Automatisierte Reduktion von reaktiver zu starker Bisimilarität

Zead Alshukairi

Agenda

EINFÜHRUNG
3

GRUNDLAGEN
23

ARBEITSGEGENSTÄNDE
50

ANMERKUNGEN
108

FAZIT
115

Einführung

- Ziel meiner Arbeit

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  - Bisimilaritäten

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  - Idee der einzigen Umgebungsaktion
  - Ursprüngliche LTS's visualisiert

Grundlagen

- Starke Bisimilarität
- Reaktive Bisimilarität
- Die Reduktion von Max

Starke Bisimilarität

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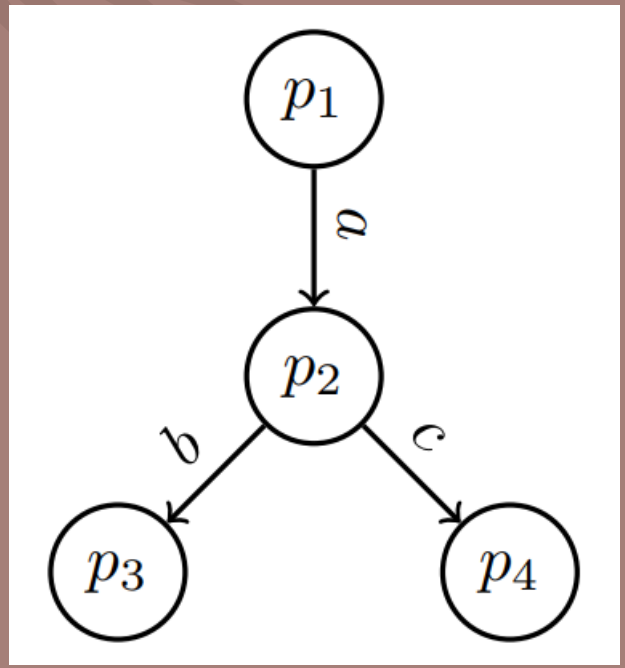

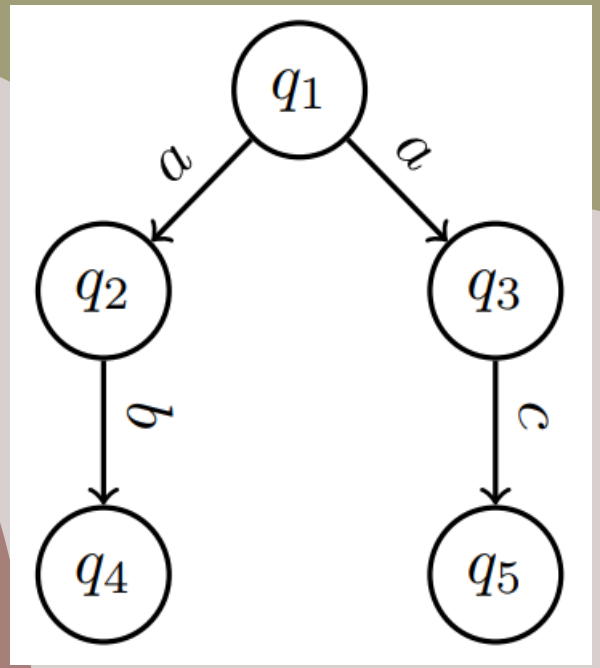

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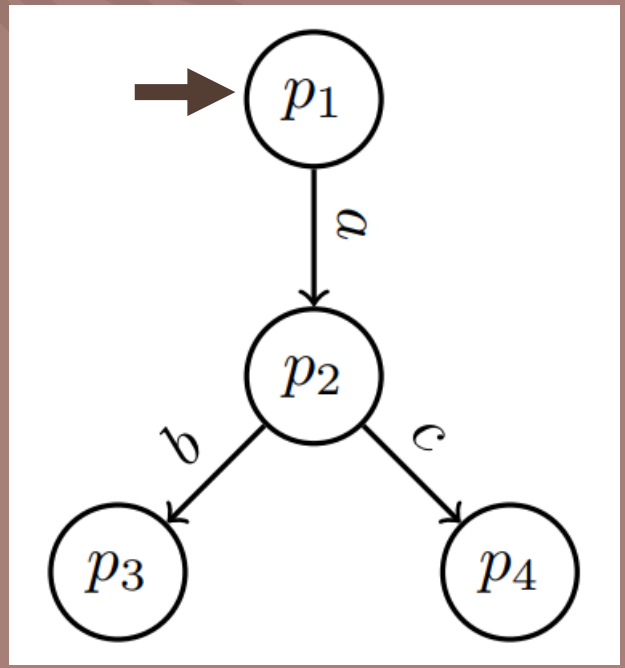

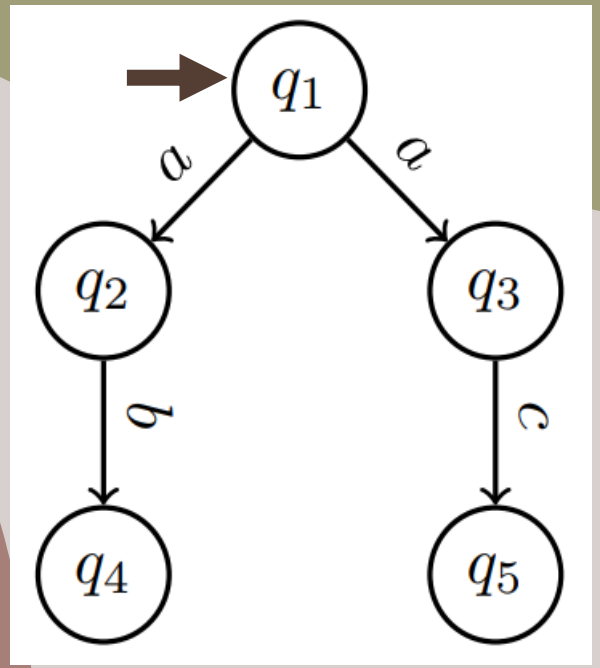

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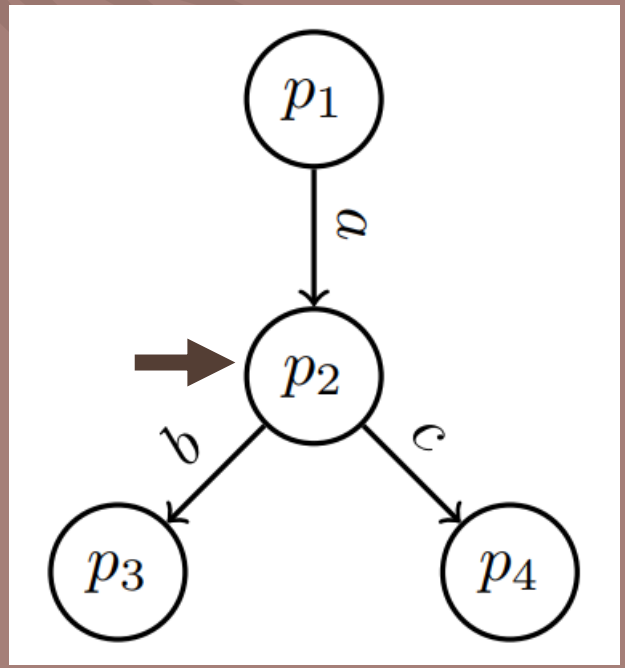

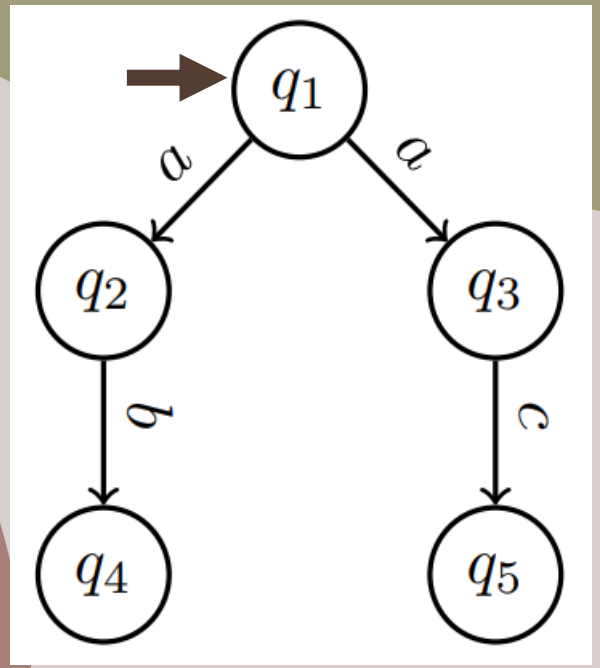

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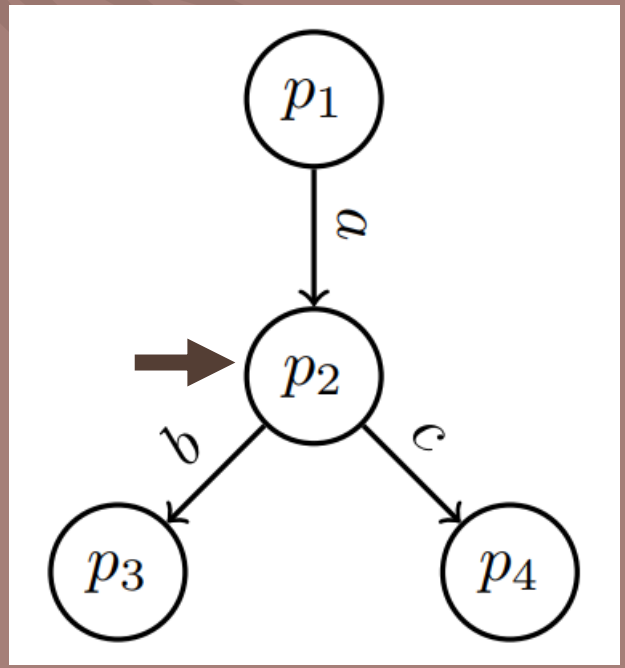

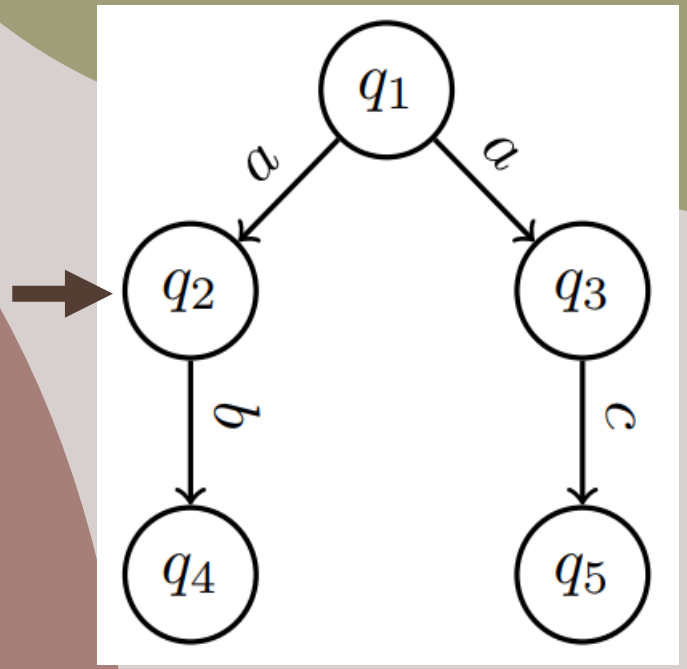

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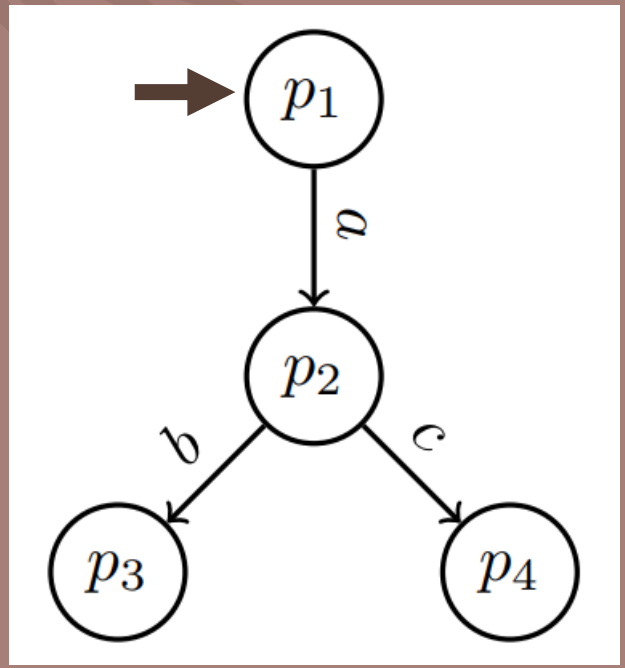

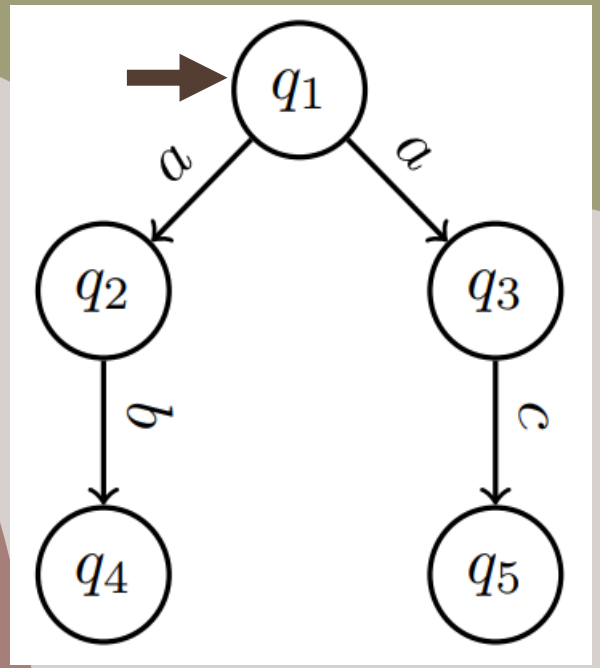

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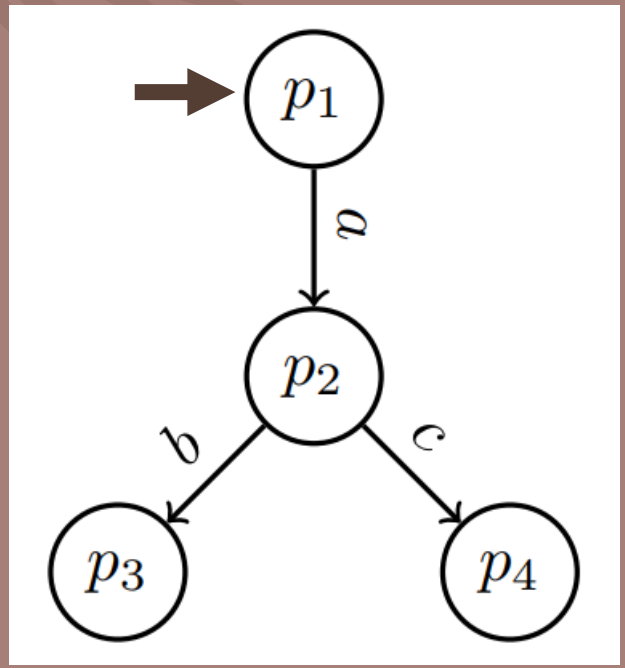

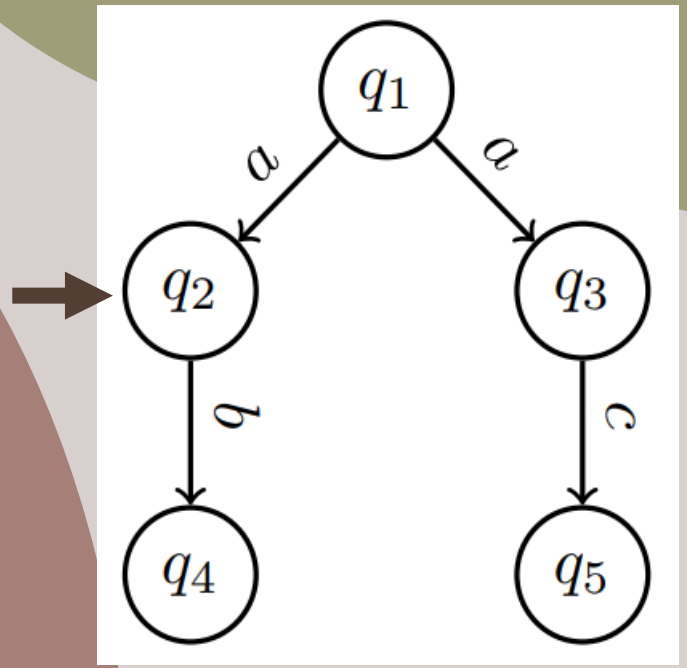

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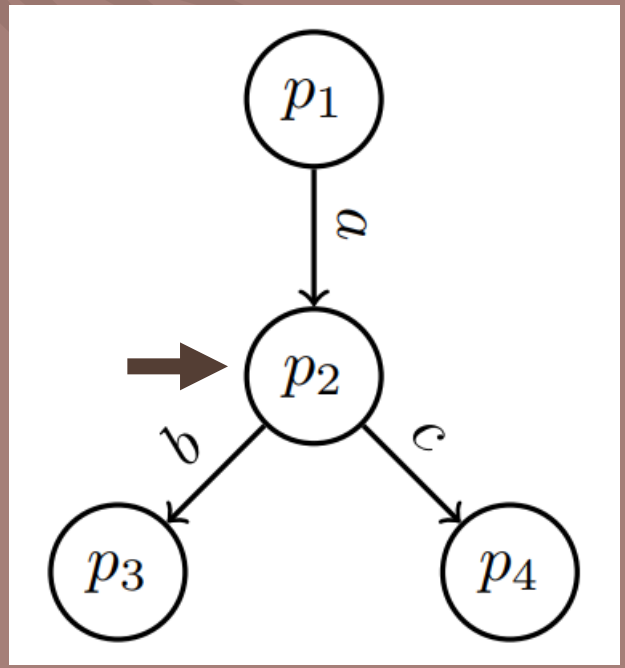

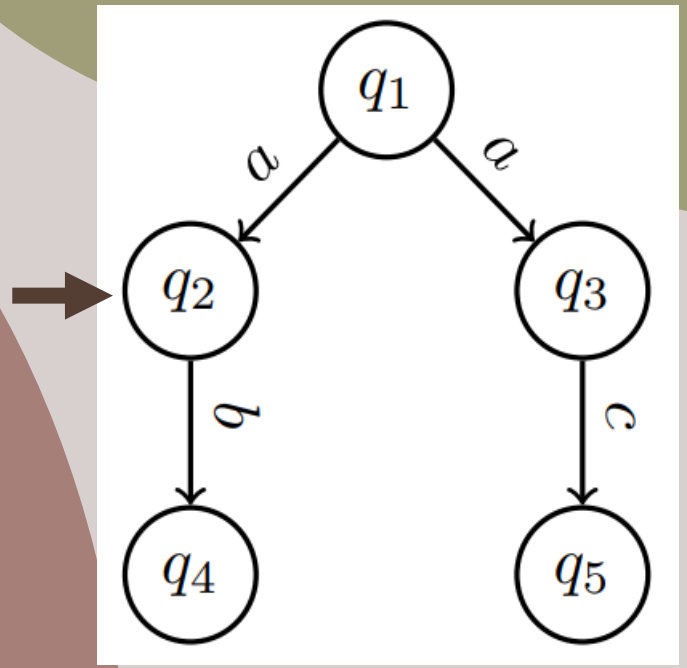

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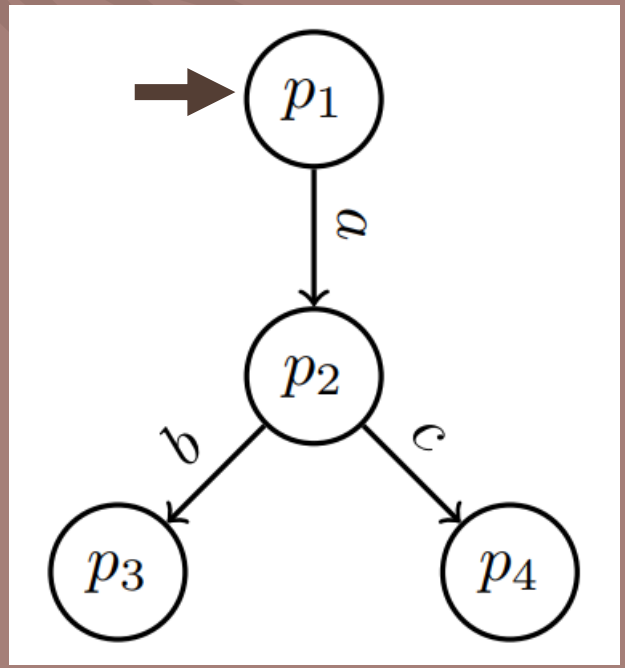

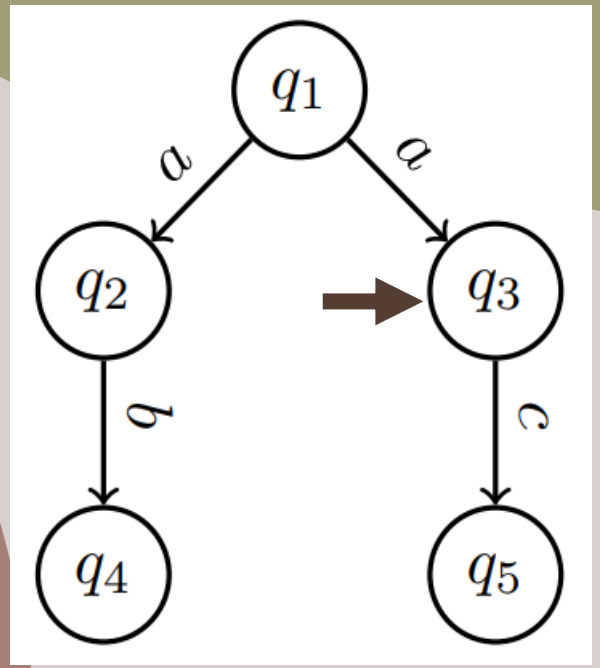

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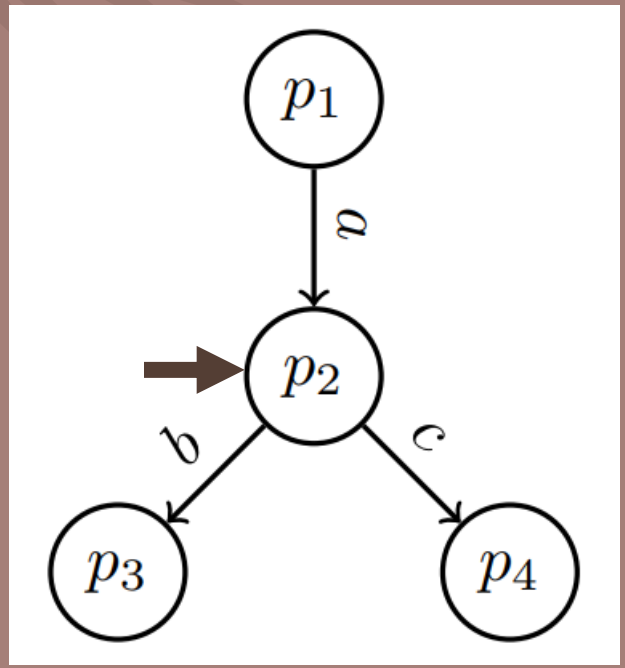

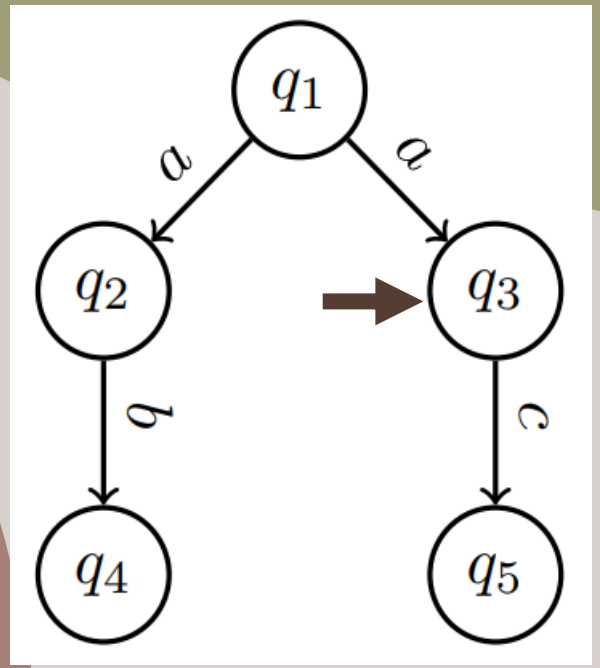

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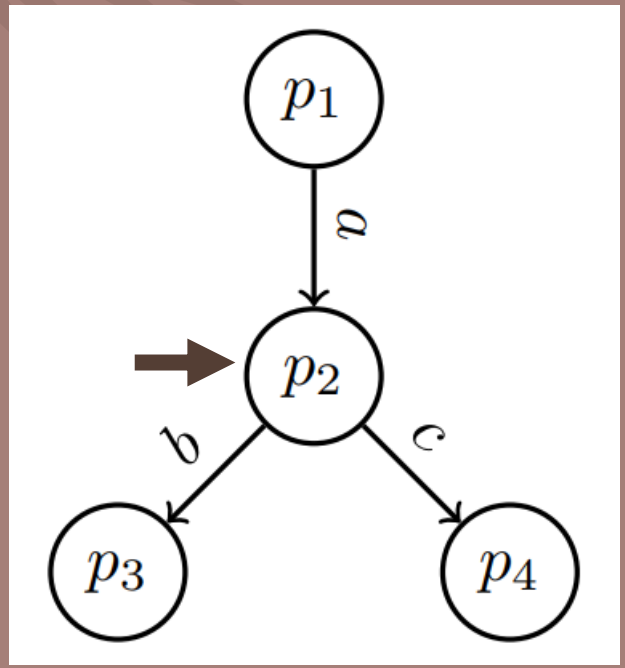

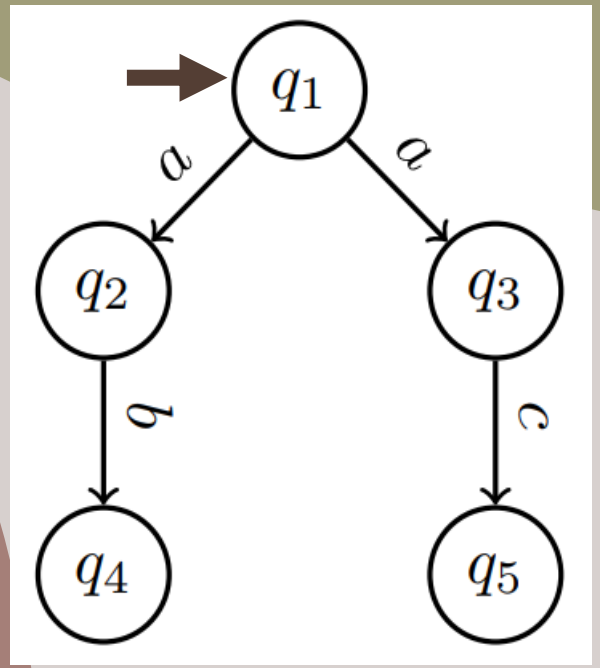

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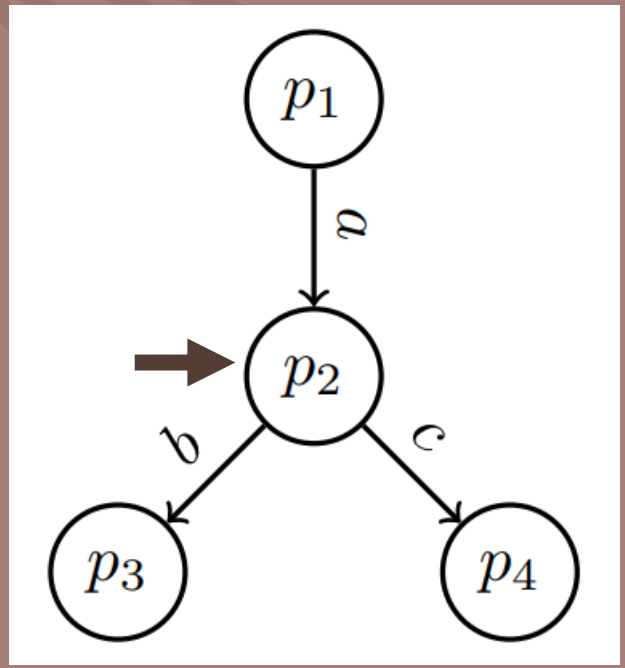

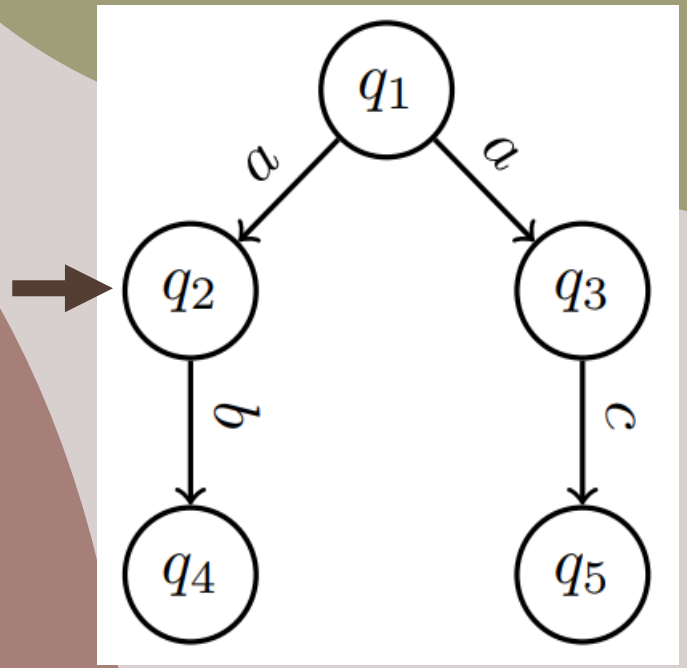

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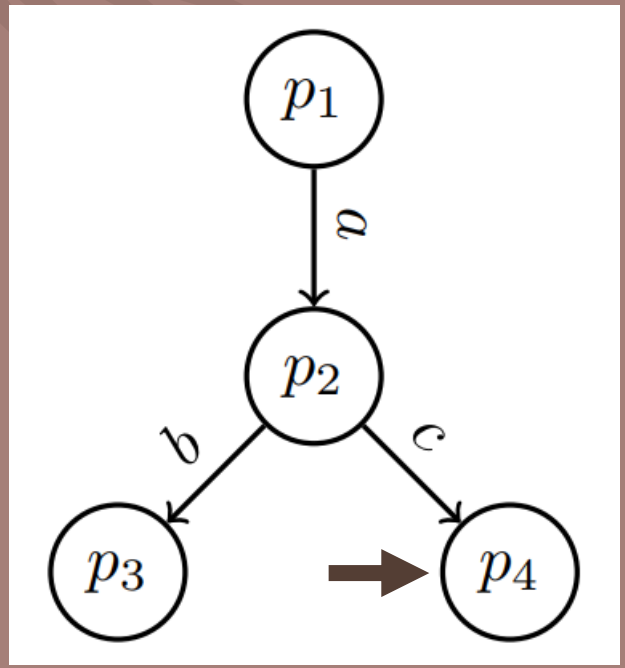

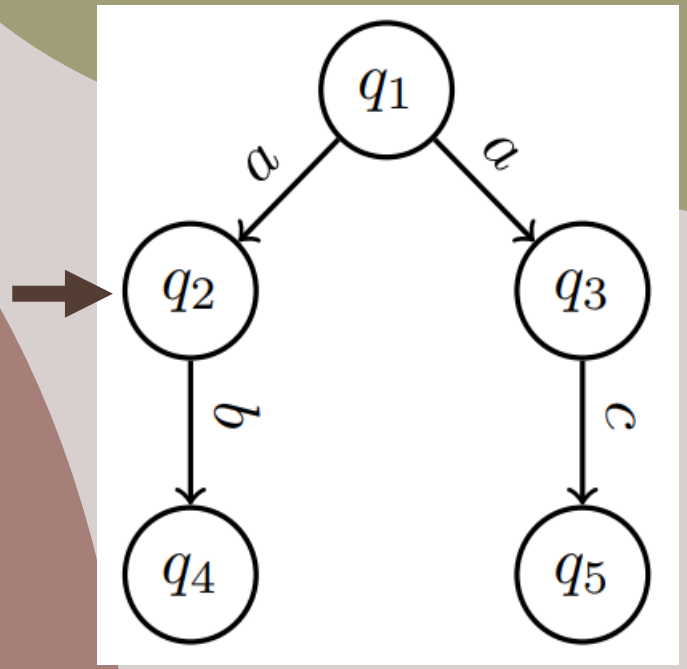

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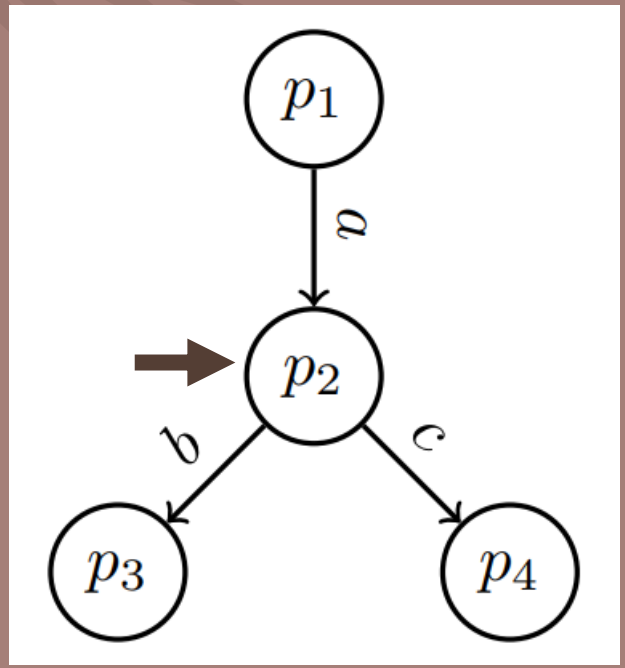

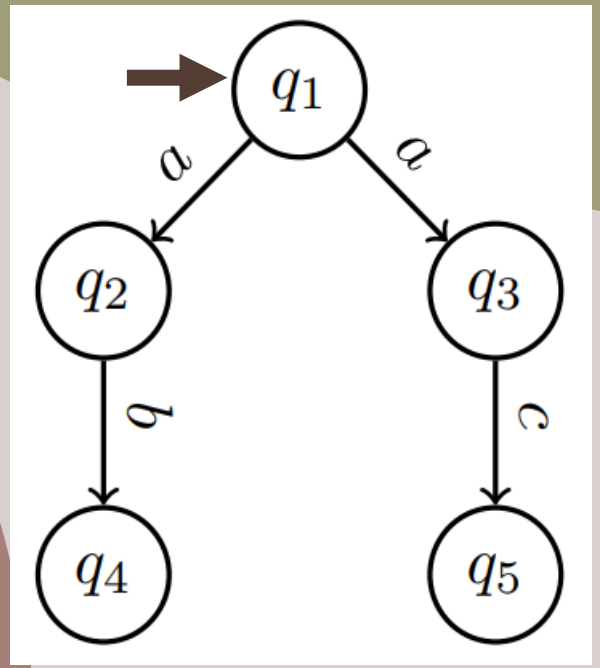

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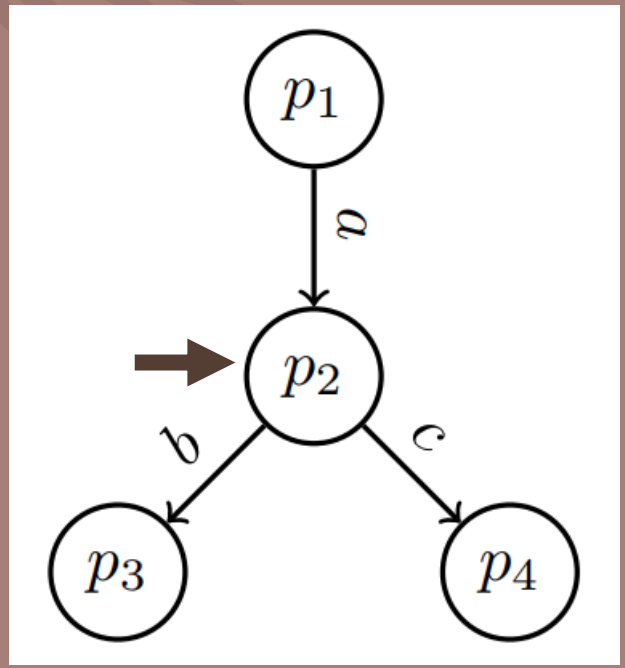

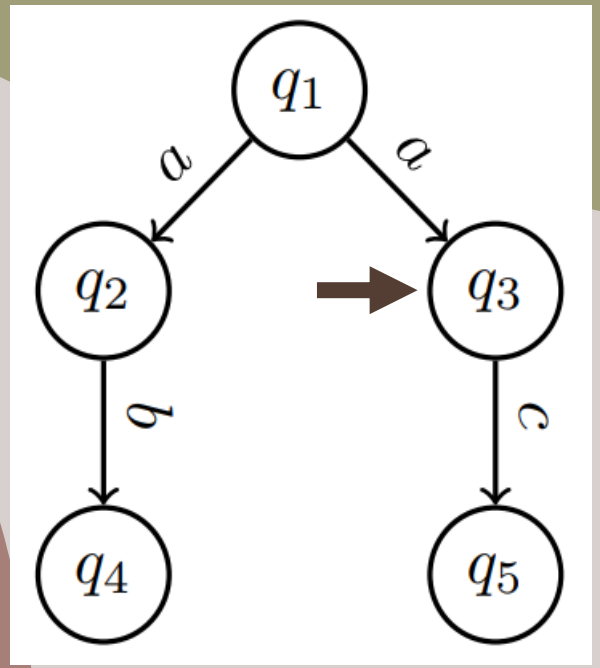

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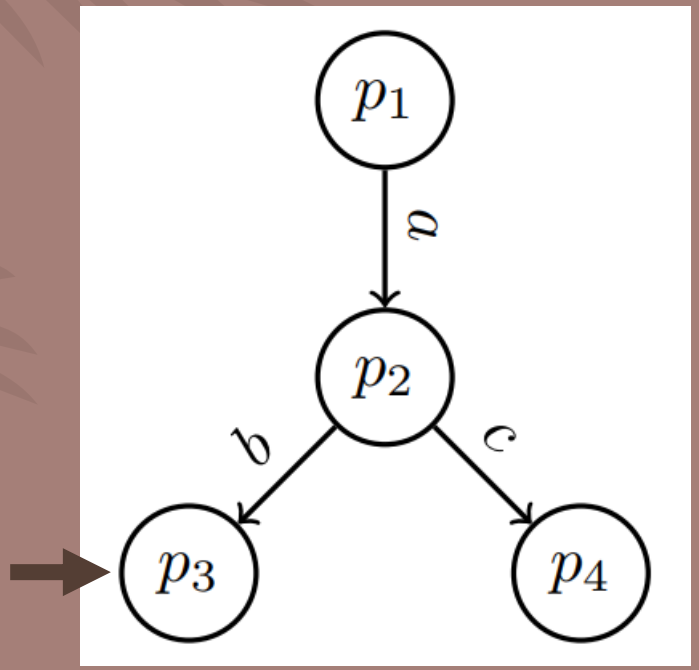

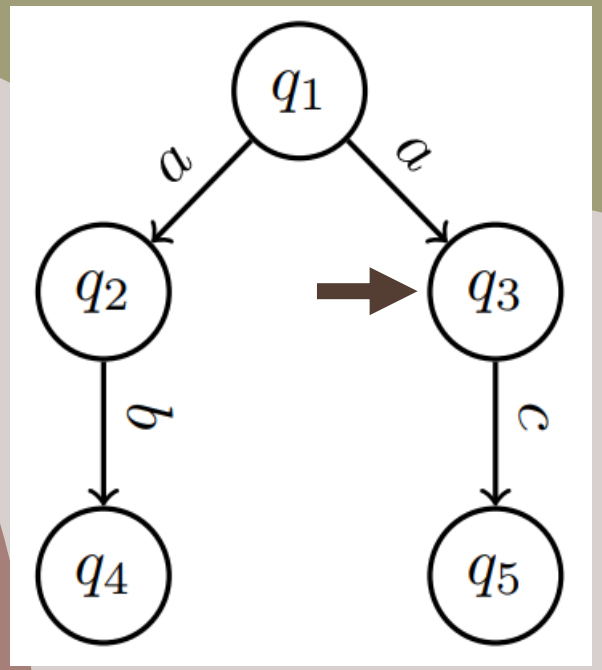

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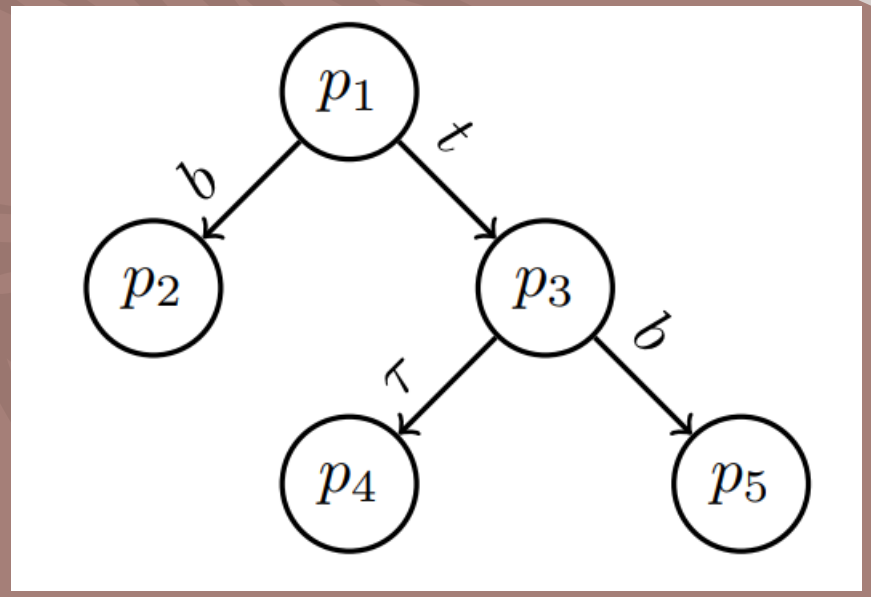

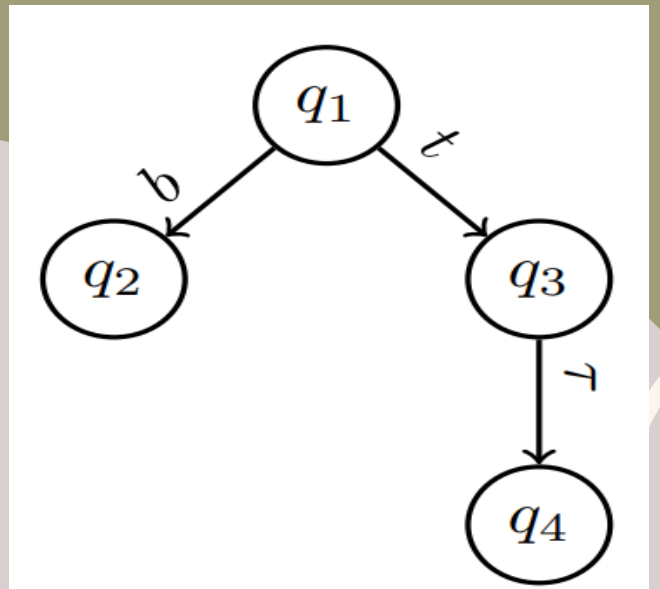

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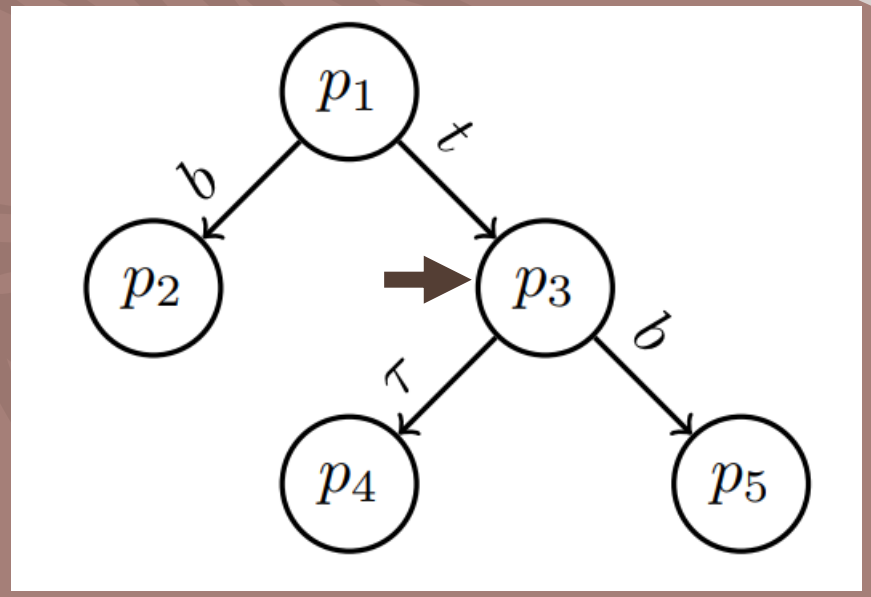

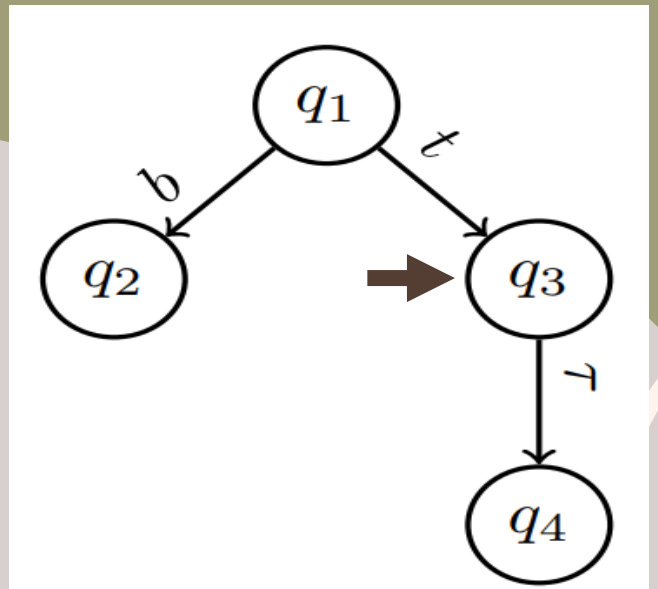

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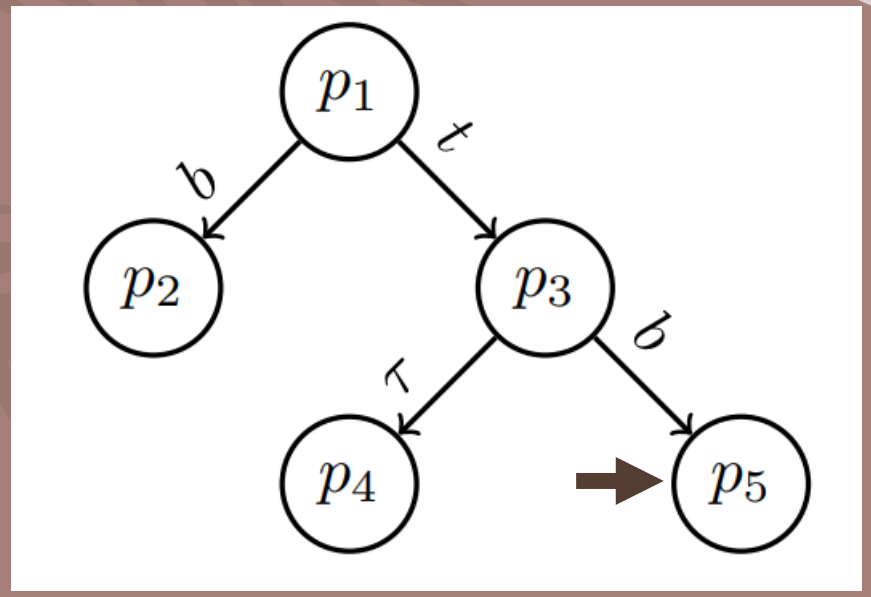

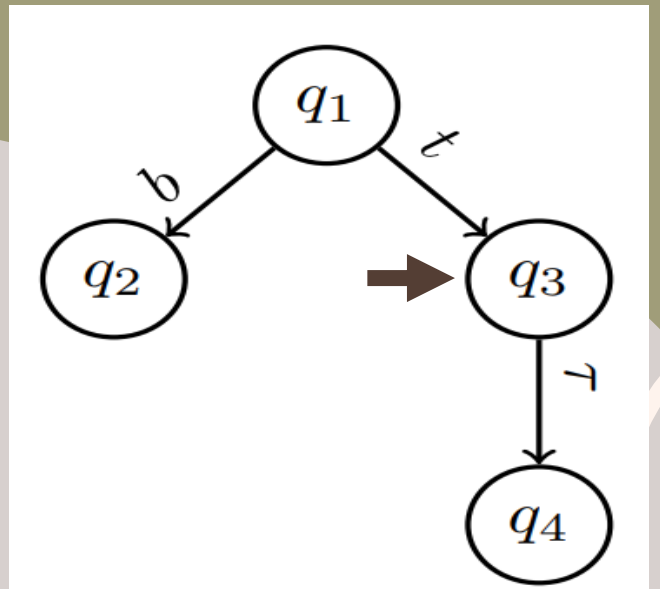

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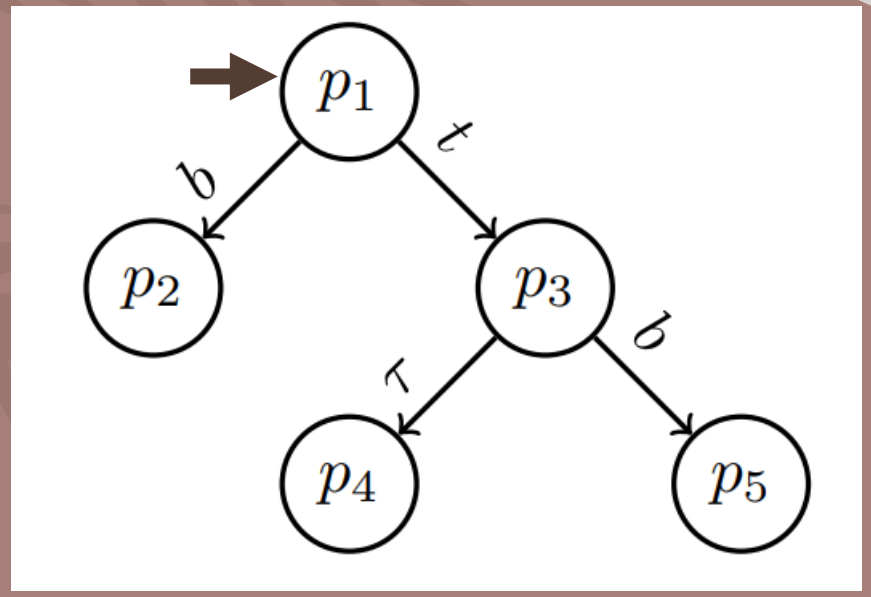
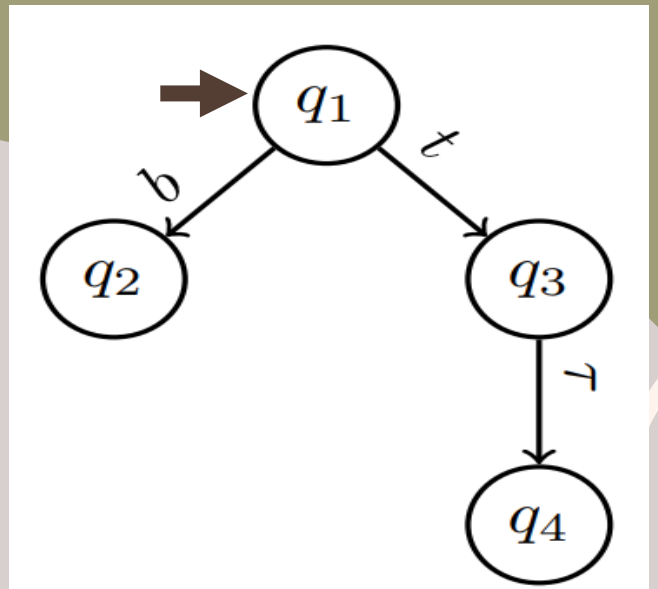
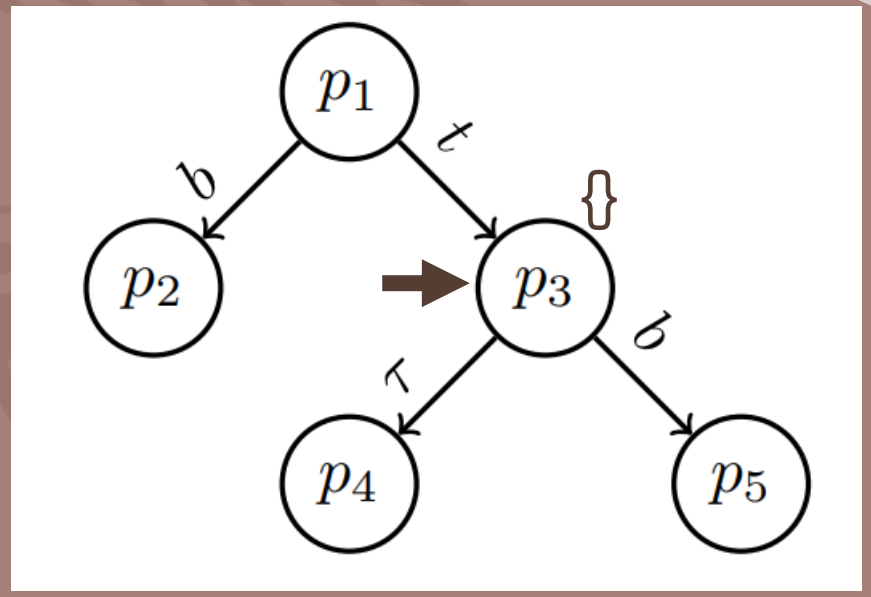
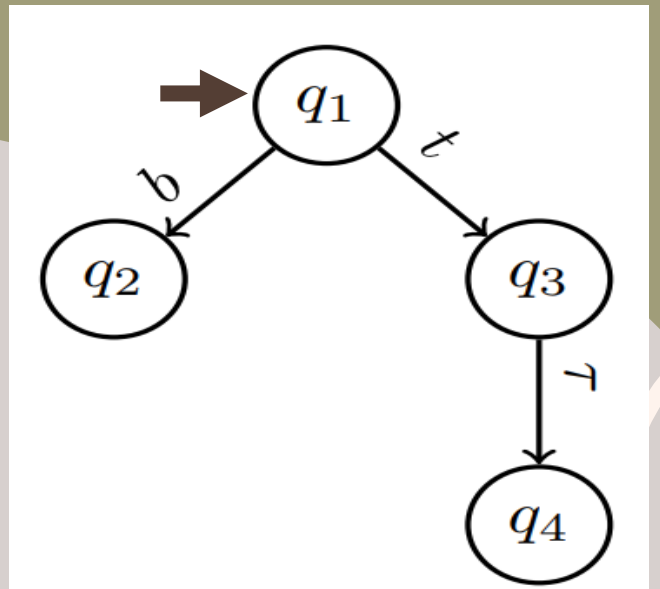


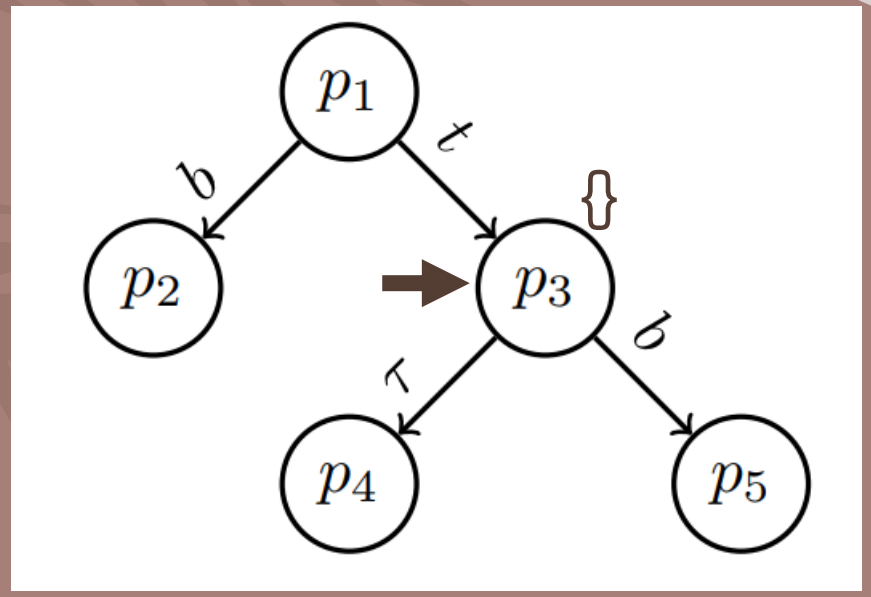


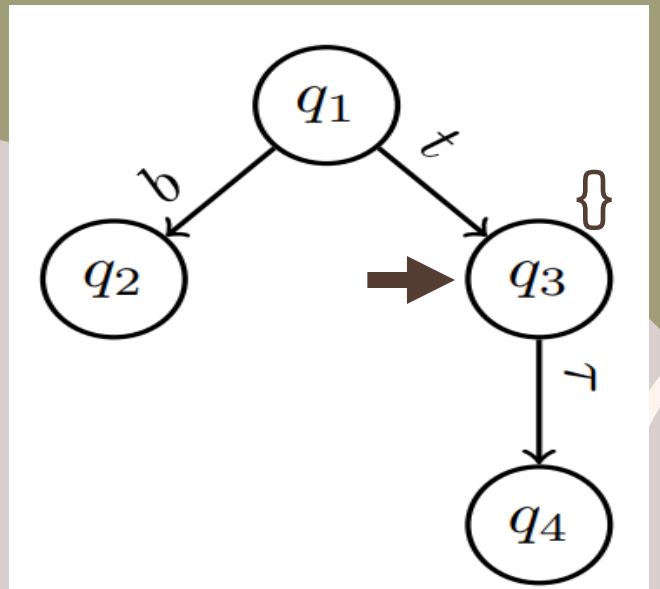
Reaktive Bisimilarität



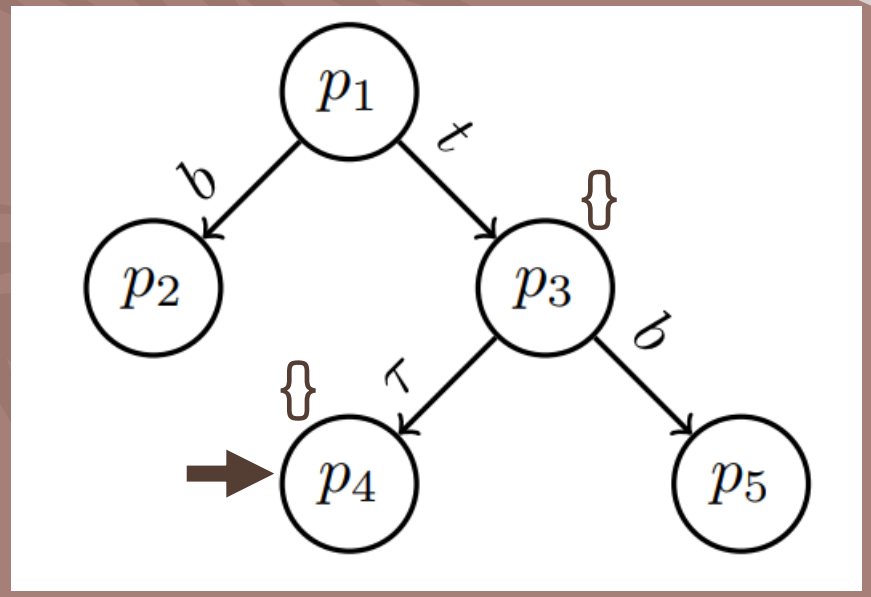


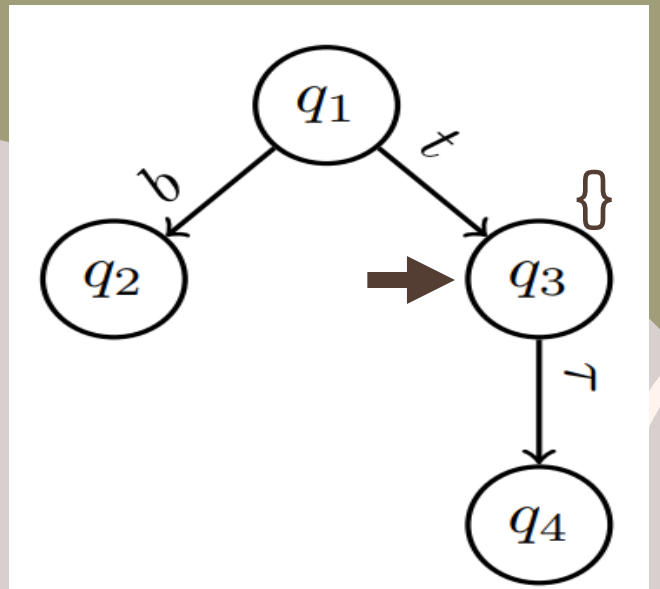
Reaktive Bisimilarität



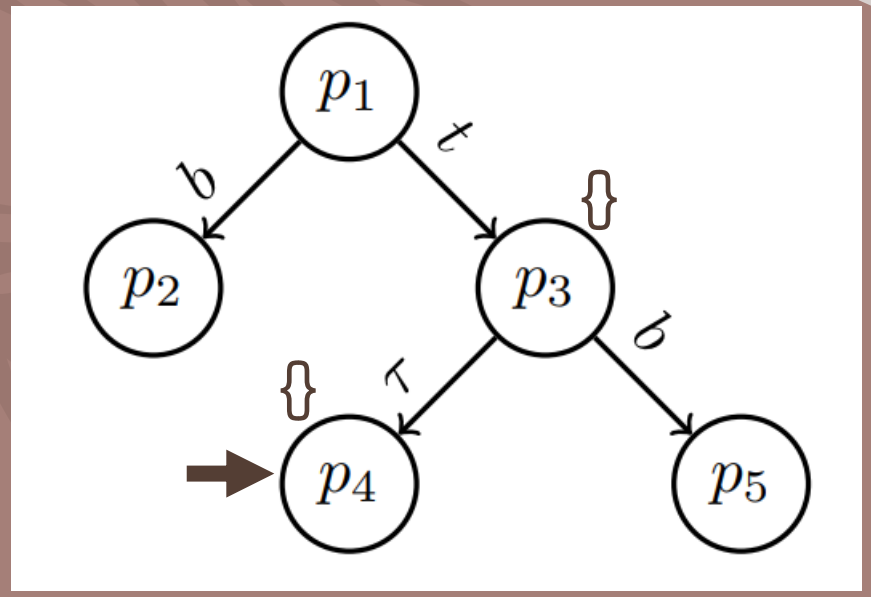


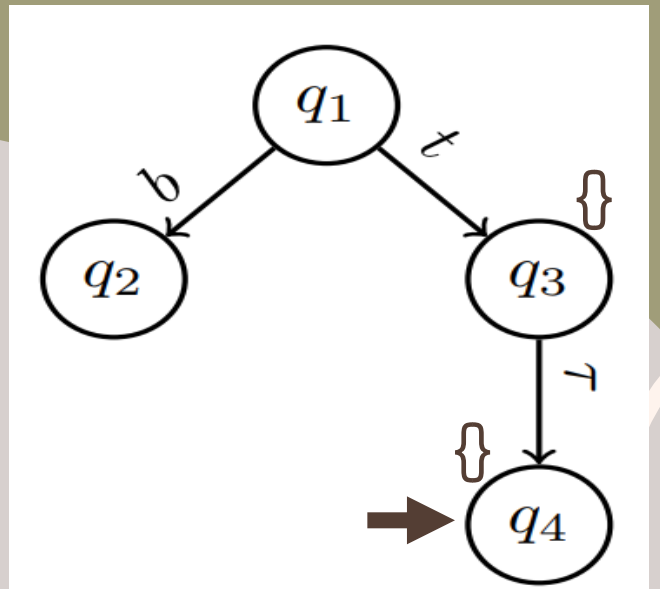
Reaktive Bisimilarität





Reaktive Bisimilarität





Die Reduktion von Max

Die Reduktion von Max

Reaktive Bisimilarität

Die Reduktion von Max

Reaktive Bisimilarität

Die Reduktion von Max

Die Reduktion von Max

Funktionsweise

Die Reduktion von Max

Funktionsweise

$$1)\ \frac{p \xrightarrow{\tau} p'}{\upsilon(p) \xrightarrow{\tau}_{\upsilon} \upsilon(p')} \qquad 2)\ \frac{}{\upsilon(p) \xrightarrow{E_X}_{\upsilon} \upsilon_X(p)}\ X \subseteq A$$

$$3)\ \frac{p \xrightarrow{a} p'}{\upsilon_X(p) \xrightarrow{a}_{\upsilon} \upsilon(p')}\ a \in X \qquad 4)\ \frac{p \xrightarrow{\tau} p'}{\upsilon_X(p) \xrightarrow{\tau}_{\upsilon} \upsilon_X(p')}$$

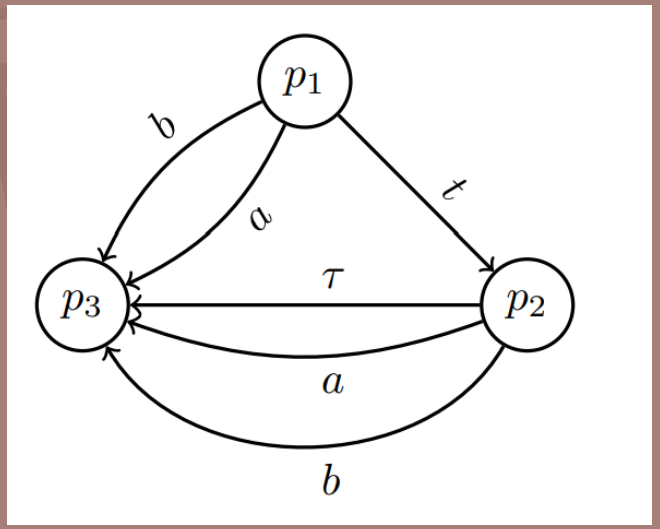
$$5)\ \frac{p \overset{\alpha}{\not\rightarrow} \forall \alpha \in X \cup \{\tau\}}{\upsilon_X(p) \xrightarrow{t_\varepsilon}_{\upsilon} \upsilon(p)} \qquad 6)\ \frac{p \overset{\alpha}{\not\rightarrow} \forall \alpha \in X \cup \{\tau\} \quad p \xrightarrow{t} p'}{\upsilon_X(p) \xrightarrow{t}_{\upsilon} \upsilon_X(p')}$$

Die Reduktion von Max

Beispiel

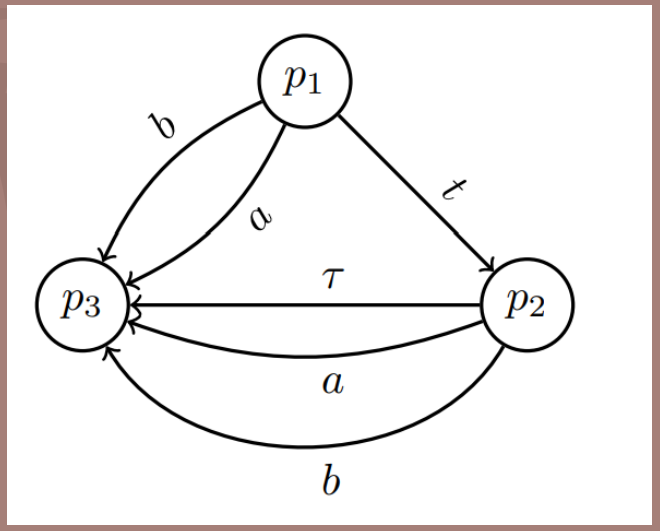
Die Reduktion von Max

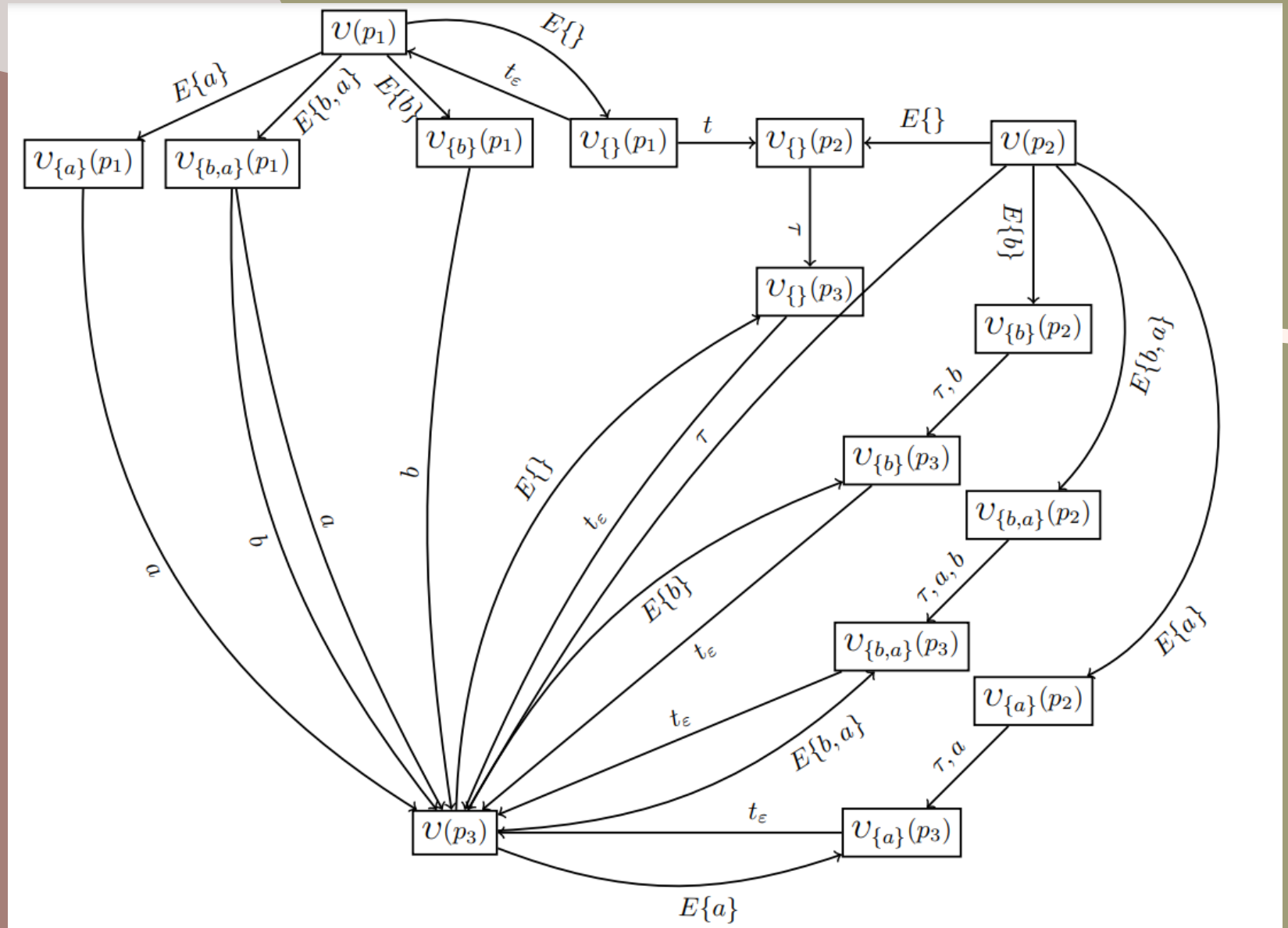
Beispiel



Die Reduktion von Max

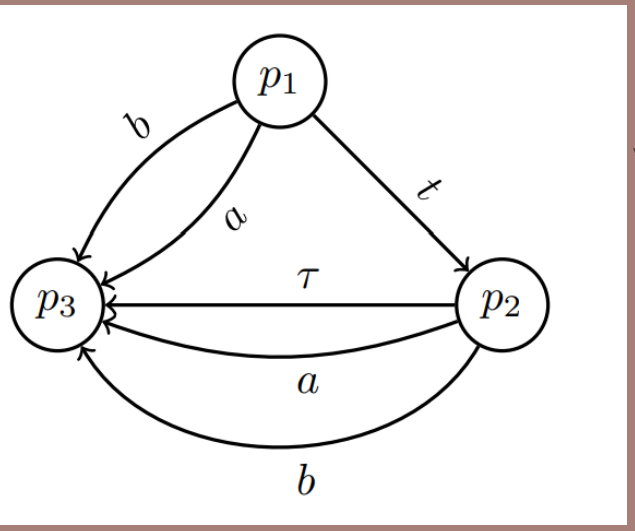
Beispiel



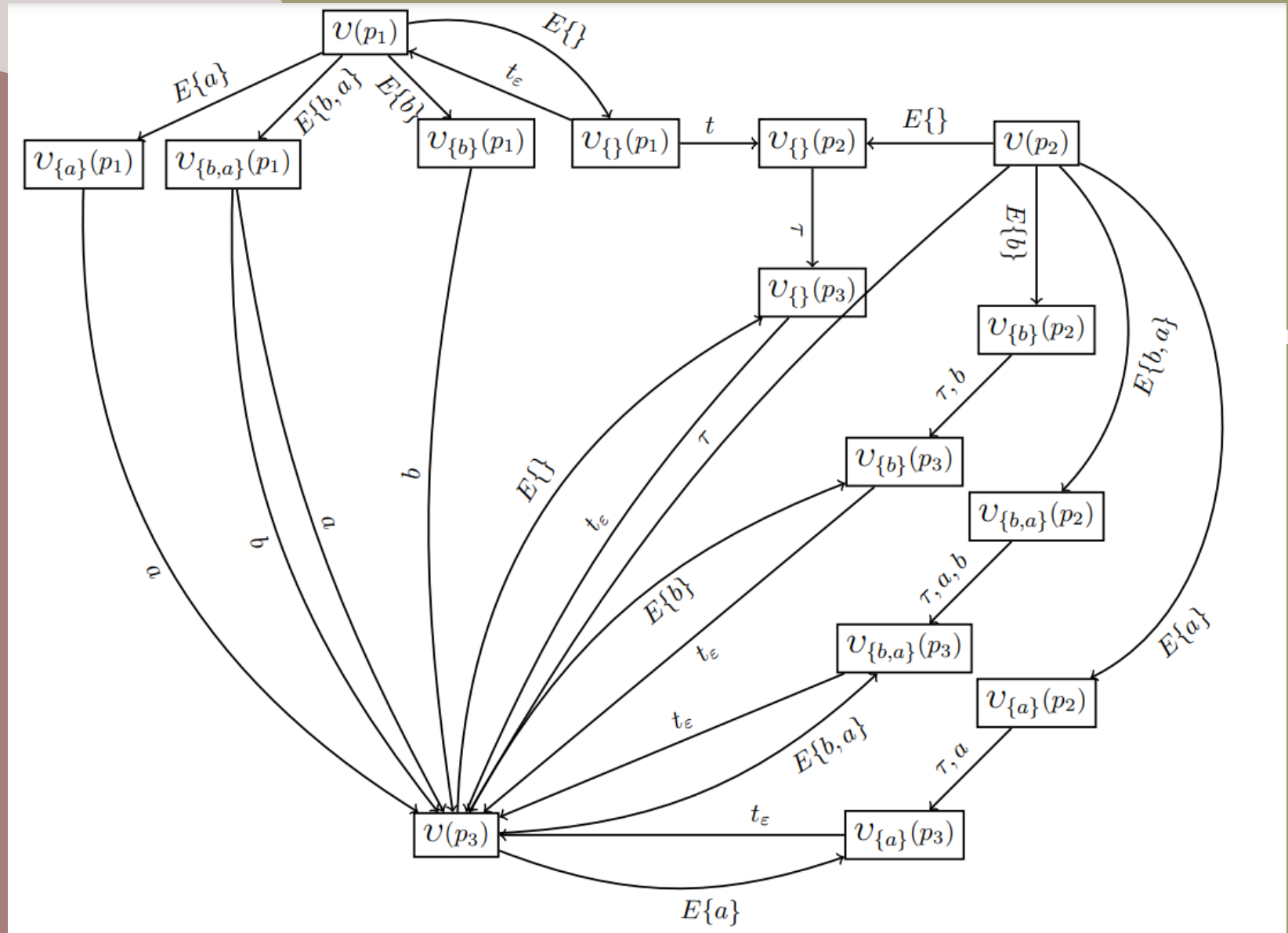


Die Reduktion von Max

Beispiel



WIE?



ARBEITSGEGENSTÄNDE

Kernidee
Ursprünglicher Algorithmus
Verbesserte Algorithmus
Einzige Umgebungsaktion
Überprüfung eines oder aller Paare

Kernidee

Kernidee

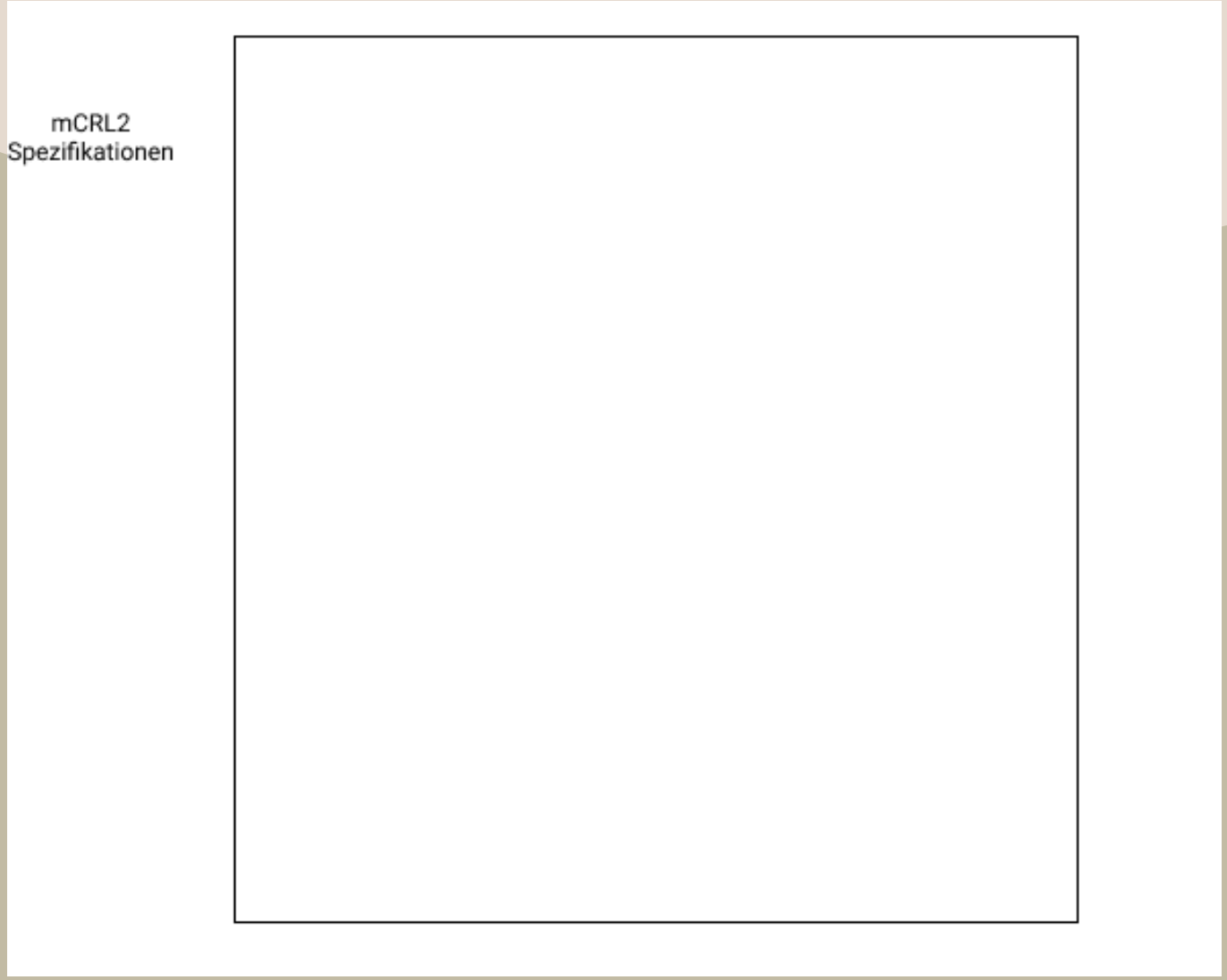
Kernidee

```
act
    a, b, f, g, c, time;

proc
    _0 = a._1 + time._2;
    _1 = b._3;
    _2 = c._4 + g._6;
    _3 = f._5 + time._2 + c._4;
    _4 = time._0;
    _5 = delta;
    _6 = delta;
init
    hide(
        {c}, _0
    );
```

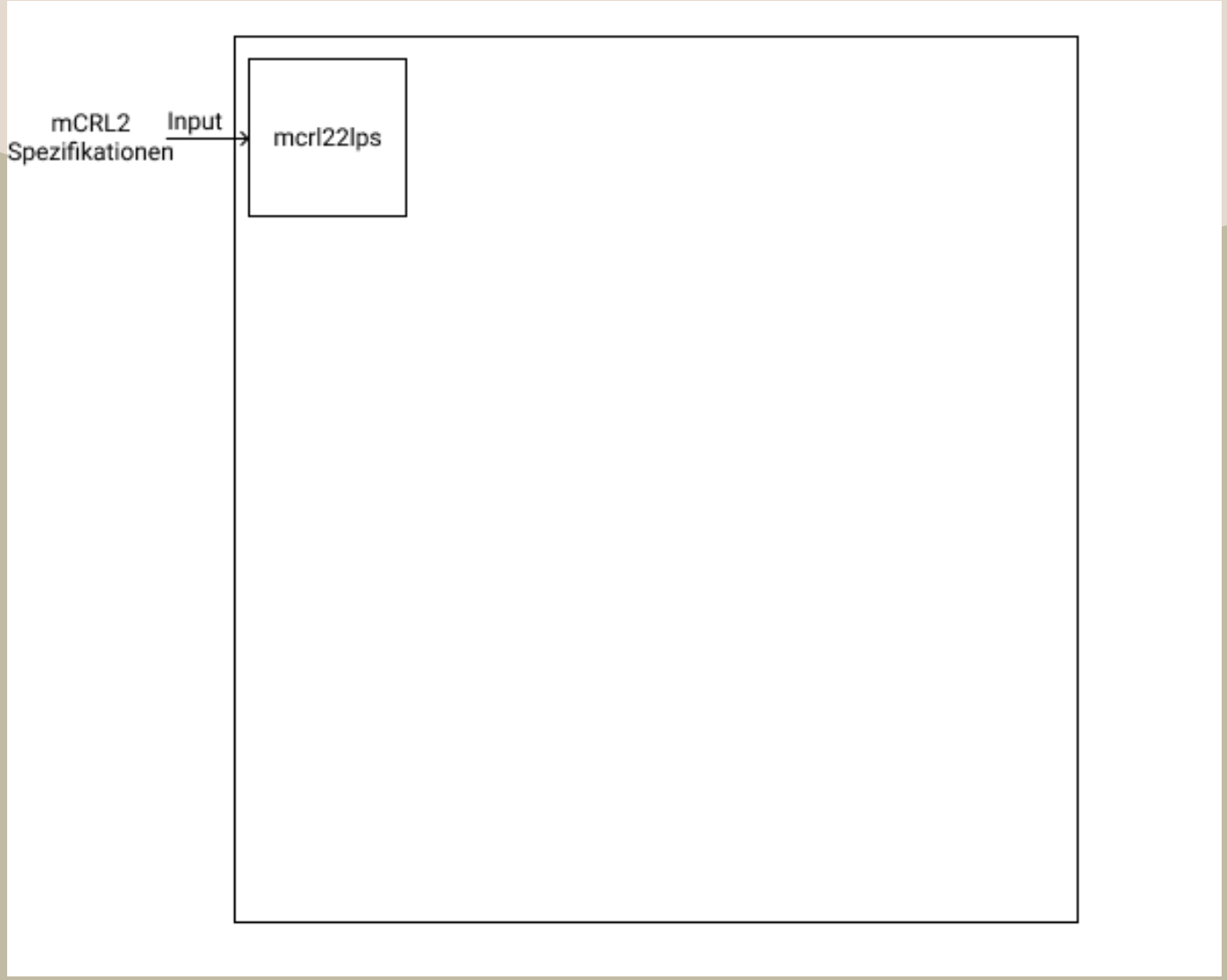
mCRL2
Spezifikationen

Kernidee



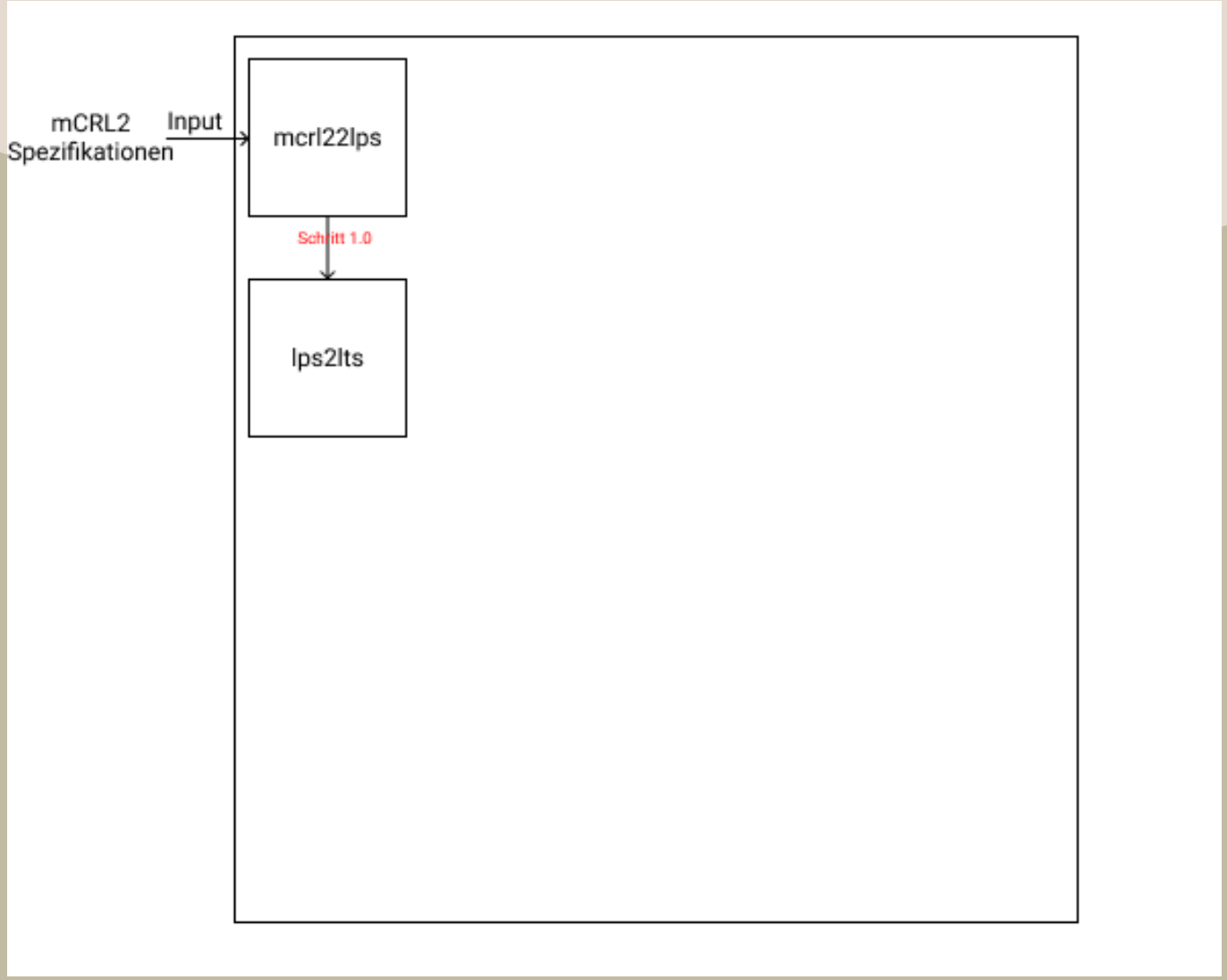
Kernidee

LPS ist in Binärformat

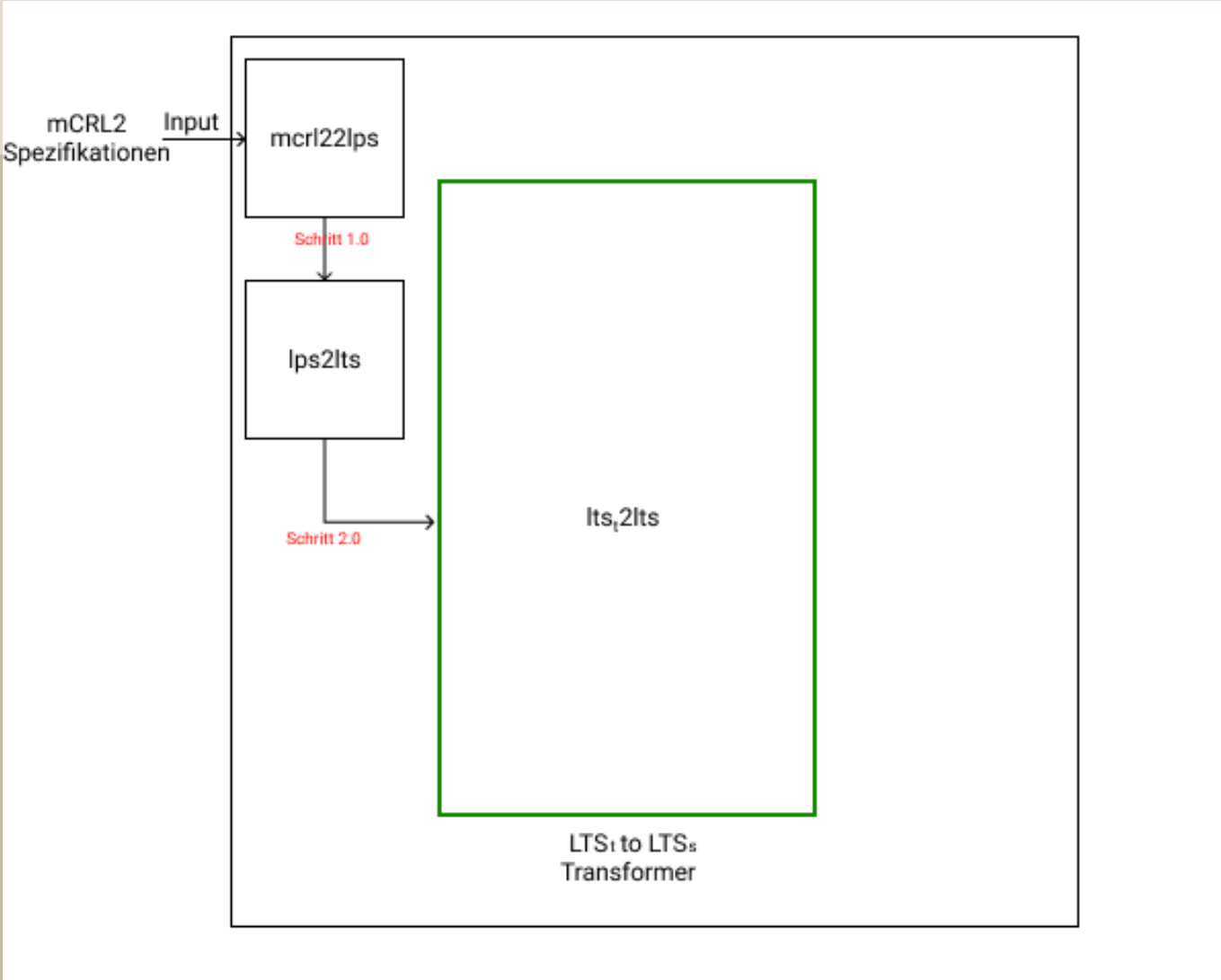


Kernidee

```
des (0,4,3)
(0,"time",1)
(0,"a",2)
(1,"tau",2)
(1,"a",2)
```

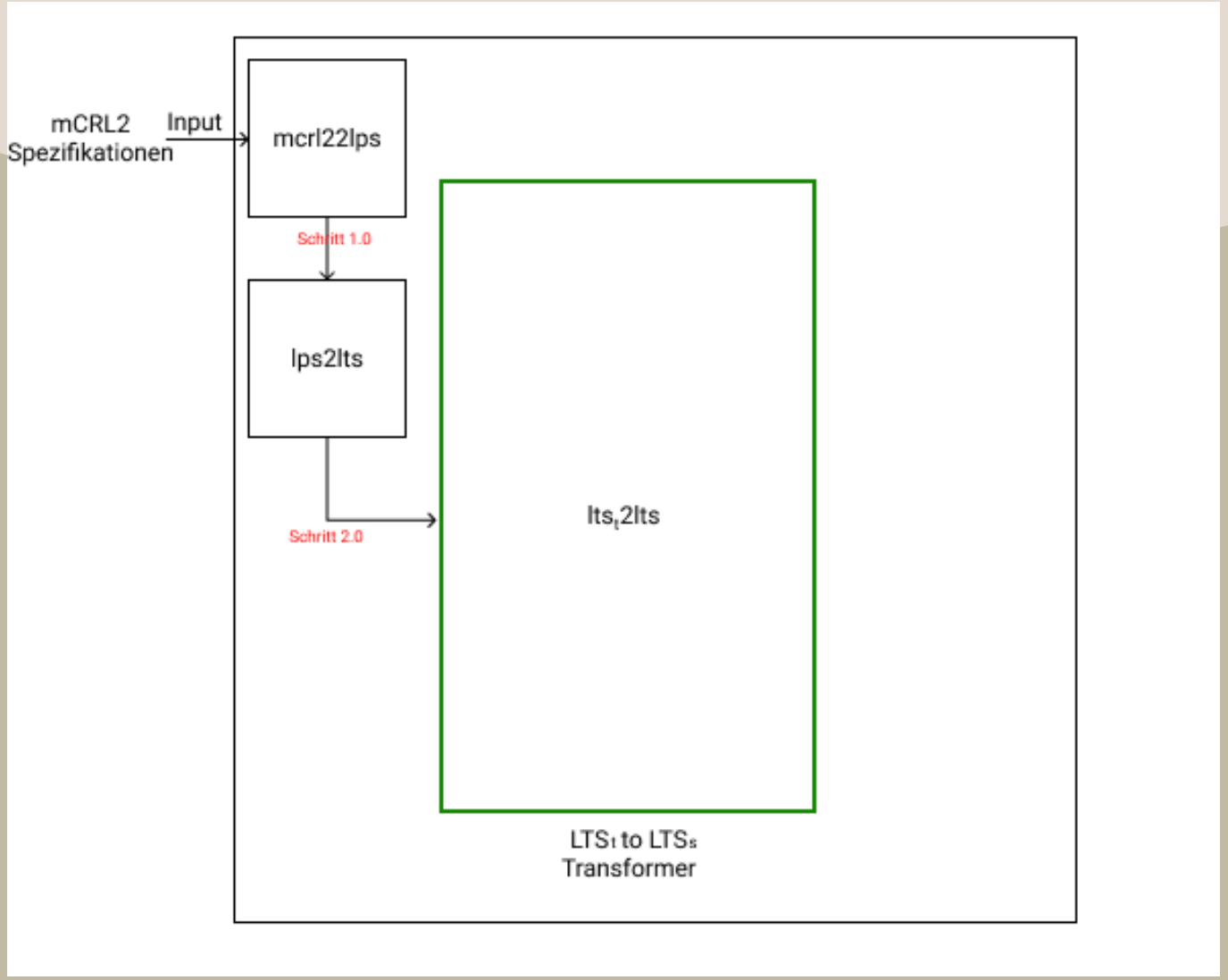


Kernidee

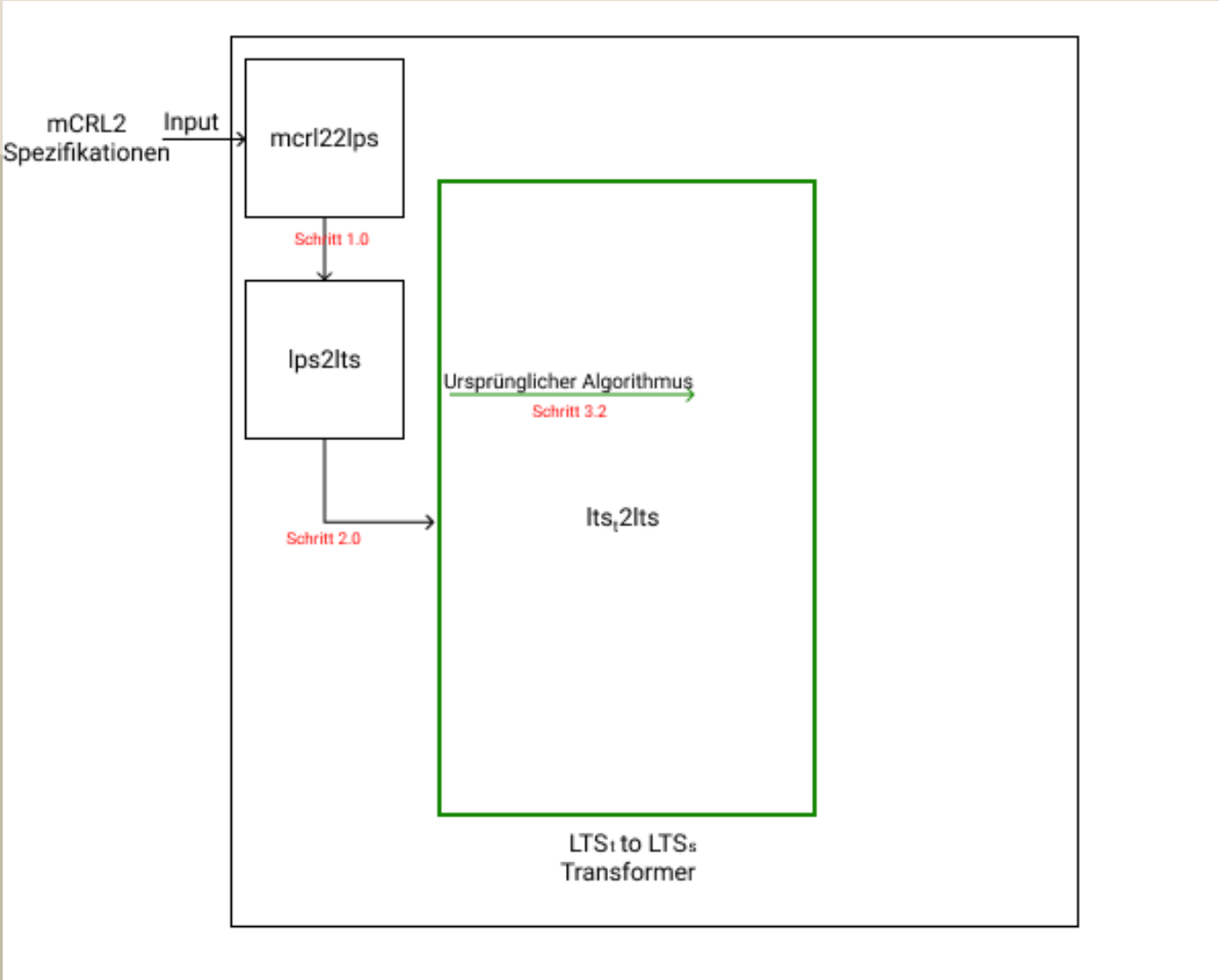

mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer

Kernidee

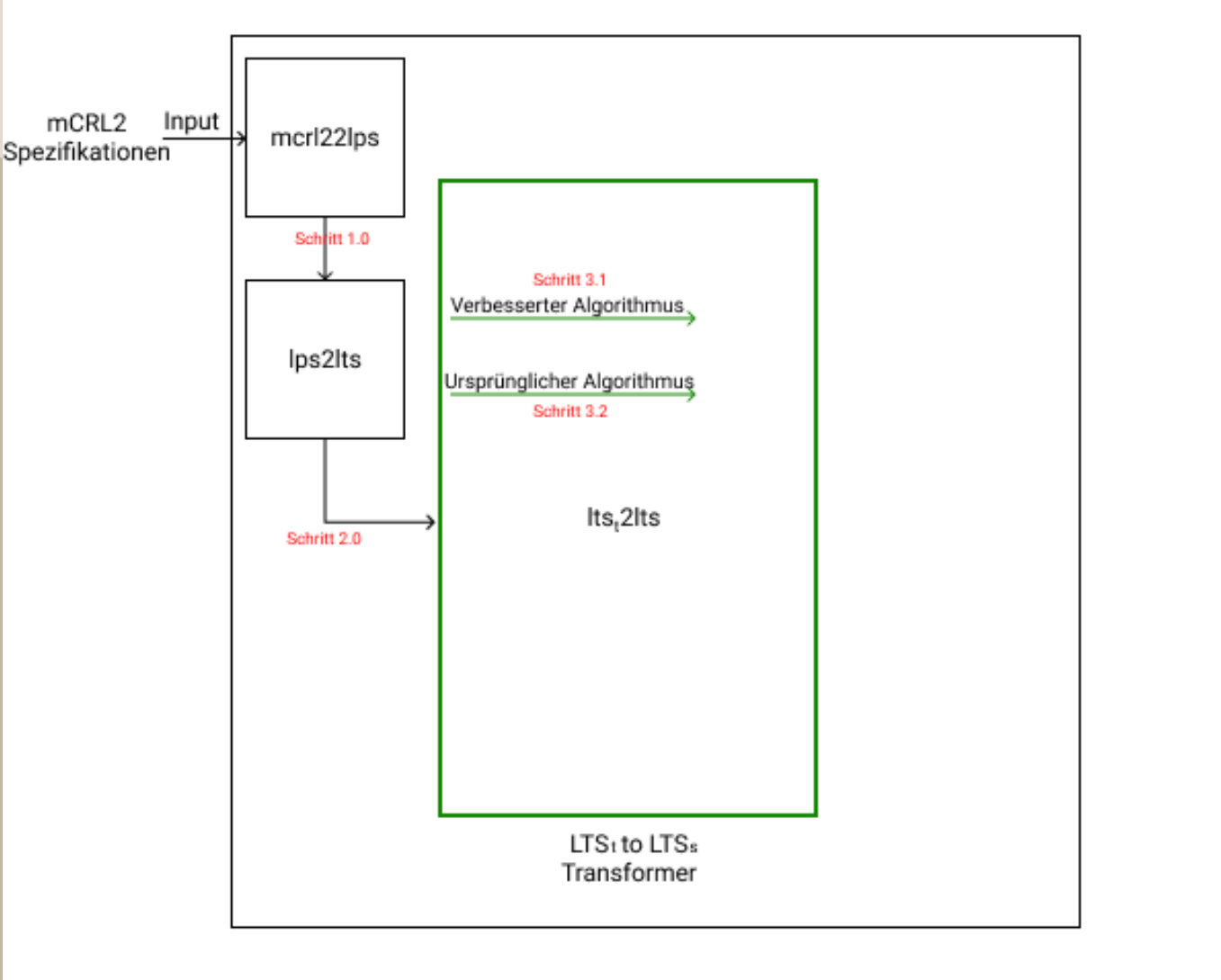
```
39   (15,"time",24)
40   (16,"t_e",0)
41   (16,"time",25)
42   (17,"noeE",26)
43   (17,"a",27)
44   (17,"a_b",28)
45   (17,"a_b_g",29)
46   (17,"a_b_g_f",30)
```



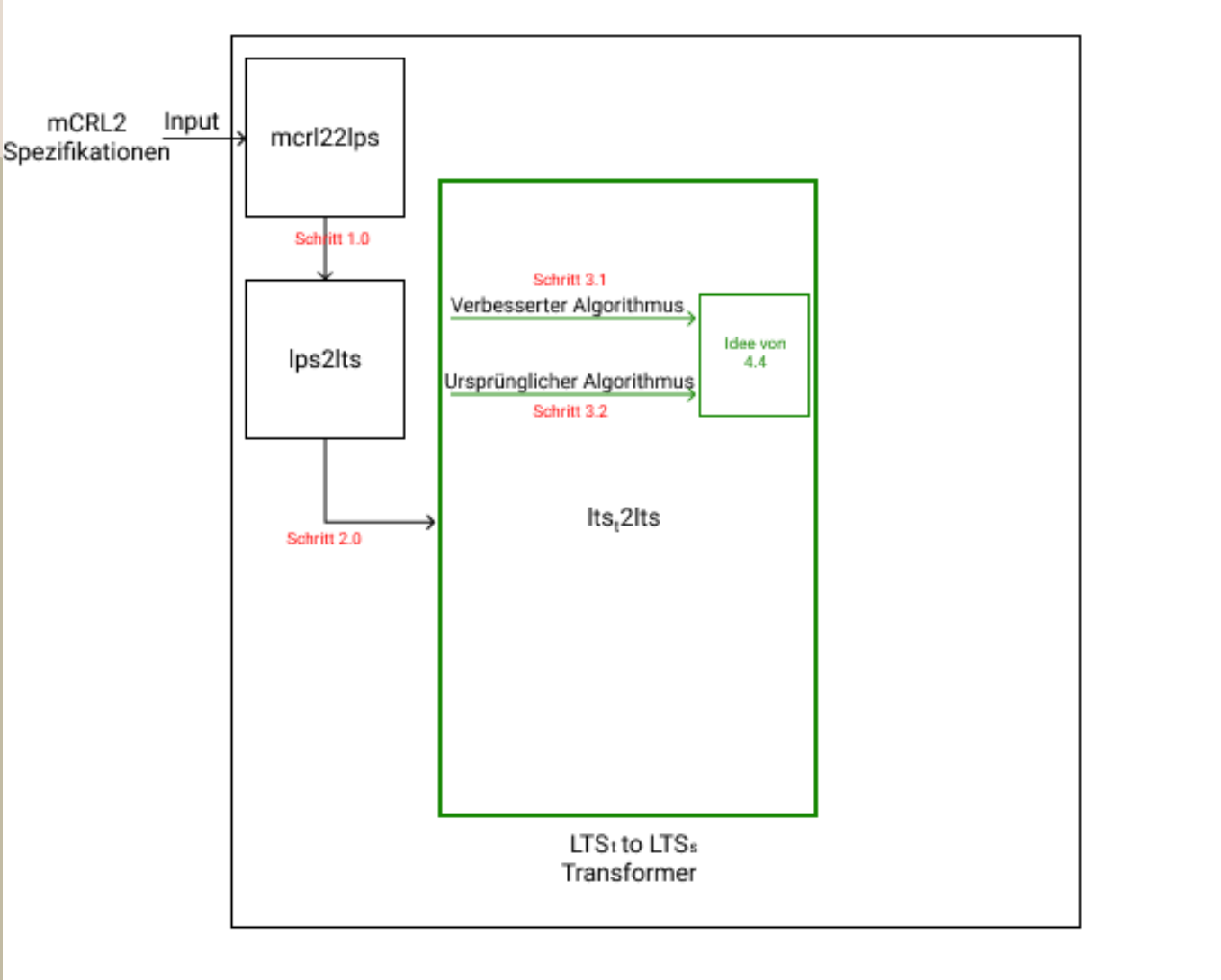
Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Ursprünglicher Algorithmus
Schritt 3.2
Schritt 2.0
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer

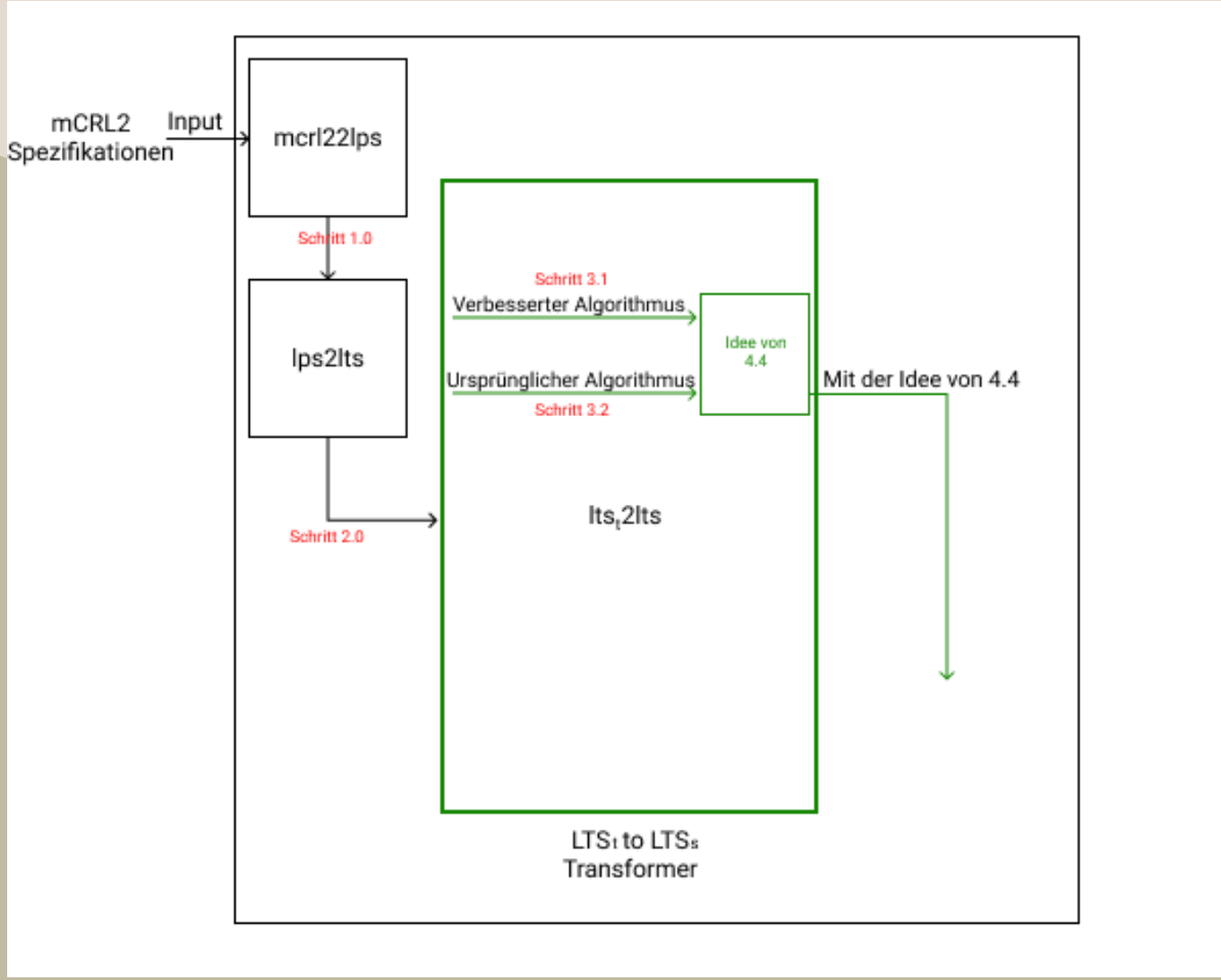
Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer

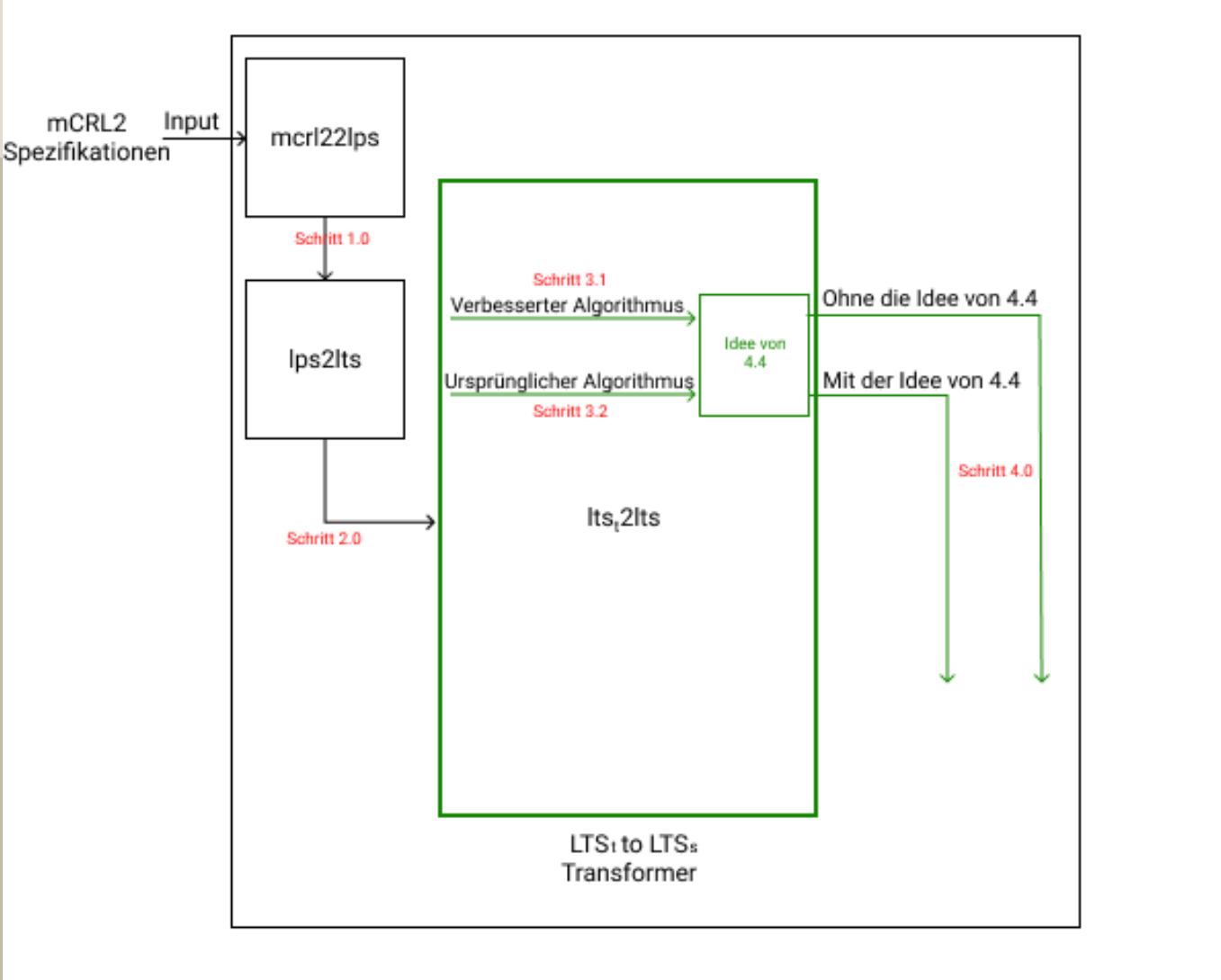
Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
Idee von
4.4
lts$_t$2lts
LTS$_I$ to LTS$_S$
Transformer

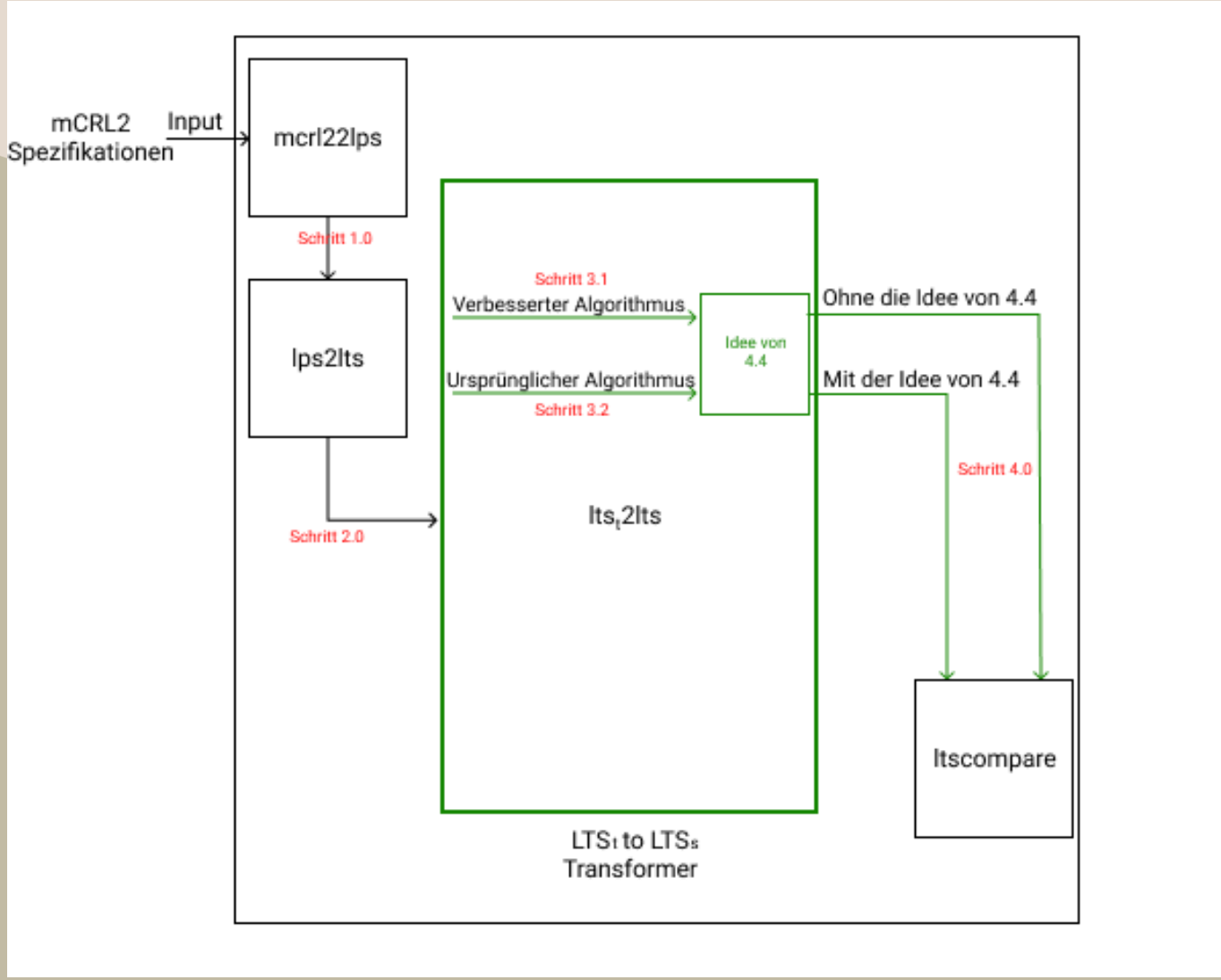
Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
Idee von 4.4
Mit der Idee von 4.4
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer

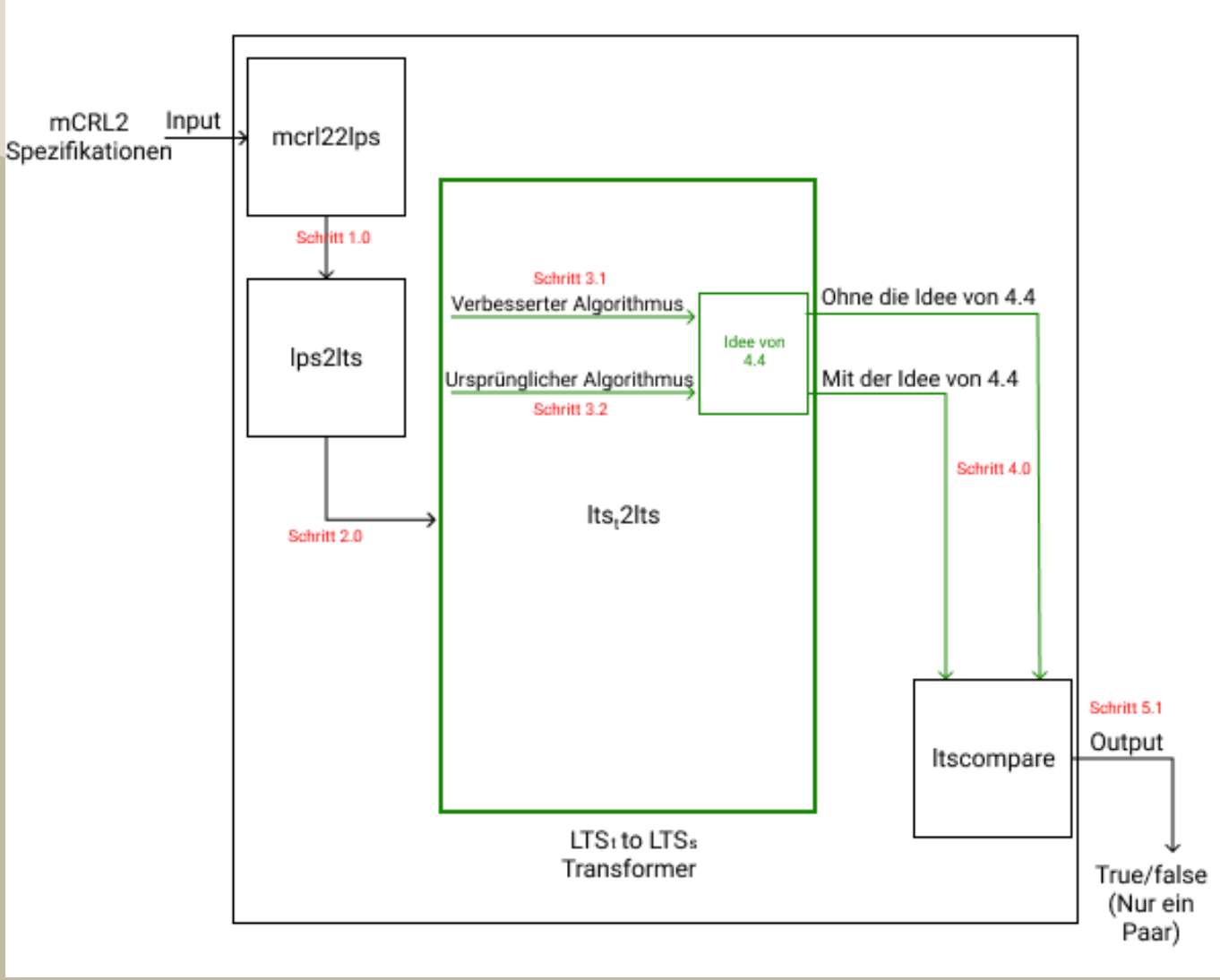
Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
Idee von 4.4
Ohne die Idee von 4.4
Mit der Idee von 4.4
Schritt 4.0
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer

Kernidee

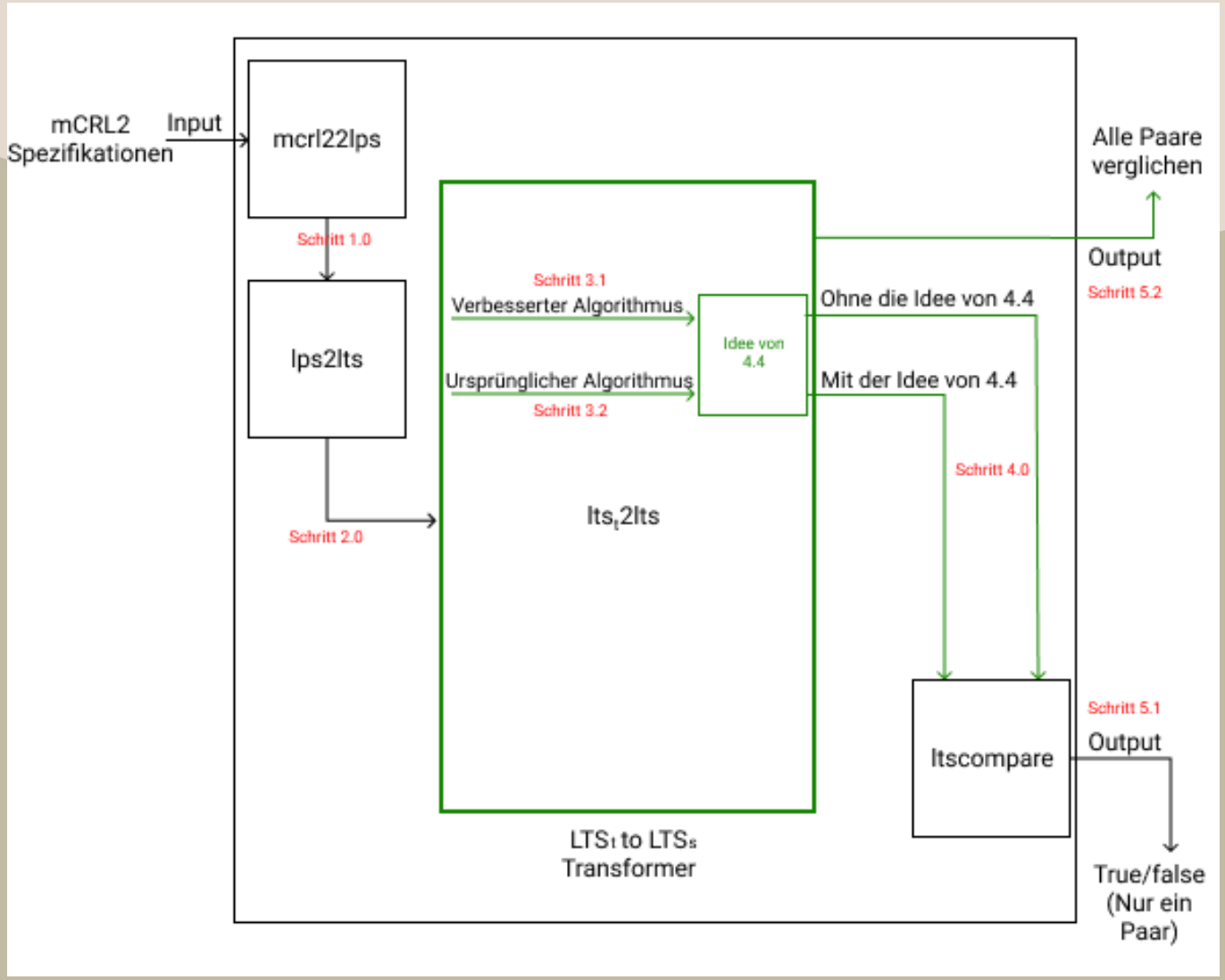

mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
Idee von 4.4
Ohne die Idee von 4.4
Mit der Idee von 4.4
Schritt 4.0
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer
ltscompare

Kernidee


mCRL2
Spezifikationen
Input
mcrl22lps
Schritt 1.0
lps2lts
Schritt 2.0
Schritt 3.1
Verbesserter Algorithmus
Ursprünglicher Algorithmus
Schritt 3.2
Idee von 4.4
Ohne die Idee von 4.4
Mit der Idee von 4.4
Schritt 4.0
lts$_t$2lts
LTS$_t$ to LTS$_s$
Transformer
ltscompare
Schritt 5.1
Output
True/false
(Nur ein Paar)

Kernidee

```
Checking if two mcrl2 files exits...
Files exists.
Transforming the files into lts_t...
Transforming lts_t into lts_s...
comparing the systems of reactive bisimilarity unsing strong bisimilarity definition...
(0,0)
(1,1)
(3,3)
(2,2)
(5,5)
(4,4)
Execution time: 2961998596956 - 2961599816341 = 398 ms
```



Ursprünglicher Algorithmus

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
2: $newProcesses \leftarrow emptyList$
3: **for** $process \in processes$ **do**
4: $processSharedEnvironment.add(process.getName(), allSharedEnvironments)$
5: $ApplyRule2(allSharedEnvironments, process)$
6: **for** $transition \in process.getOriginalTransitions()$ **do**
7: $processEnvironments \leftarrow processSharedEnvironment.getValueOf(process.getName())$
8: **for** $environment \in processEnvironments$ **do**
9: **if** $transition.getAction().isTauAction()$ **then**
10: $ApplyRule1(process, transition)$
11: $ApplyRule4(process, transition, environment)$
12: **else if** $transition.getAction().isNormalAction()$ **then**
13: $ApplayRule3(process, transition, environment)$
14: **else if** $transition.getAction().isTimeAction()$ **then**
15: $ApplyRule5(process, environment)$
16: $ApplyRule6(process, transition, environment)$
17: **end if**
18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

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19: **end for**
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22: $result \leftarrow getNewProcesses()$

$$2)\ \frac{}{\mathcal{U}(p) \xrightarrow{E_X}_{\upsilon} \mathcal{U}_X(p)}\ X \subseteq A$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

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19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$1)\ \frac{p \xrightarrow{\tau} p'}{\upsilon(p) \xrightarrow{\tau}_{\upsilon} \upsilon(p')}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

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2: $newProcesses \leftarrow emptyList$
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13: $ApplayRule3(process, transition, environment)$
14: **else if** $transition.getAction().isTimeAction()$ **then**
15: $ApplyRule5(process, environment)$
16: $ApplyRule6(process, transition, environment)$
17: **end if**
18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$4)\ \frac{p \xrightarrow{\tau} p'}{\upsilon_X(p) \xrightarrow{\tau}_{\upsilon} \upsilon_X(p')}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
2: $newProcesses \leftarrow emptyList$
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13: $ApplayRule3(process, transition, environment)$
14: **else if** $transition.getAction().isTimeAction()$ **then**
15: $ApplyRule5(process, environment)$
16: $ApplyRule6(process, transition, environment)$
17: **end if**
18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$3)\ \frac{p \xrightarrow{a} p'}{\upsilon_X(p) \xrightarrow{a}_{\upsilon} \upsilon(p')}\ a \in X$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
2: $newProcesses \leftarrow emptyList$
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15: $ApplyRule5(process, environment)$
16: $ApplyRule6(process, transition, environment)$
17: **end if**
18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$5)\ \frac{p \overset{\alpha}{\not\mapsto} \forall \alpha \in X \cup \{\tau\}}{\upsilon_X(p) \xrightarrow{t_\varepsilon}_\upsilon \upsilon(p)}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
2: $newProcesses \leftarrow emptyList$
3: **for** $process \in processes$ **do**
4: $processSharedEnvironment.add(process.getName(), allSharedEnvironments)$
5: $ApplyRule2(allSharedEnvironments, process)$
6: **for** $transition \in process.getOriginalTransitions()$ **do**
7: $processEnvironments \leftarrow processSharedEnvironment.getValueOf(process.getName())$
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9: **if** $transition.getAction().isTauAction()$ **then**
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11: $ApplyRule4(process, transition, environment)$
12: **else if** $transition.getAction().isNormalAction()$ **then**
13: $ApplayRule3(process, transition, environment)$
14: **else if** $transition.getAction().isTimeAction()$ **then**
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17: **end if**
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21: **end for**
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$$6)\ \frac{p \overset{\alpha}{\not\rightarrow} \forall \alpha \in X \cup \{\tau\} \quad p \overset{t}{\rightarrow} p'}{\upsilon_X(p) \overset{t}{\rightarrow}_\upsilon \upsilon_X(p')}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

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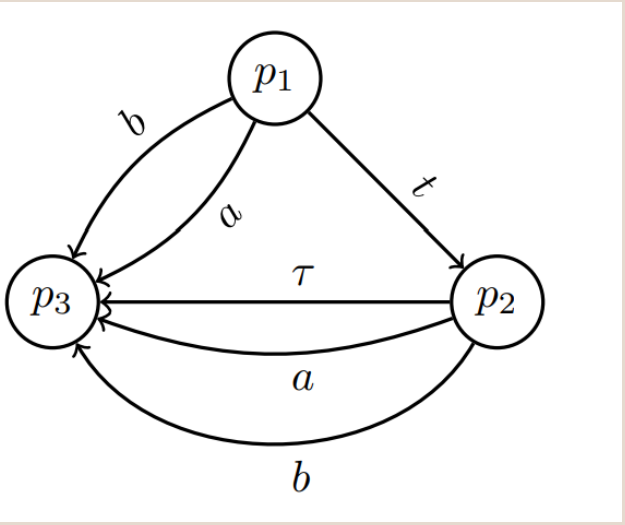
Ursprünglicher Algorithmus



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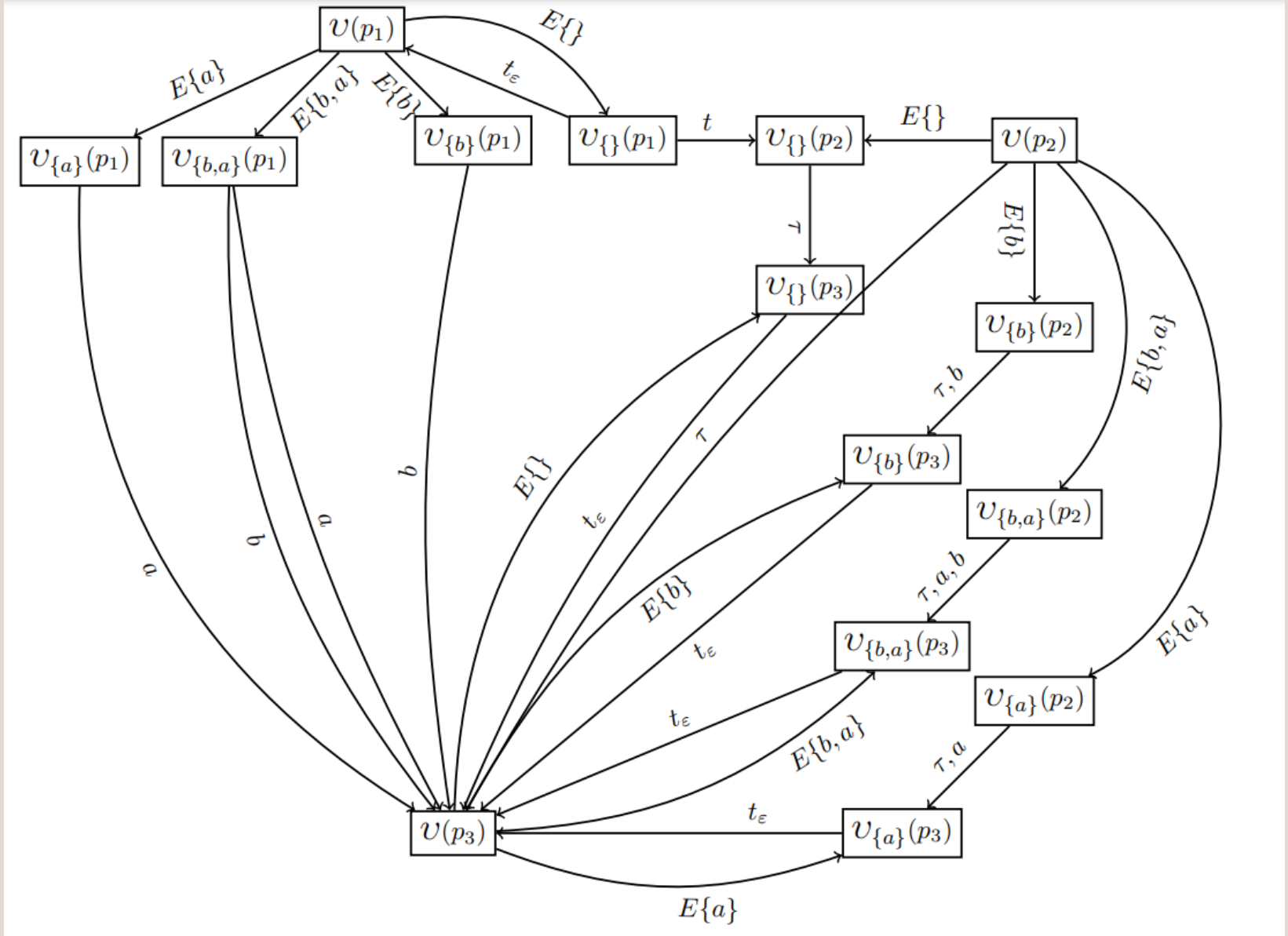
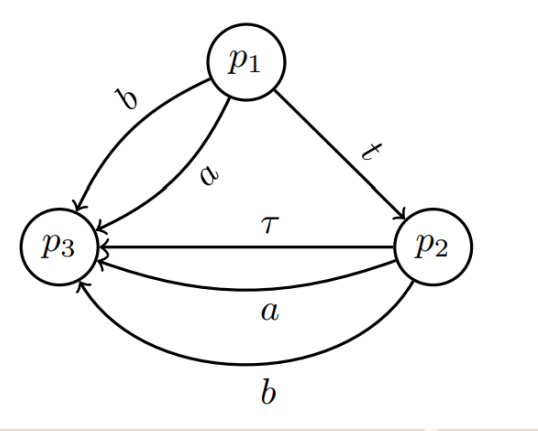


Ursprünglicher Algorithmus



Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

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{{}, {a}, {b}, {a, b}}

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

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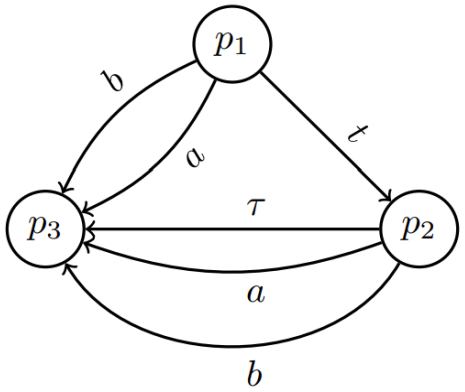
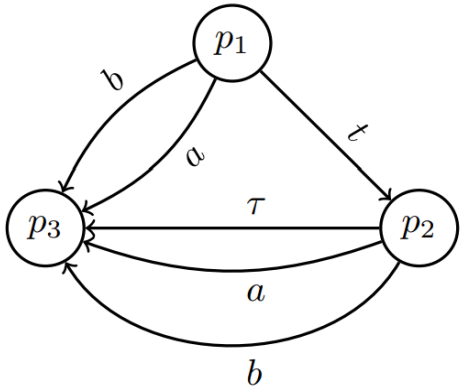


$$2)\ \frac{}{\mathcal{U}(p) \xrightarrow{E_X}_{\upsilon} \mathcal{U}_X(p)}\ X \subseteq A$$

Ursprünglicher Algorithmus

$\boxed{\upsilon(p_1)}$



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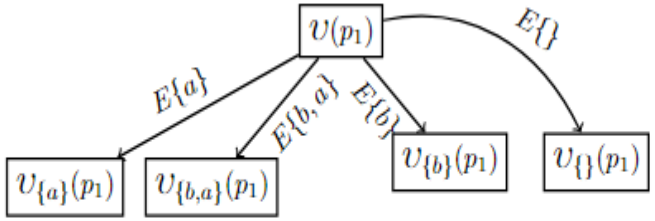
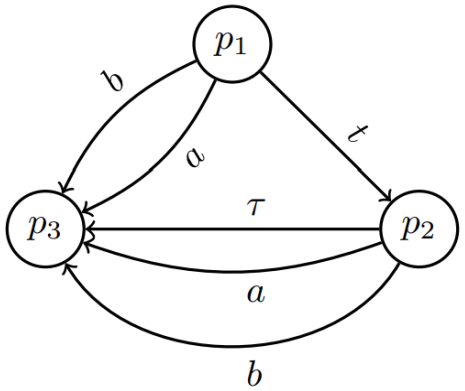
Ursprünglicher Algorithmus





$$2)\ \frac{}{\upsilon(p) \xrightarrow{E_X}_{\upsilon} \upsilon_X(p)}\ X \subseteq A$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
2: $newProcesses \leftarrow emptyList$
3: **for** $process \in processes$ **do**
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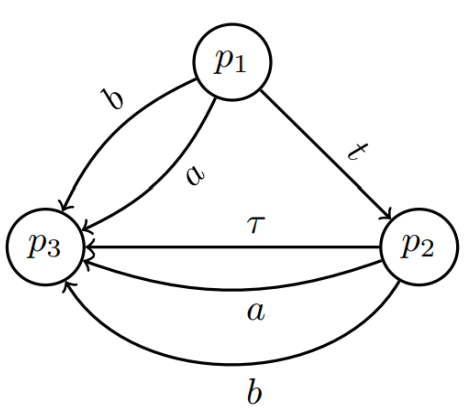
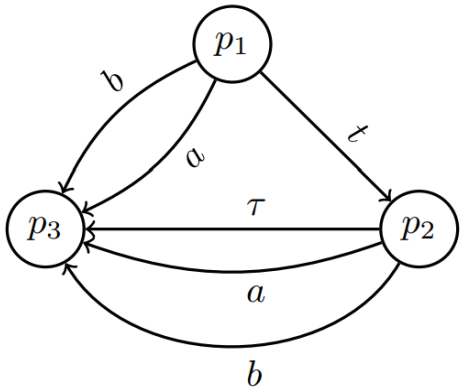
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$



$$2)\ \frac{}{\upsilon(p) \xrightarrow{E_X}_{\upsilon} \upsilon_X(p)}\ X \subseteq A$$

Ursprünglicher Algorithmus



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Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

```
1: processes, allSharedEnvironments, processSharedEnvironment
2: newProcesses ← emptyList
3: for process ∈ processes do
4:     processSharedEnvironment.add(process.getName(), allSharedEnvironments)
5:     ApplyRule2(allSharedEnvironments, process)
6:     for transition ∈ process.getOriginalTransitions() do
7:         processEnvironments ← processSharedEnvironment.getValueOf(process.getName())
8:         for environment ∈ processEnvironments do
9:             if transition.getAction().isTauAction() then
10:                ApplyRule1(process, transition)
11:                ApplyRule4(process, transition, environment)
12:            else if transition.getAction().isNormalAction() then
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14:            else if transition.getAction().isTimeAction() then
15:                ApplyRule5(process, environment)
16:                ApplyRule6(process, transition, environment)
17:            end if
18:        end for
19:    end for
20:    applyRule5OfRemainingEnvironments(process, processSharedEnvironment)
21: end for
22: result ← getNewProcesses()
```

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

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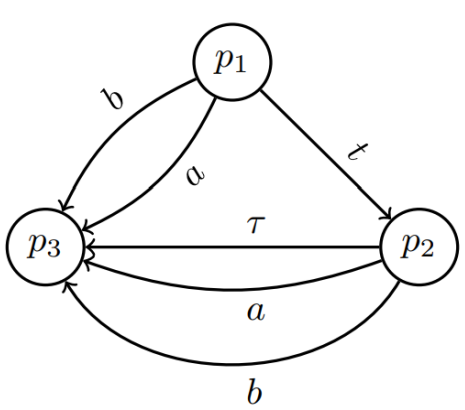
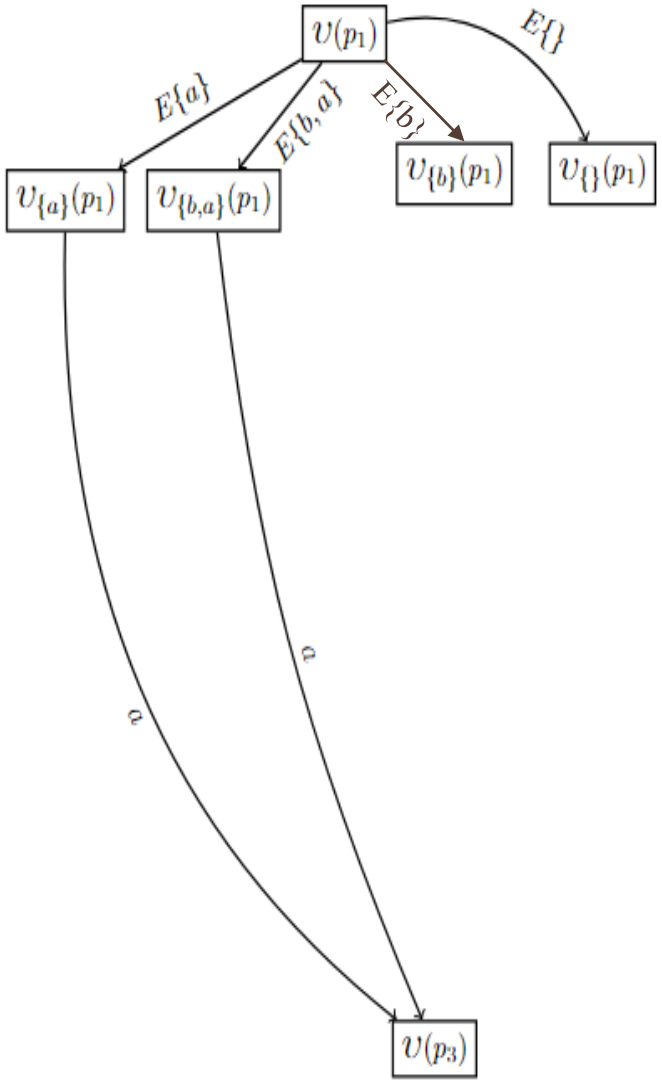
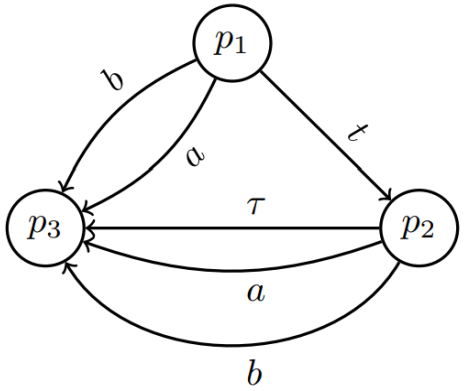


$$2)\ \frac{}{\mathcal{U}(p) \xrightarrow{E_X}_{\upsilon} \mathcal{U}_X(p)}\ X \subseteq A$$

$$3)\ \frac{p \xrightarrow{a} p'}{\mathcal{U}_X(p) \xrightarrow{a}_{\upsilon} \mathcal{U}(p')}\ a \in X$$

Ursprünglicher Algorithmus





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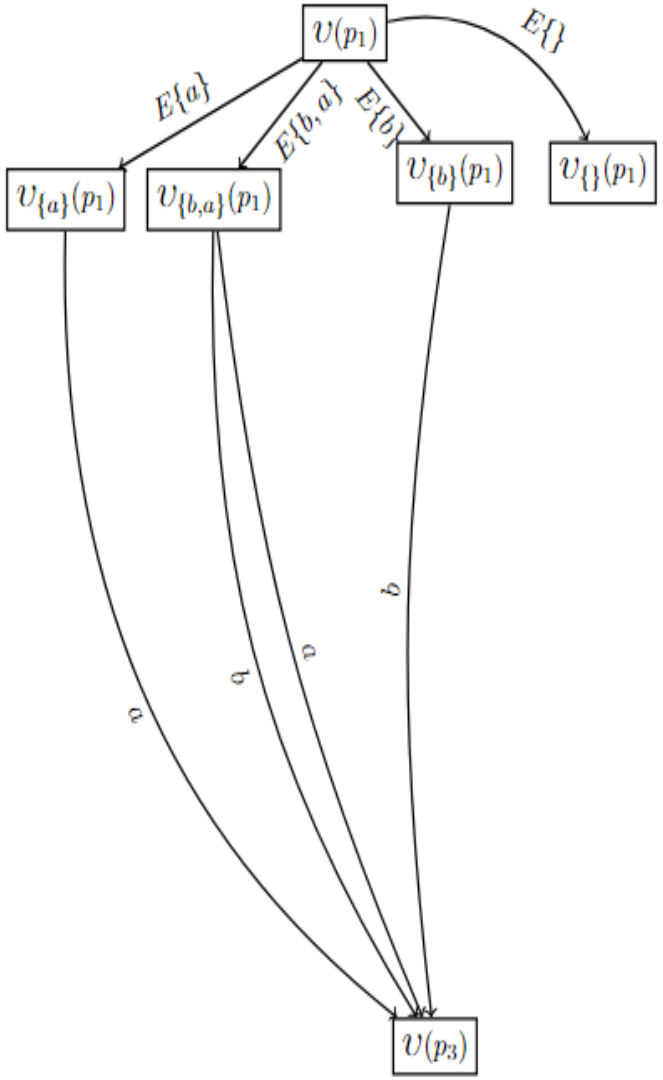
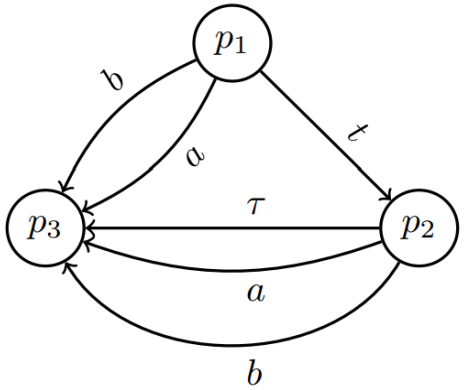
Ursprünglicher Algorithmus





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Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
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3: **for** $process \in processes$ **do**
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21: **end for**
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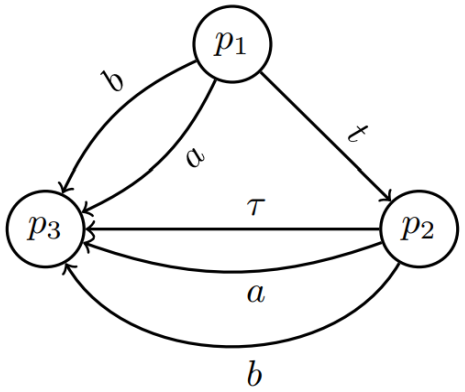

2) $$\frac{}{\mathcal{U}(p) \xrightarrow{E_X}_{\upsilon} \mathcal{U}_X(p)} \; X \subseteq A$$

3) $$\frac{p \xrightarrow{a} p'}{\mathcal{U}_X(p) \xrightarrow{a}_{\upsilon} \mathcal{U}(p')} \; a \in X$$

5) $$\frac{p \not\xrightarrow{\alpha} \forall \alpha \in X \cup \{\tau\}}{\mathcal{U}_X(p) \xrightarrow{t_\varepsilon}_{\upsilon} \mathcal{U}(p)}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

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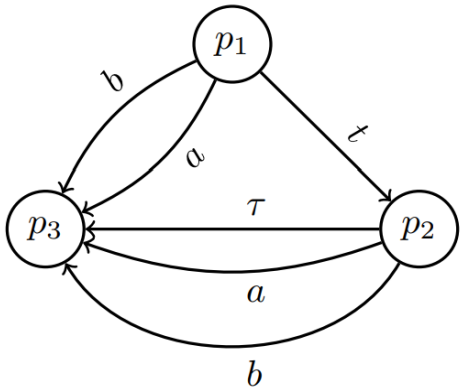

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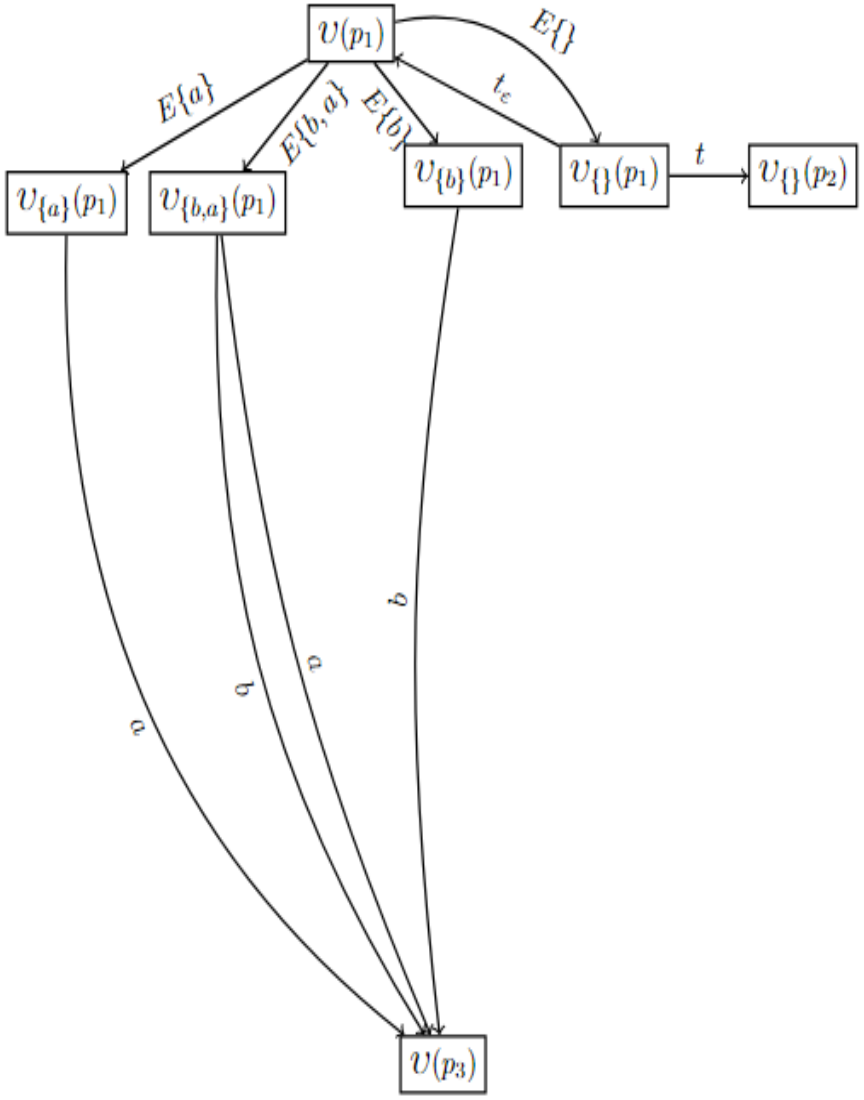
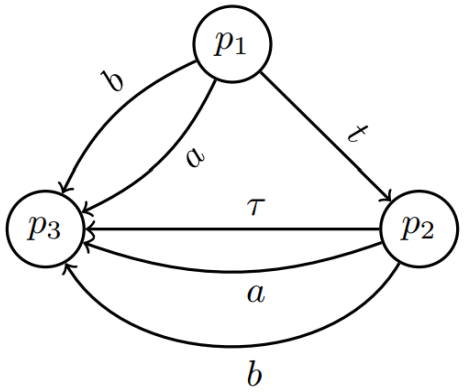
Ursprünglicher Algorithmus





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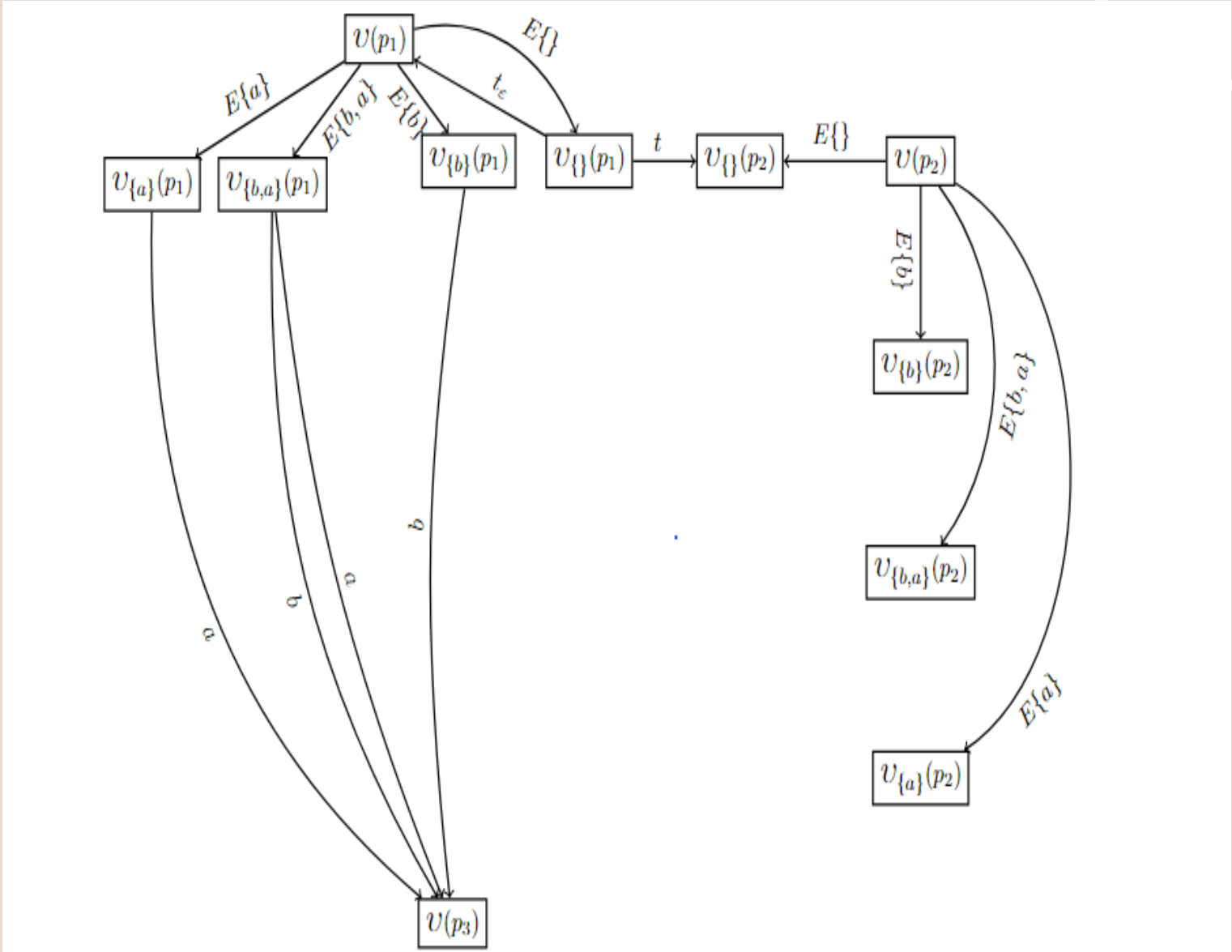
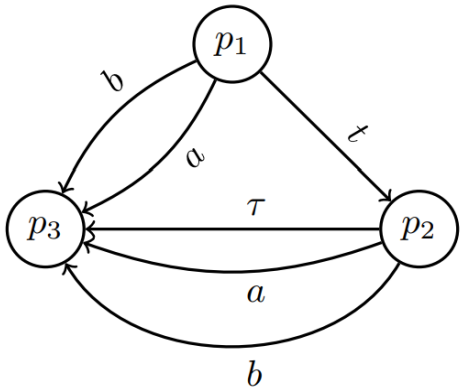
Ursprünglicher Algorithmus





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Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

1: $processes, allSharedEnvironments, processSharedEnvironment$
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18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$1)\ \frac{p \xrightarrow{\tau} p'}{\upsilon(p) \xrightarrow{\tau}_{\upsilon} \upsilon(p')}$$

Ursprünglicher Algorithmus

Algorithm 1 LTS_t zu LTS_s Transformationsalgorithmus ($getLTS_s$)

Require:

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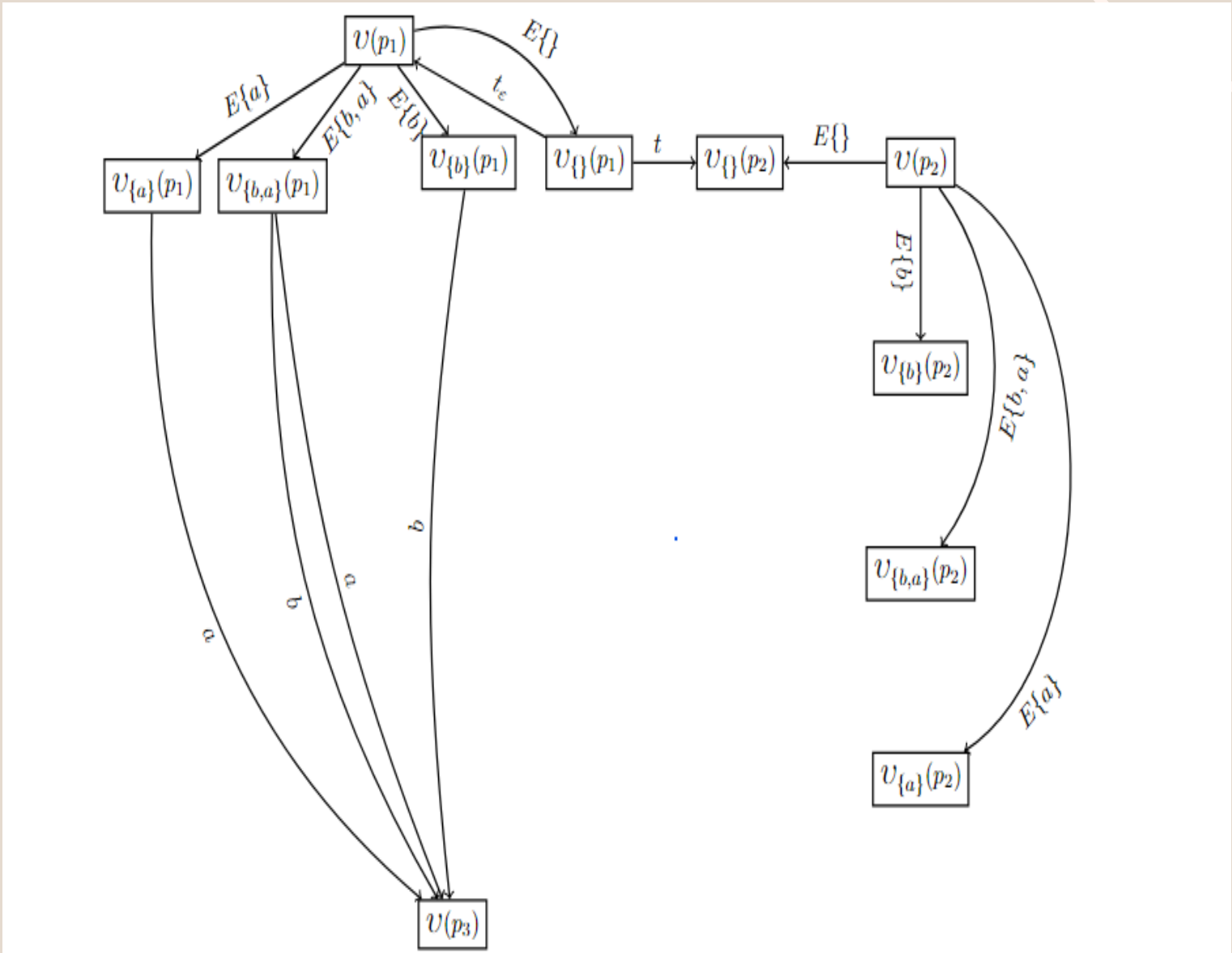
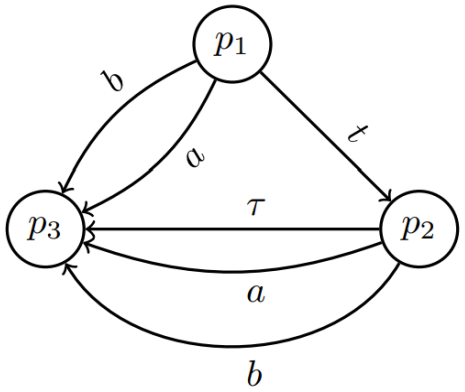
5: $ApplyRule2(allSharedEnvironments, process)$
6: **for** $transition \in process.getOriginalTransitions()$ **do**
7: $processEnvironments \leftarrow processSharedEnvironment.getValueOf(process.getName())$
8: **for** $environment \in processEnvironments$ **do**
9: **if** $transition.getAction().isTauAction()$ **then**
10: $ApplyRule1(process, transition)$
11: $ApplyRule4(process, transition, environment)$
12: **else if** $transition.getAction().isNormalAction()$ **then**
13: $ApplayRule3(process, transition, environment)$
14: **else if** $transition.getAction().isTimeAction()$ **then**
15: $ApplyRule5(process, environment)$
16: $ApplyRule6(process, transition, environment)$
17: **end if**
18: **end for**
19: **end for**
20: $applyRule5OfRemainingEnvironments(process, processSharedEnvironment)$
21: **end for**
22: $result \leftarrow getNewProcesses()$

$$4)\ \frac{p \xrightarrow{\tau} p'}{\upsilon_X(p) \xrightarrow{\tau}_{\upsilon} \upsilon_X(p')}$$

Ursprünglicher Algorithmus





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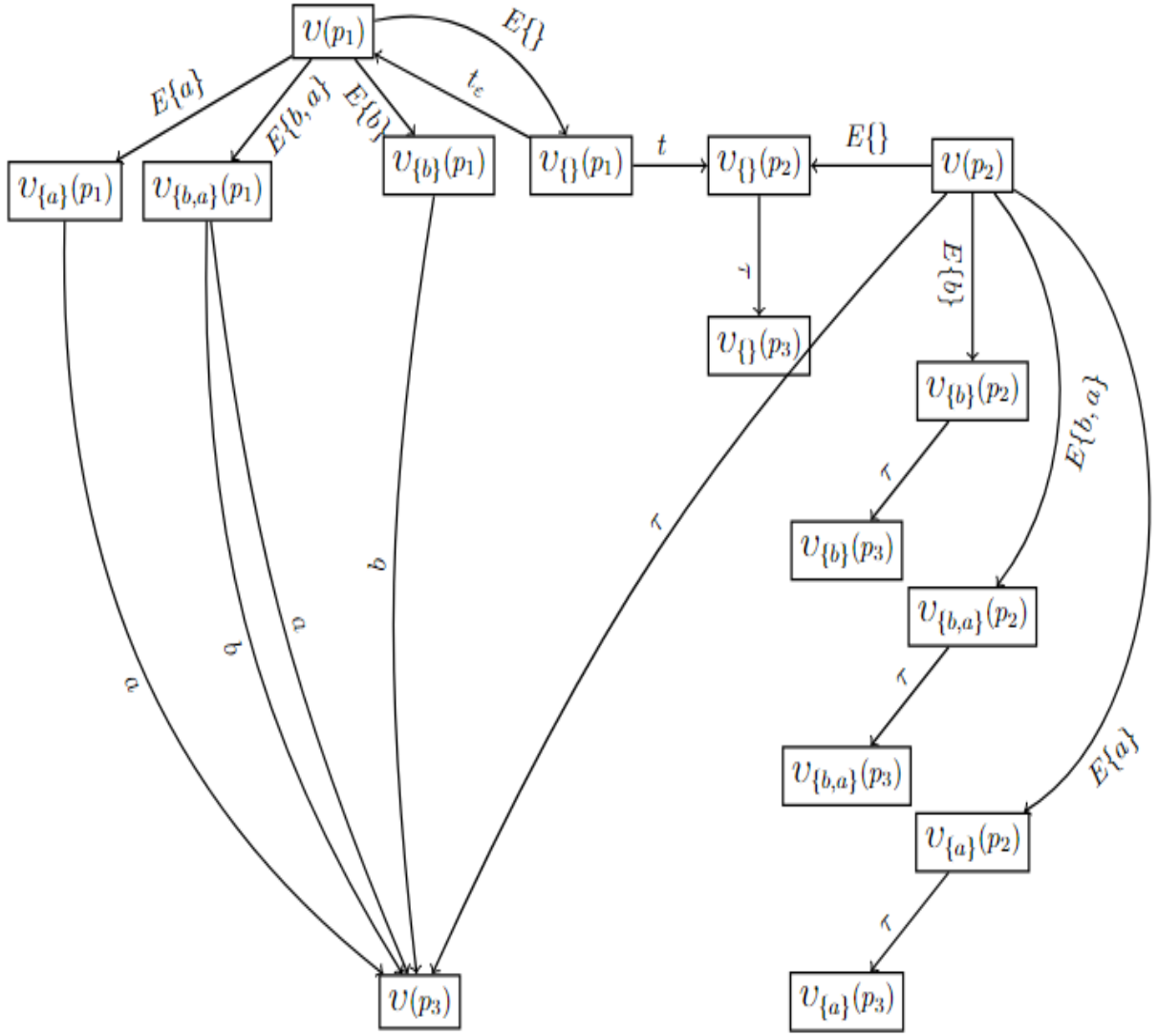

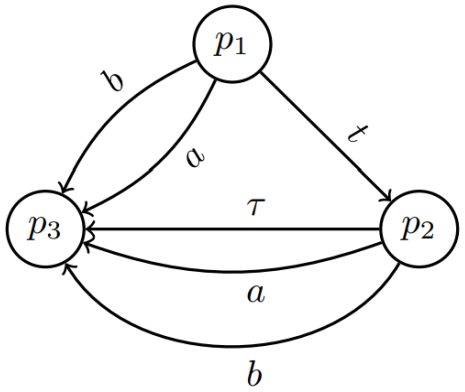

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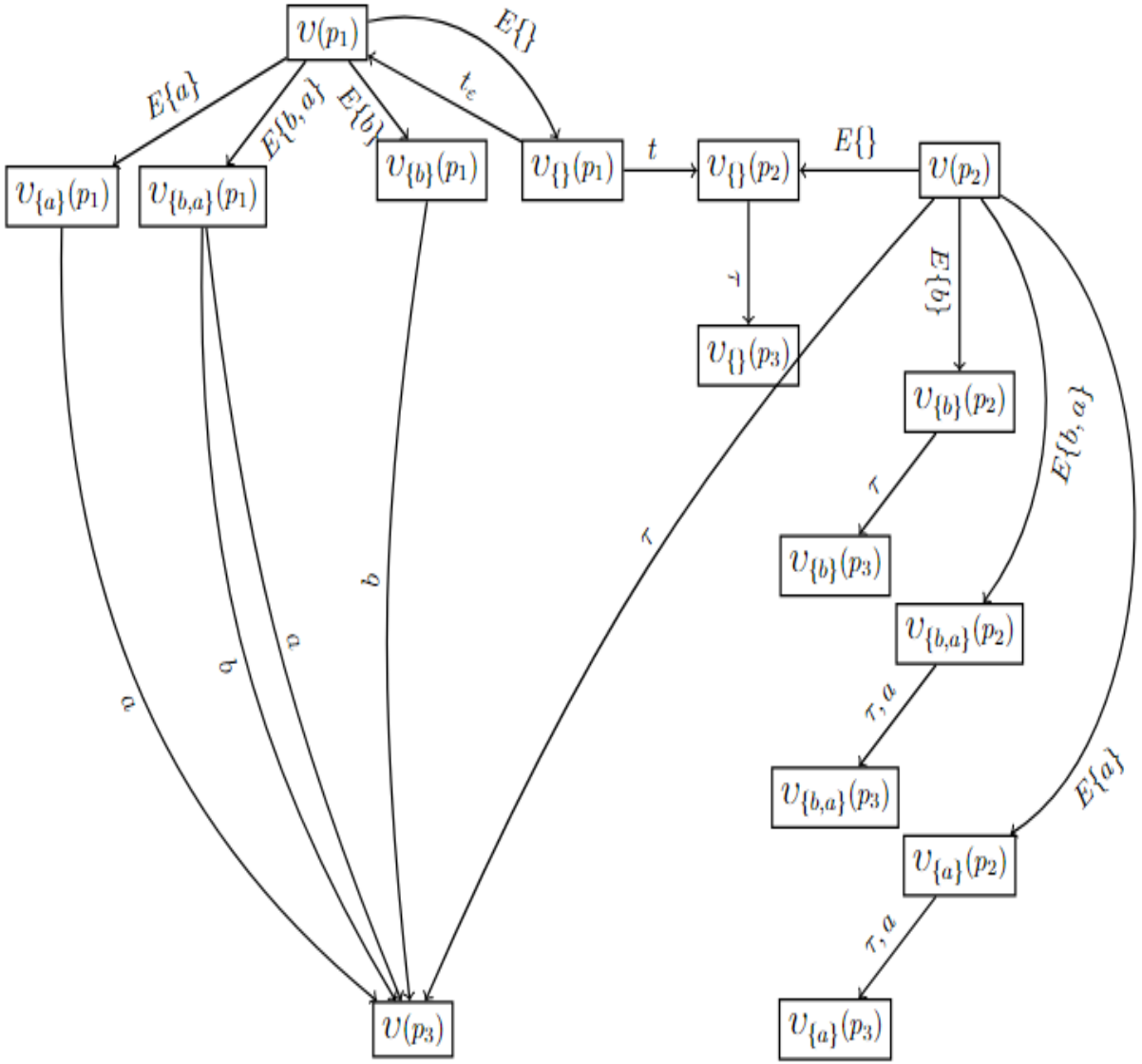

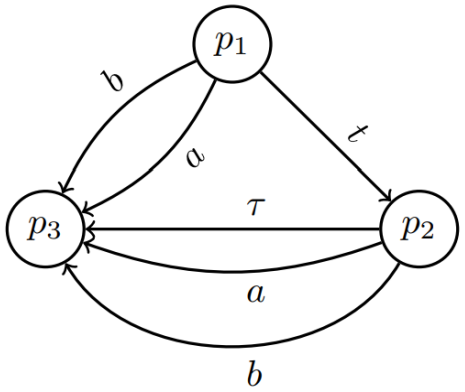

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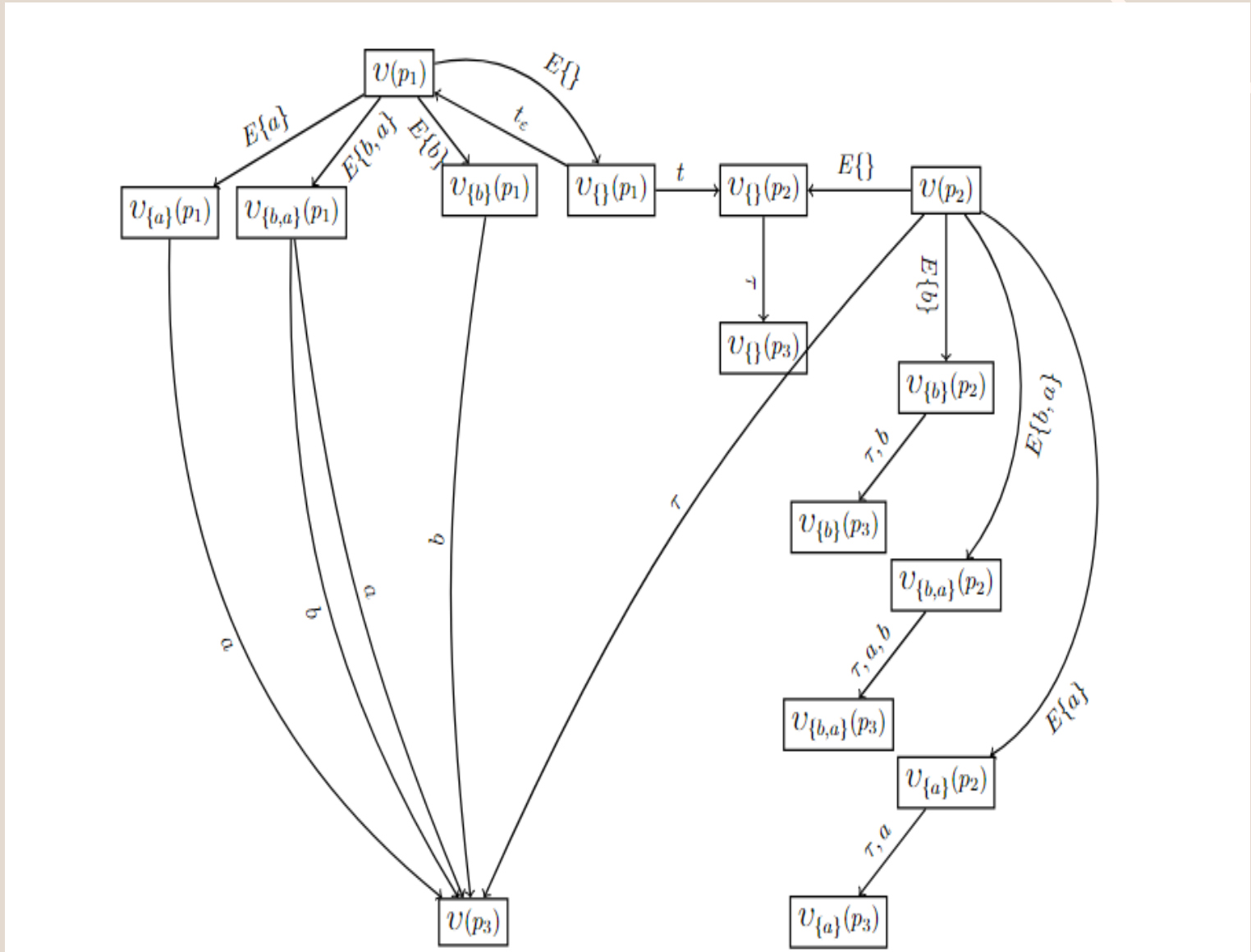

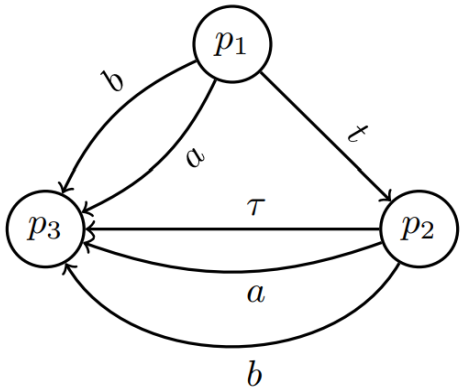

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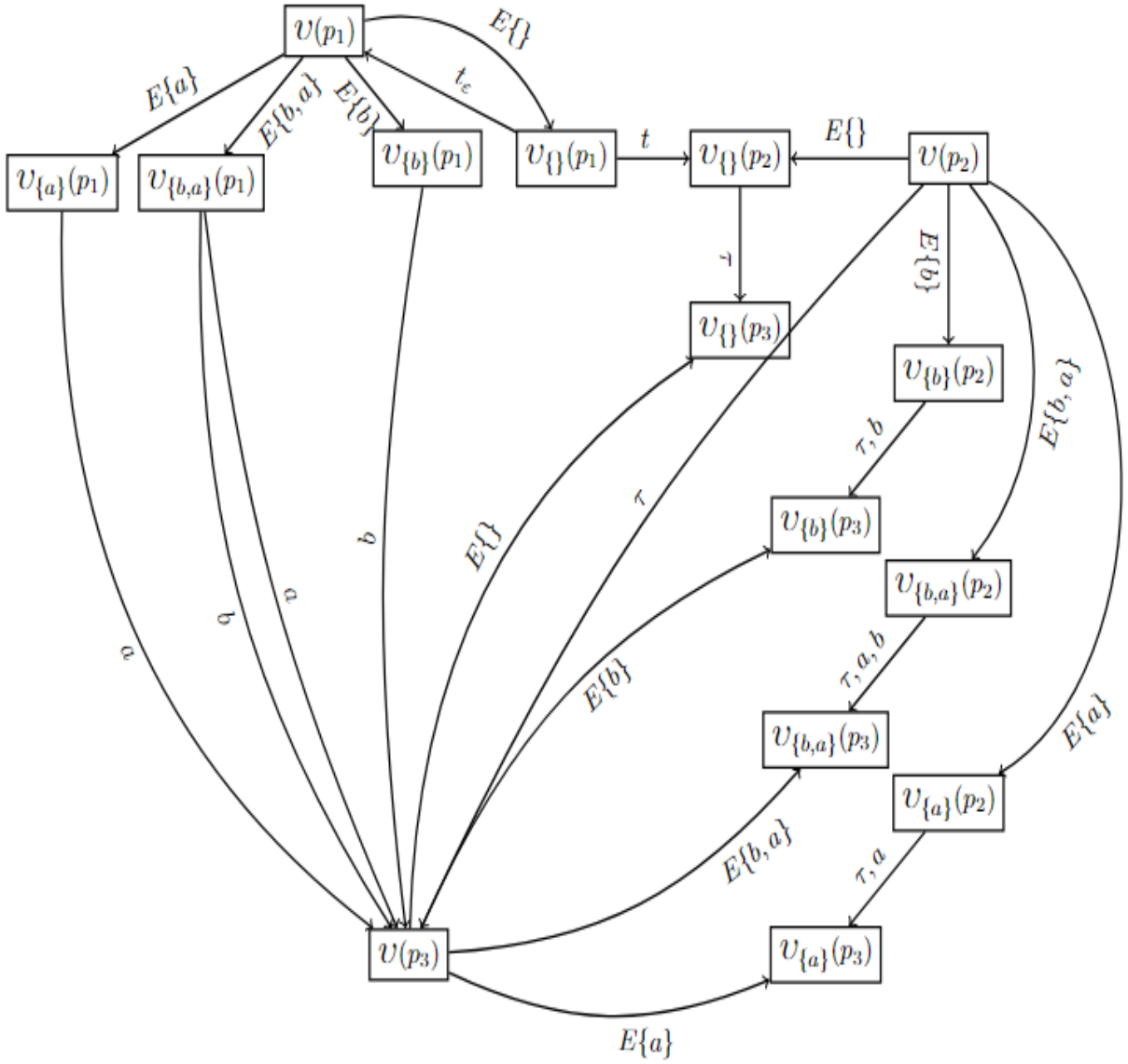

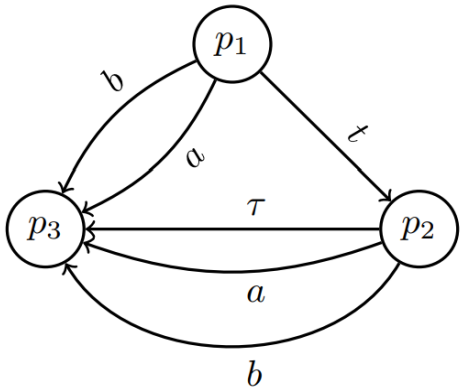

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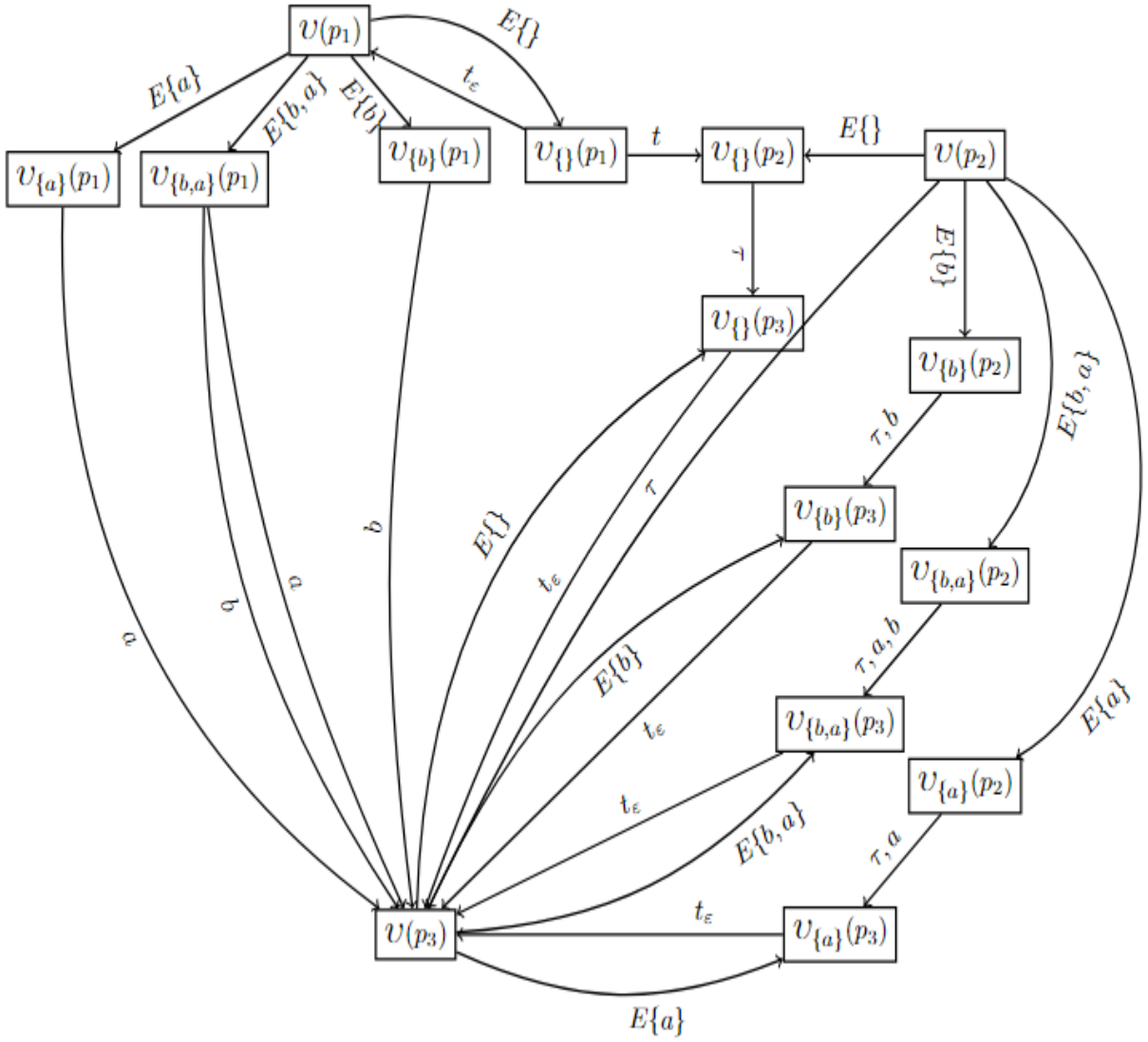

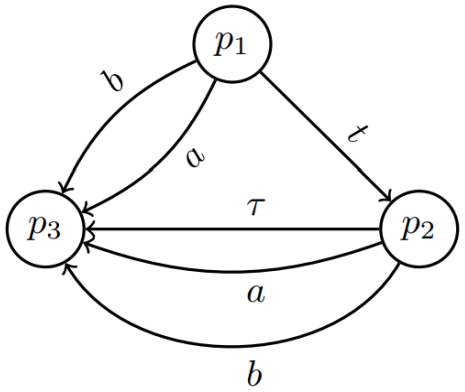

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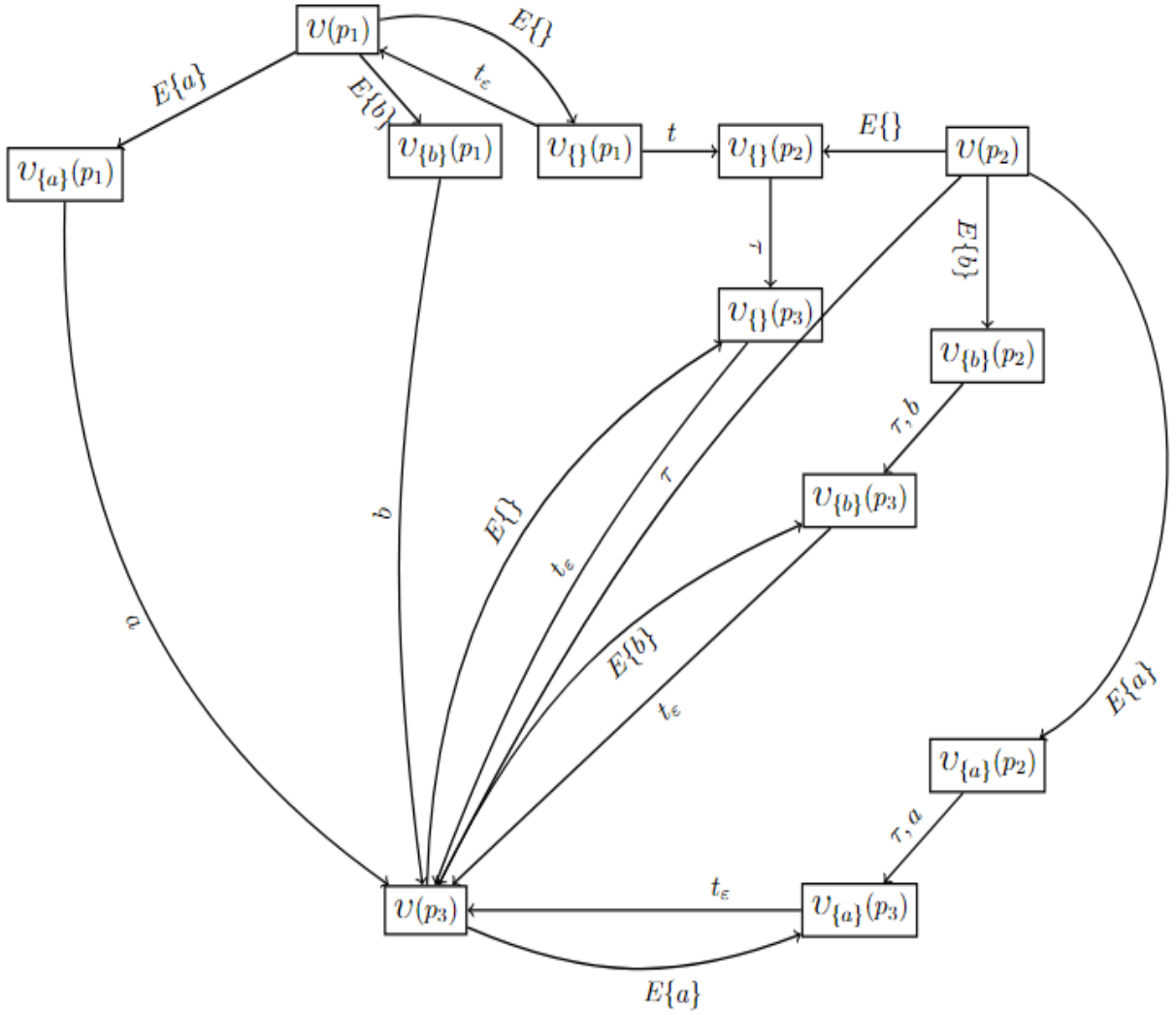
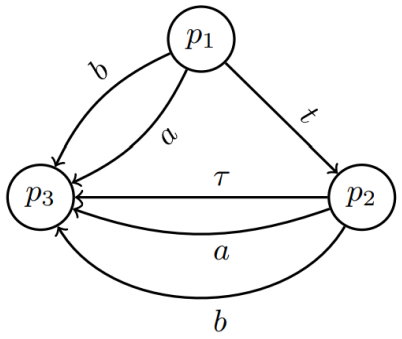
Verbesserte Algorithmus





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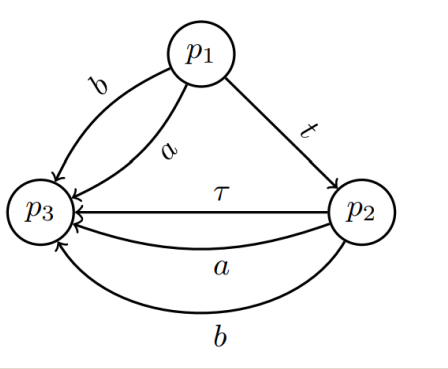

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Einzige Umgebungsaktion

{{}, {a}, {b}, {a, b}}

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{{}, {a}, {b}, {a, b}} ⟶ $E_{\{\ldots\}}$

```
42  (17,"noeE",26)
43  (17,"a",27)
44  (17,"a_b",28)
45  (17,"a_b_g",29)
46  (17,"a_b_g_f",30)
47  (17,"a_b_f",31)
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```

Einzige Umgebungsaktion

{{}, {a}, {b}, {a, b}} → $E_{\{...\}}$

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→

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```

→

```
41  (16,"time",25)
42  (17,"E{...}",26)
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56  (17,"E{...}",40)
57  (17,"E{...}",41)
58  (18,"tau",53)
59  (19,"tau",62)
60  (20,"tau",63)
61  (20,"g",69)
```

Überprüfung eines oder aller Paare

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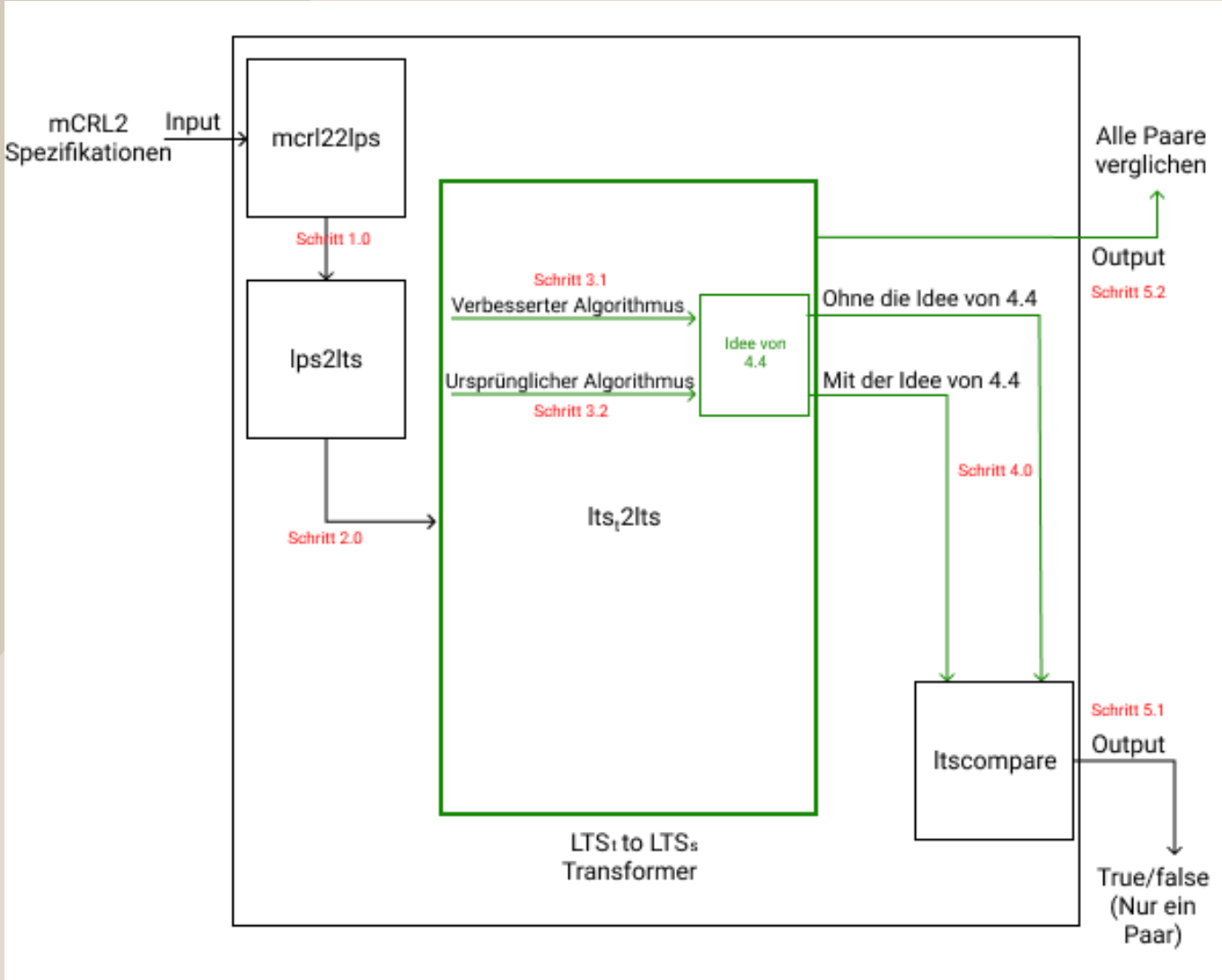


Überprüfung eines oder aller Paare

Algorithm 2 Algorithmus von starker Bisimilarität

Require:

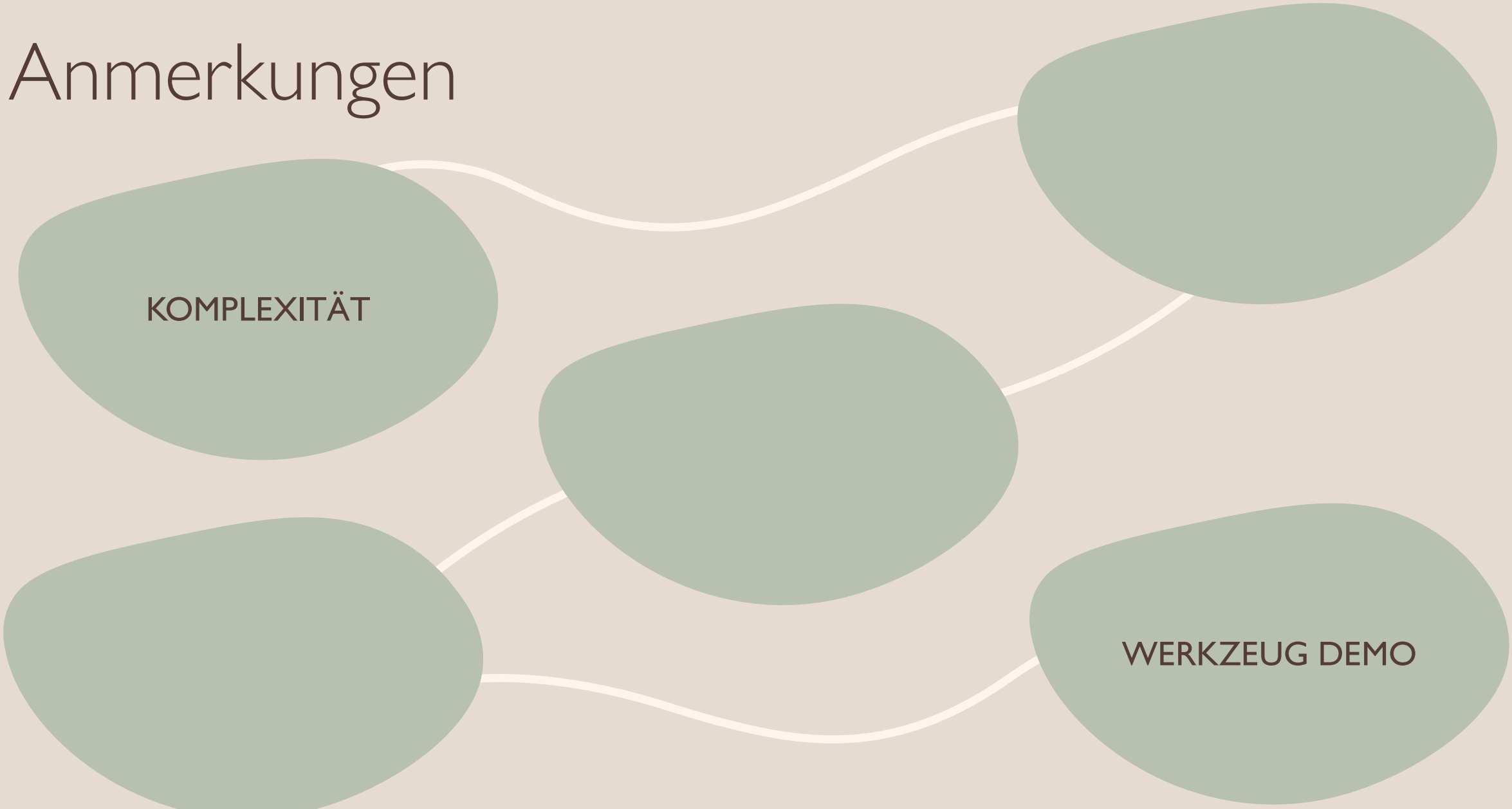
```
1: processList1
2: processList2
3: pairs ← processList1 × processList2
4: while true do
5:     pairs.removeIf(p →
6:         !checkSimulation(p2q, pairs, p.getFirst(), p.getLast())||
7:         !checkSimulation(q2p, pairs, p.getLast(), p.getFirst())
8:     )
9:     If pairs does not change beark
10: end while
11: return pairs
```

Algorithm 3 checkSimulation

Require:

```
1: leftToRight (check (p,q) or (q,p))
2: pairs
3: Prozess p from pair
4: Prozess q from pair
5: return p.getTransitions().allMatch(t1 →
6:             q.getTransitions().anyMatch(t2 →
7:                 t1.getAction().getName().equals(t2.getAction().getName())
8:             &&
9:     areSuccessorsInR(leftToRight, pairs, t1.getSuccessor(), t2.getSuccessor())))
```

Anmerkungen



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$$|Proc_{\upsilon}| = |Proc| \cdot (1 + 2^{|A|})$$

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$$|Proc_\upsilon| = |Proc| \cdot (|A| + |P_t| + 1)$$

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Werkzeug Demo

Fazit

- Werkzeug zur Überprüfung reaktiver Bisimilarität
- Reduktion verbessert aber nicht bewiesen
- Ein Paar oder alle Paare
- Idee der einzigen Aktion

Vielen Dank

Zead Alshukairi

alshukairi@campus.tu-berlin.de