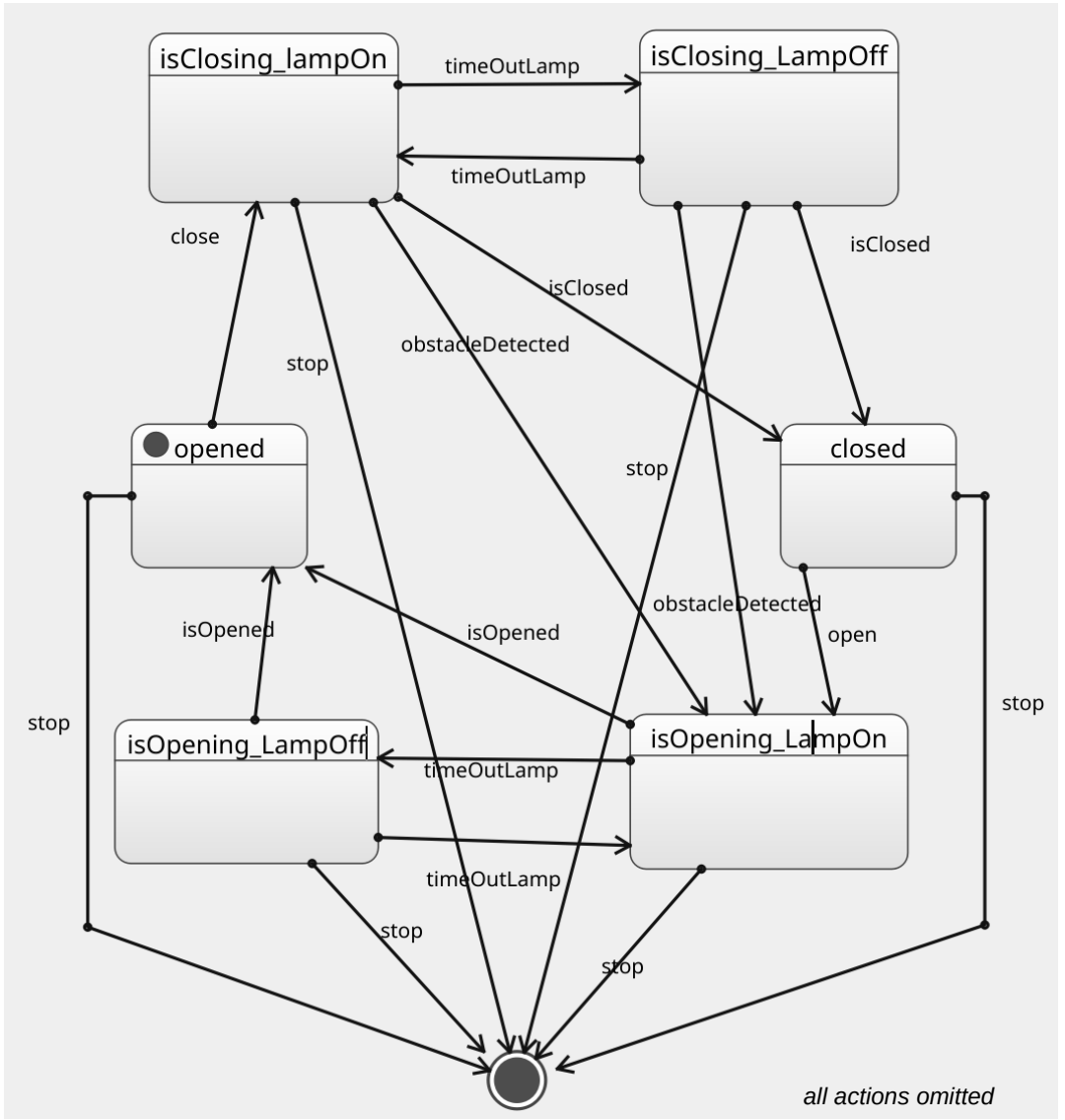
Finite State Machine

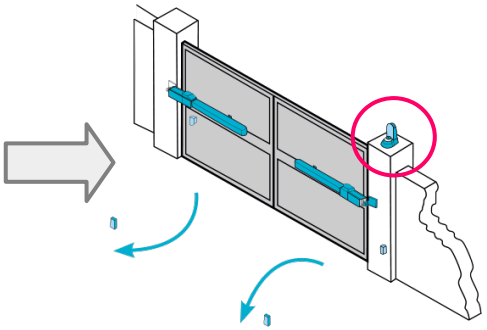
composition et mise à plat

composition et mise à plat: pourquoi ?

- D’un côté….

Running Example





wasn’t it supposed to help ?

State Charts

statecharts = state-diagrams + depth

+ orthogonality + broadcast-communication.

David Harel
Statecharts: A visual formalism for complex systems
Science of computer programming 8 (3), 231-274
1987

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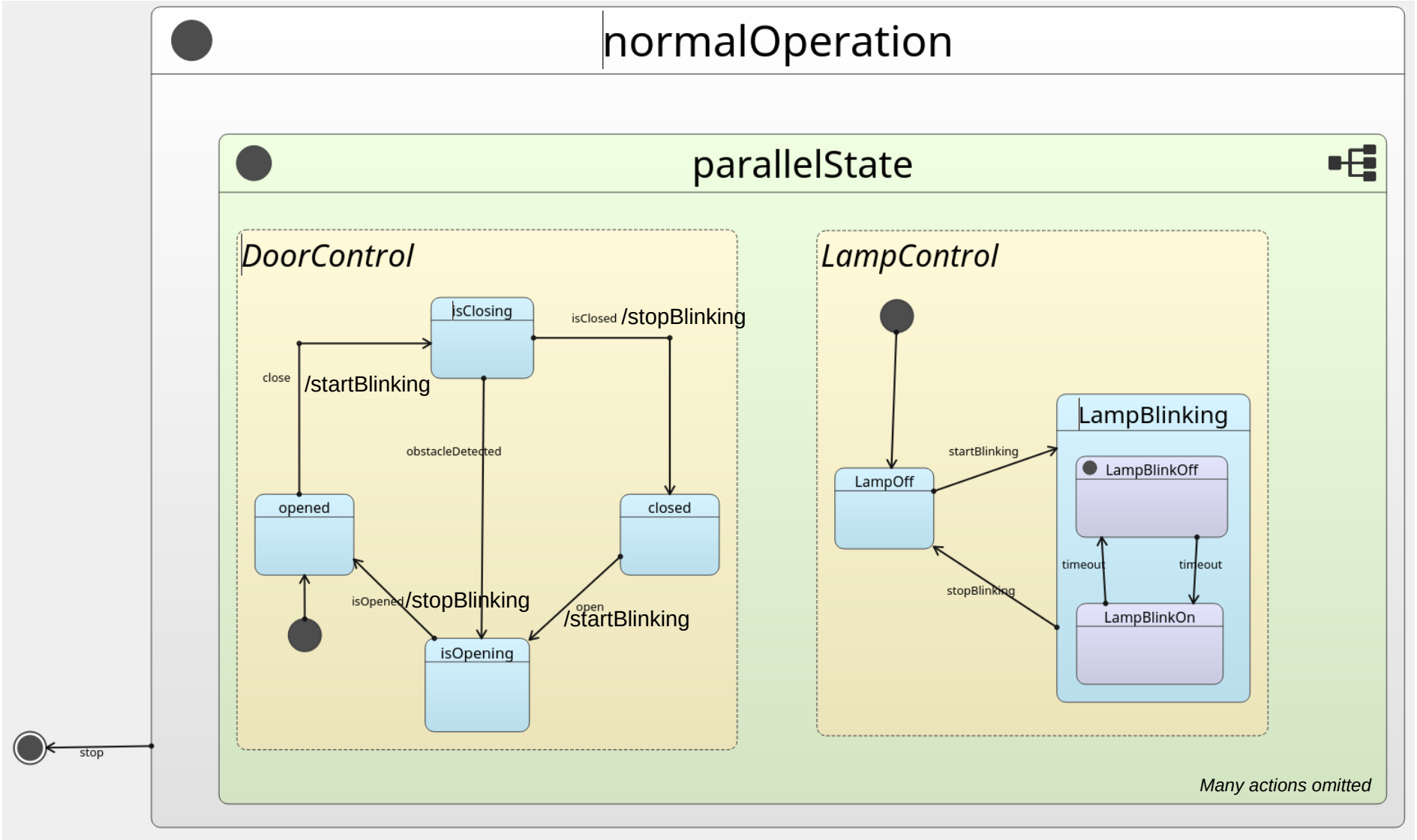
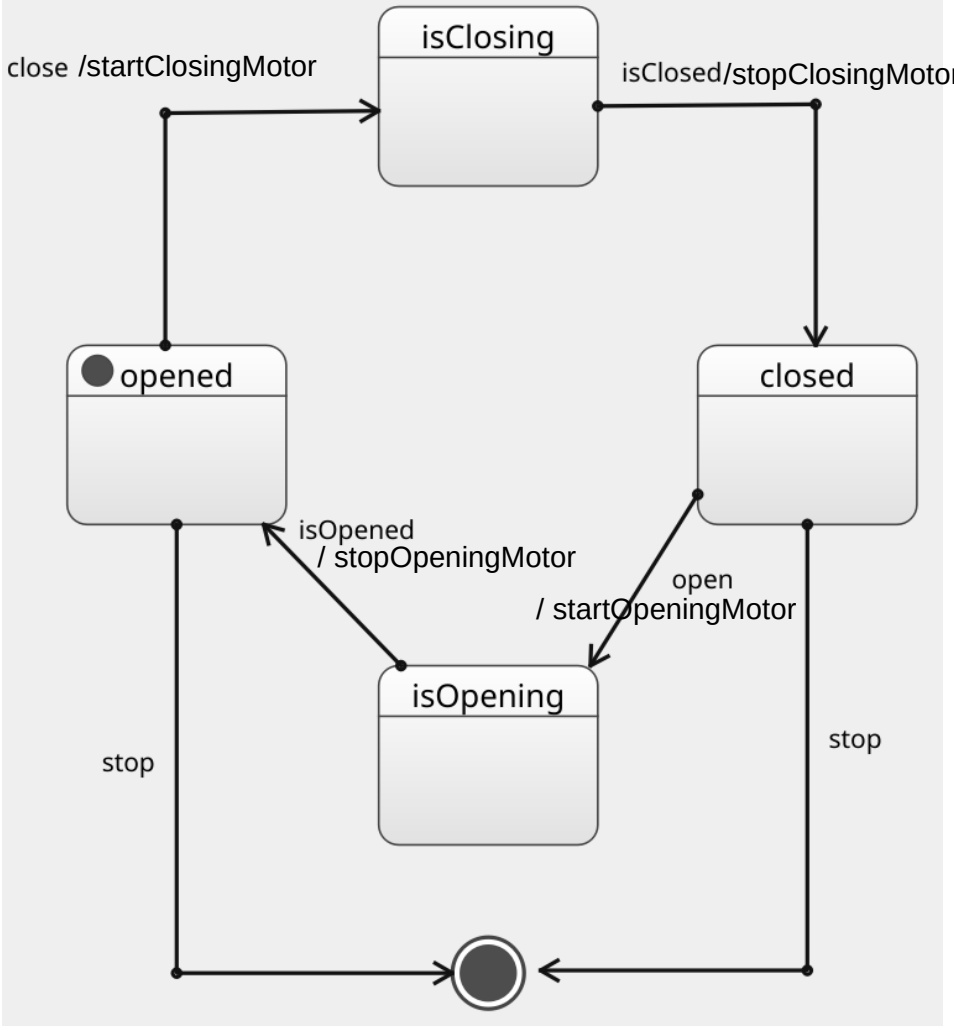


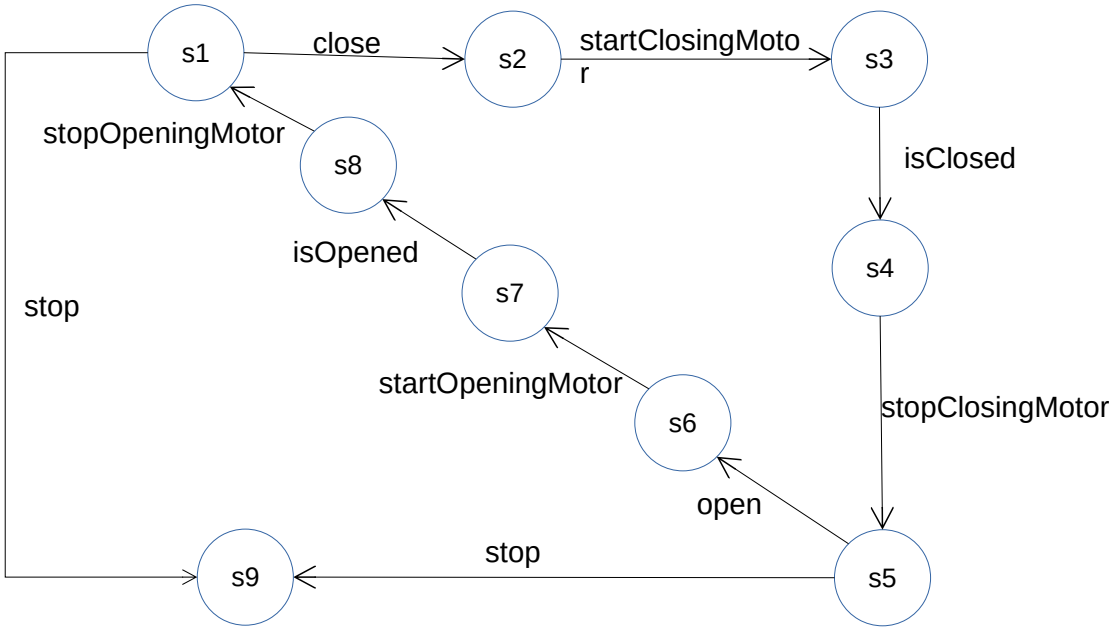
composition et mise à plat: pourquoi ?

- D’un autre côté….

V&V ?

- ensemble de chemins d'exécutions finis ?
  - Énumération de l'espace d'état (**habituellement un graphe orienté d'une forme particulière : *Labelled Transition system* ou *Kripke structure***)





Plus les actions *onEnter* et *onExit !*

composition et mise à plat: but

- La composition (aussi appelé produit) d'automate permet de n'obtenir qu'un seul transducteur à partir de plusieurs transducteur en parallèle. Il existe différentes manières (i.e., sémantiques) des les composer :
  - Produit synchrone (noté **X** dans la suite): *garder le langage commun à 2 automates.*
  - Produit asynchrone (produit parallèle, noté **||** dans la suite): *faire l'union des langages de chaque automate*
- La mise à plat (*flattening*) permet de "gommer" les états hiérarchiques tout en *gardant le même comportement* (notion que nous n'aurons pas le temps de voir, mais proche de l'équivalence de langages)

Produit Synchrone[1]

- Soit 2 transducers:
  - A1 = $<Q1 , q1_0, \mathcal{F}1 , \Sigma 1_I, \Sigma 1_O, \delta 1>$
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[1] différentes variantes mineures existent dans la littérature selon la formalisation de l'automate

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  - $Q \subseteq Q1 \otimes Q2$ (produit cartésien)

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Where $q1_1 \in Q1,\ q1_2 \in Q1,\ q2_1 \in Q2,\ q2_2 \in Q2,\ i1 \in \Sigma 1_I,\ i2 \in \Sigma 2_I,\ o1 \in \Sigma 1_O,\ o2 \in \Sigma 2_O$

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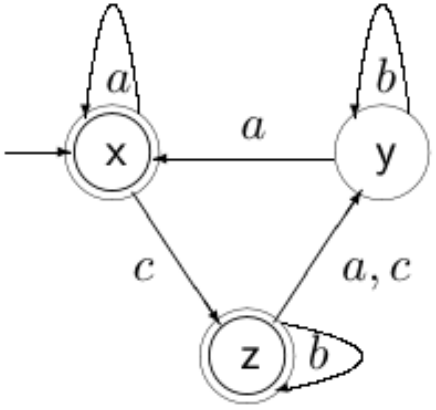
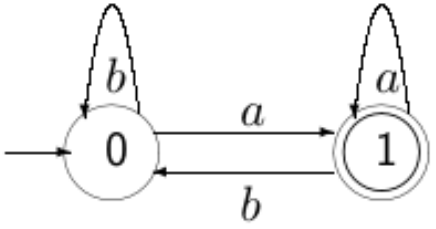
Si la FSM est plus compliquée,(e.g., avec des conditions booléennes), il faut bien sûr le prendre en compte (en faisant la conjonction des conditions)

[1] différentes variantes mineures existent dans la littérature selon la formalisation de l'automate

Produit Synchrone: simplified example



A



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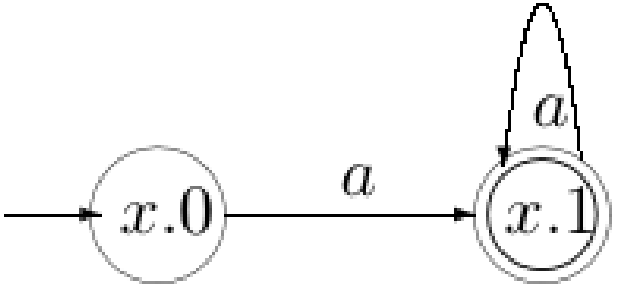

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$\delta(<q1_1, q2_1>, i, o2, <q1_1, q2_2>)$ if $i \notin \Sigma 1_I$ and $\delta 2(q2_1, i, o2, q2_2)$ defined

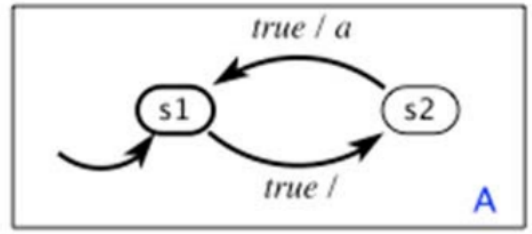
$\delta(<q1_1, q2_1>, i, o1, <q1_2, q2_1>)$ if $\delta 1(q1_1, i, o1, q1_2)$ defined and $i \notin \Sigma 2_I$

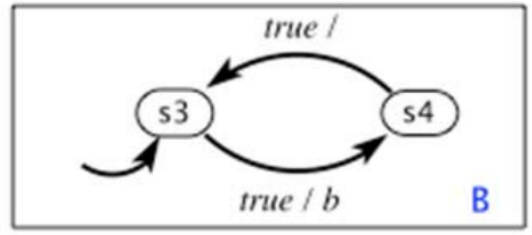
undefined otherwise

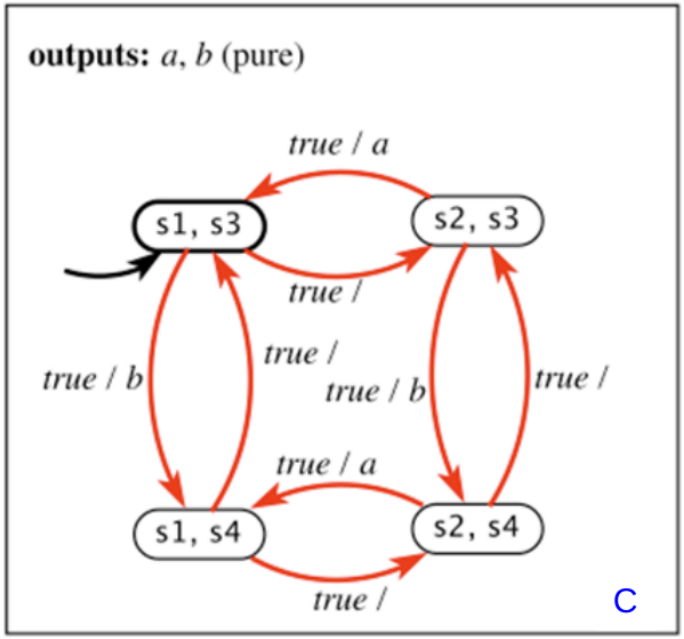
Produit Asynchrone: simplified example

Asynchronous Composition

$S_C \subseteq S_A \parallel S_B$







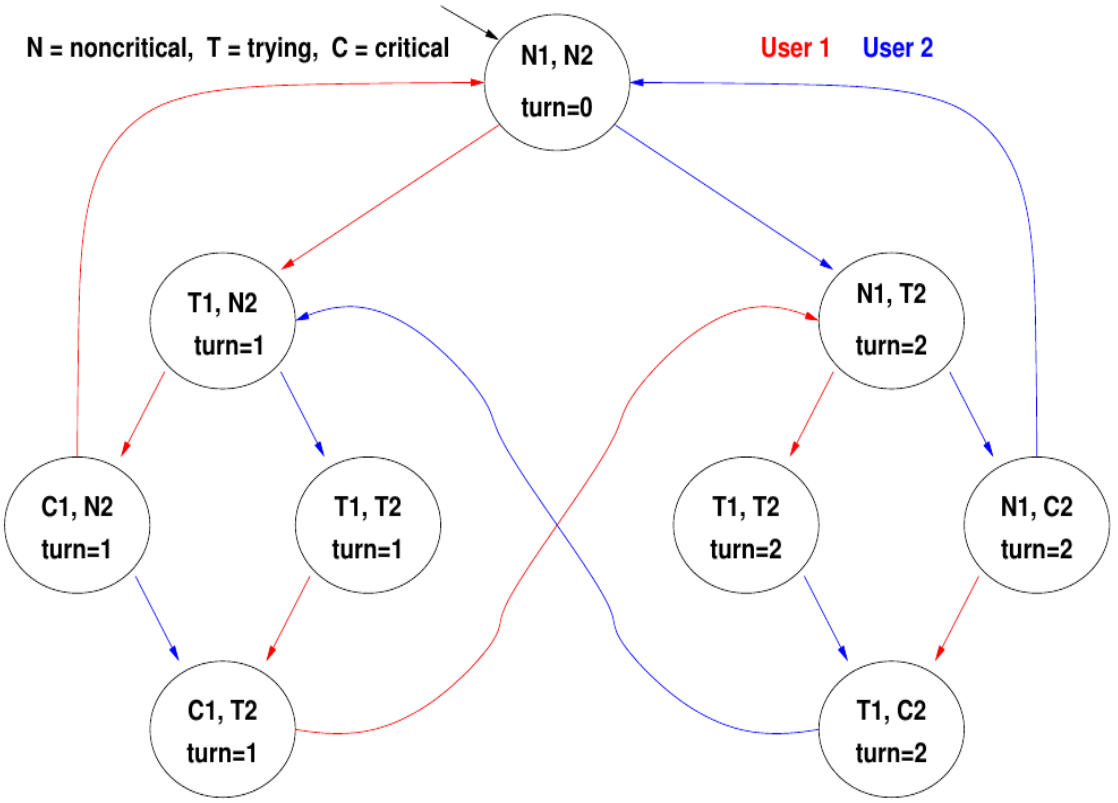
Asynchronous composition using interleaving semantics

Note that now all states are reachable.

Utilisation de la composition

- En Model Checking

  Permet de passer d'automates parallèles, à une structure plus proche d'une structure adaptée (LTS, kripke)



$$\models \Box(T_1 \Rightarrow \Diamond C_1) \ ?$$

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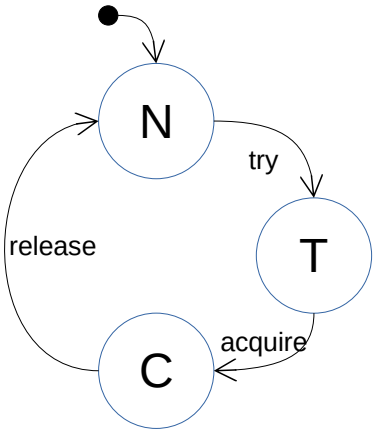

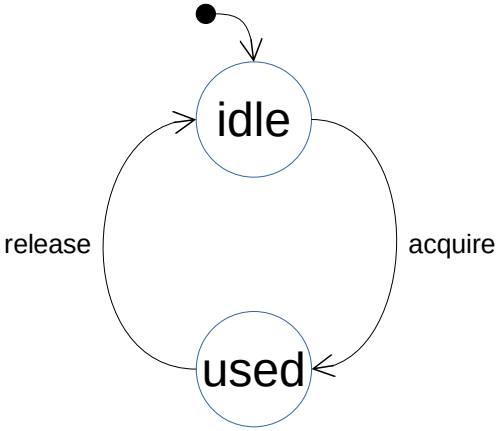

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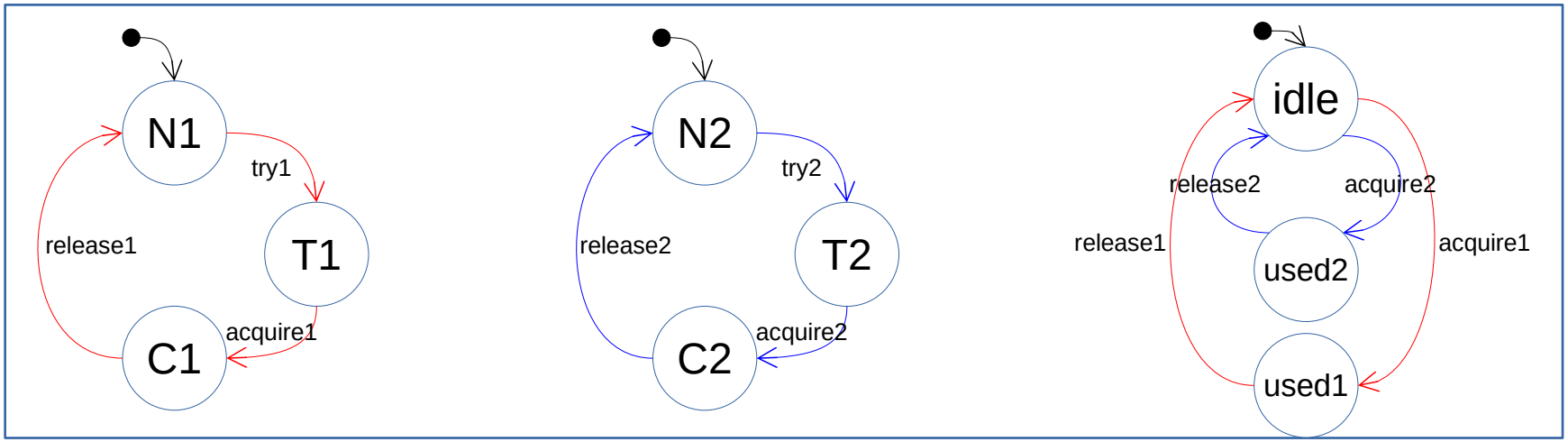

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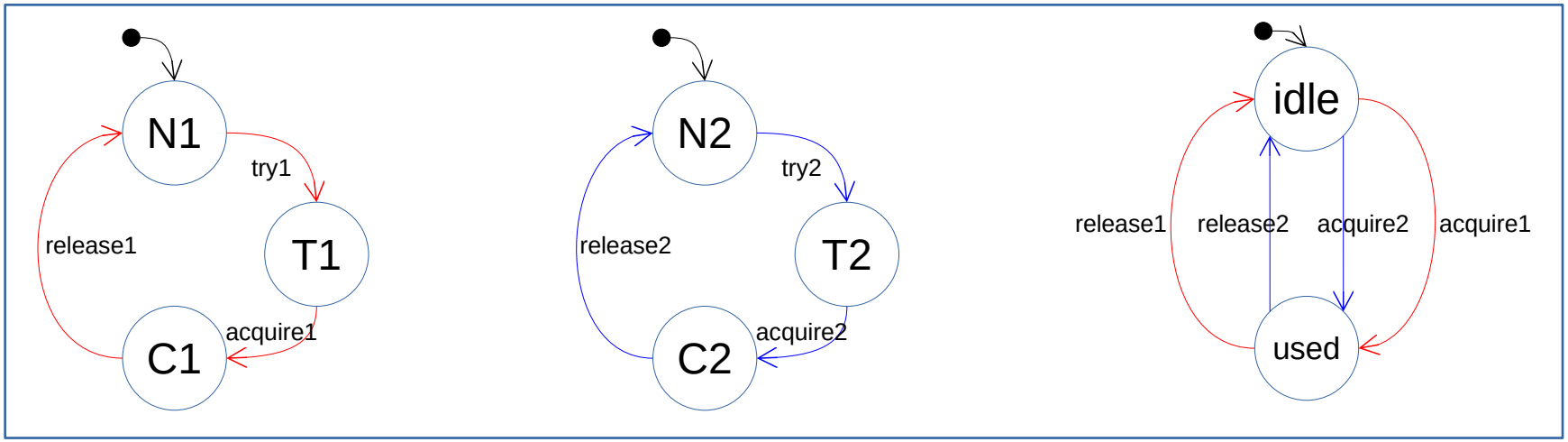

Simplification uniquement pour faciliter la lecture par la suite !

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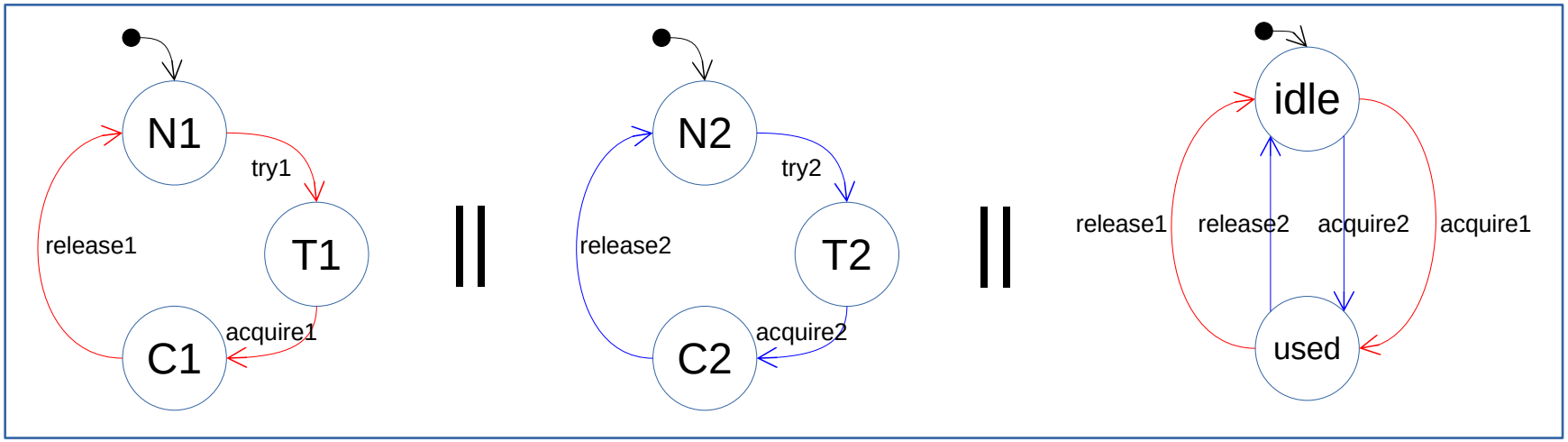

→ Le produit asynchrone nous donne l'automate au comportement équivalent...

Utilisation de la composition

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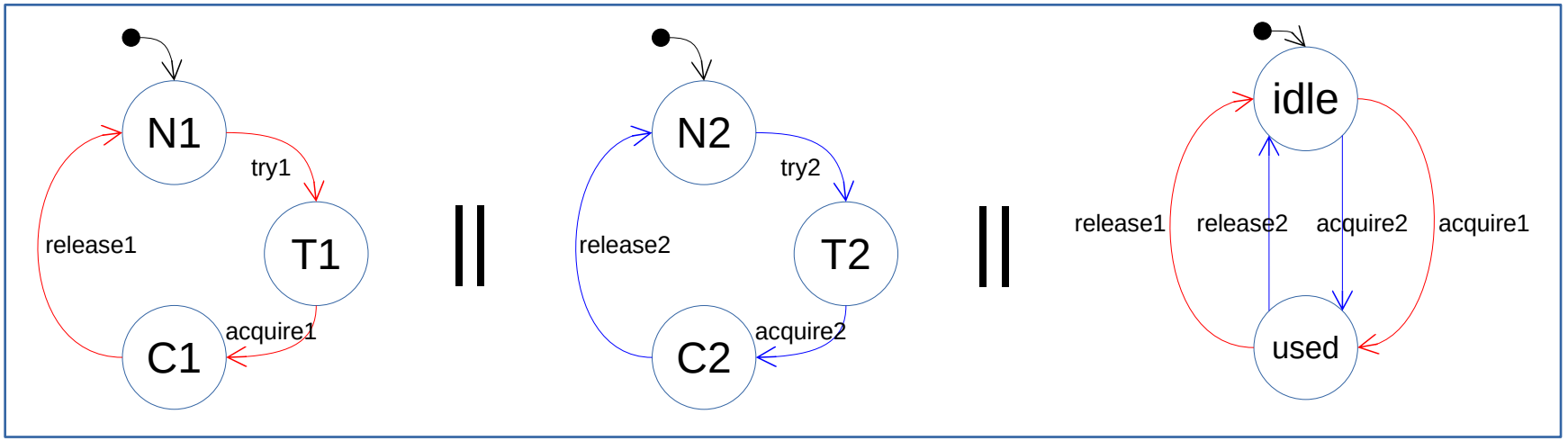

$\models \Box ($ **try1** $\Rightarrow \Diamond$ **acquire1** $)$?

→ Le produit asynchrone nous donne l'automate au comportement équivalent..... Que l'on va pouvoir questionner.

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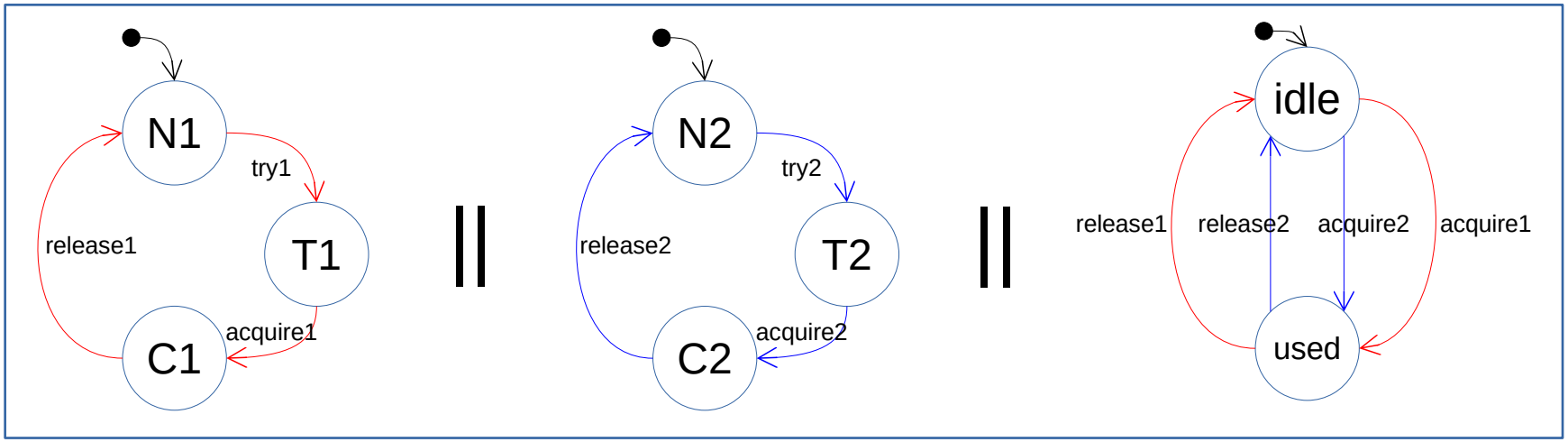

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Safety or liveness ?

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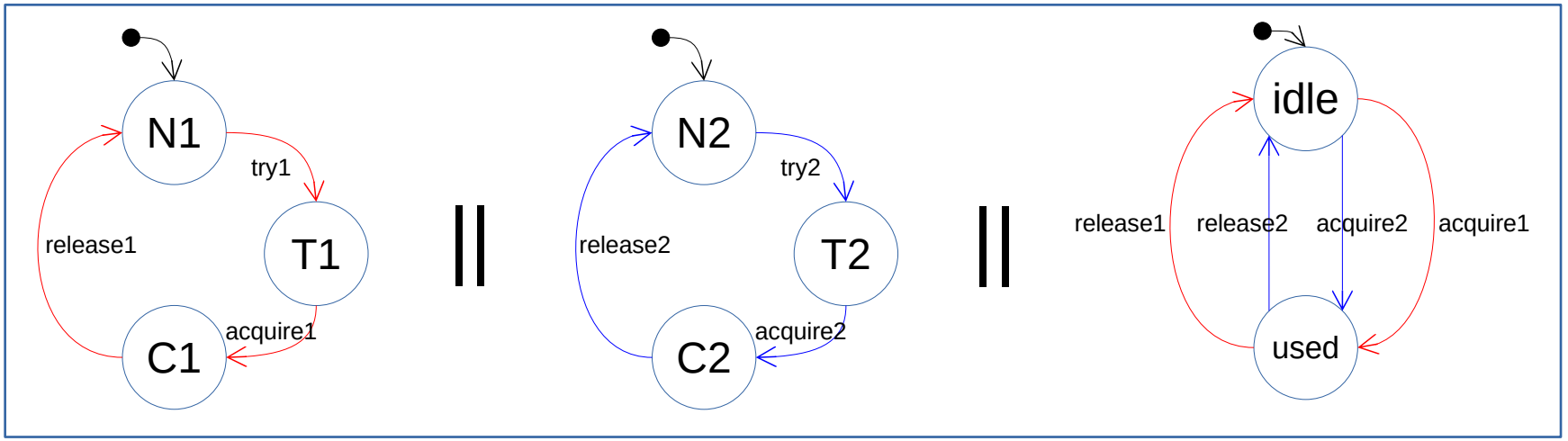


$\models \Box ($ **try1** $\Rightarrow \Diamond$ **acquire1** $)$?

Safety or **liveness**

Something good eventually happens….

→ Le produit asynchrone nous donne l'automate au comportement équivalent…… Que l'on va pouvoir questionner.

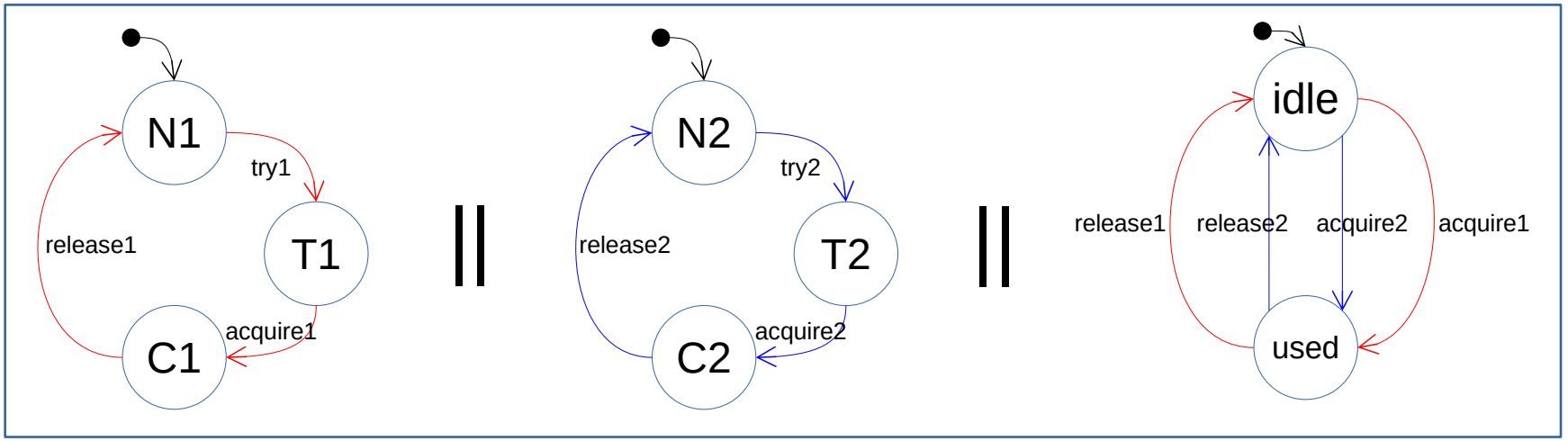
Checking properties on traces

- Specifying properties over time.
- Two types of properties:
  - **Safety property:** asserts that nothing bad happens.
    - *If user1 possesses a mutex then user2 cannot take it until user1 releases it.*
  - **Liveness property:** asserts that something good eventually happens.
    - If user1 asks to take a mutex, he will eventually possess it.

Safety properties violation can be determinate over finite execution while liveness properties cannot (something good can always happen latter)

Utilisation de la composition

- En Model Checking



$\models \Box ($ **try1** $\Rightarrow \Diamond$ **acquire1** $)$?

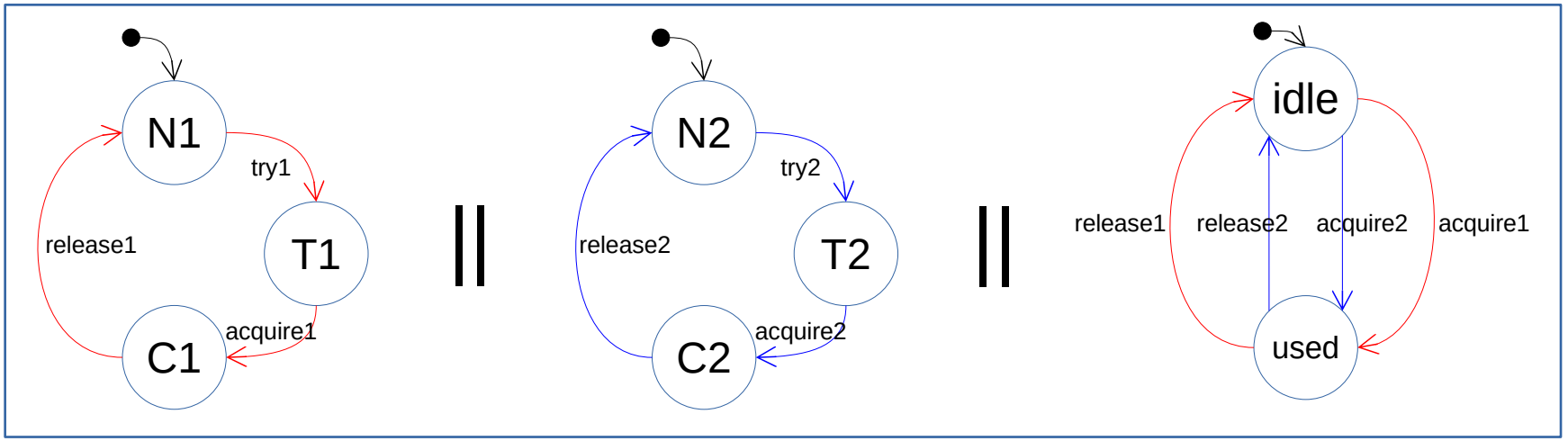
Safety or **liveness**

Something good eventually happens….

→ Le produit asynchrone nous donne l'automate au comportement équivalent…… Que l'on va pouvoir questionner.

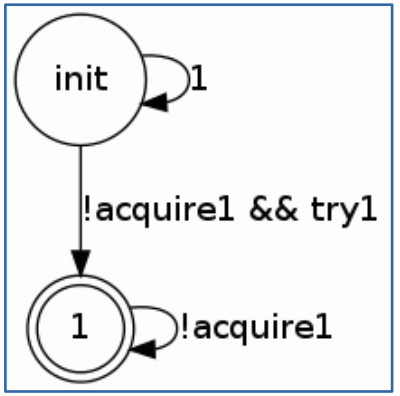
Utilisation de la composition

- En Model Checking



$\neg \models \Box(\text{try1} \Rightarrow \Diamond \text{acquire1})$? $\equiv$

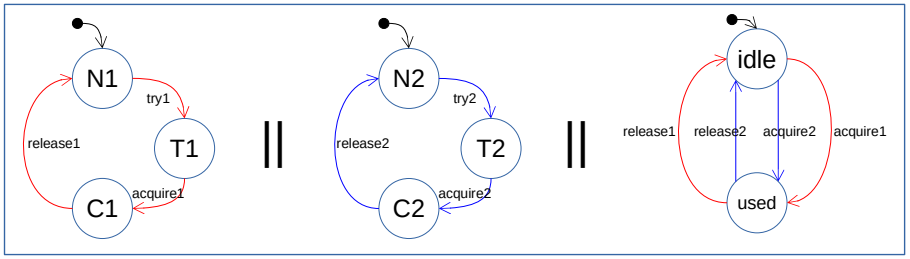
X



→ Le produit synchrone d'automate ne gardera que les chemins problématiques. Si l'automate résultant possède un cycle passant par un état acceptant, la propriété n'est pas vérifiée.

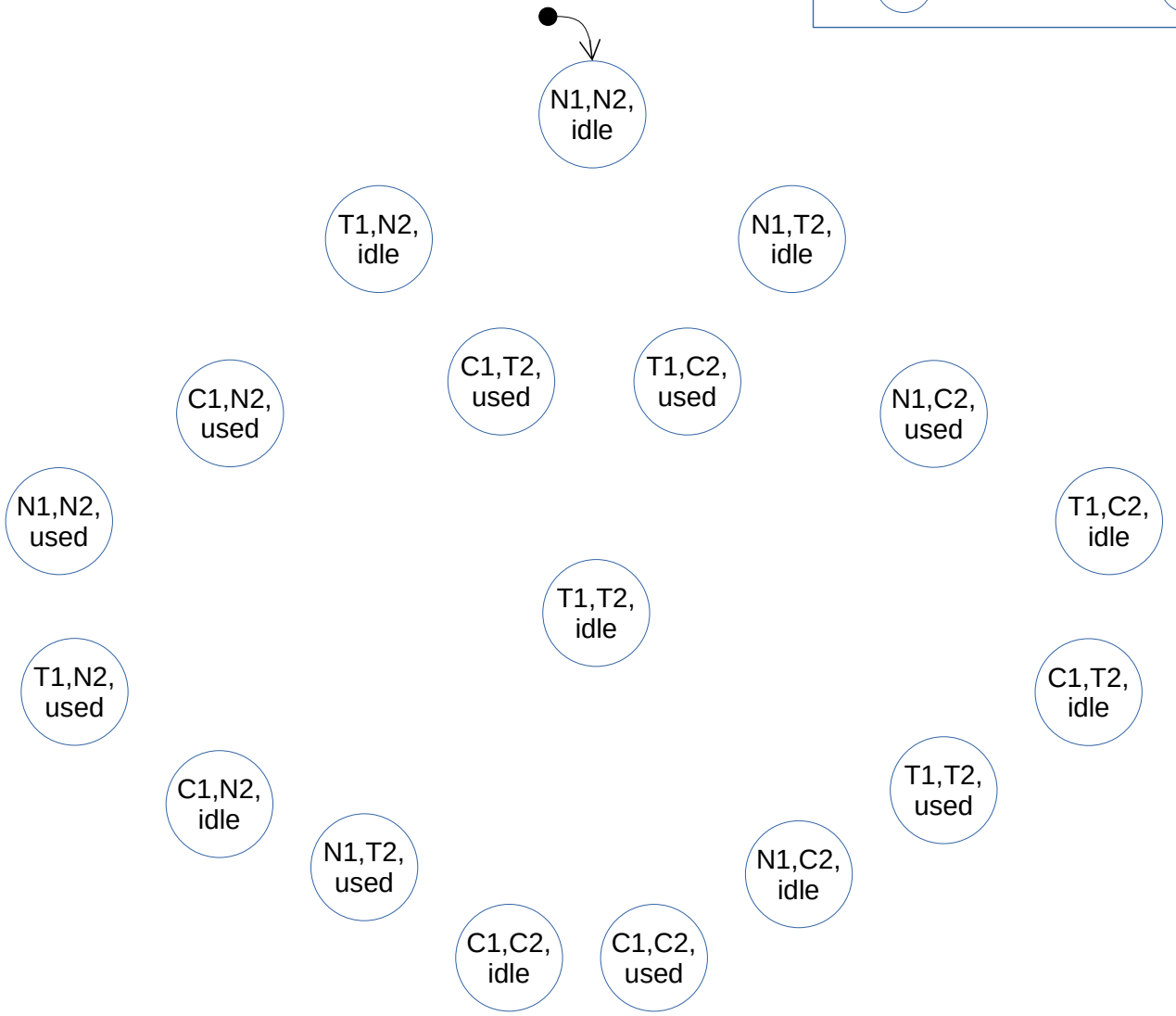
Utilisation de la composition

- En Model Checking



$Q = Q1 \otimes Q2$

$q_0 = <q1_0, q2_0>$



Utilisation de la composition

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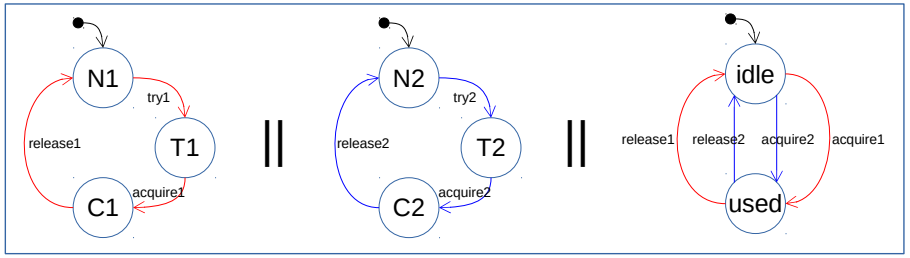
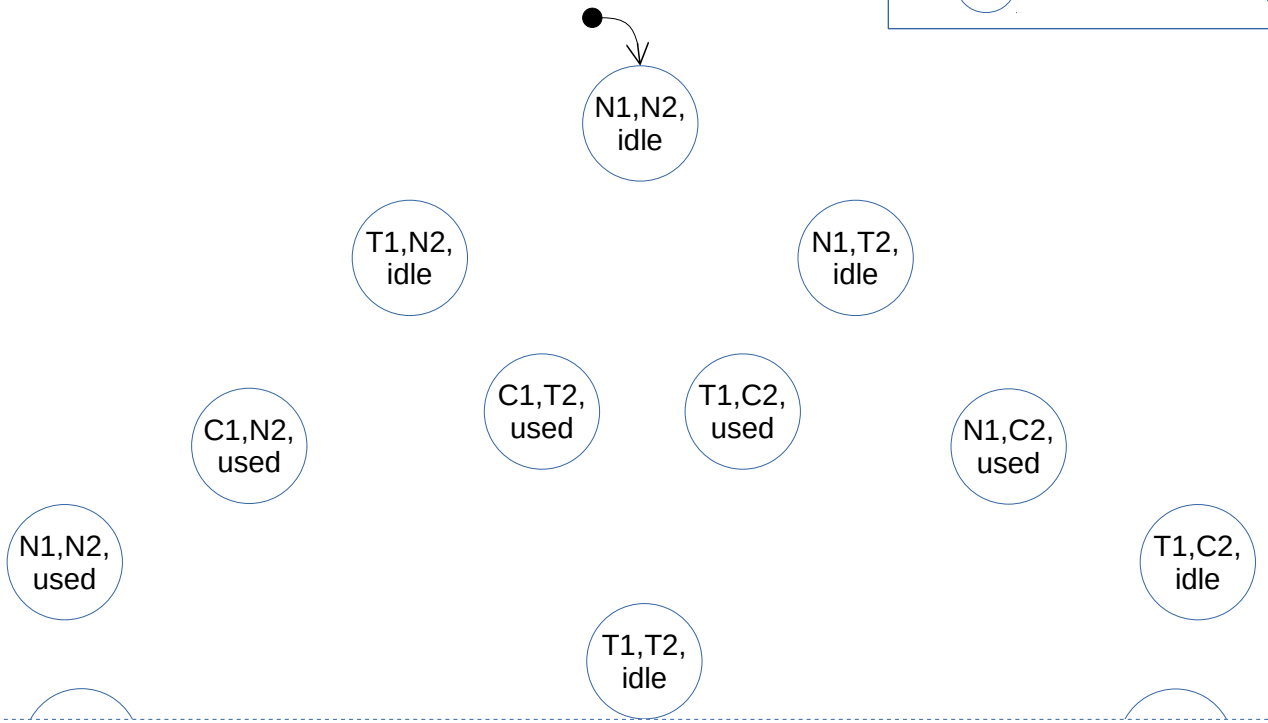




$\delta = \delta 1 \cup \delta 2$ s.t. $\delta(<q1_1, q2_1>, i, *, <*,*>) :=$

$\delta(<q1_1, q2_1>, i, o, <q1_2, q2_2>)$ if $\delta 1(q1_1, i, o1, q1_2)$ and $\delta 2(q2_1, i, o2, q2_2)$ defined, where $o = o1 \cup o2$

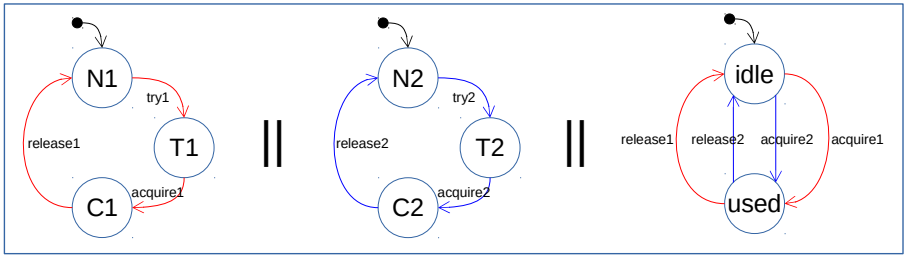
$\delta(<q1_1, q2_1>, i, o2, <q1_1, q2_2>)$ if $i \notin \Sigma 1_I$ and $\delta 2(q2_1, i, o2, q2_2)$ defined

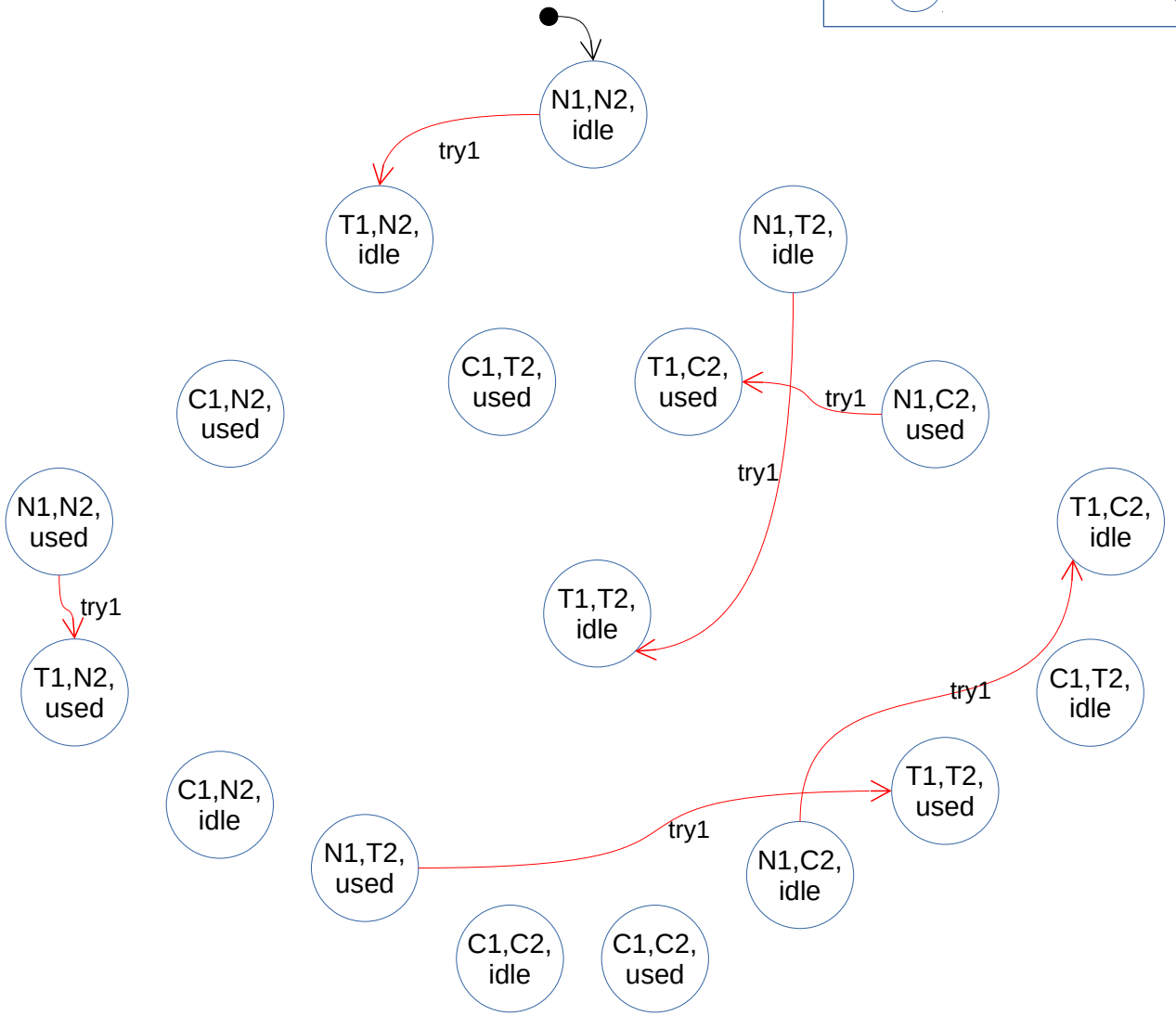
$\delta(<q1_1, q2_1>, i, o1, <q1_2, q2_1>)$ if $\delta 1(q1_1, i, o1, q1_2)$ defined and $i \notin \Sigma 2_I$

undefined otherwise

Utilisation de la composition

- En Model Checking





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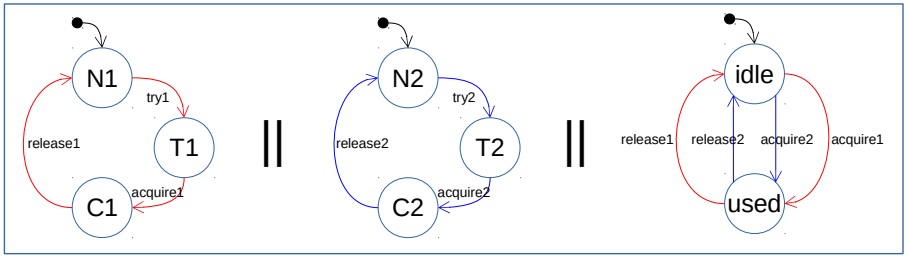

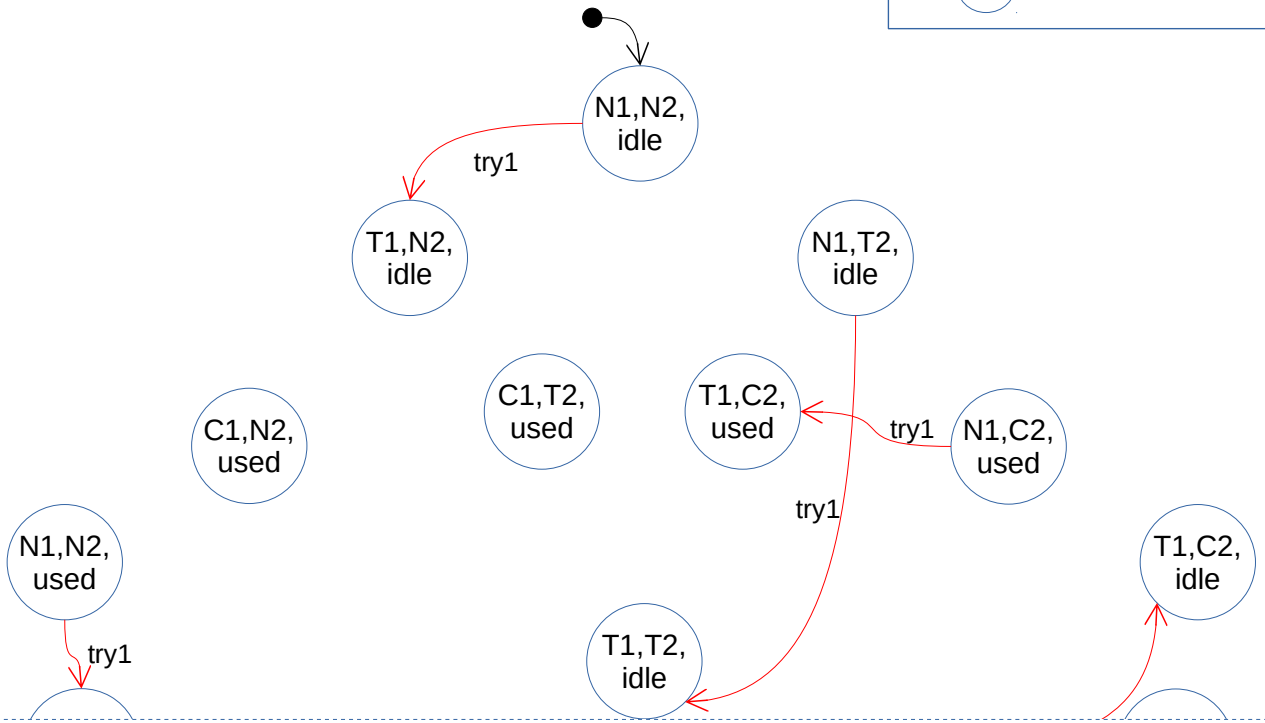

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undefined otherwise

Utilisation de la composition

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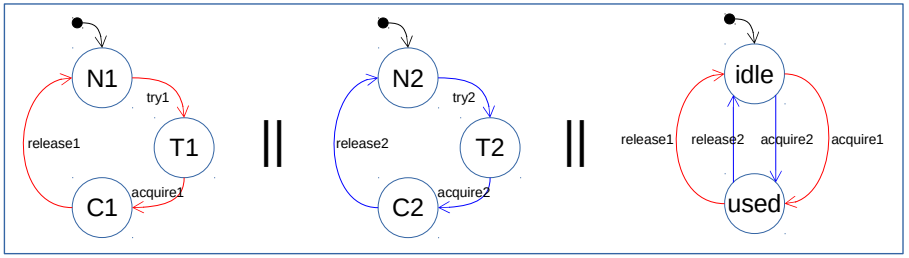

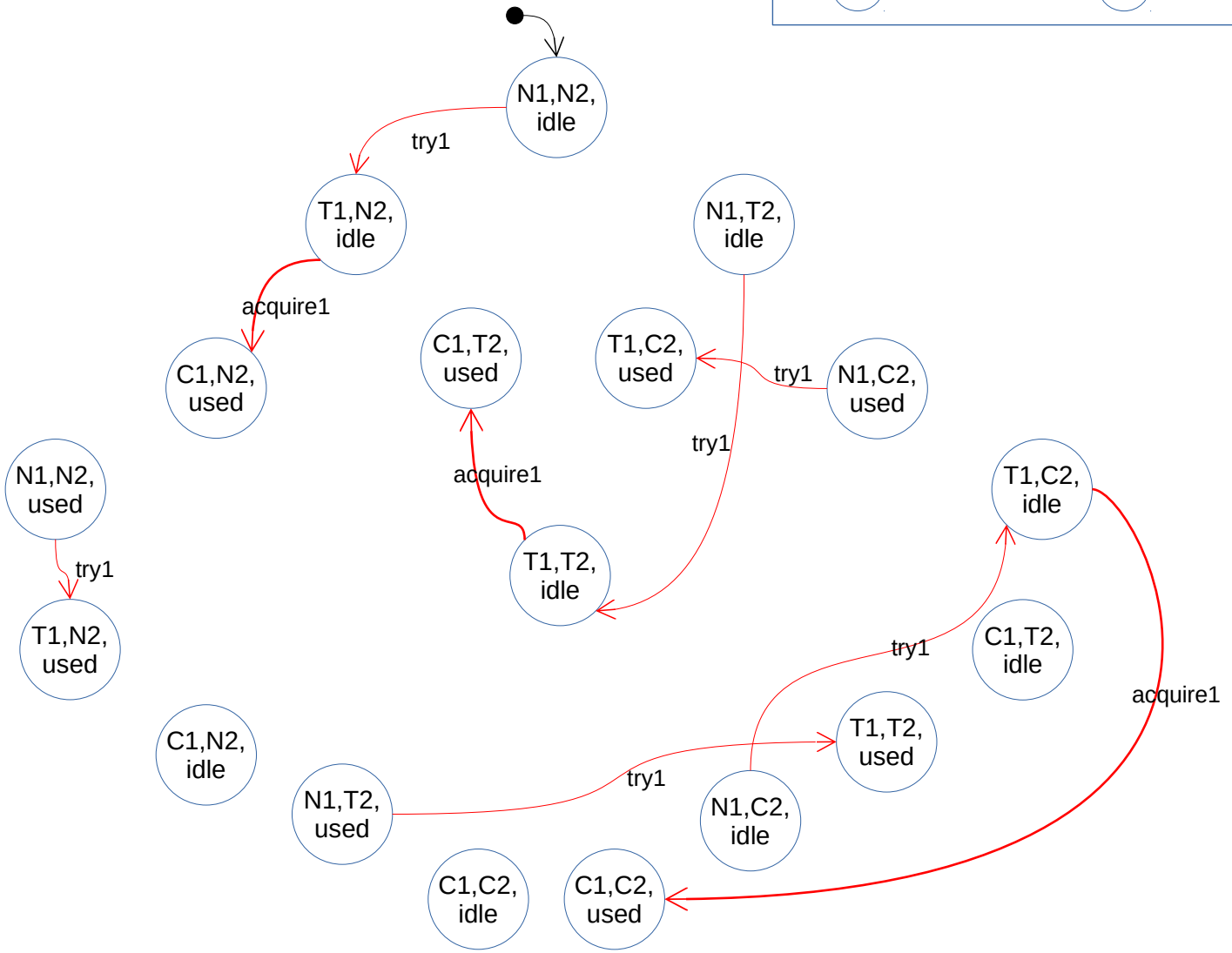

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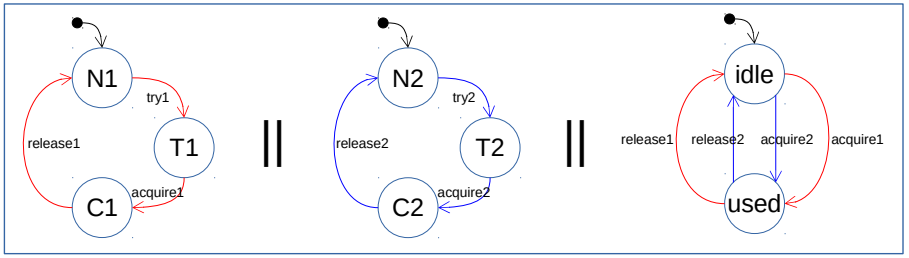

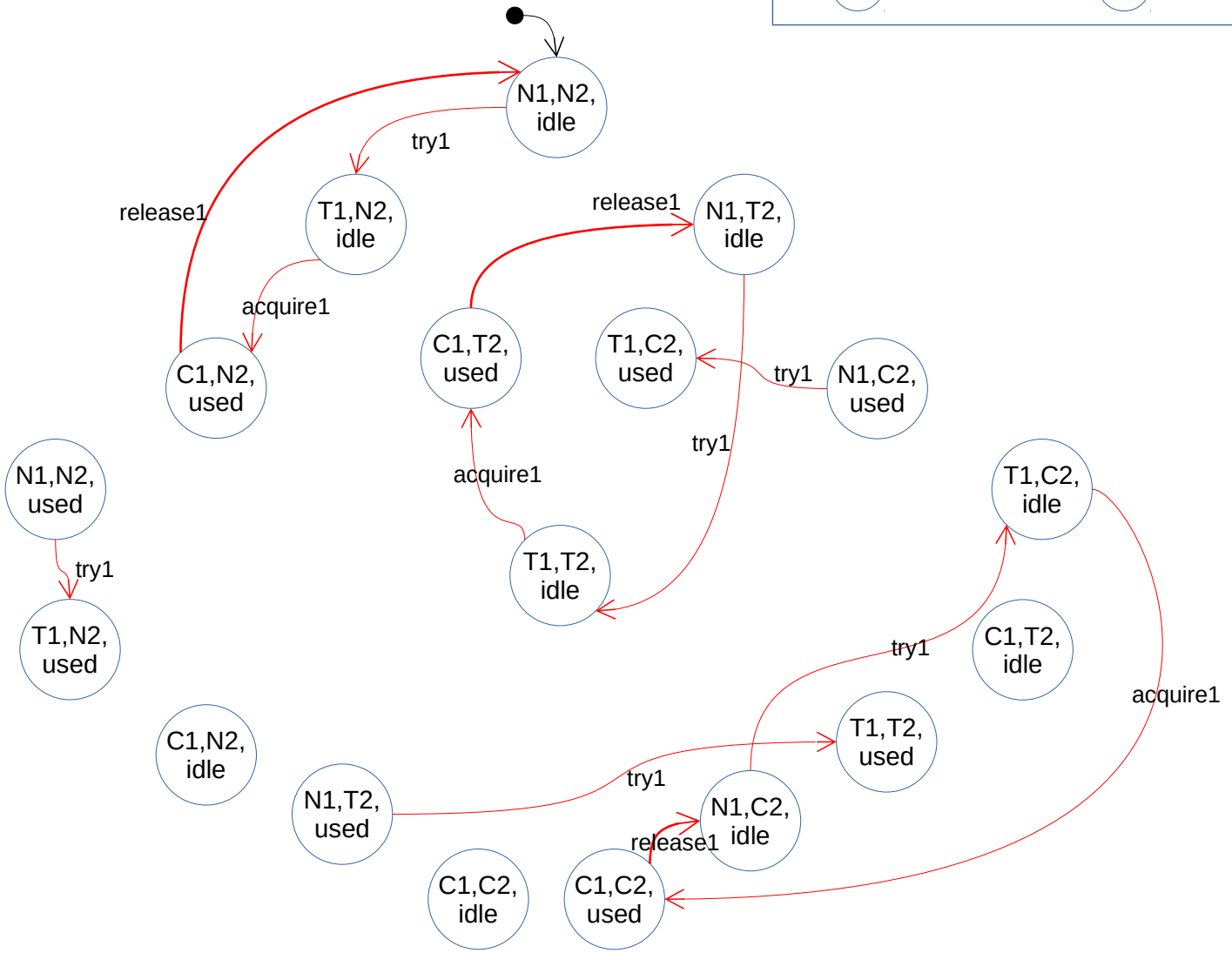

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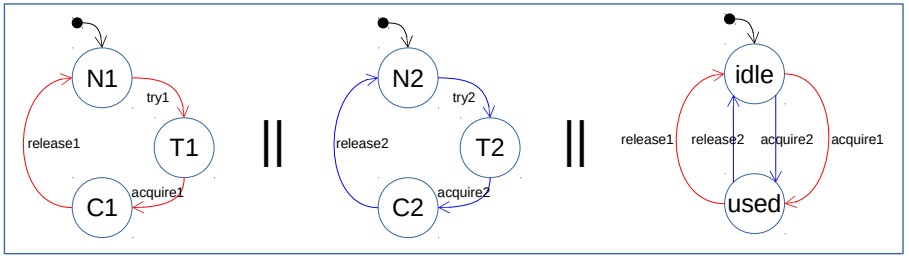

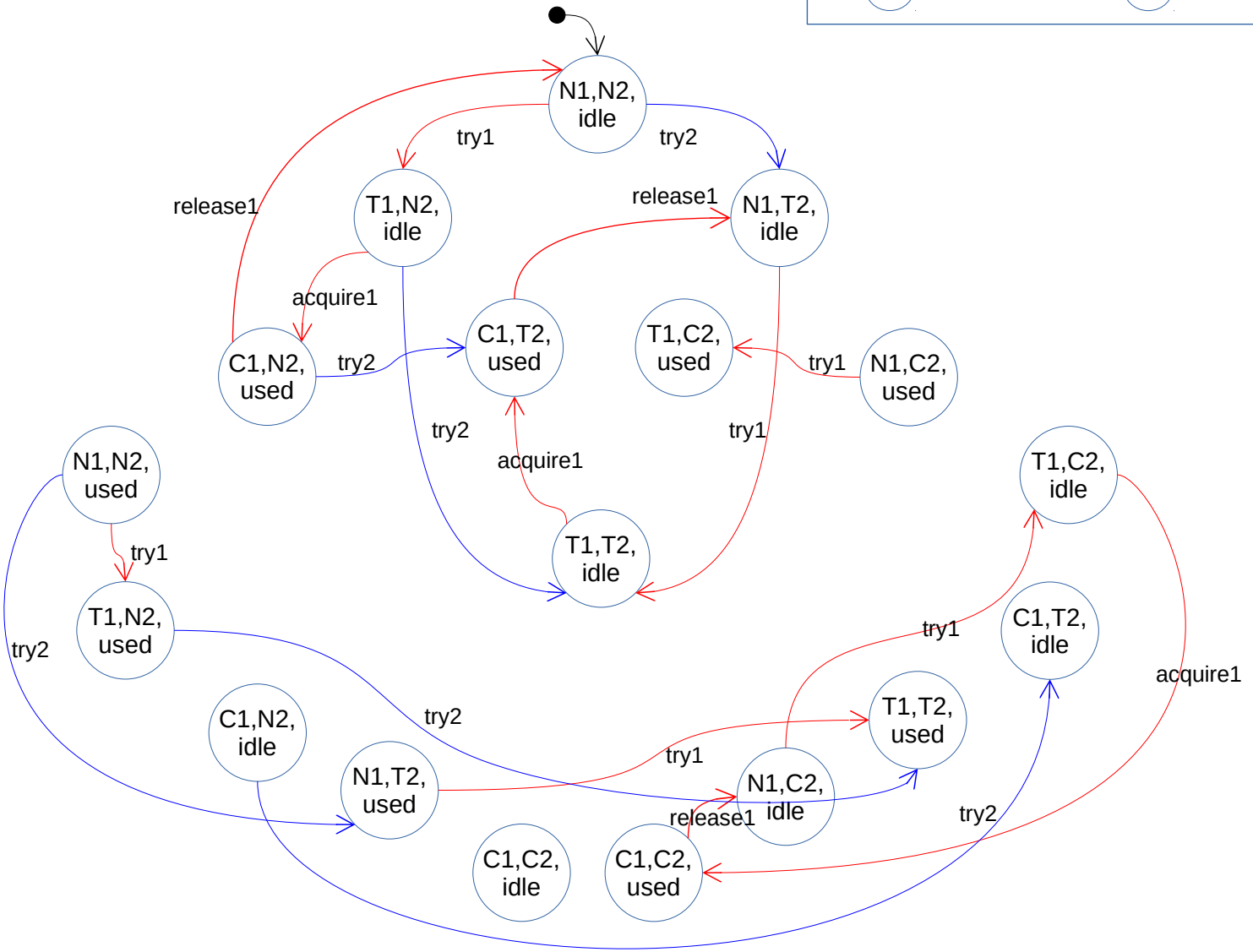

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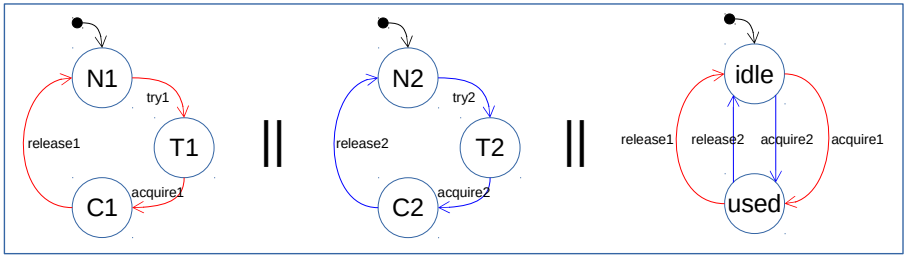

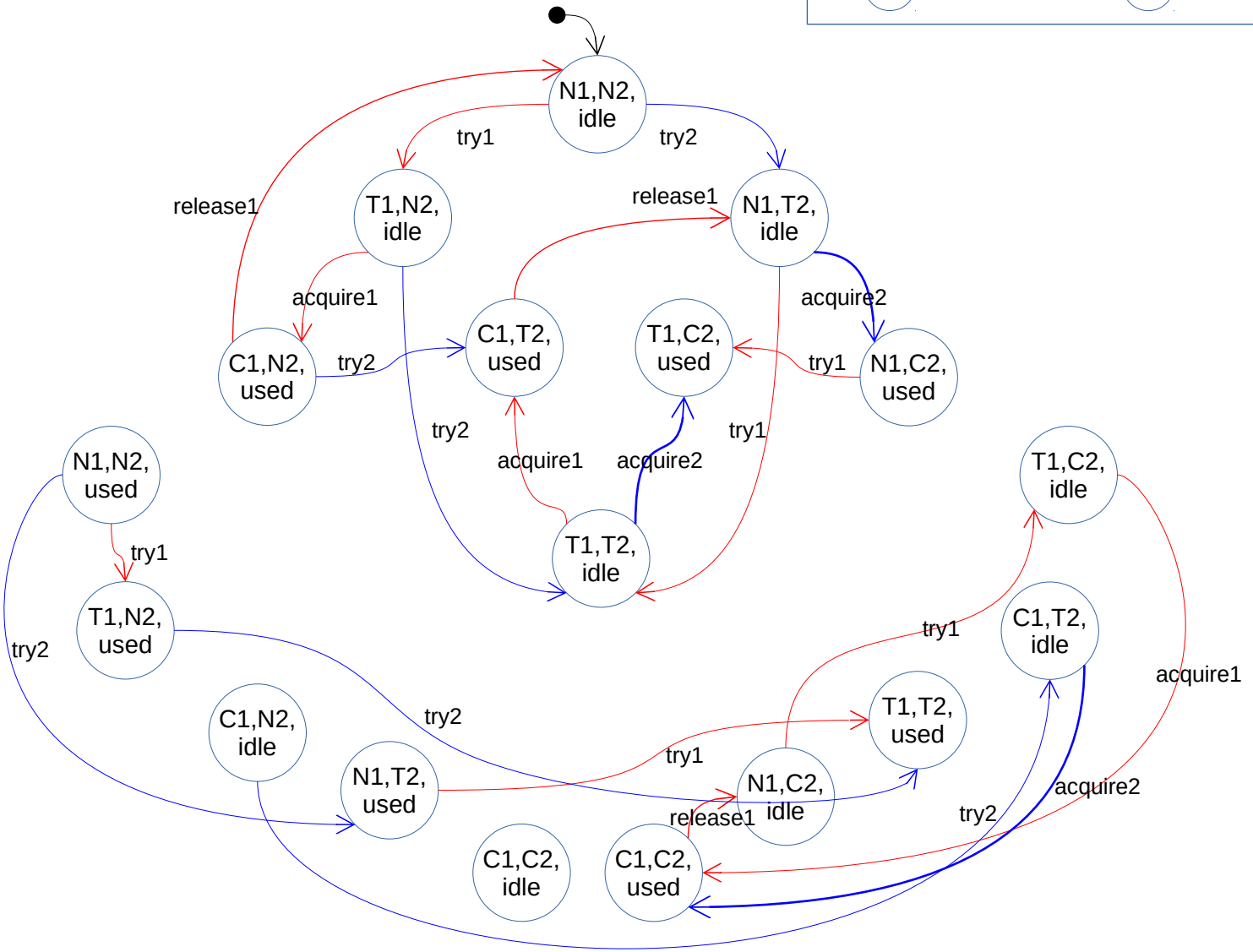

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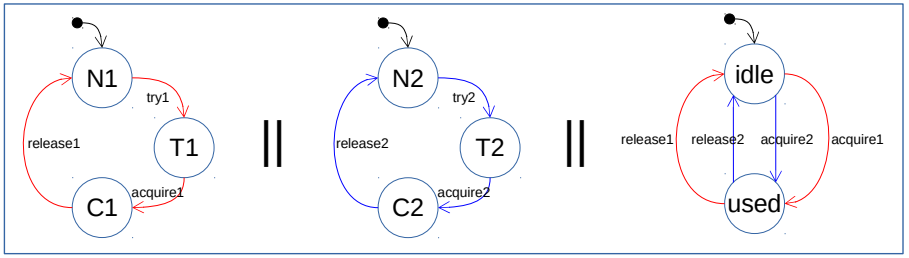

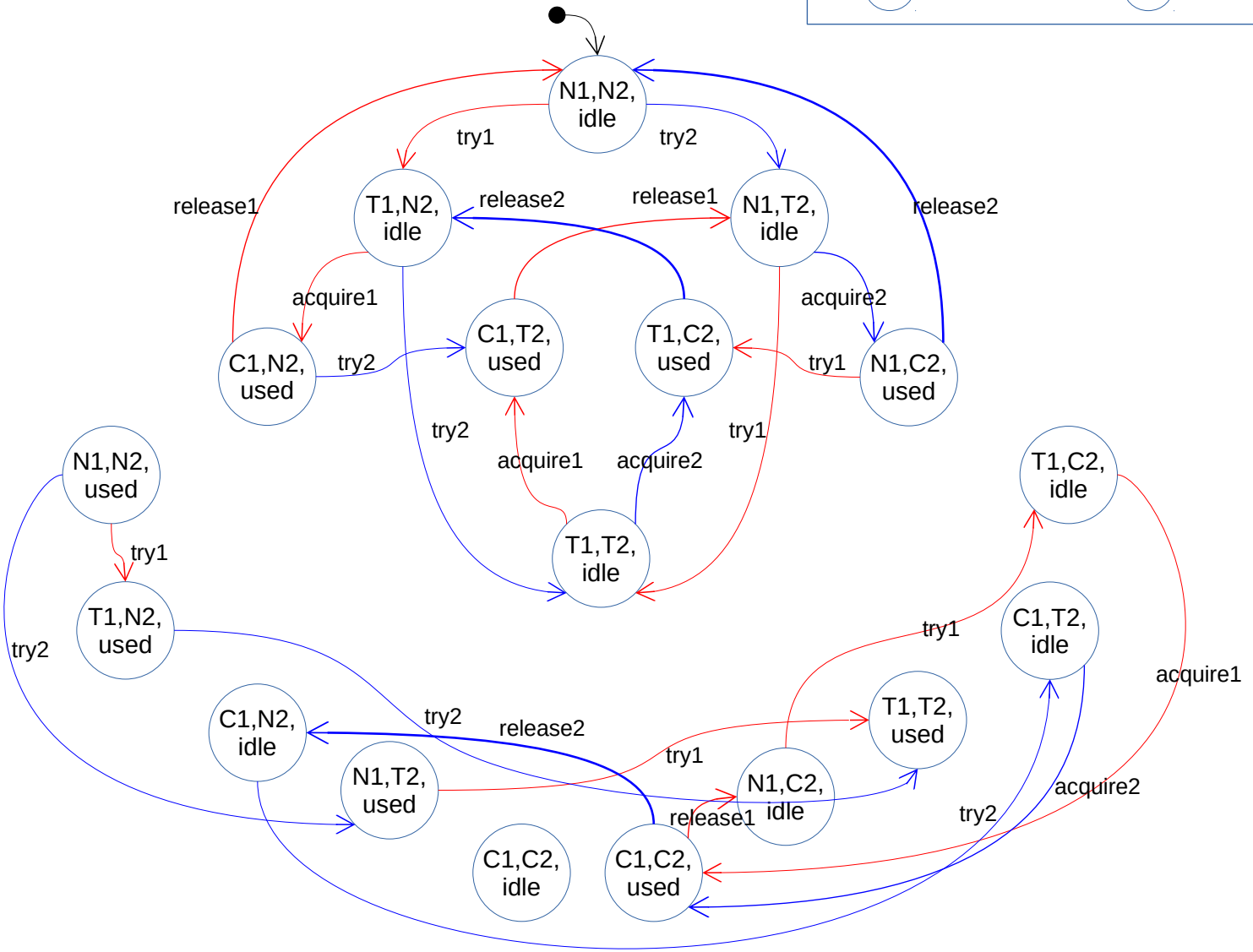

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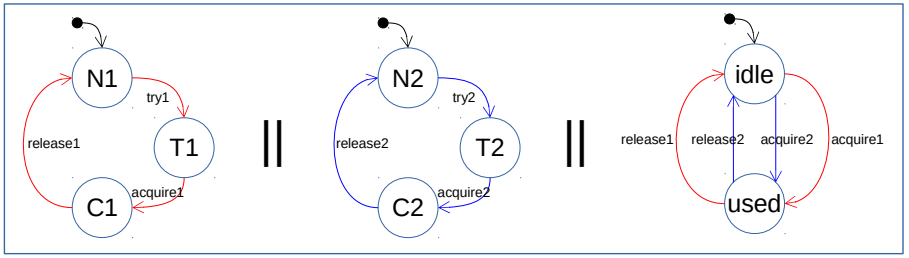

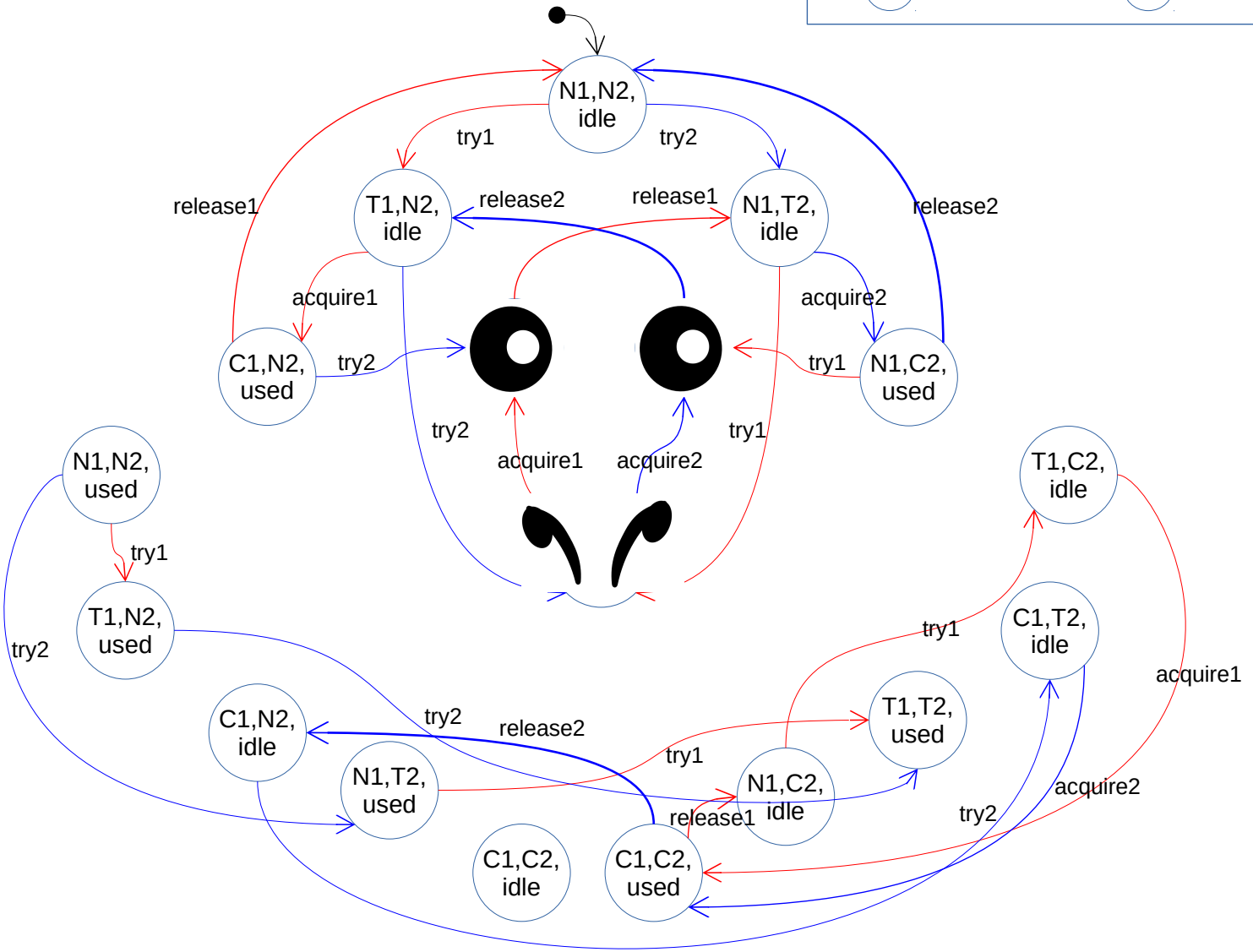

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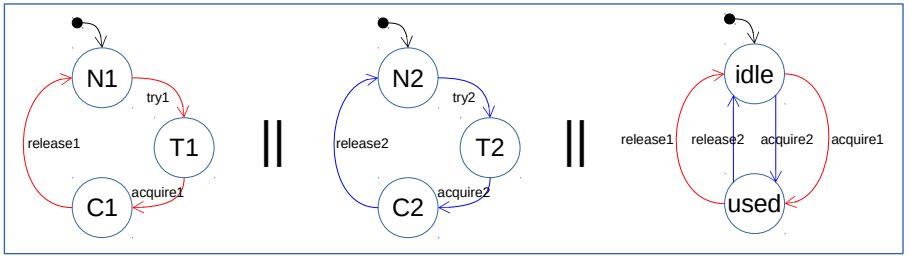
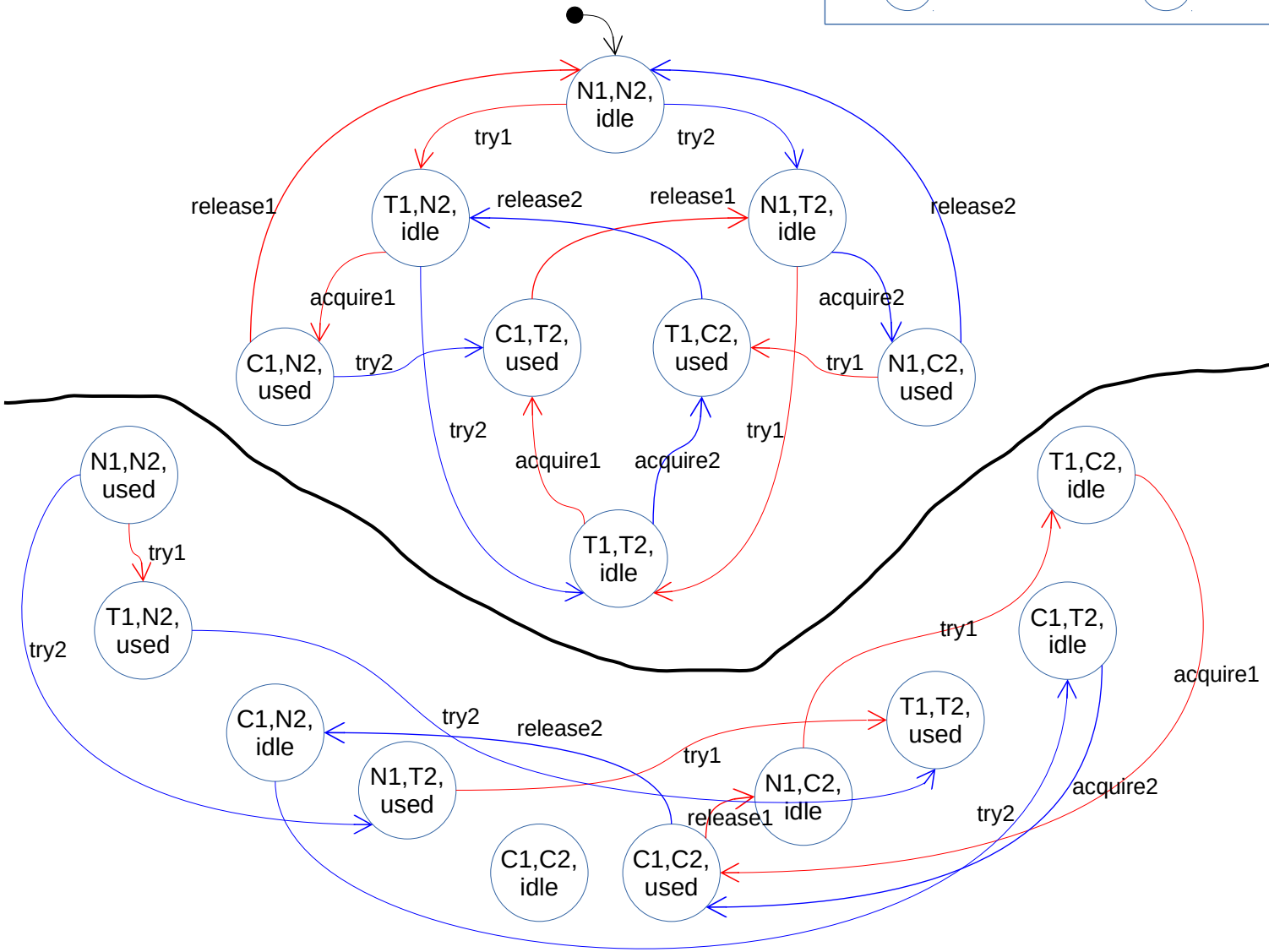
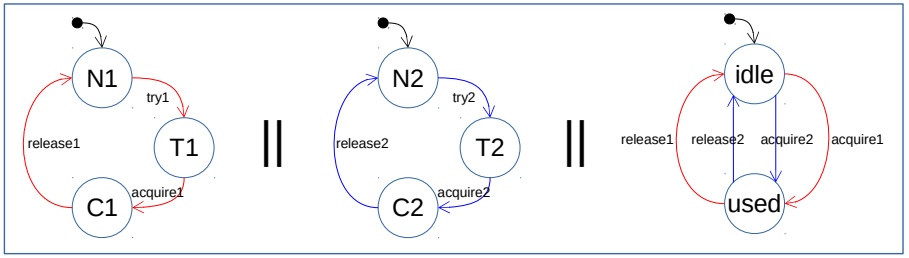


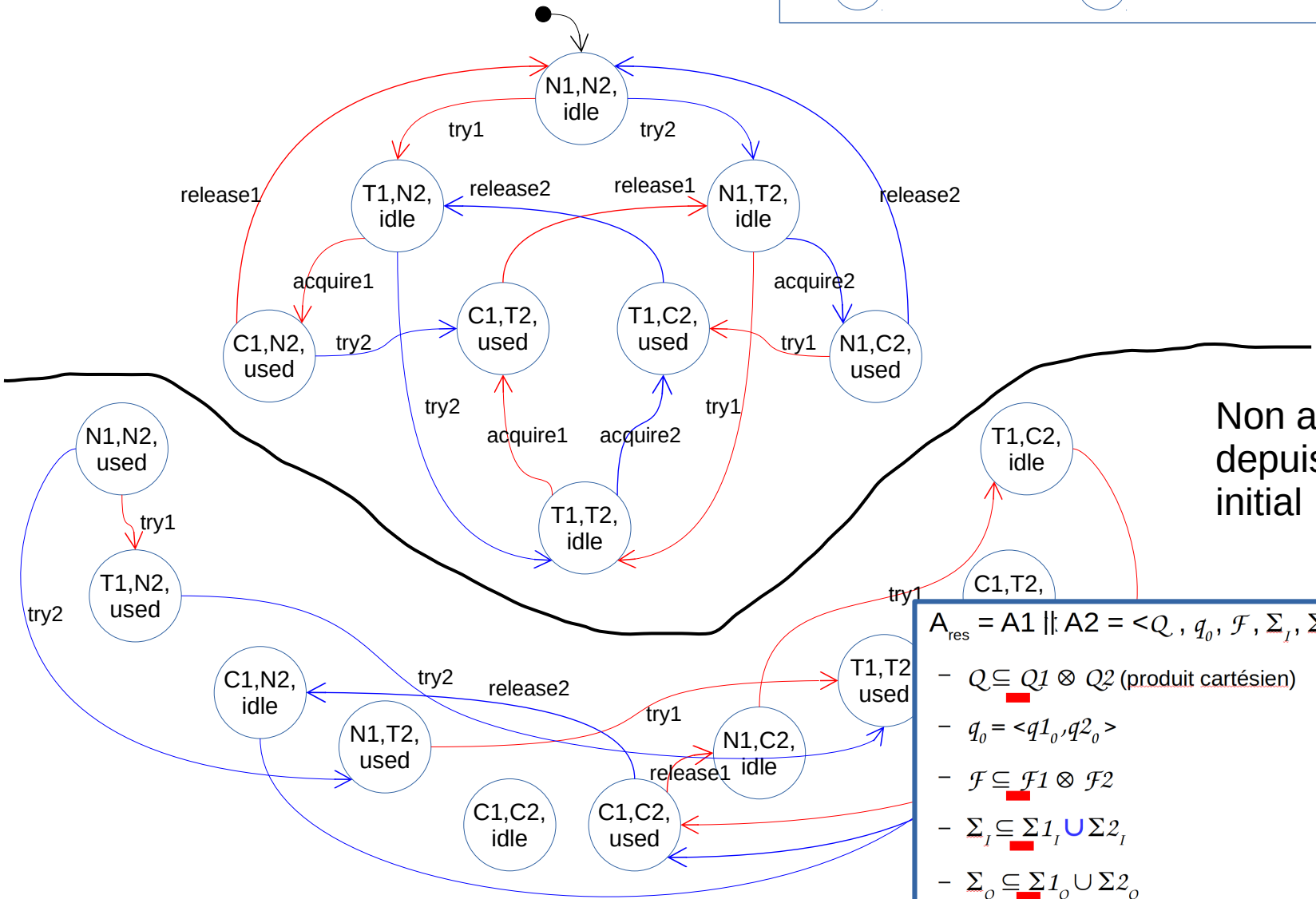


Non accessible depuis l'état initial !

Utilisation de la composition

- En Model Checking





Non accessible depuis l'état initial !

$A_{res} = A1 \,||\, A2 = \langle Q, q_0, \mathcal{F}, \Sigma_I, \Sigma_O, \delta \rangle$ tel que

- $Q \subseteq Q1 \otimes Q2$ (produit cartésien)
- $q_0 = \langle q1_0, q2_0 \rangle$
- $\mathcal{F} \subseteq \mathcal{F}1 \otimes \mathcal{F}2$
- $\Sigma_I \subseteq \Sigma 1_I \cup \Sigma 2_I$
- $\Sigma_O \subseteq \Sigma 1_O \cup \Sigma 2_O$

Utilisation de la composition

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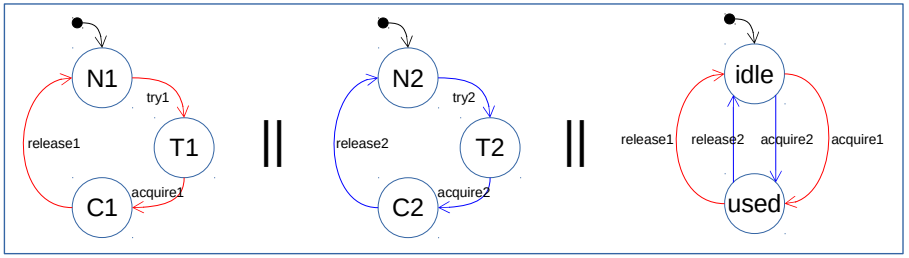

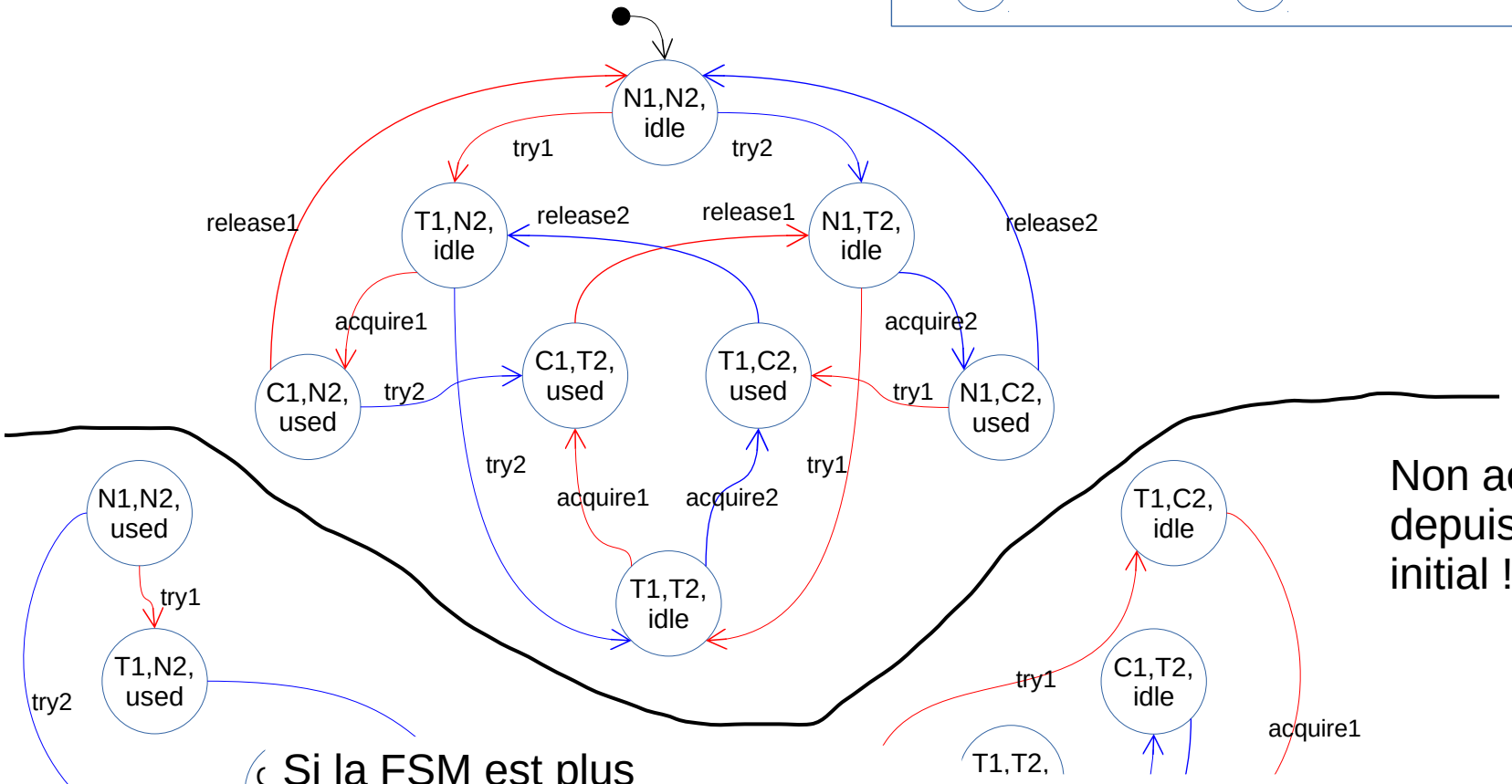

Non accessible depuis l'état initial !

Si la FSM est plus compliquée,(e.g., avec des conditions booléennes), il faut bien sûr le prendre en compte (en faisant la conjonction des conditions)

=> La simplication peut devenir compliquée…

Utilisation de la composition

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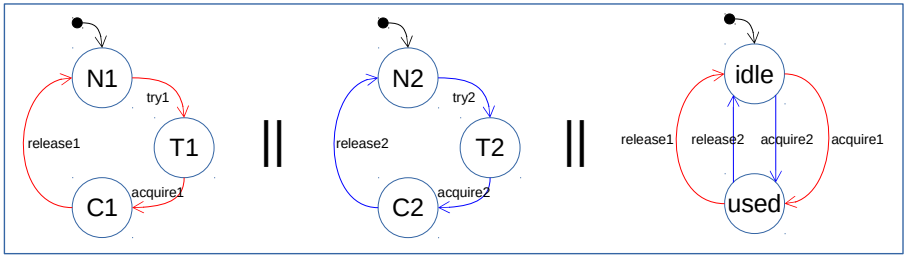
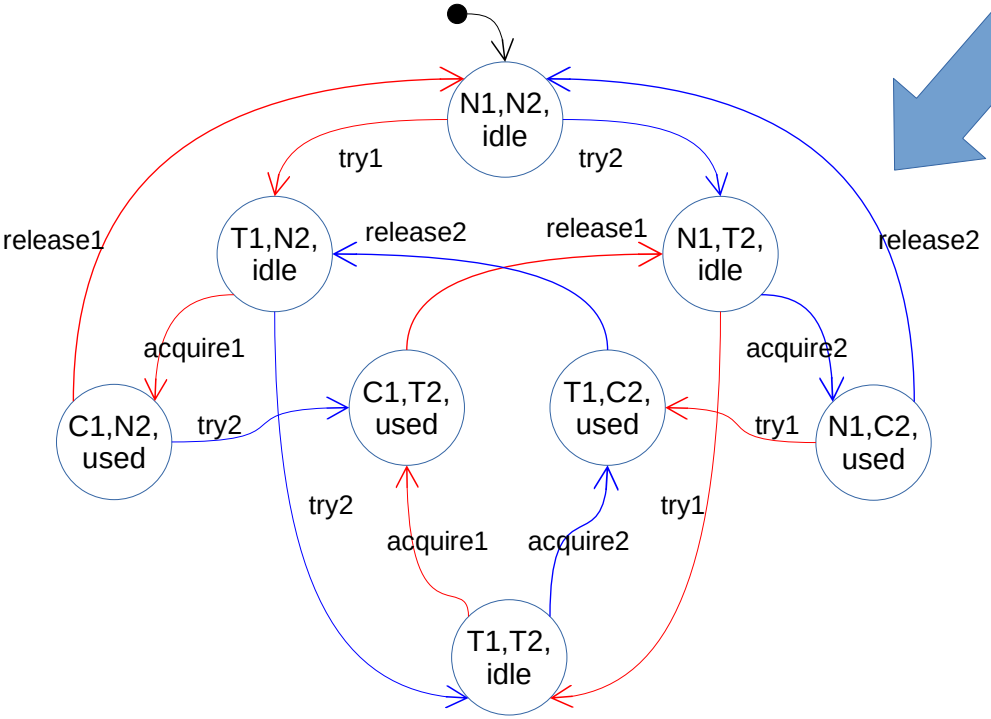


Équivalent



Utilisation de la composition

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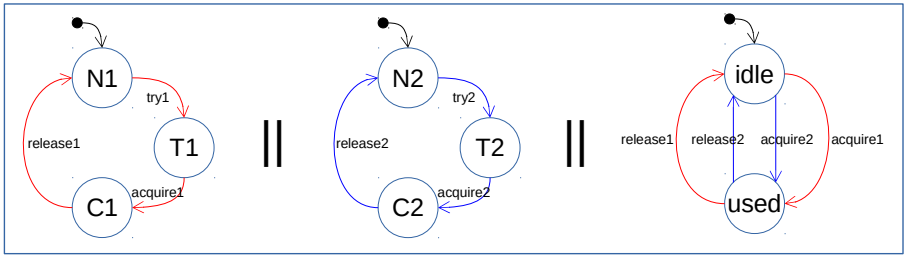
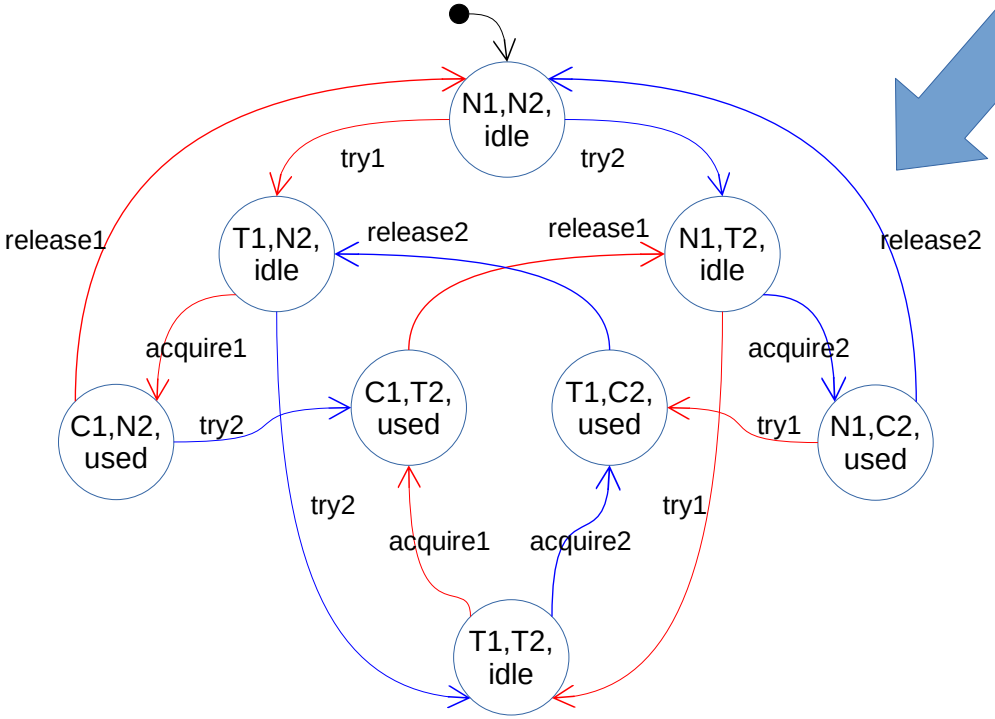


Équivalent ?



Utilisation de la composition

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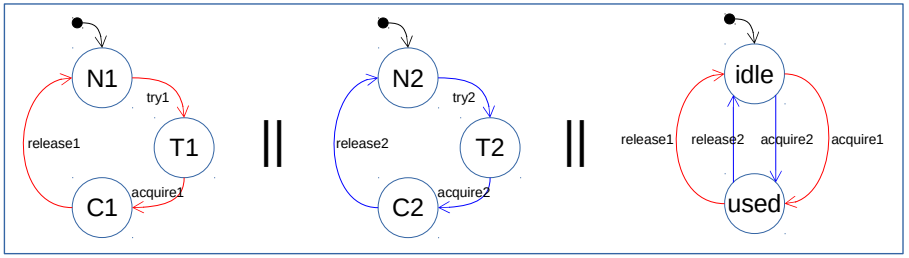
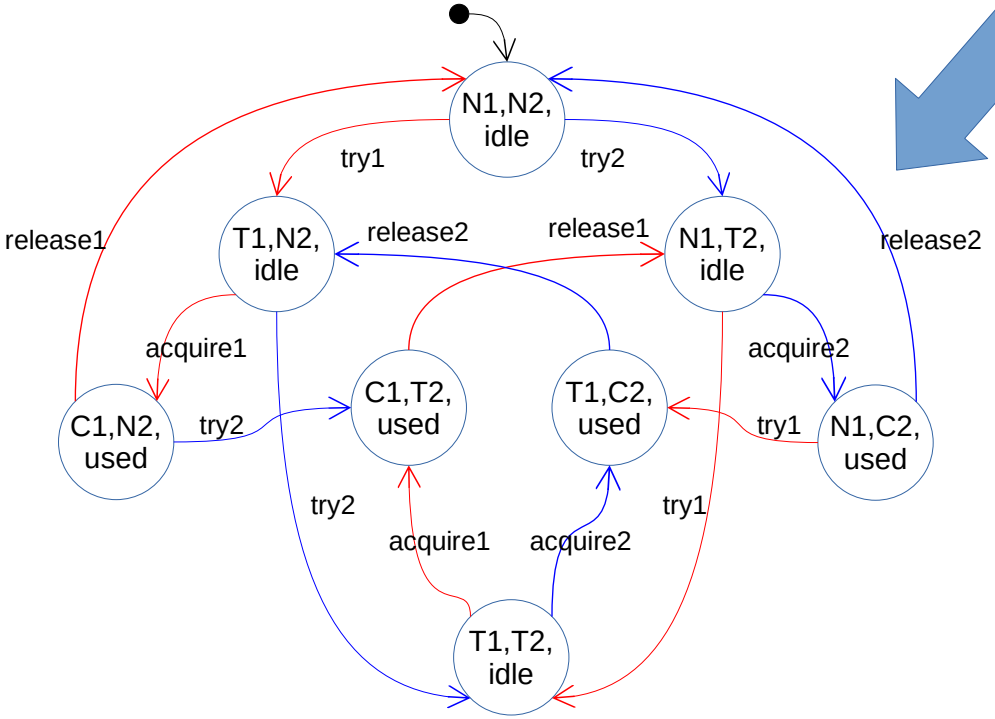
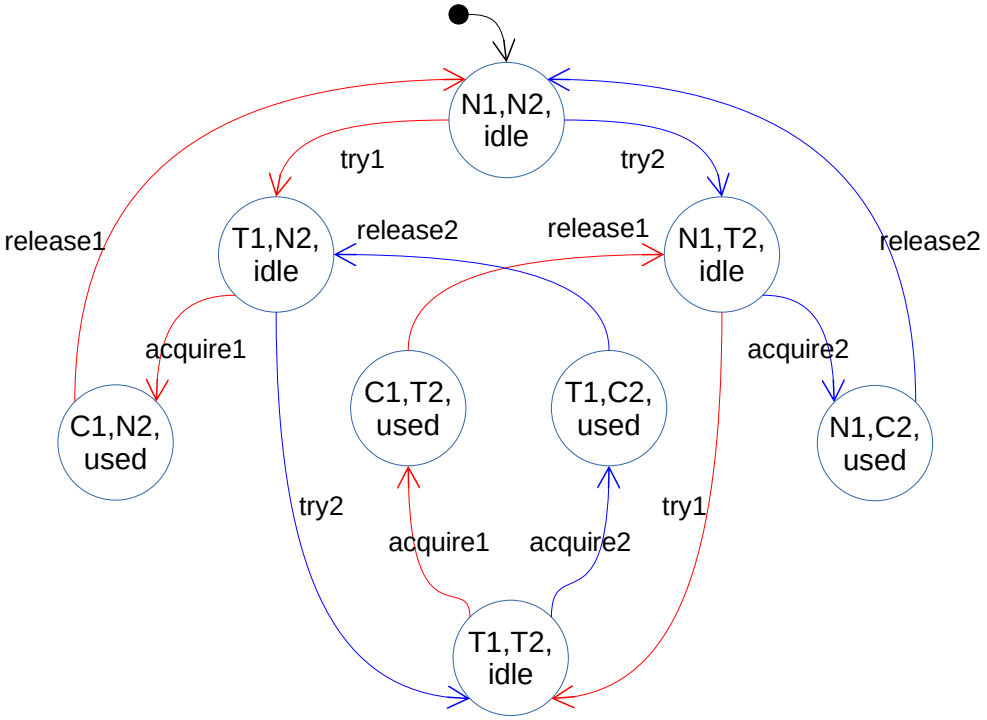




Équivalent :
Sémantique synchrone ou pas

Utilisation de la composition

- En Model Checking



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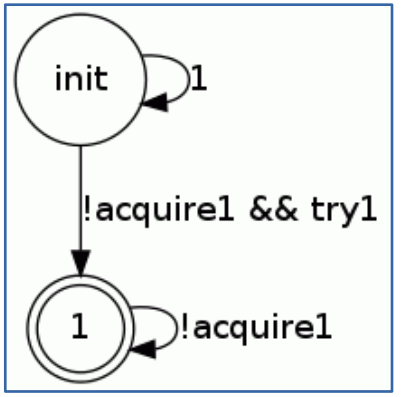

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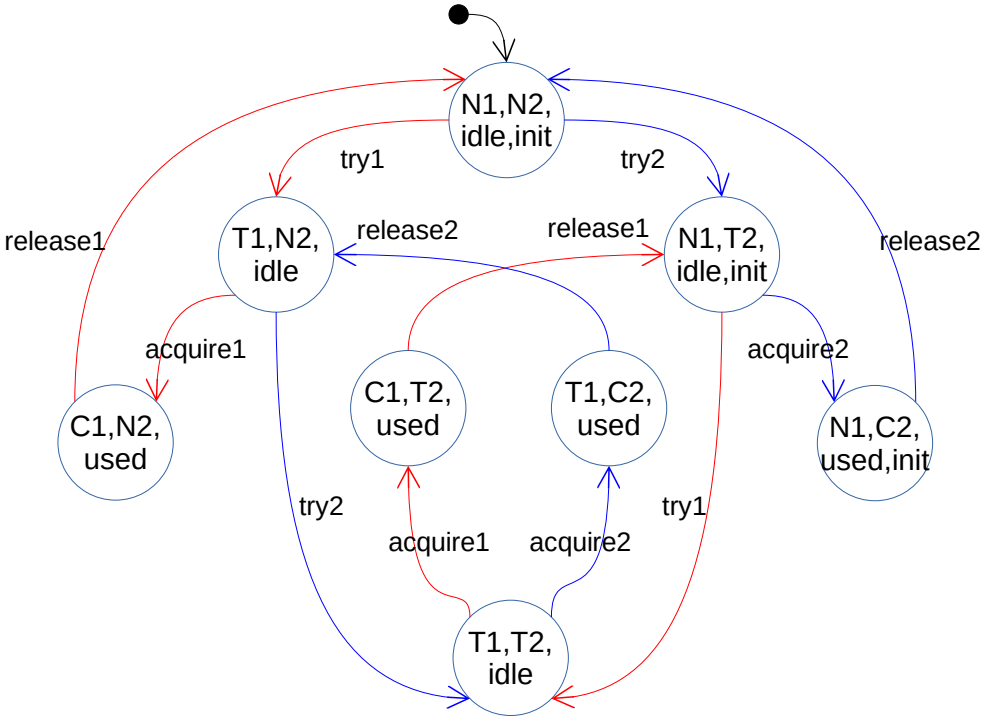

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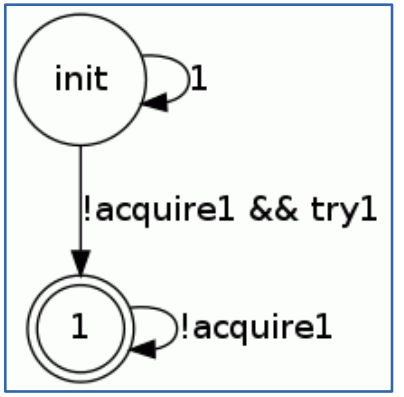

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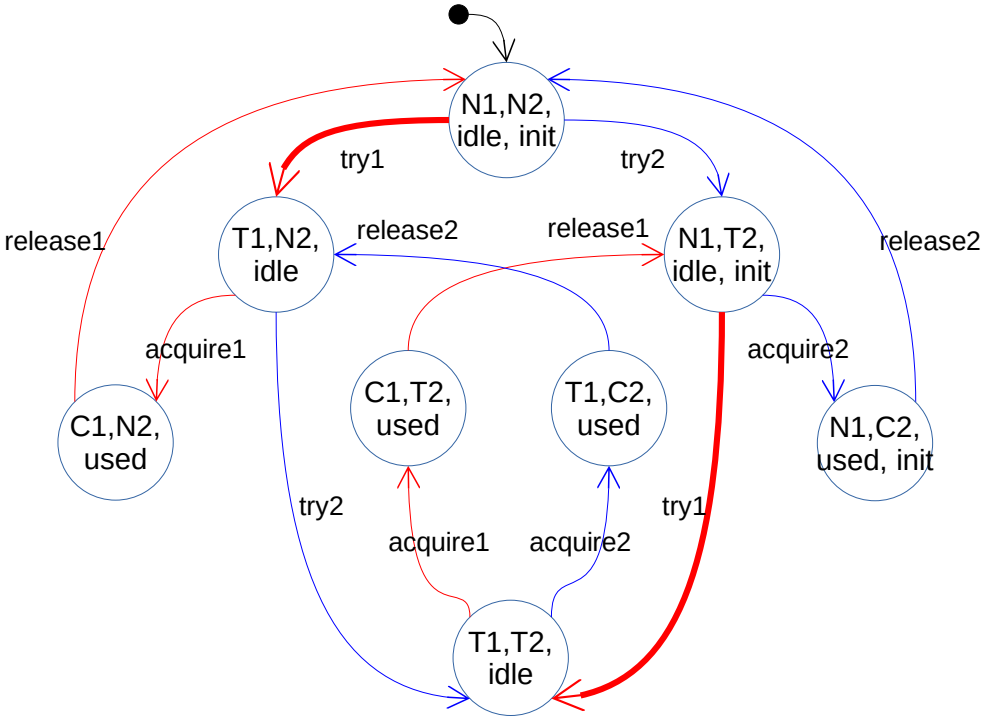

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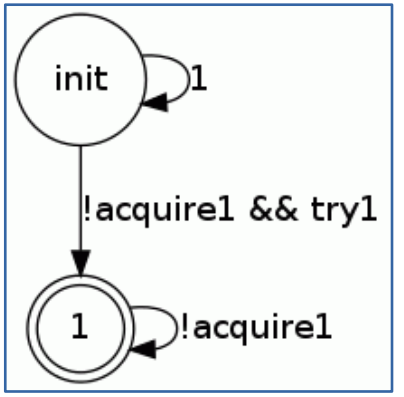

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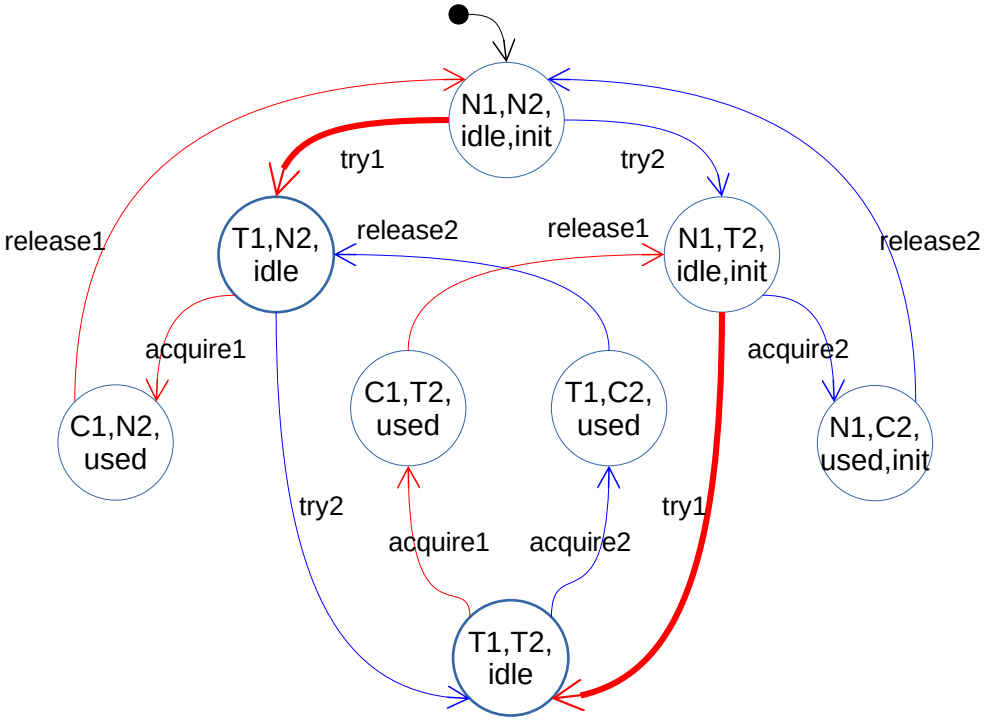

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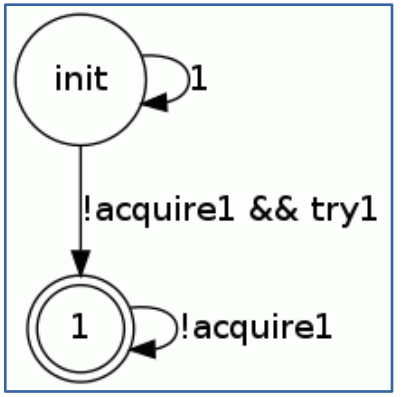

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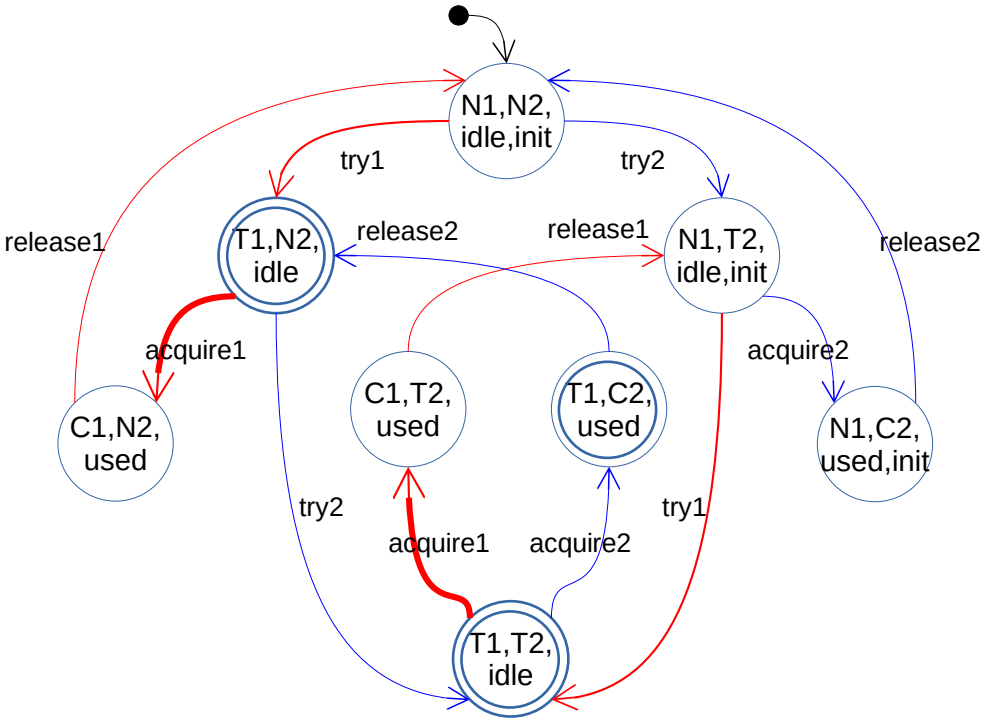

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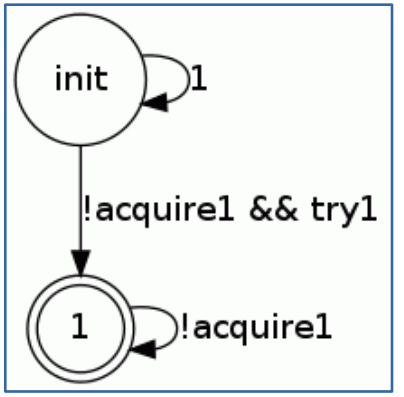

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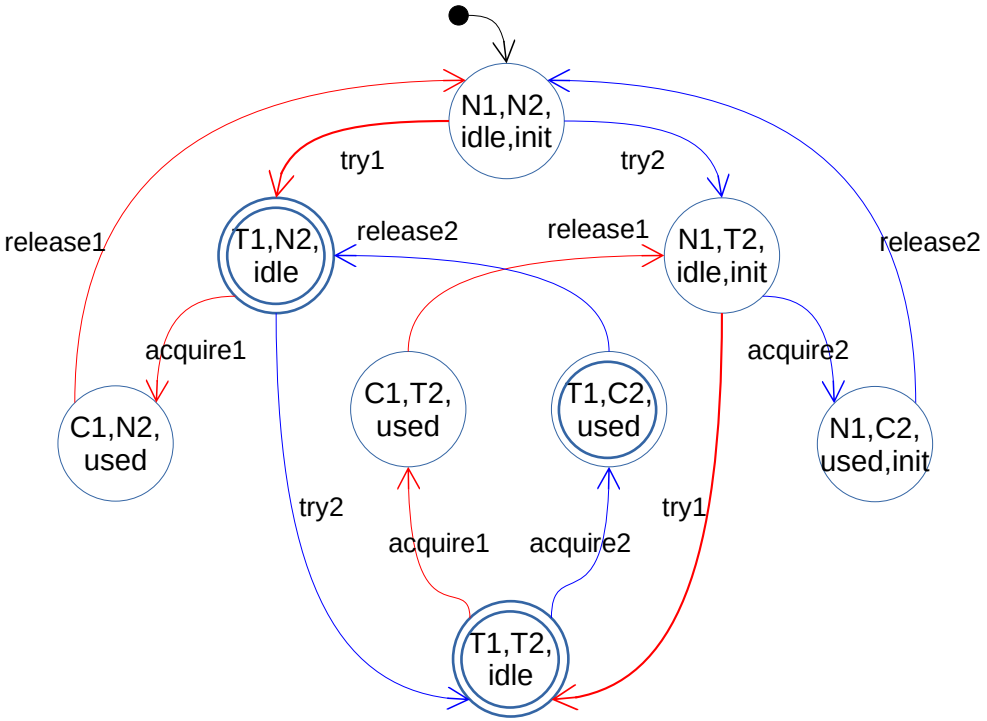

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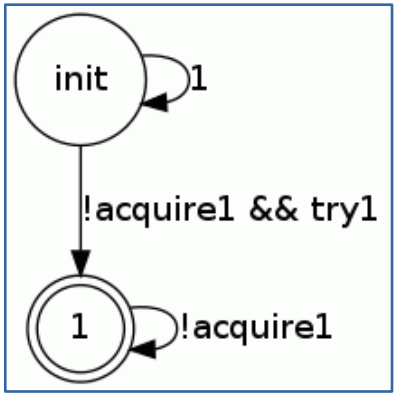
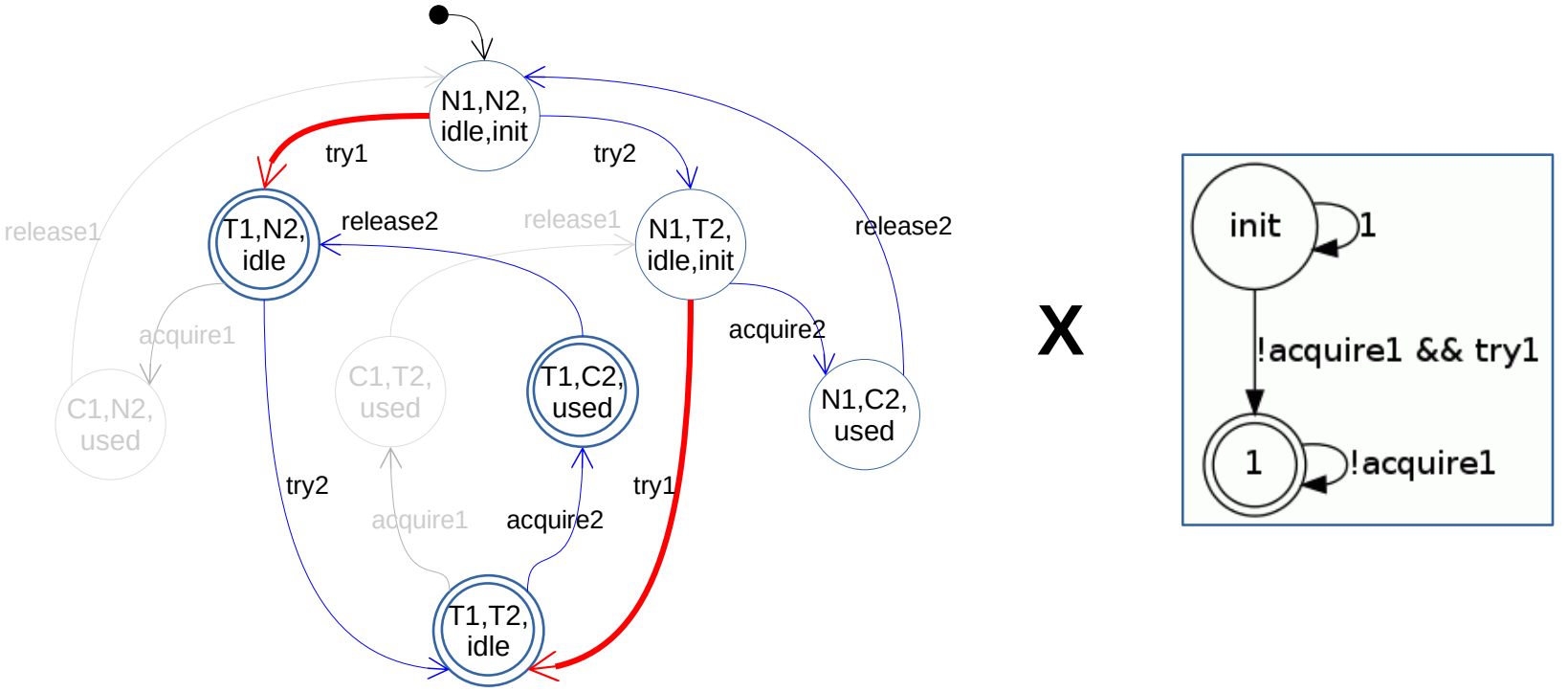


Are you fair or not ?

Fair => that if a choice is possibly infinitely often, then each branch will be chosen infinitely often

Utilisation de la composition

- En Model Checking



Are you fair or not ?

Fair => that if a choice is possibly infinitely often, then each branch will be chosen infinitely often

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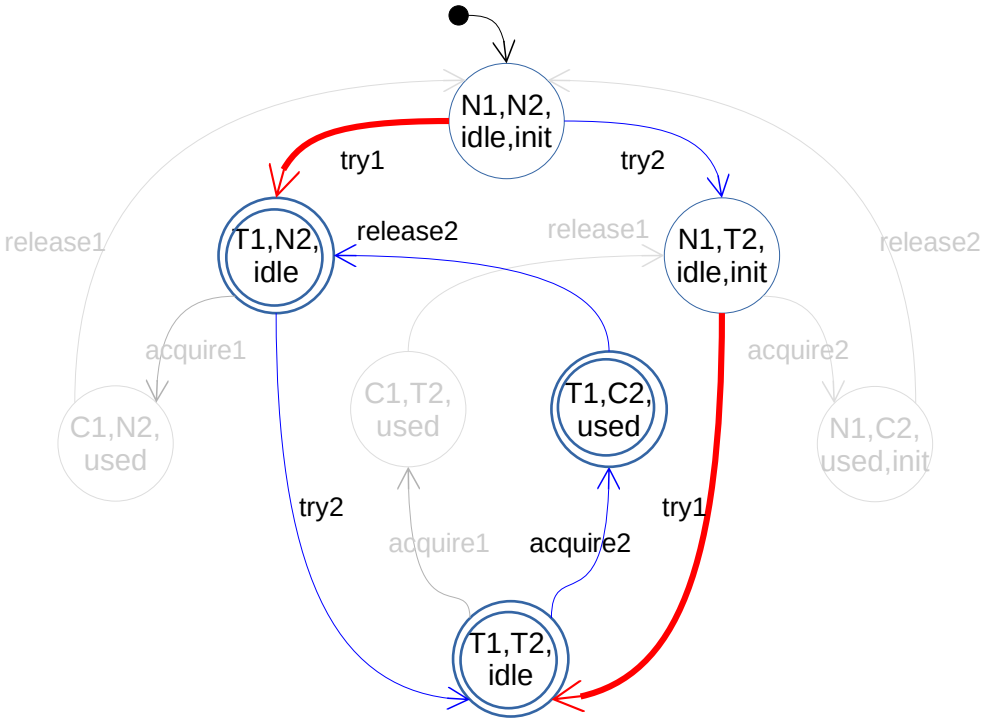
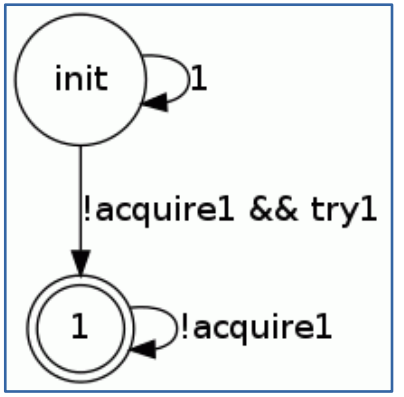


X



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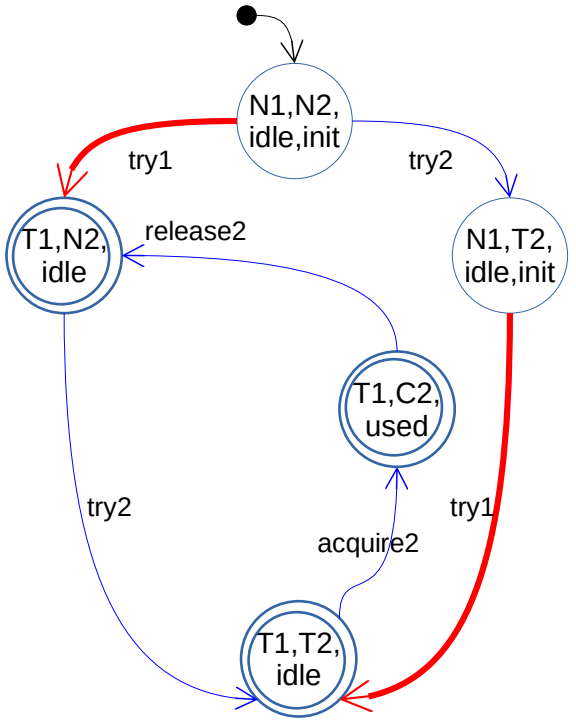

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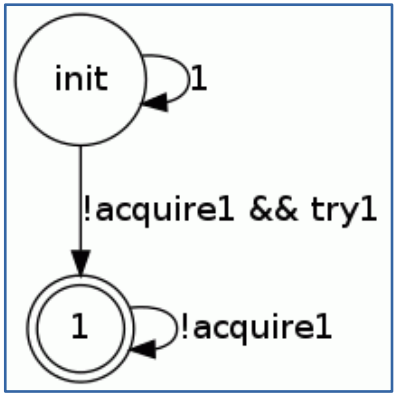

→ L'automate résultant possède un cycle passant par des états acceptants (le visitant infiniment souvent) donc **la propriété n'est pas vérifiée**

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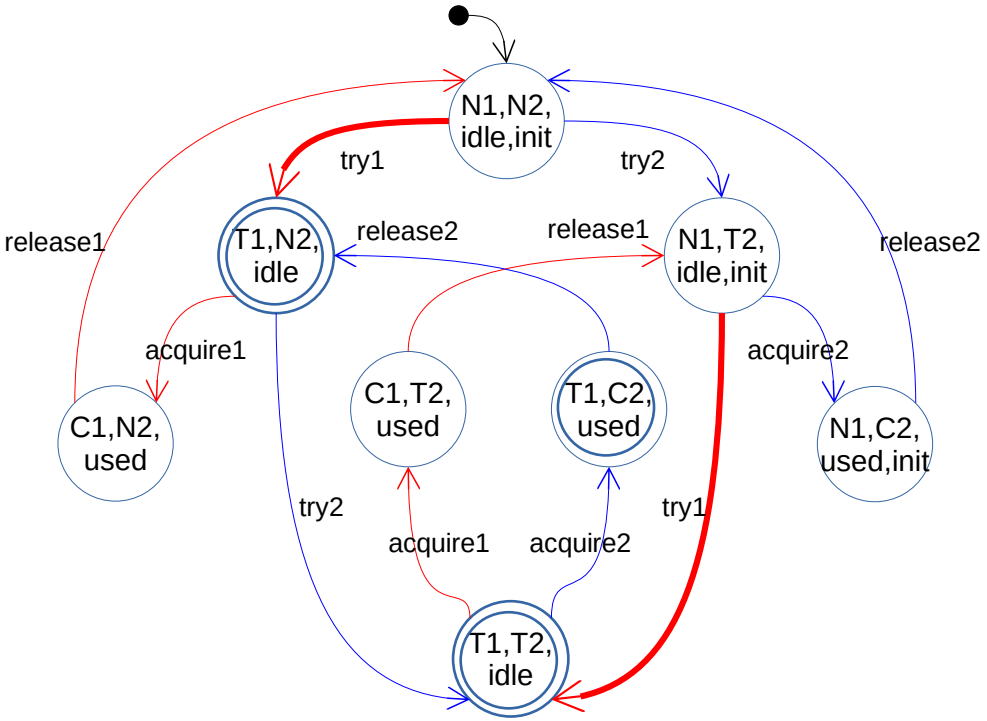

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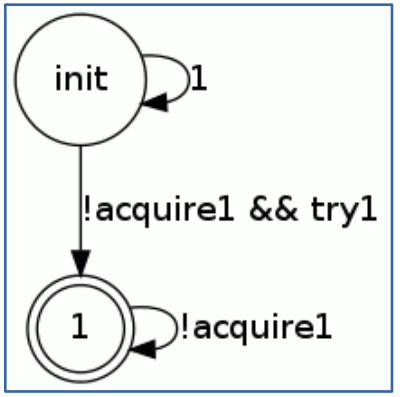

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LTS analyser en 2 slides

- Outil académique permettant la simulation et verification de réseaux d'automates
- Disponible ici: http://www.doc.ic.ac.uk/~jnm/book/ltsa/download.html mais une version avec une meilleure layout est disponible ici: http://lvl.info.ucl.ac.be/Tools/LTSADelforge

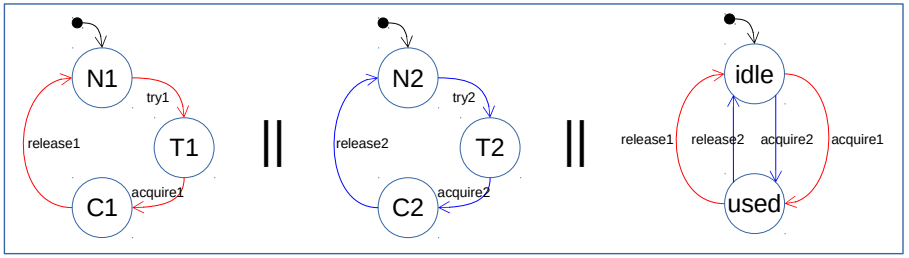
```
User1 = (try1 -> acquire1-> release1 -> User1)
User2 = (try2 -> acquire2-> release2 -> User2).

Mutex   = (acquire1 -> release1 -> Mutex
          |acquire2 -> release2 -> Mutex).

assert Prop = [] ( try1 -> (<> acquire1))
```

Utilisation de la composition

- Génération de code



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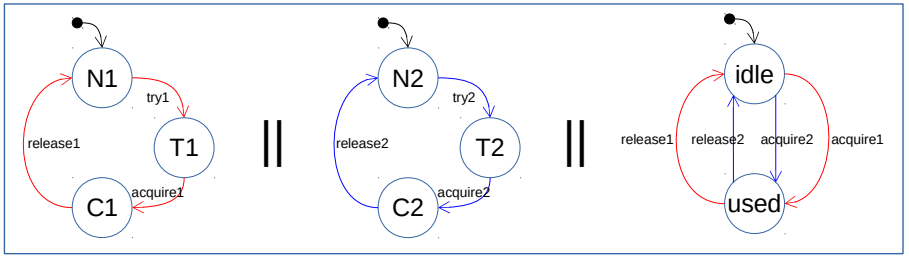
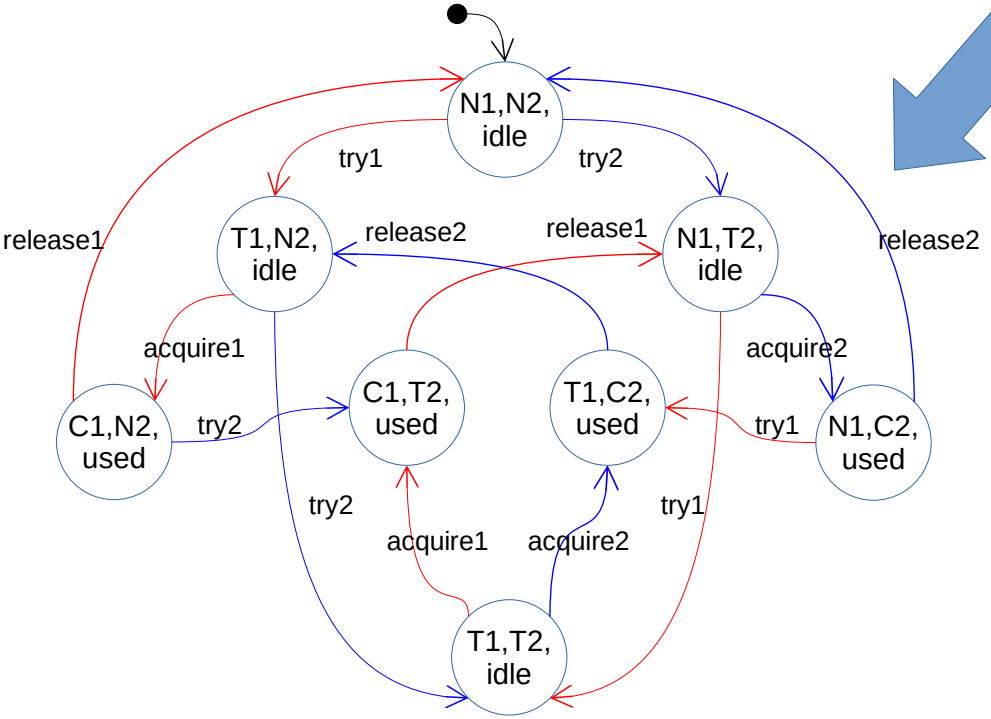


Équivalent



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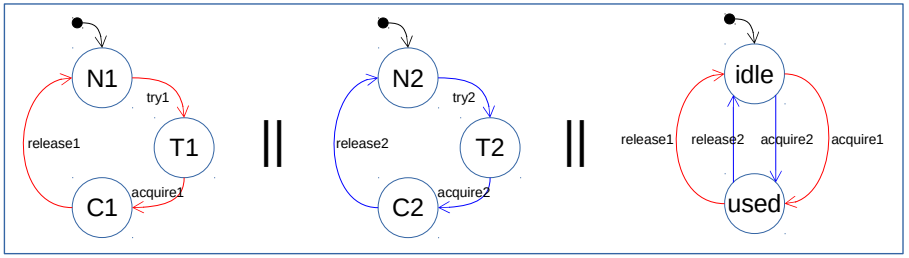

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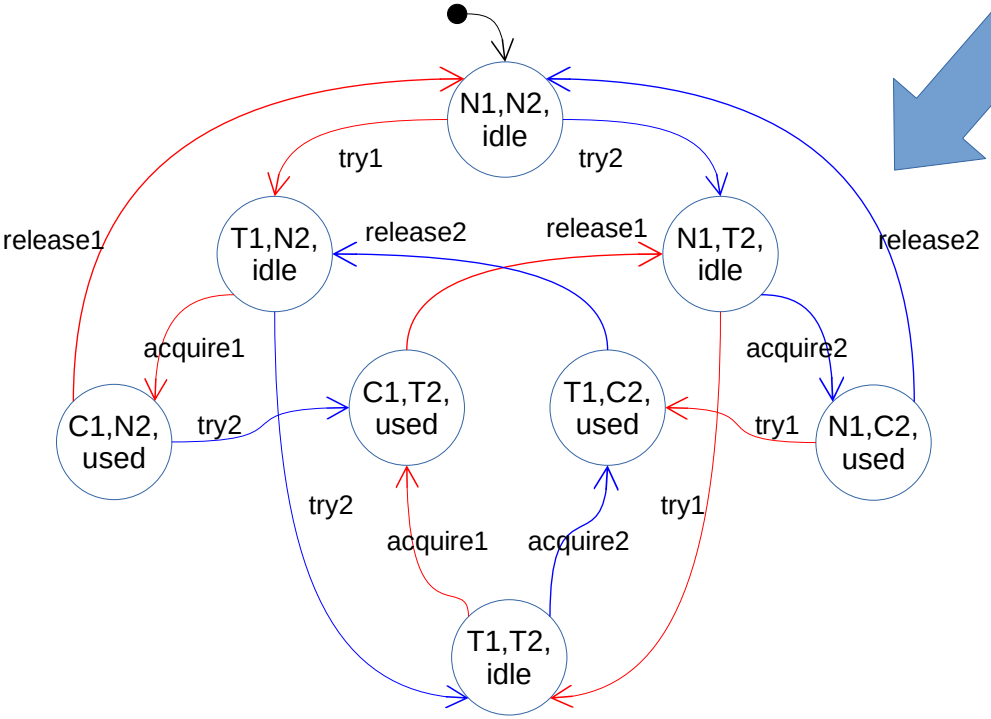

Vous savez générer le code d'un automate non parallèle et vous savez faire le produits asynchrone d'automates ==> vous savez générer le code d'automates parallèles.

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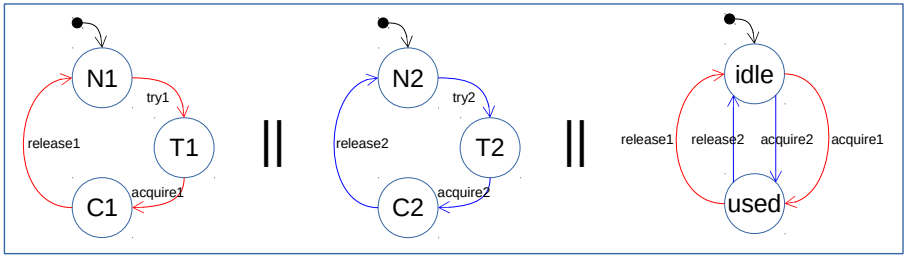
- Génération de code



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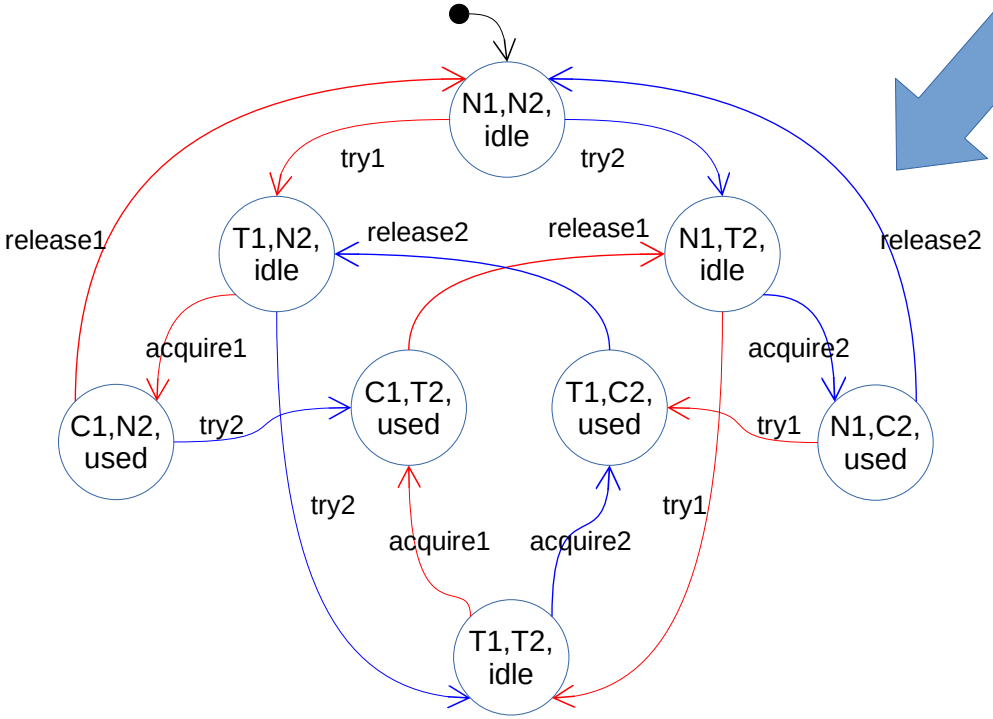

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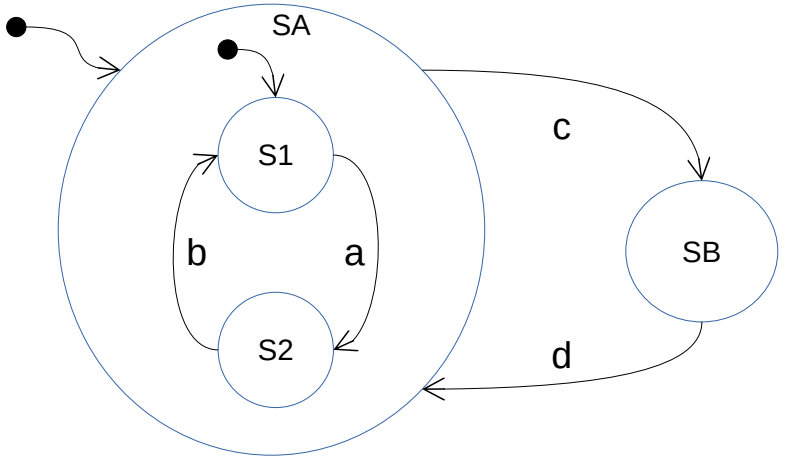
attention à la sémantique de votre dialecte de FSM !
attention à l'explosion en mémoire du produit des automates !

Mise à plat

- Intuitivement: on remplace tous les états hiérachiques par leur contenu, Les alphabets restent les même, seules des actions sont mergées



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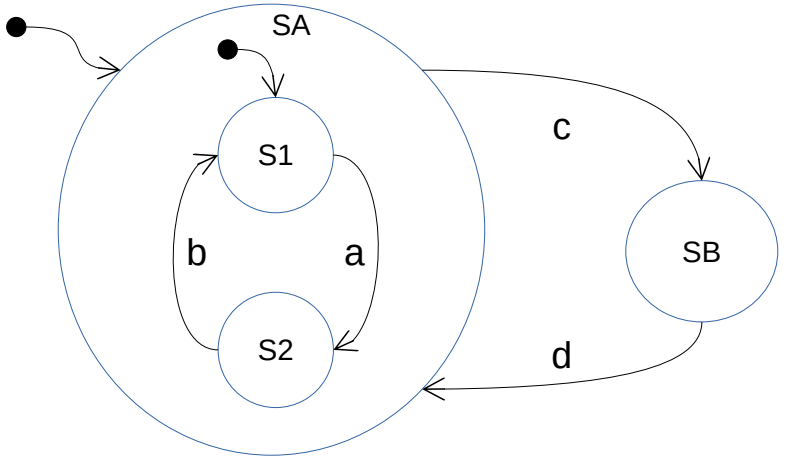

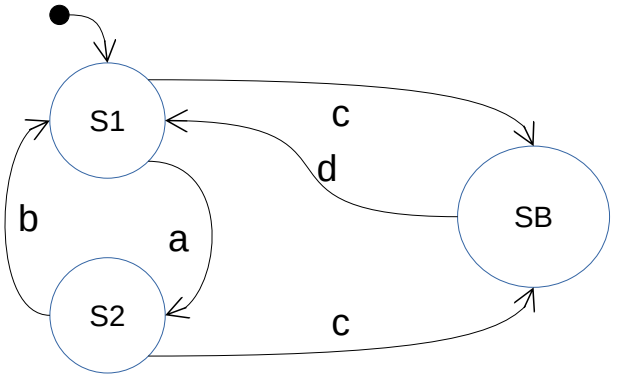

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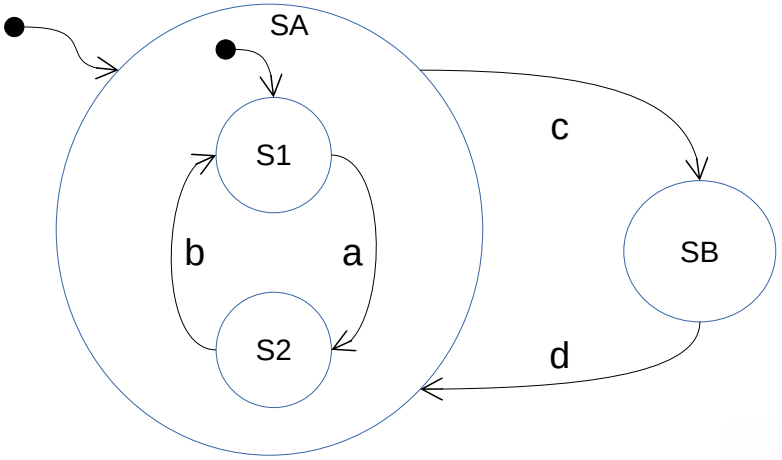
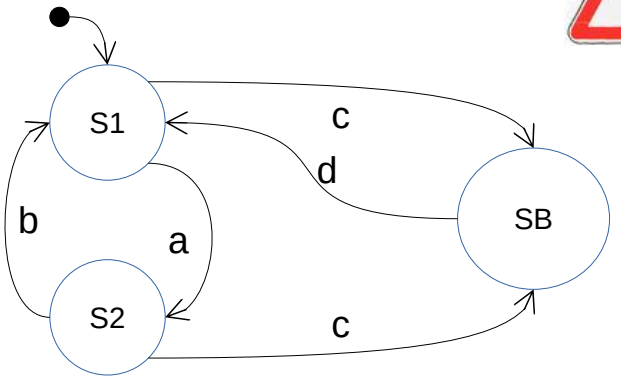


Ne pas oublier la gestion des *onEnter* / *onExit*



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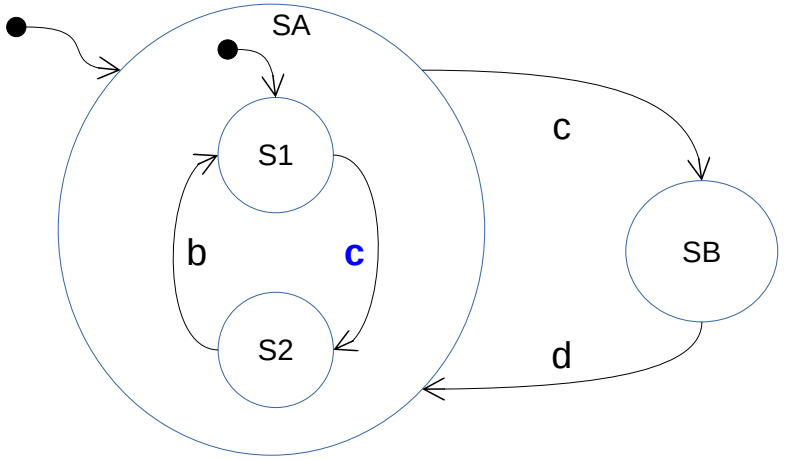

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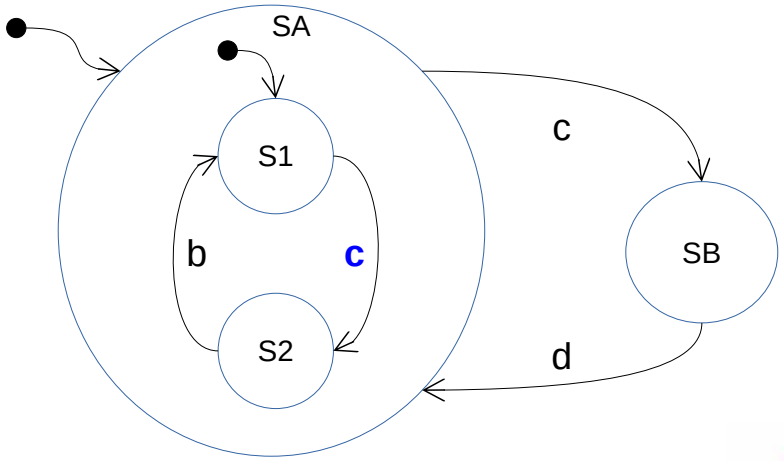

s’assurer de la sémantique de la FSM

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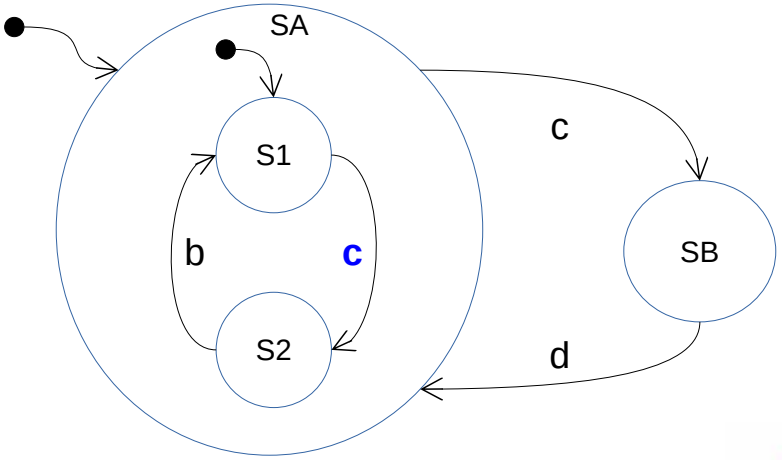

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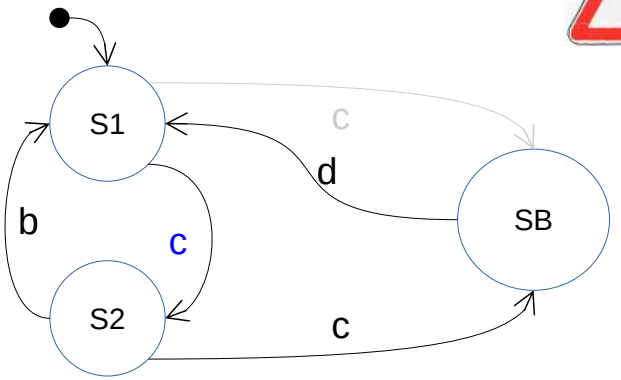

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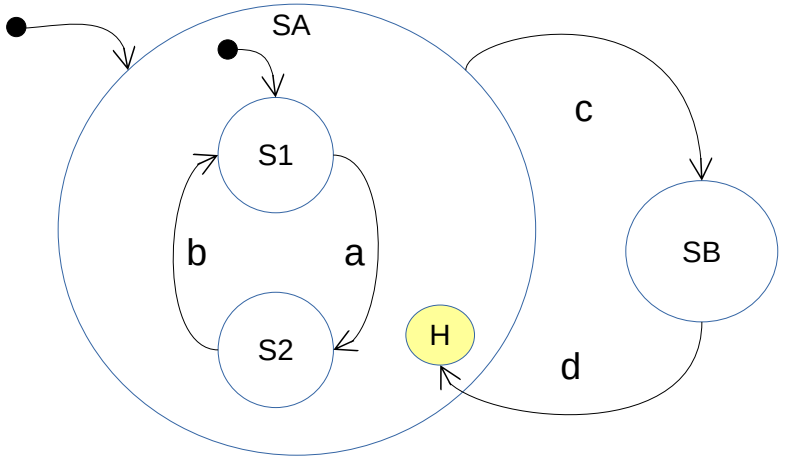

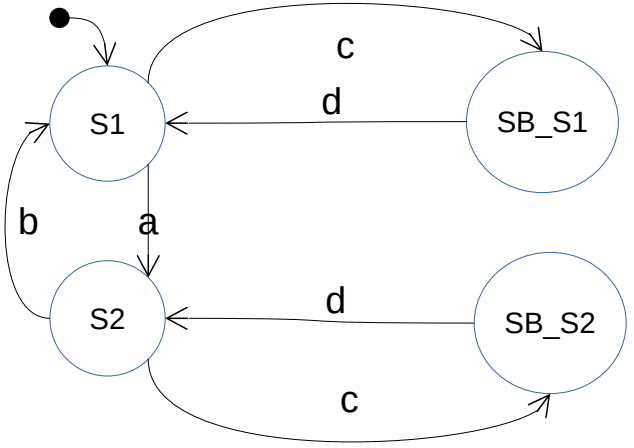

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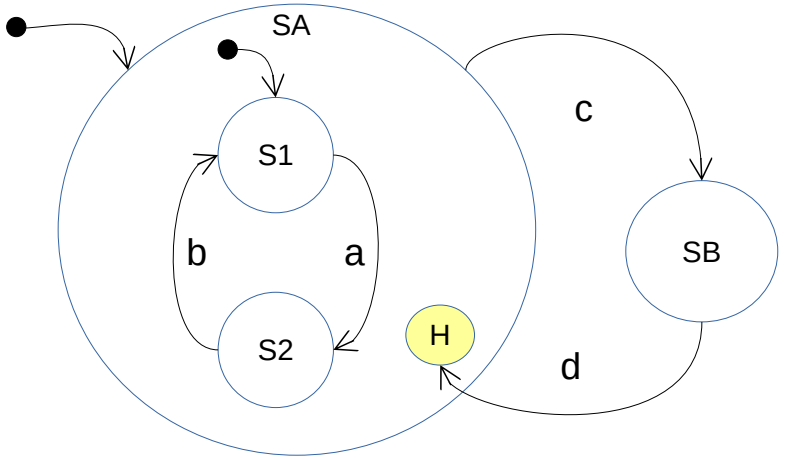
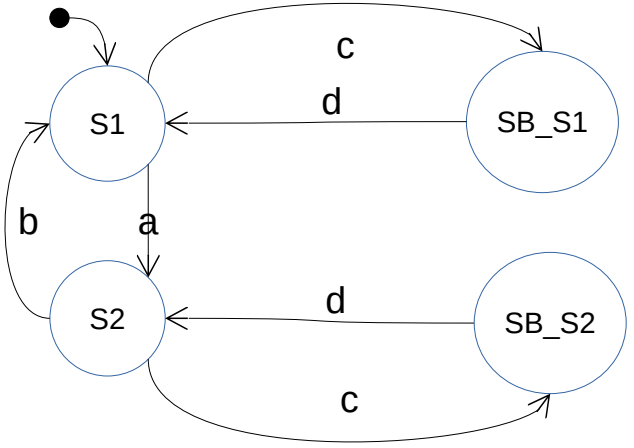


Etc...



Conclusion

- Il existe une littérature importante sur la manipulation de state machine à états finis. Derrière cette littérature ce cache une multitude de dialectes plus ou moins complexes.
- La difficulté de manipulation dépend beaucoup de l’expressivité du dialecte et de sa concision.
- Il est possible de passer de “state chart” à des FSM simples mais le coup est exponentiel
- Les FSM devraient au minimum vous aider à structurer votre pensée, au mieux à structurer/générer/vérifier/valider le code de contrôle de vos programmes.