</b> — there exists a reachable marking from which no transition can be fired .....	✓ (r)
<b>reversible</b> — from every reachable marking, there is a transition path going back to the initial marking .....	✗ (s)
<b>live</b> — for every transition $t$ , from every reachable marking, one can reach a marking in which $t$ can fire .....	✗ (t)

(a) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(b) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(c) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(d) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(e) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(f) the net is not connected and, thus, not strongly connected.

(g) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(h) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(i) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(j) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(k) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(l) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(m) stated by [CÆSAR.BDD](#) version 2.8 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(n) the definition of Nested-Unit Petri Nets (NUPN) is available from <http://mcc.lip6.fr/nupn.php>

(o) stated by [CÆSAR.BDD](#) version 3.5 on all 8 instances ((5, 8, 10, 15, 20, 25, and 30)).

(p) stated by [CÆSAR.BDD](#) version 3.3 to be false on 2 instance(s) out of 8, and unknown on the remaining 6 instance(s).

(q) stated by [CÆSAR.BDD](#) version 3.3 to be false on 2 instance(s) out of 8, and unknown on the remaining 6 instance(s).

(r) stated by [CÆSAR.BDD](#) version 2.8 to be true on 2 instance(s) out of 8, and unknown on the remaining 6 instance(s).

(s) stated by [CÆSAR.BDD](#) version 2.8 to be false on 2 instance(s) out of 8, and unknown on the remaining 6 instance(s).

(t) stated by [CÆSAR.BDD](#) version 2.8 to be false on 2 instance(s) out of 8, and unknown on the remaining 6 instance(s).

## 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
$n = 5$	462 <sup>(u)</sup>	1295	1	30 <sup>(v)</sup>
$n = 8$	118,969 <sup>(w)</sup>	564,880	1	48 <sup>(x)</sup>
$n = 10$	?	?	1 <sup>(y)</sup>	60 <sup>(z)</sup>
$n = 12$	?	?	1 <sup>(aa)</sup>	72 <sup>(ab)</sup>
$n = 15$	?	?	1 <sup>(ac)</sup>	90 <sup>(ad)</sup>
$n = 20$	?	?	1 <sup>(ae)</sup>	120 <sup>(af)</sup>
$n = 25$	?	?	1 <sup>(ag)</sup>	150 <sup>(ah)</sup>
$n = 30$	?	?	1 <sup>(ai)</sup>	180 <sup>(aj)</sup>

---

<sup>(u)</sup> stated by [CÆSAR.BDD](#) version 2.8.

<sup>(v)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(w)</sup> confirmed by [CÆSAR.BDD](#) version 3.3.

<sup>(x)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(y)</sup> stated by [CÆSAR.BDD](#) version 3.3.

<sup>(z)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(aa)</sup> the instance is safe.

<sup>(ab)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(ac)</sup> the instance is safe.

<sup>(ad)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(ae)</sup> the instance is safe.

<sup>(af)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(ag)</sup> the instance is safe.

<sup>(ah)</sup> number of initial tokens, because the net is sub-conservative.

<sup>(ai)</sup> the instance is safe.

<sup>(aj)</sup> number of initial tokens, because the net is sub-conservative.