Structure Preserving Bisimilarity,

Supporting an Operational Petri Net Semantics of CCSP

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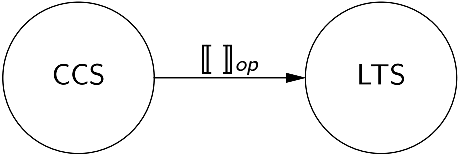
Milner:



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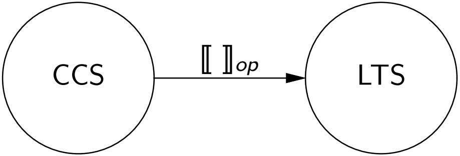
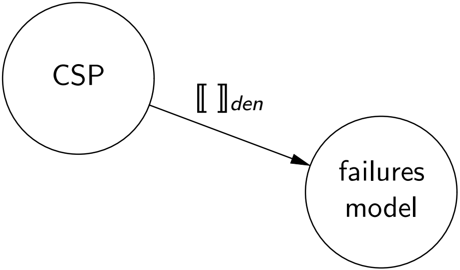


Hoare:



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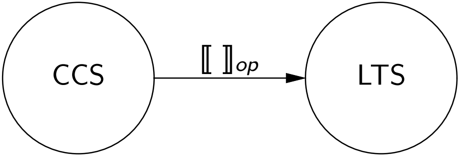

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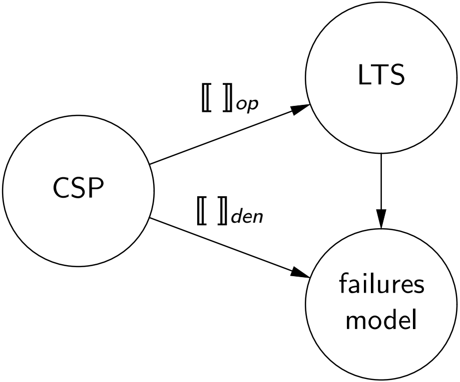
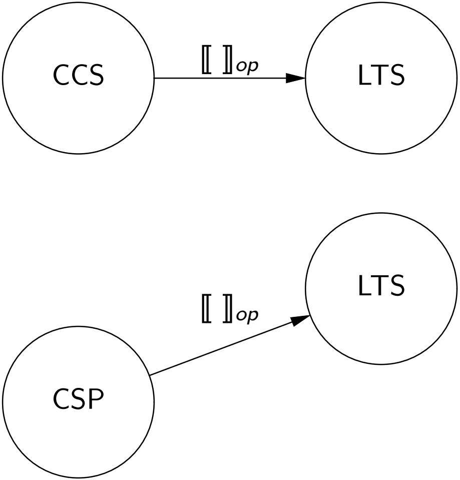
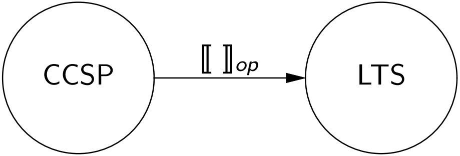


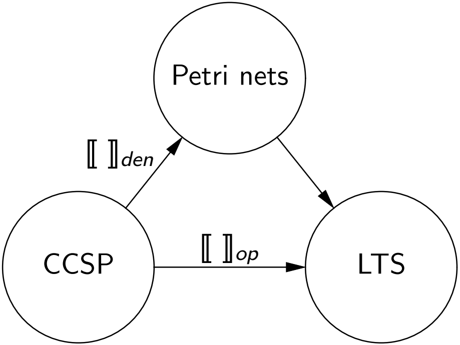
[Olderog & Hoare '86]


CCS
⟦ ⟧op
LTS
LTS
⟦ ⟧op
CSP

Nielsen:
Olderog:



Goltz & Mycroft
Winskel
van Glabbeek & Vaandrager:



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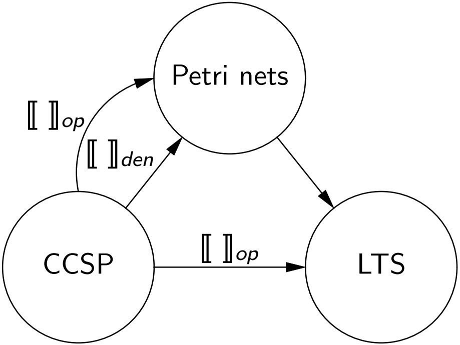

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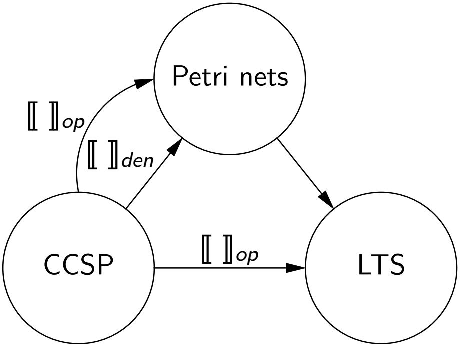
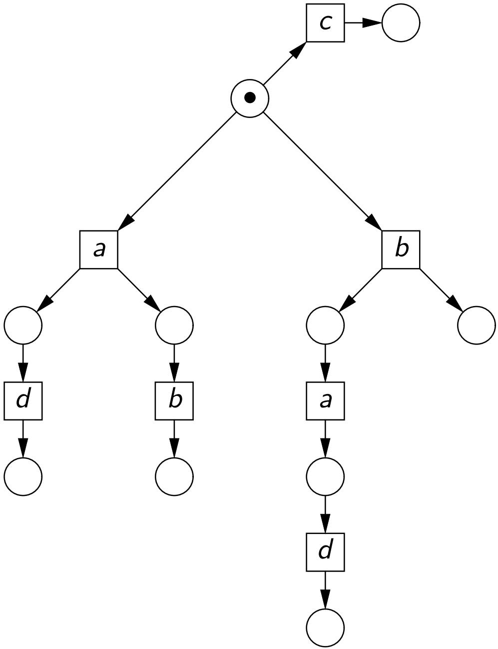
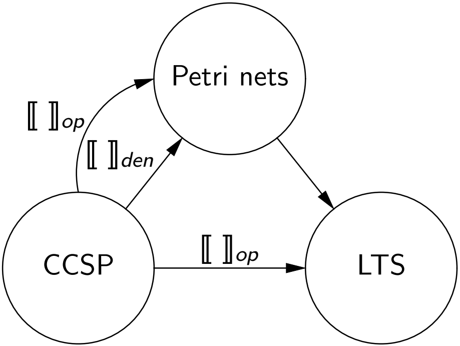


including a treatment of recursion.
But initial concurrency is not respected.

$$[\![(ad \| b) + c]\!]^{\mathrm{DDM}}_{op} =$$

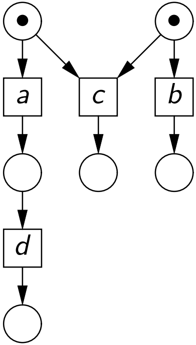


Olderog, 1987:



including a treatment of recursion.
Concurrency is fully respected.

$$[\![(ad \| b) + c]\!]_{op}^{\mathrm{Old}} =$$



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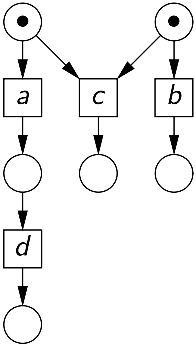

This is the same result as for the denotational Petri net semantics found in the literature.

How to formalise the statement that Olderog's operational semantics respects concurrency?

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But this fails in the same way as the operational versus denotational semantics of CCSP in terms of labelled transition systems: $[\![a + a]\!]_{op} \neq [\![a + a]\!]_{den}$.

So instead one shows $[\![P]\!]_{op} \approx [\![P]\!]_{den}$ for a suitable relation $\approx$.

Showing agreement between an operational and denotational net semantics of CCSP

Aim: propose a relation $\approx$ between nets, and show $[\![P]\!]_{op} \approx [\![P]\!]_{den}$.

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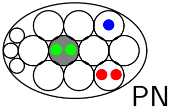
2. $\approx$ respects concurrency.
3. $\approx$ is a congruence relation for CCSP.



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$\equiv_{caus}$ respects concurrency.

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$\equiv_{caus}$ is a *linear time* equivalence:

$$[\![a(b+c)]\!]_{op} \equiv_{caus} [\![ab+ac]\!].$$

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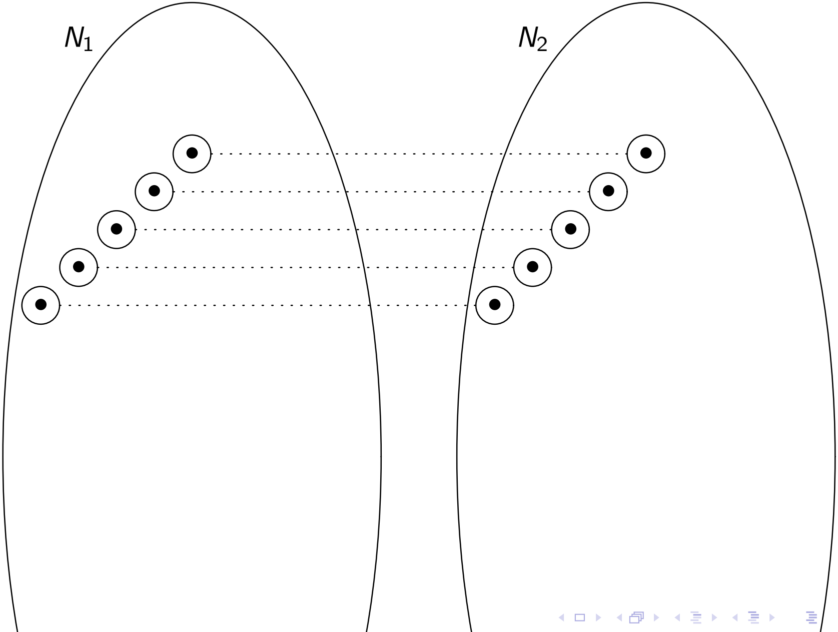
My contribution today is the proposal of a new branching time equivalence that can play the rôle of $\equiv_{caus}$.

I call it *structure preserving bisimilarity* $\underline{\leftrightarrow}_{sp}$.

Structure Preserving Bisimulation



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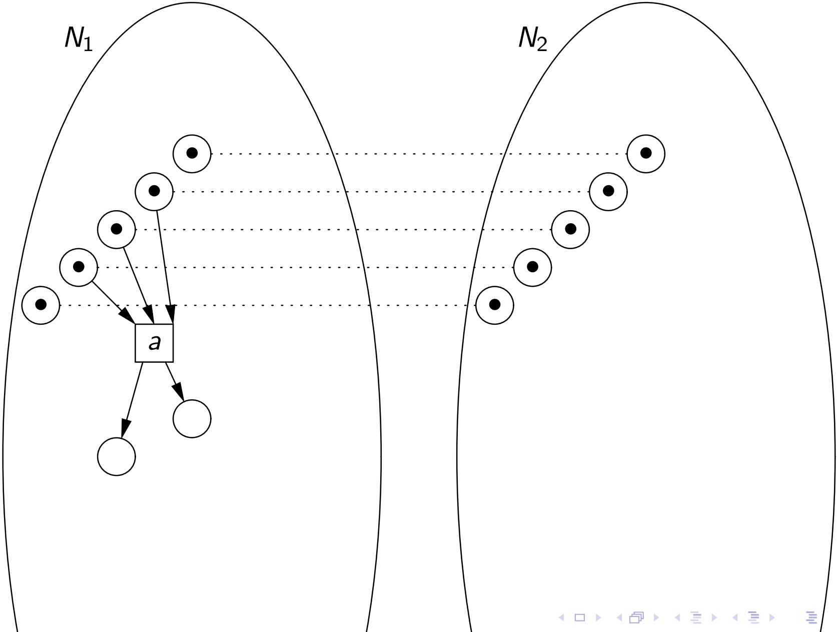

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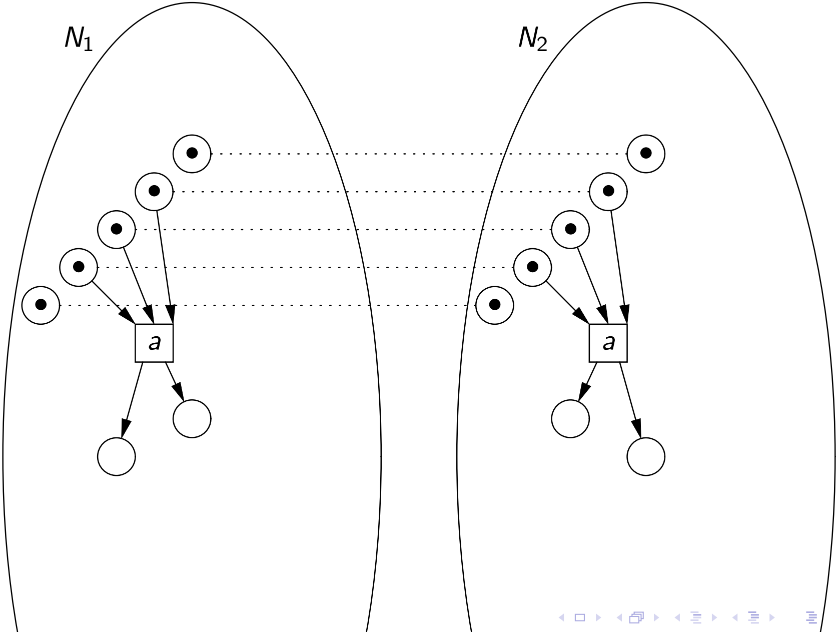

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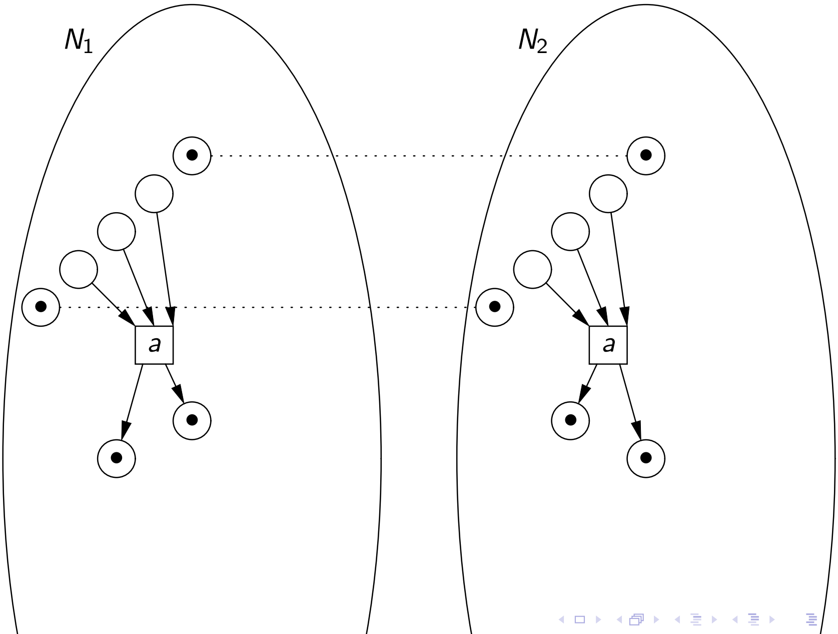

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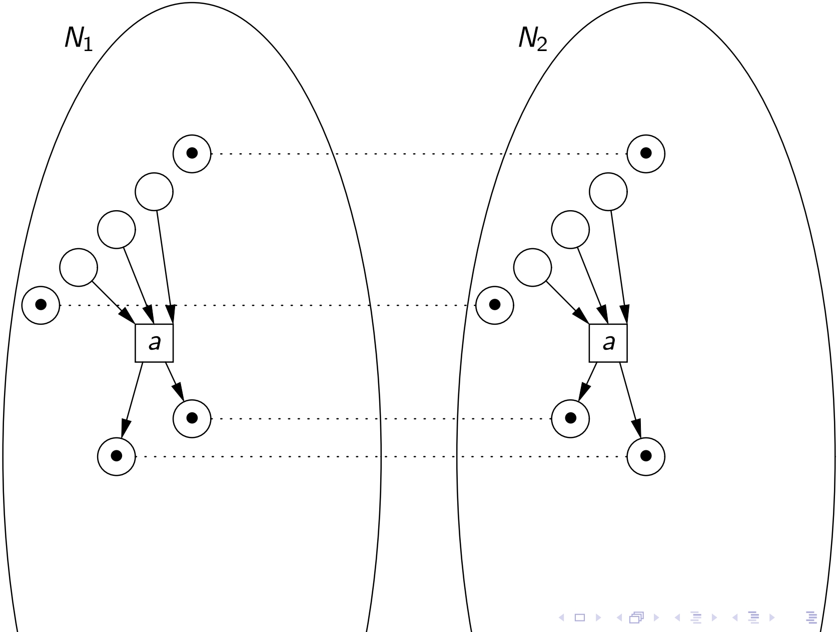

Criteria for choosing this equivalence

2. It should capture concurrency. $a \| b \neq ab + ba$ causality

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Semantic equivalences on Petri nets

BRANCHING TIME

↕

LINEAR TIME

ABSTRACT FROM CAUSALITY/CONCURRENCY ⟷ CAPTURE CAUSALITY/CONCURRENCY

Semantic equivalences on Petri nets

BRANCHING TIME

bisimulation semantics $\approx_{ib}$

LINEAR TIME

trace semantics $\approx_{it}$

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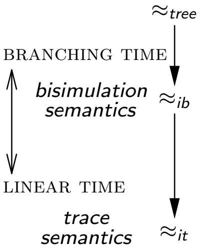

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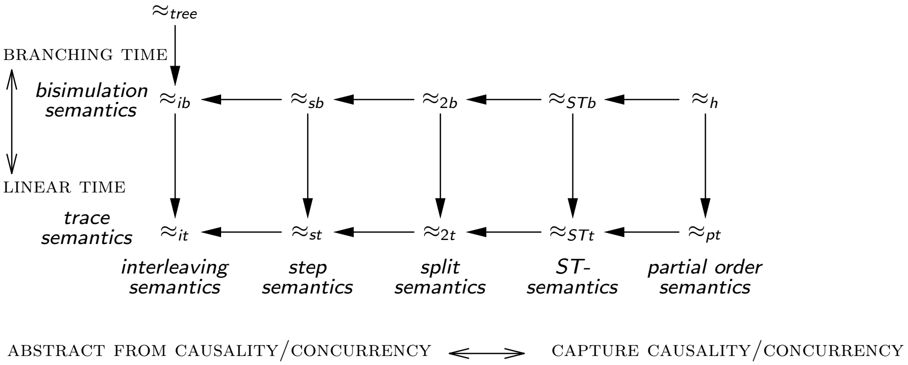

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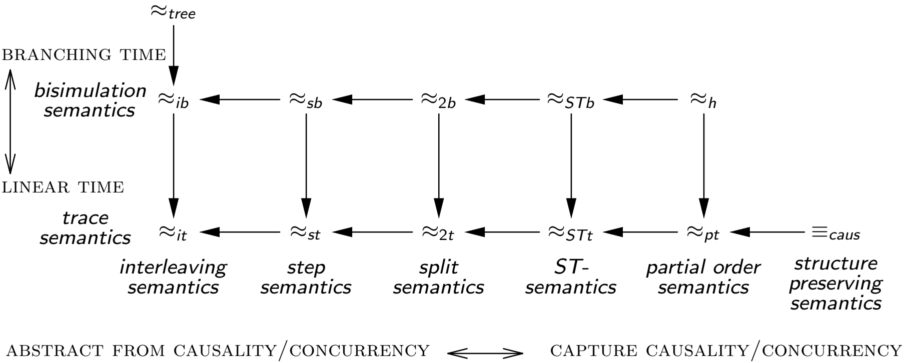

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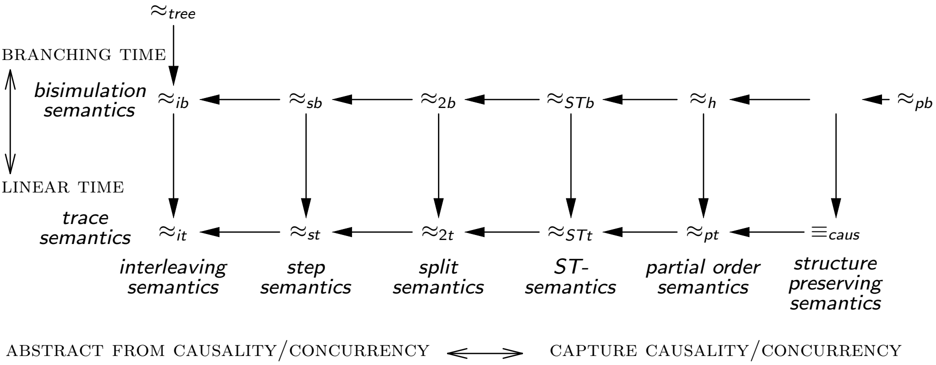

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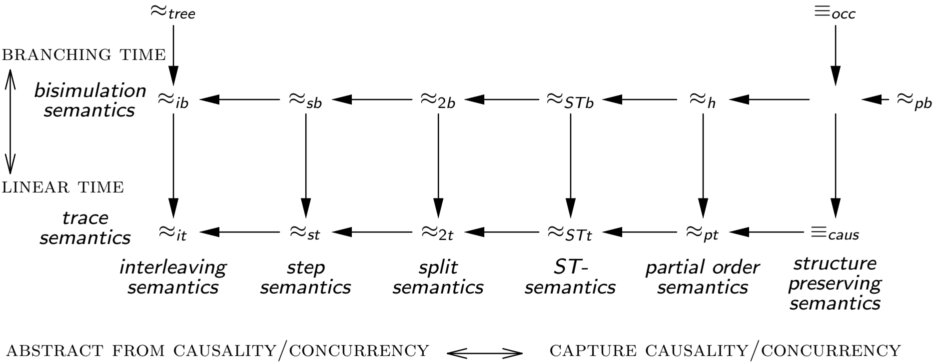

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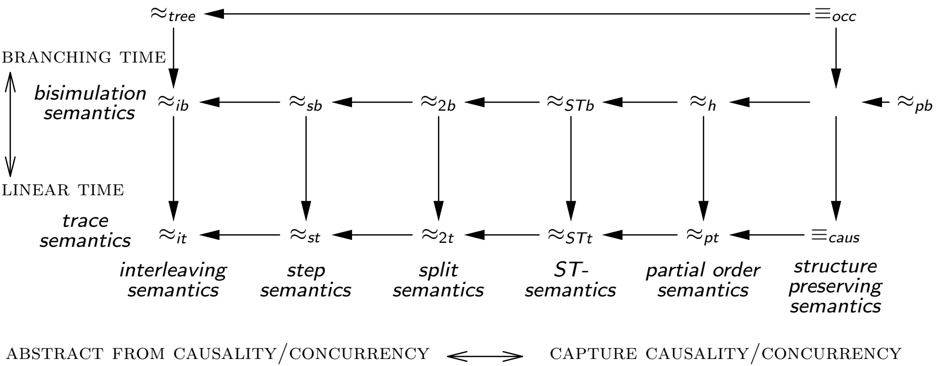

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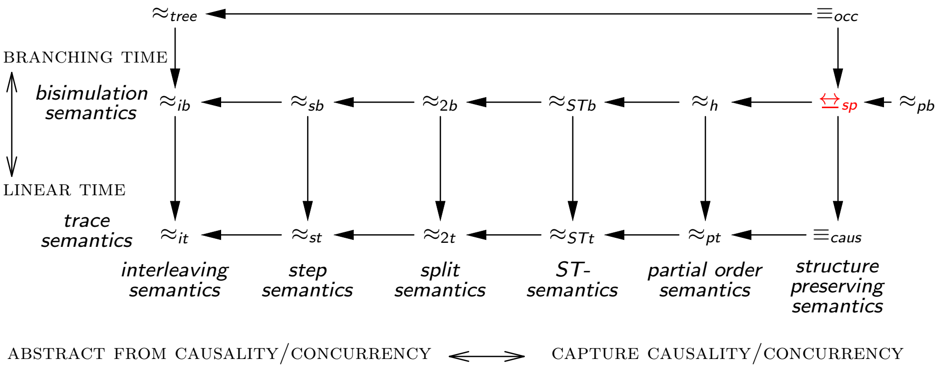

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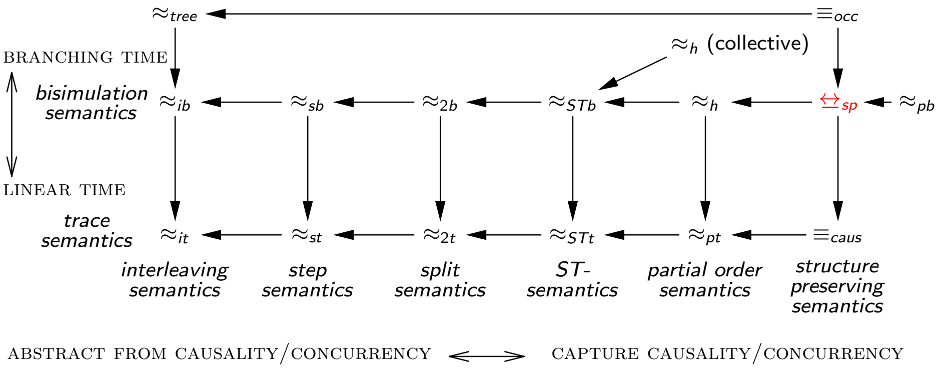

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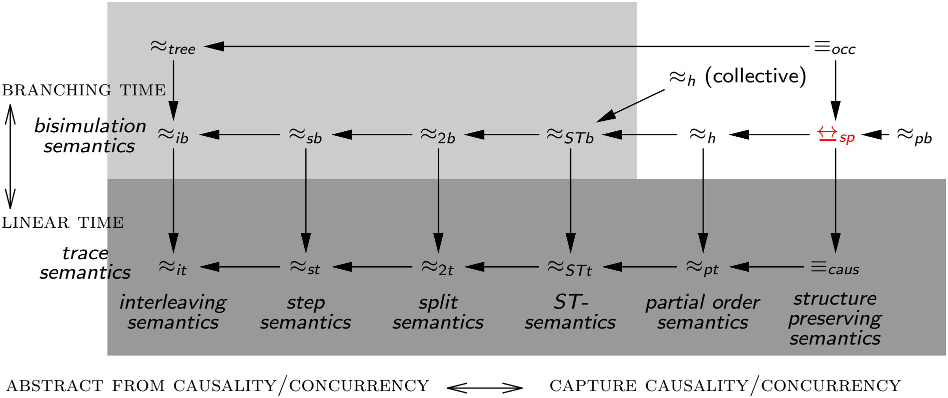

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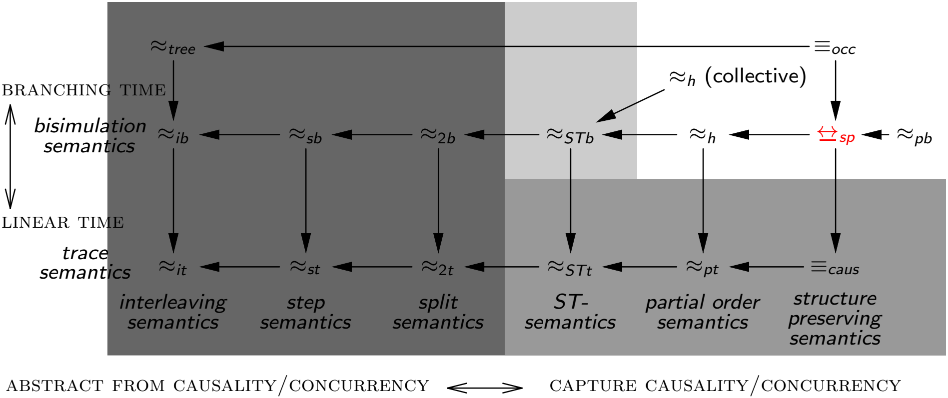

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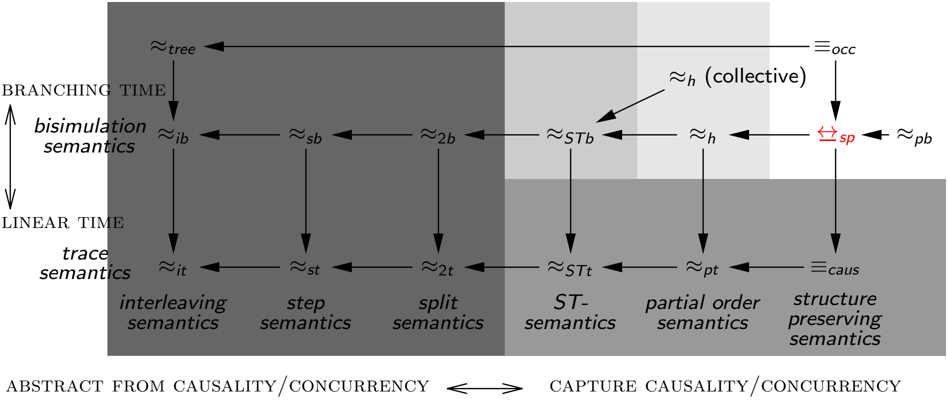

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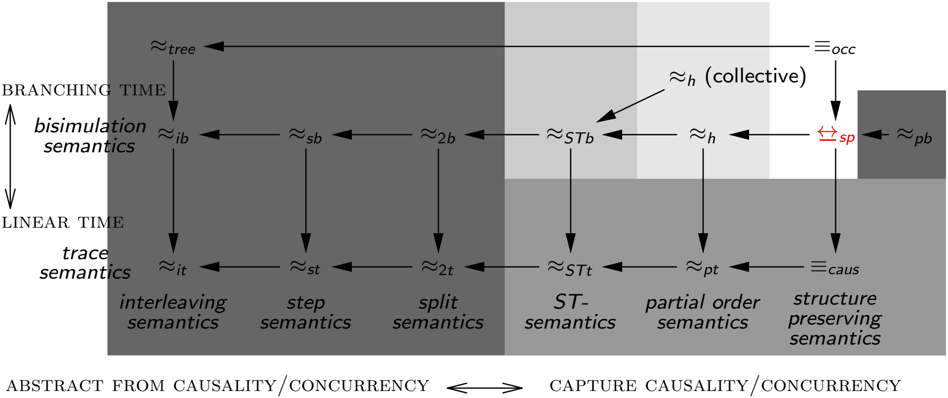

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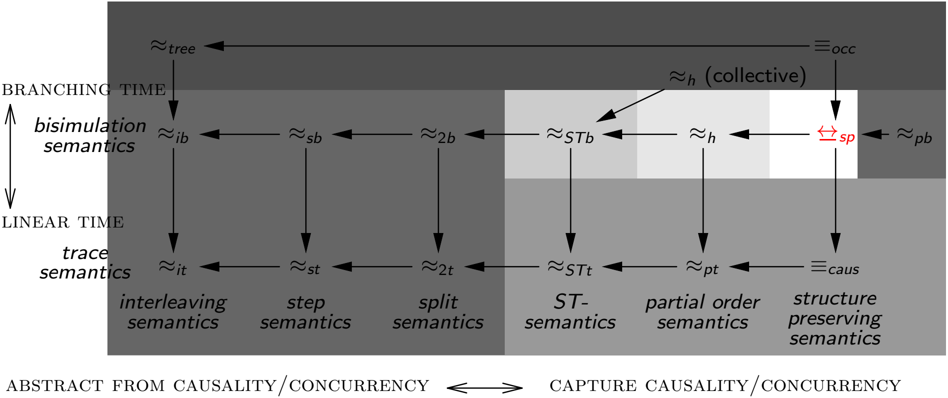

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3. It should respect *inevitability*. [Mazurkiewicz]
4. It should be *real-time consistent*. a and b one minute each
5. It should be *preserved under action refinement*. $a \mapsto a_1 ; a_2$
6. It should be finer than $\equiv_{caus}$.
7. It should not distinguish nets whose behaviours are patently the same, i.e. when differing only in unreachable parts.
8. It should be a congruence for CCSP.
9. $[\![P]\!]_{op} \approx [\![P]\!]_{den}$ for any P for which both sides are defined.

Inevitability

I will show you Petri nets featuring a transition b.
I will ask you by a show of hands whether you hold b to be inevitable.

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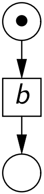
Question 0: Are you insufficiently familiar with Petri nets to answer such questions, or decline to answer for any other reason?

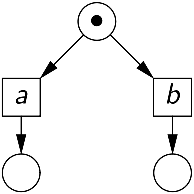
Question 1:



(CCSP expression: b)

Inevitability

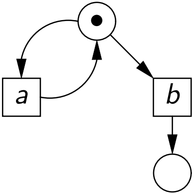
Question 2:



(CCSP expression: $a + b$)

Inevitability

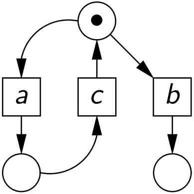
Question 3:



(CCSP expression: E with $E \stackrel{def}{=} a.E + b$.)

Inevitability

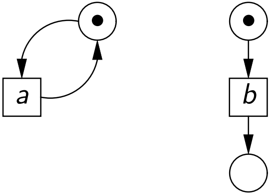
Question 4:



(CCSP expression: E' with $E' \stackrel{def}{=} a.c.E' + b$.)

Inevitability

Question 5:



(CCSP expression: $A \| b$ with $A \stackrel{def}{=} a.A$.)

Fairness

In the literature I found only 4 meaningful types of fairness assumptions:

1. Progress
2. Justness
3. Weak Fairness
4. Strong Fairness

These form a hierarchy, thus creating 5 assumptional states.

Fairness

Shop with 2 customers.
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Upon being served, the customer leaves the shop, but usually returns right away to buy something else.

A customer may leave the shop anytime, and possibly return later.

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Failure of justness: There are two counters with a clerk each. Customer A is the only customer at counter 1, yet never is served, while customer B is being served repeatedly at counter 2.

Fairness in CCSP

Are the following processes guaranteed to do action b eventually?

Assuming	nothing	progr.	justness	wk. f.	str. fair.
b					
$a + b$					
E with $E \stackrel{def}{=} a.E + b$.					
E' with $E' \stackrel{def}{=} a.c.E' + b$.					
$A \| b$ with $A \stackrel{def}{=} a.A$					

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$a+b$	–	–	–	–	–
E with $E \stackrel{def}{=} a.E + b.$	–	–	–	✓	✓
E' with $E' \stackrel{def}{=} a.c.E' + b.$	–	–	–	–	✓
$A\|\|b$ with $A \stackrel{def}{=} a.A$	–				

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b	–	✓	✓	✓	✓
$a + b$	–	–	–	–	–
E with $E \stackrel{def}{=} a.E + b.$	–	–	–	✓	✓
E' with $E' \stackrel{def}{=} a.c.E' + b.$	–	–	–	–	✓
$A \| b$ with $A \stackrel{def}{=} a.A$	–	–	✓	✓	✓

Fairness in process algebra

Strong or weak fairness can be

- indispensable for certain applications, such as a correctness proof of the alternating bit protocol.
- patently wrong when used where not appropriate.

E with $E \stackrel{def}{=} a.E + b.0$.

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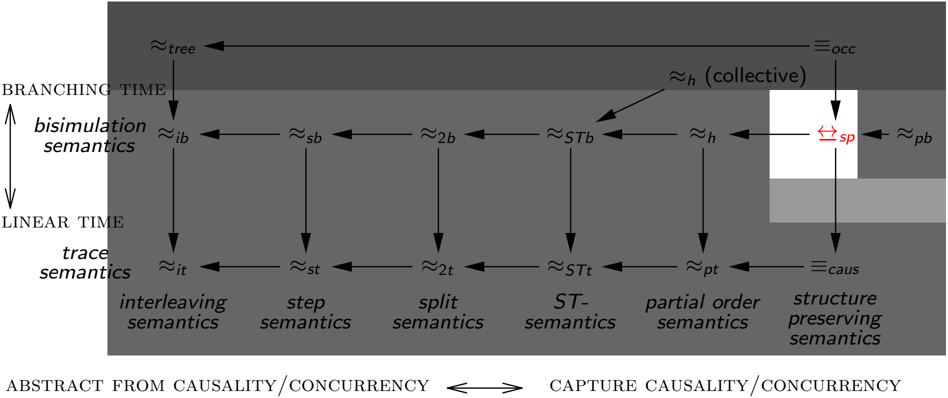
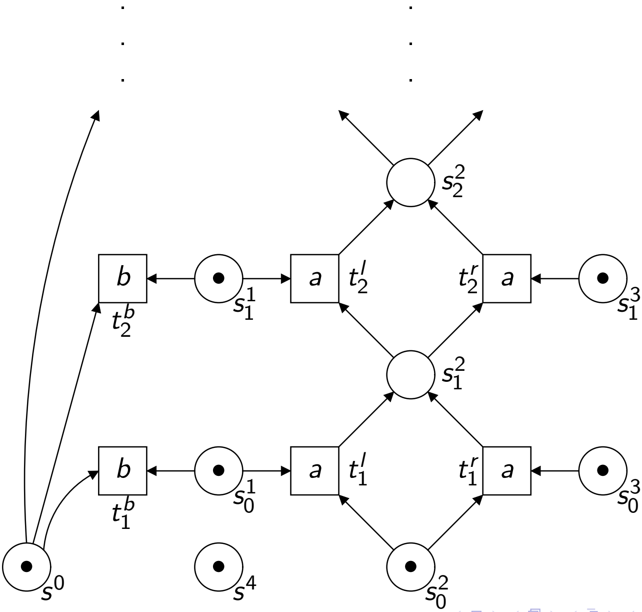
  Fairness amounts to saying that if you try often enough, dialling will succeed.
  This is wishful thinking.
  The real world is not fair.
- When assuming strong or weak fairness, we loose the ability to finitely specify a system like E above that *does* allow an infinite sequences of *a*s without a b.

Semantic equivalences on Petri nets



HP bisimilarity does not respect inevitability



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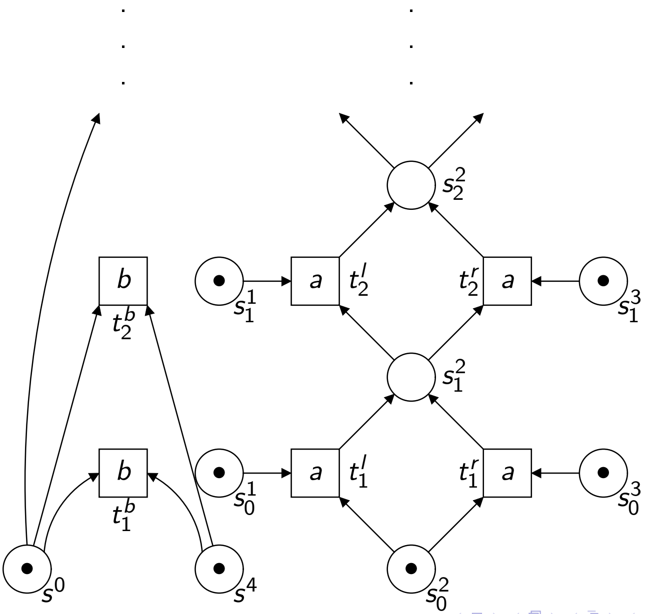
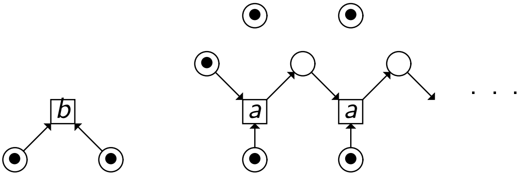


Causal equivalence does not respect inevitability



The causal nets of both systems are the infinite one above, and all its finite prefixes.

Conclusion

1. I proposed 9 requirements on semantic equivalences on Petri nets.
2. None of the existing equivalences satisfies all (or almost all) of these requirements.
3. I propose a new equivalence that does.
4. A major motivation of this equivalence is its suitability in establishing agreement between the denotational and operational Petri net semantics of CCSP.