

*This form is a summary description of the model entitled “DLCshifumi” 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 DLC compiler [2,3,4] has been developed to automatically generate a distributed implementation of a concurrent system described using the LNT language. The implementation generated by DLC consists of processes (in the C language) executing in parallel and connected with POSIX sockets. These processes synchronize together and communicate using a distributed protocol for value-passing multiway rendezvous. Besides generating a distributed implementation, the DLC compiler can also produce an LNT model of this implementation by combining the source LNT description of the system with the protocol itself [1]. This implementation model can then be used to check the correctness of the distributed implementation using the [CADP](#) toolbox.

This collection of P/T nets was obtained by using DLC to generate implementation models to various instances of the “rock-paper-scissor” game (also known as *shifumi*). This game can be extended to  $N \geq 2$  players who interact using 2 among  $N$  rendezvous. Each generated LNT model was translated automatically to LOTOS, and then to an interpreted Petri net using the [CADP](#) toolbox. Finally, a P/T net was 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.

Each instance of the model is parameterized by the number  $N$  of players.

Each instance is also parameterized by its version  $V$ , which specifies how the NUPN has been produced from the LOTOS specification.  $V$  is either equal to “a” if the NUPN has been generated *after* applying all the structural and data-flow optimizations of the [CÆSAR](#) compiler for LOTOS, or to “b” if the NUPN has been generated *before* these optimizations.

## References

- [1] Hugues Evrard and Frédéric Lang. *Formal Verification of Distributed Branching Multiway Synchronization Protocols*. Proceedings of the IFIP Joint International Conference on Formal Techniques for Distributed Systems (FORTE/FMOODS’2013), Florence, Italy. LNCS 7892, pages 146-160, Springer, 2013. Available from <https://hal.inria.fr/hal-00818788>.
- [2] Hugues Evrard and Frédéric Lang. *Automatic Distributed Code Generation from Formal Models of Asynchronous Concurrent Processes*. Proceedings of the 23rd Euromicro International Conference on Parallel, Distributed and Network-based Processing, Special Session on Formal Approaches to Parallel and Distributed Systems (PDP/4PAD’2015), Turku, Finland. IEEE, 2015. Available from <https://hal.inria.fr/hal-01086522>.
- [3] Hugues Evrard. *DLC: Compiling a Concurrent System Formal Specification to a Distributed Implementation*. Proceedings of the 22nd International Conference on Tools and Algorithms for the Construction and Analysis of Systems (TACAS’2016), Eindhoven, Netherlands. Springer, 2016.
- [4] <http://hevrard.org/DLC>

## Scaling parameter

| Parameter name | Parameter description   | Chosen parameter values             |
|----------------|---|-------------------------------------|
| $(N, V)$       | $N$ is the number of players and $V$ is the version defined above | $\{2, 3, 4, 5, 6\} \times \{a, b\}$ |

## Size of the model

| Parameter      | Number of places | Number of transitions | Number of arcs | Number of units | HWB code        |
|----------------|------------------|-----------------------|----------------|-----------------|-----------------|
| $N = 2, V = a$ | 188              | 888                   | 3166           | 80              | 2-79-116        |
| $N = 2, V = b$ | 2483             | 3183                  | 7756           | 157             | 63-79-445       |
| $N = 3, V = a$ | 544              | 3097                  | 11545          | 283             | 2-282-370       |
| $N = 3, V = b$ | 7058             | 9611                  | 24573          | 563             | 241-282-1535    |
| $N = 4, V = a$ | 1178             | 7504                  | 28610          | 692             | 2-691-854       |
| $N = 4, V = b$ | 15015            | 21341                 | 56284          | 1381            | 613-691-3691    |
| $N = 5, V = a$ | 2162             | 14865                 | 57457          | 1379            | 2-1378-1640     |
| $N = 5, V = b$ | 27146            | 39849                 | 107425         | 2755            | 1251-1378-7273  |
| $N = 6, V = a$ | 3568             | 25936                 | 101182         | 2416            | 2-2415-2800     |
| $N = 6, V = b$ | 44243            | 66611                 | 182532         | 4829            | 2227-2415-12641 |

## 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<sup>(n)</sup> ..... ✓

## 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)

(a) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(b) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(c) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(d) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(e) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(f) from place 1 one cannot reach place 0.

(g) place 0 is a source place.

(h) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(i) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(j) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(k) stated by [CÆSAR.BDD](#) version 2.6 to be true on 5 instance(s) out of 10, and false on the remaining 5 instance(s).

(l) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(m) stated by [CÆSAR.BDD](#) version 2.6 on all 10 instances (5 values of  $N \times 2$  values of  $V$ ).

(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 3.3 to be false on 5 instance(s) out of 10, and unknown on the remaining 5 instance(s).

(q) stated by [CÆSAR.BDD](#) version 3.3 to be false on 5 instance(s) out of 10, and unknown on the remaining 5 instance(s).

**deadlock** — there exists a reachable marking from which no transition can be fired .....? <sup>(r)</sup>  
**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 reach-able markings | Number of tran-sition firings | Max. number of tokens per place | Max. number of tokens per marking |
|----------------|-------------------------------|-------------------------------|---------------------------------|-----------------------------------|
| $N = 2, V = a$ | 4.74756e+14 <sup>(s)</sup>    | ?                             | 1                               | 79                                |
| $N = 2, V = b$ | ?                             | ?                             | 1 <sup>(t)</sup>                | 79                                |
| $N = 3, V = a$ | 9.09544e+35 <sup>(u)</sup>    | ?                             | 1                               | 282                               |
| $N = 3, V = b$ | ?                             | ?                             | 1 <sup>(v)</sup>                | 282                               |
| $N = 4, V = a$ | 2.41187e+67 <sup>(w)</sup>    | ?                             | 1                               | 691                               |
| $N = 4, V = b$ | ?                             | ?                             | 1 <sup>(x)</sup>                | 691                               |
| $N = 5, V = a$ | 8.85236e+108 <sup>(y)</sup>   | ?                             | 1                               | 1378                              |
| $N = 5, V = b$ | ?                             | ?                             | 1 <sup>(z)</sup>                | 1378                              |
| $N = 6, V = a$ | ?                             | ?                             | 1 <sup>(aa)</sup>               | 2415                              |
| $N = 6, V = b$ | ?                             | ?                             | 1 <sup>(ab)</sup>               | 2415                              |

<sup>(r)</sup> stated by CÆSAR.BDD version 2.6 to be false on 5 instance(s) out of 10, and unknown on the remaining 5 instance(s).  
<sup>(s)</sup> stated by CÆSAR.BDD version 2.6.  
<sup>(t)</sup> stated by the CÆSAR compiler.  
<sup>(u)</sup> stated by CÆSAR.BDD version 2.6.  
<sup>(v)</sup> stated by the CÆSAR compiler.  
<sup>(w)</sup> stated by CÆSAR.BDD version 2.6.  
<sup>(x)</sup> stated by the CÆSAR compiler.  
<sup>(y)</sup> stated by CÆSAR.BDD version 3.3.  
<sup>(z)</sup> stated by the CÆSAR compiler.  
<sup>(aa)</sup> stated by the CÆSAR compiler.  
<sup>(ab)</sup> stated by the CÆSAR compiler.