Nutzen der Automatentheorie zur Verbesserung der Sicherheit durch Verifikation in IT-Systemen von KRITIS-Betreibern

Gustav Grabolle

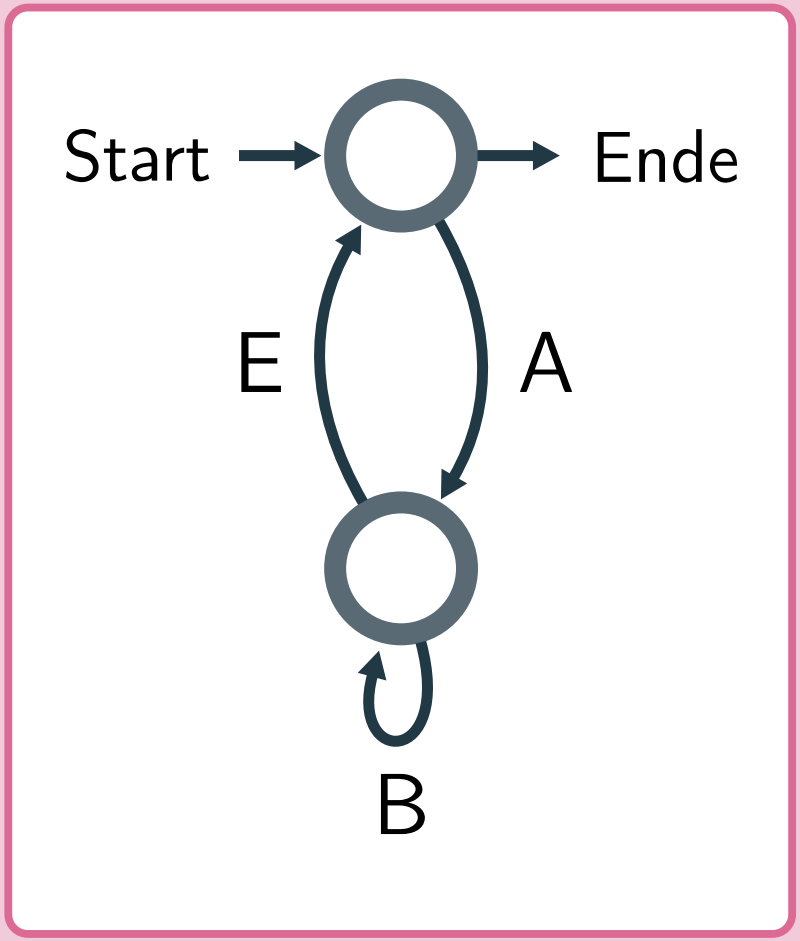
Halle
August 4, 2025

Theoretische Grundlagen

Praktische Einsicht

KRITIS Einsatz

Was sind diese Automaten?



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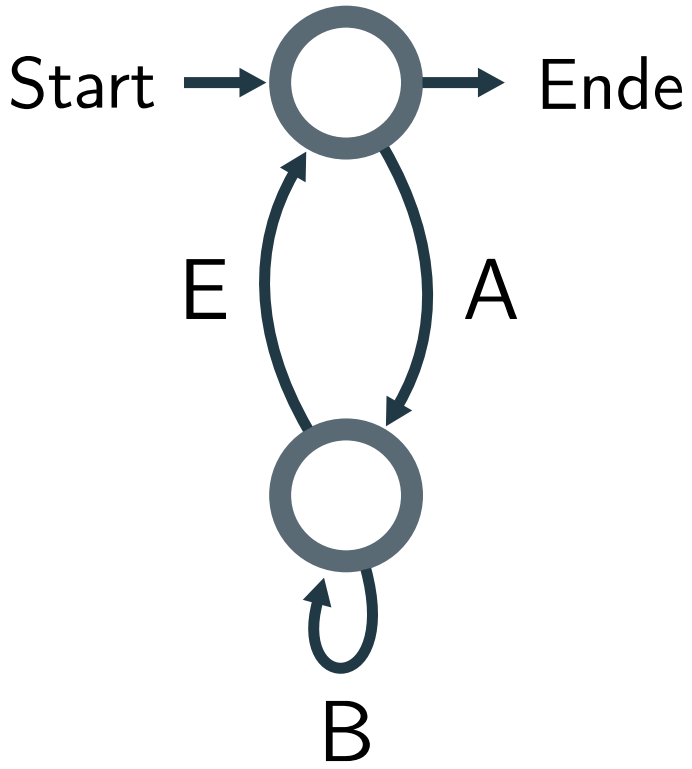

ABE

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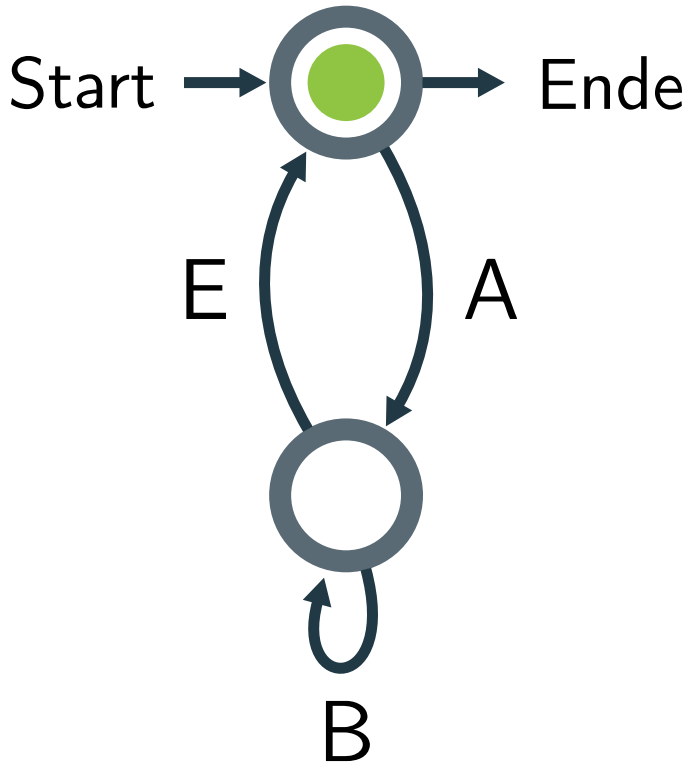

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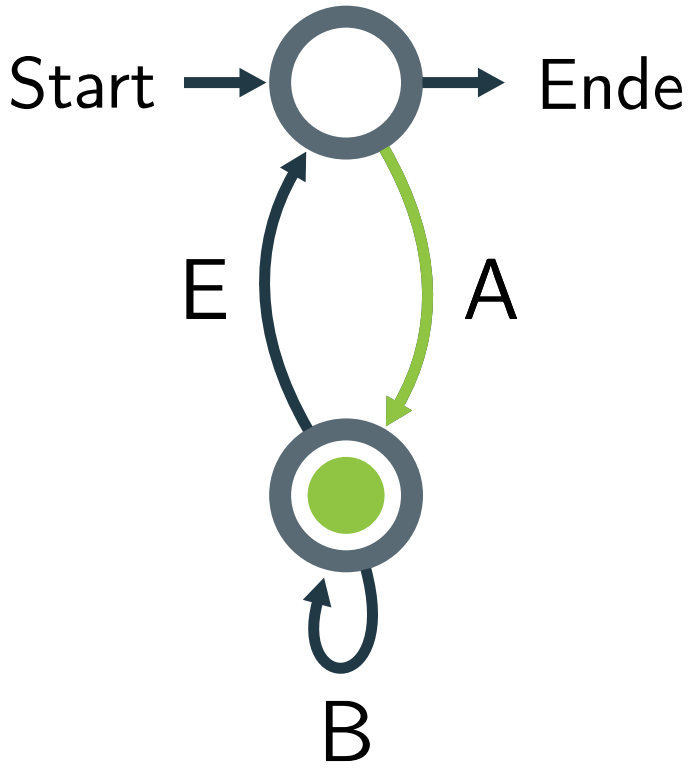

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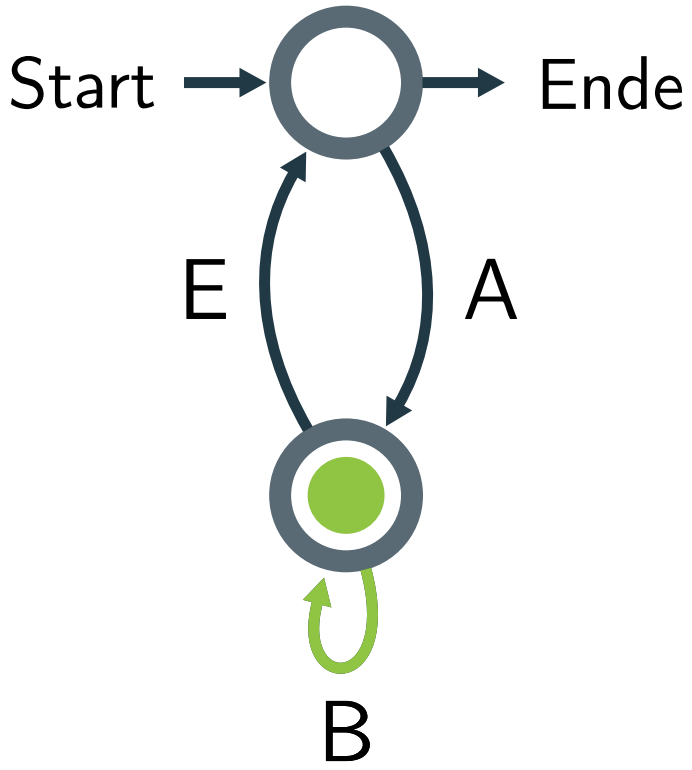

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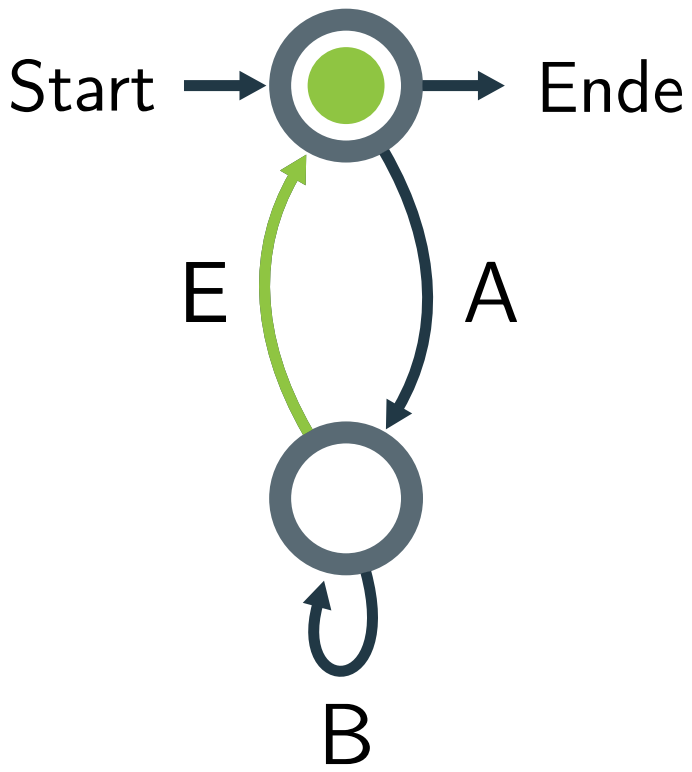

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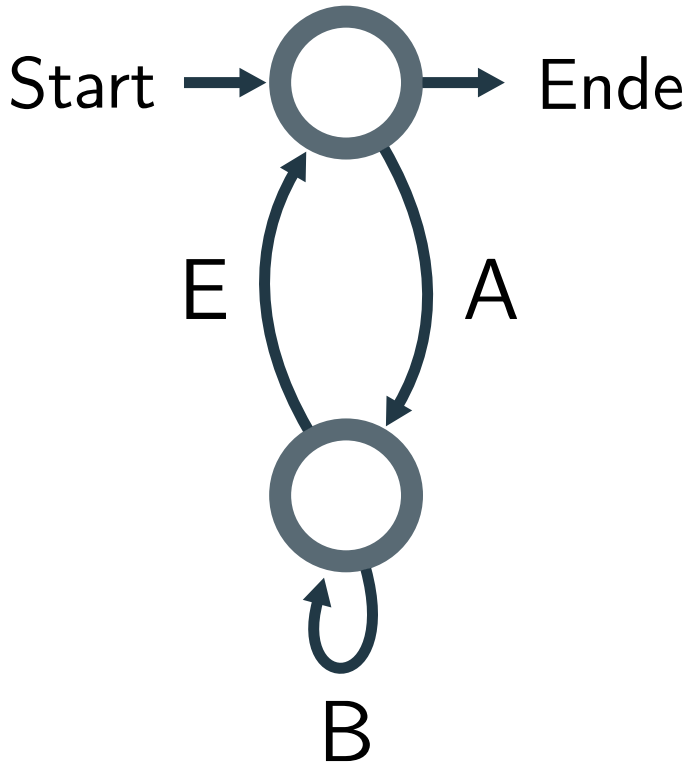

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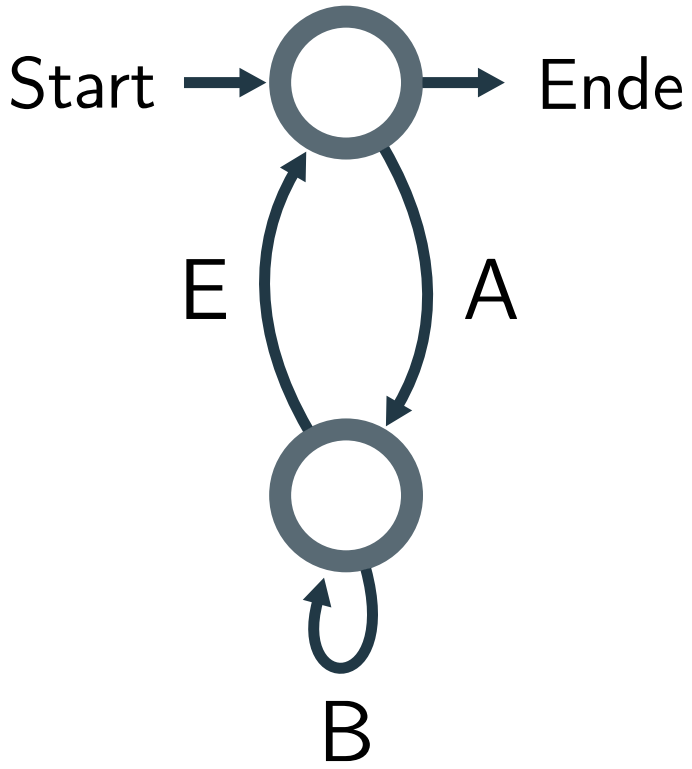

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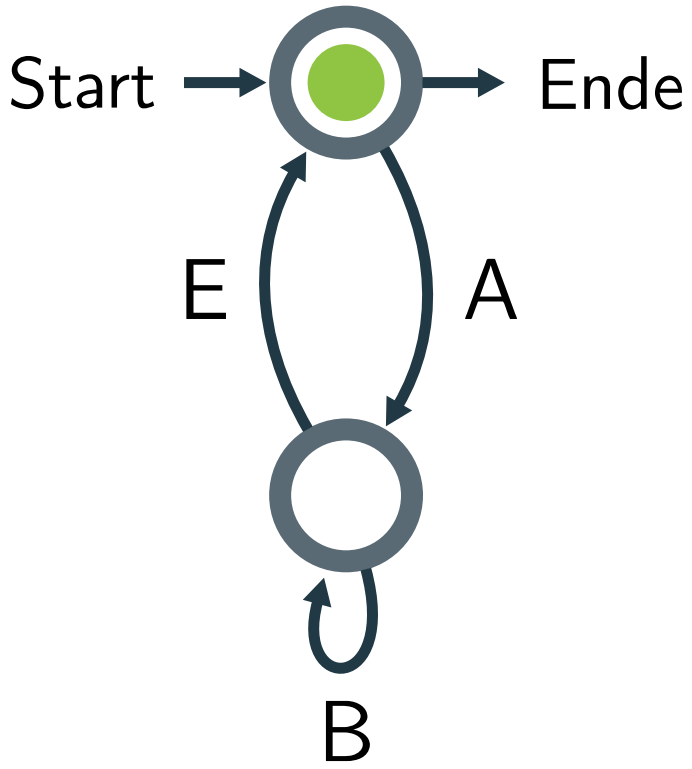

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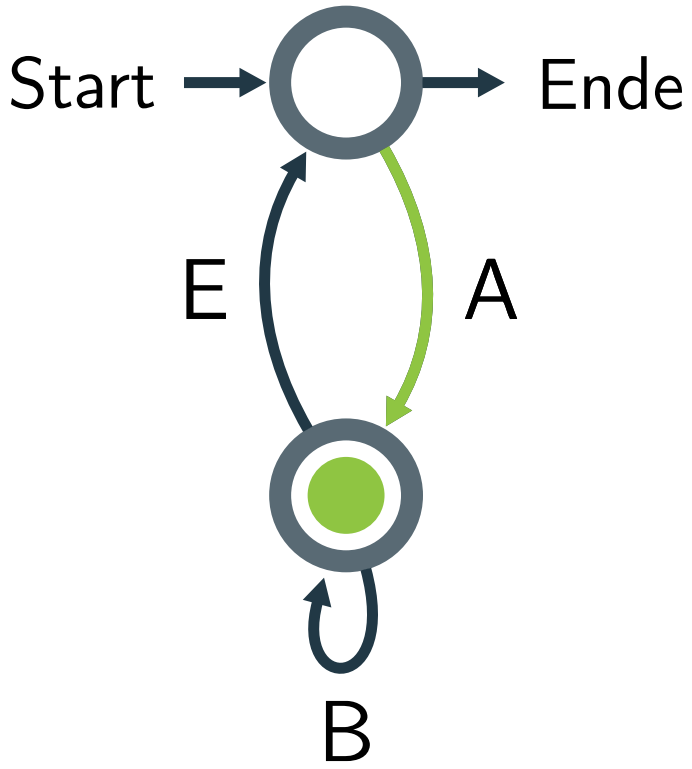

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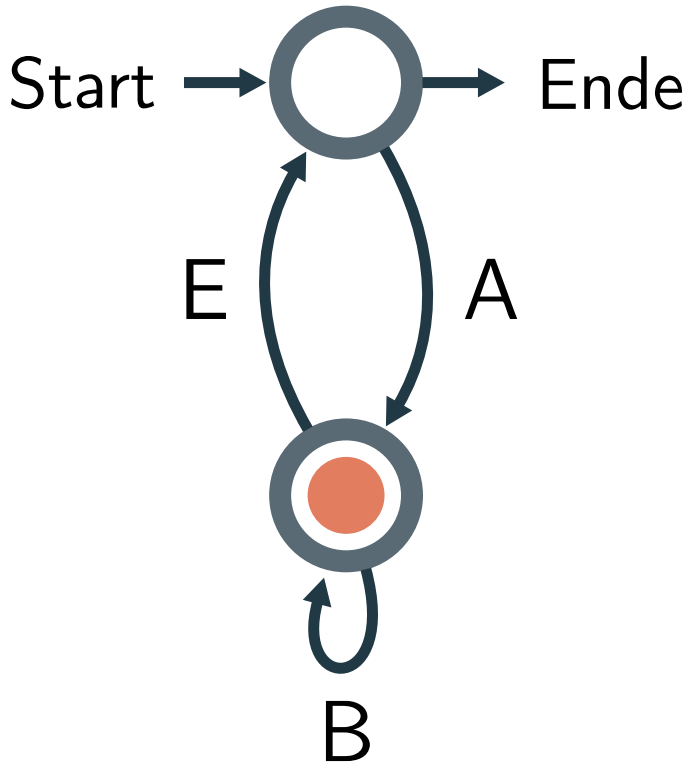

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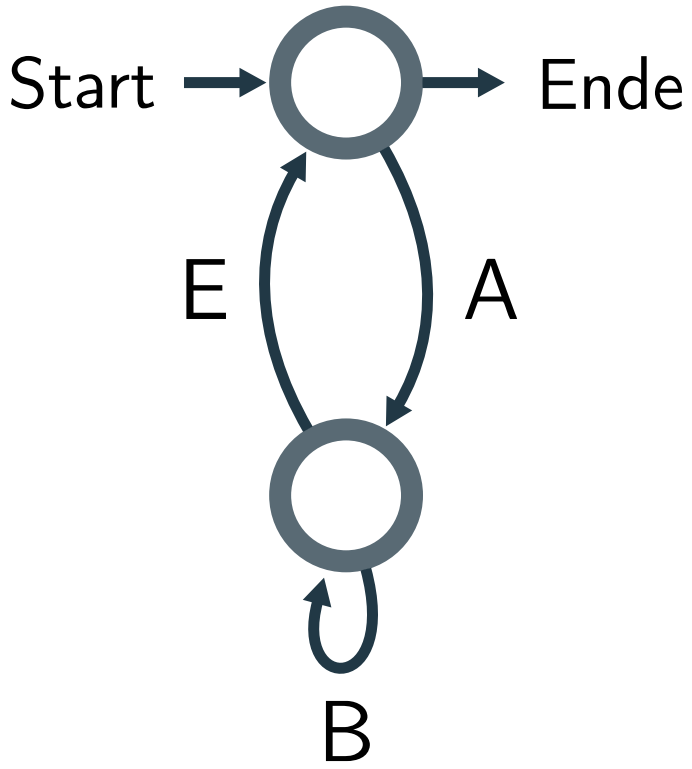

ABE ⭘

AAE ✖

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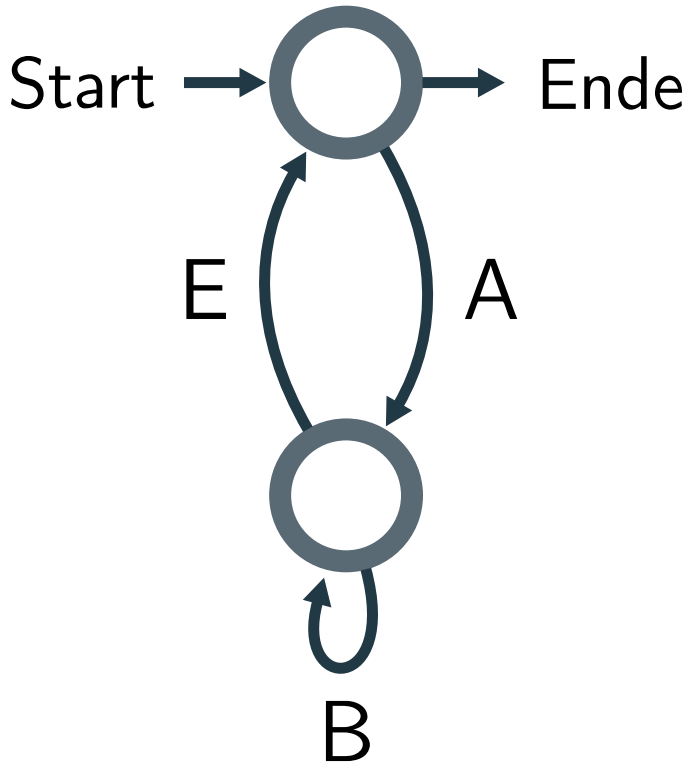

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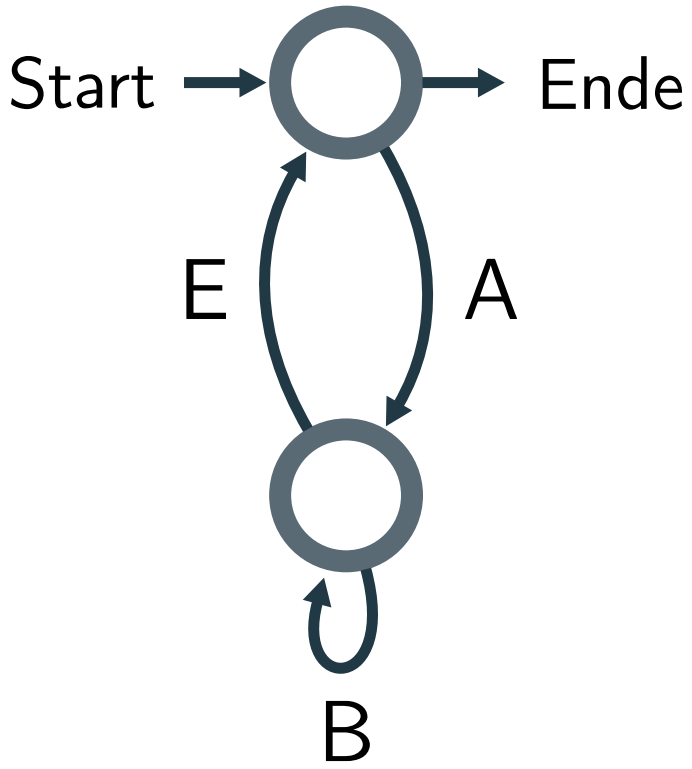


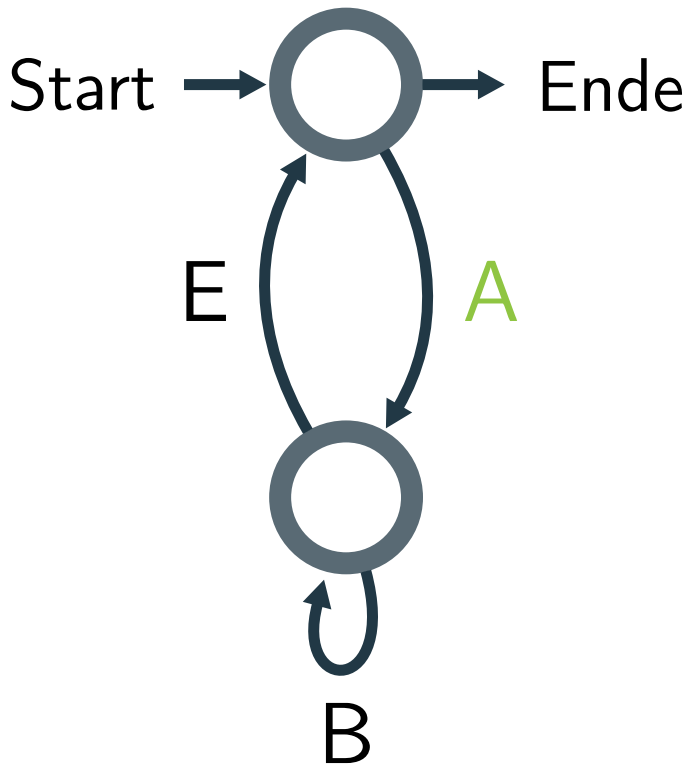
ABE ⭘

AAE ✖

ABEAE ⭘

Was sind diese Automaten?

A $\hat{=}$ Aufnahme



ABE ⭘
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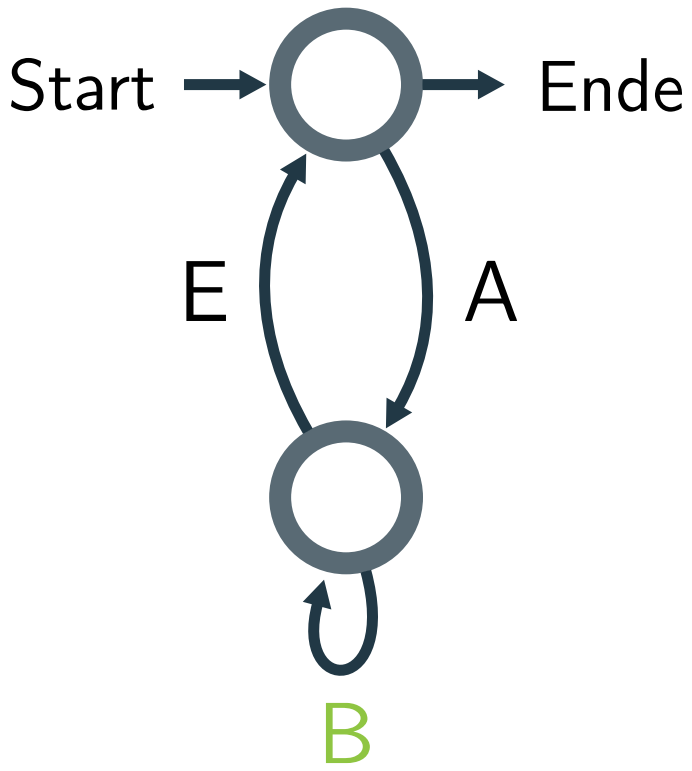
ABEAE ⭘

Was sind diese Automaten?

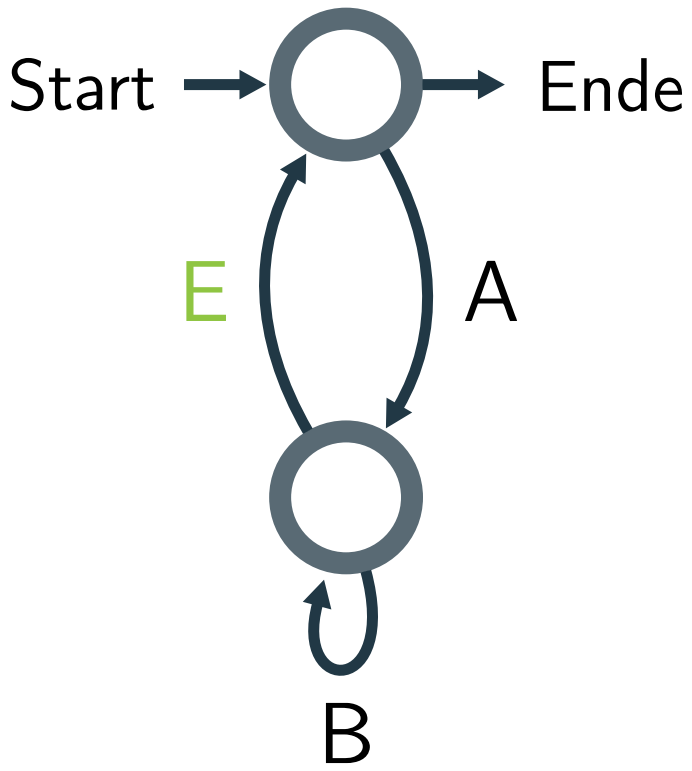
A $\hat{=}$ Aufnahme B $\hat{=}$ Bearbeitung



ABE	⊙
AAE	✖
ABEAE	⊙

Was sind diese Automaten?

A ≙ Aufnahme B ≙ Bearbeitung E ≙ Einreichung



ABE ⊙
AAE ✖
ABEAE ⊙

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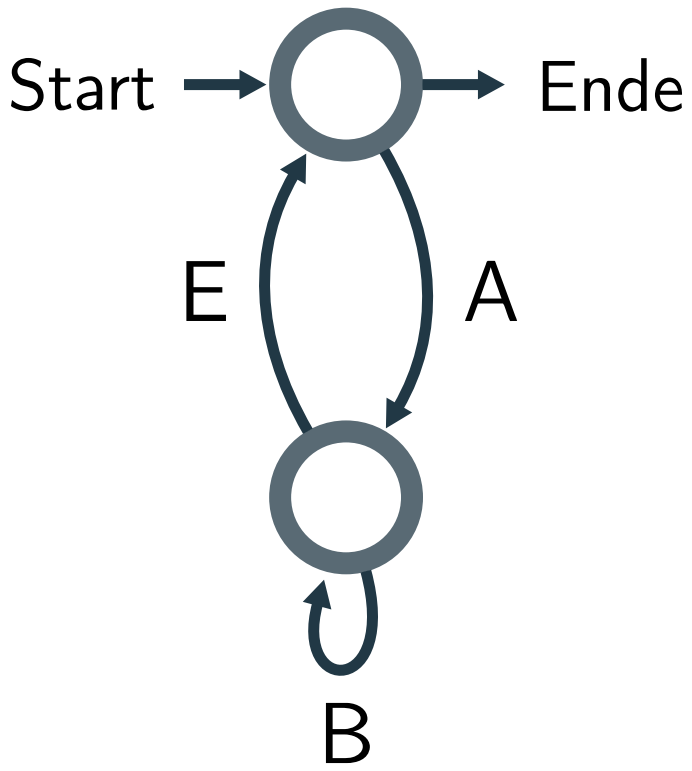

ABE ⊙
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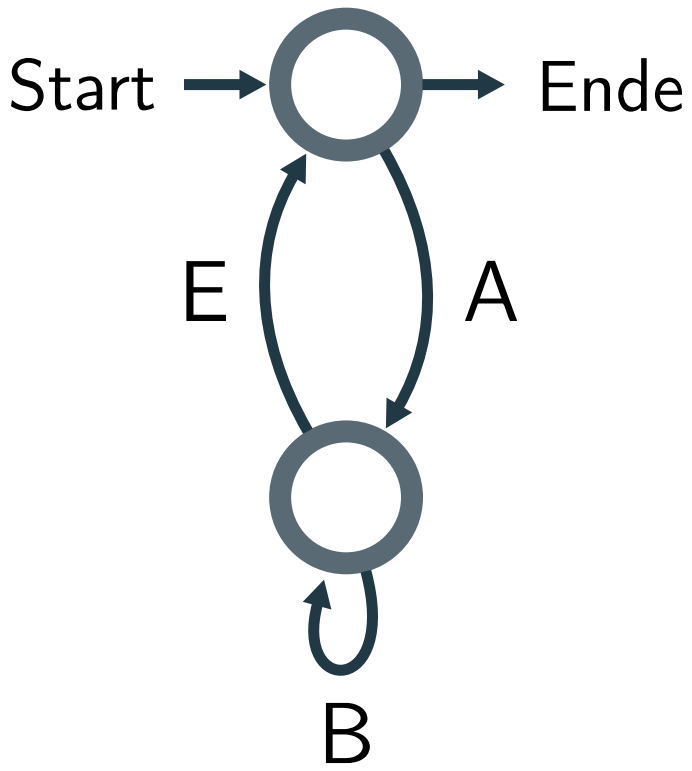
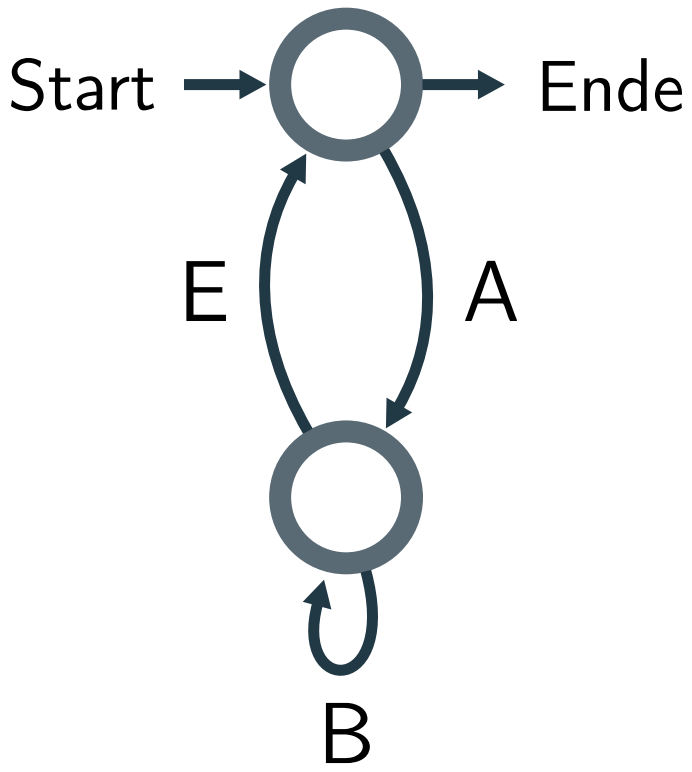


ABE ⭘
AAE ✖
ABEAE ⭘

Jede Aufnahme benötigt eine Einreichung, bevor eine neue Aufnahme erfolgt.

Was sind diese Automaten?

A $\hat{=}$ Aufnahme B $\hat{=}$ Bearbeitung E $\hat{=}$ Einreichung



ABE ⊙
AAE ✖
ABEAE ⊙

Jede Aufnahme benötigt eine Einreichung, bevor eine neue Aufnahme erfolgt.

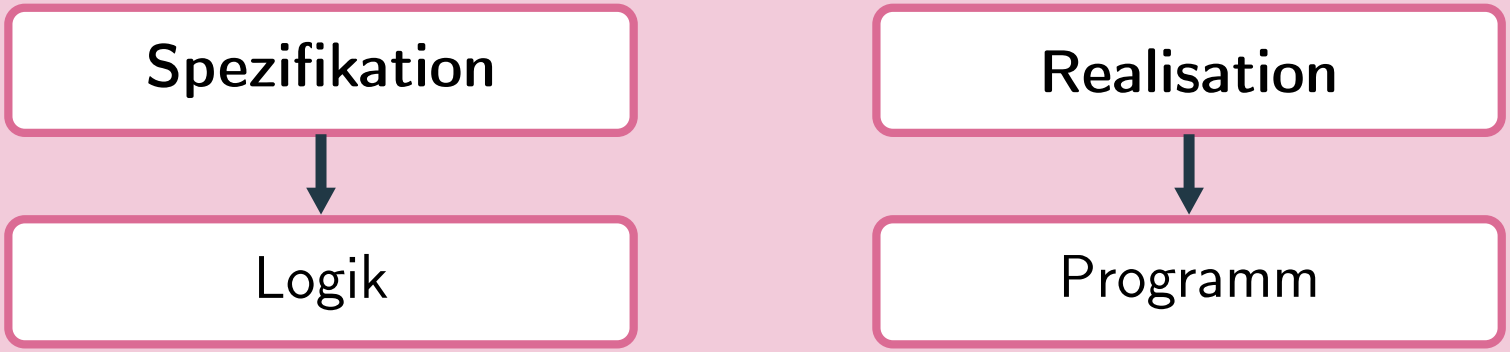
$|u|_A = |u|_E$ oder $|u|_A = |u|_E + 1$

Verifikation mit Modelchecking

Spezifikation

Realisation

Verifikation mit Modelchecking



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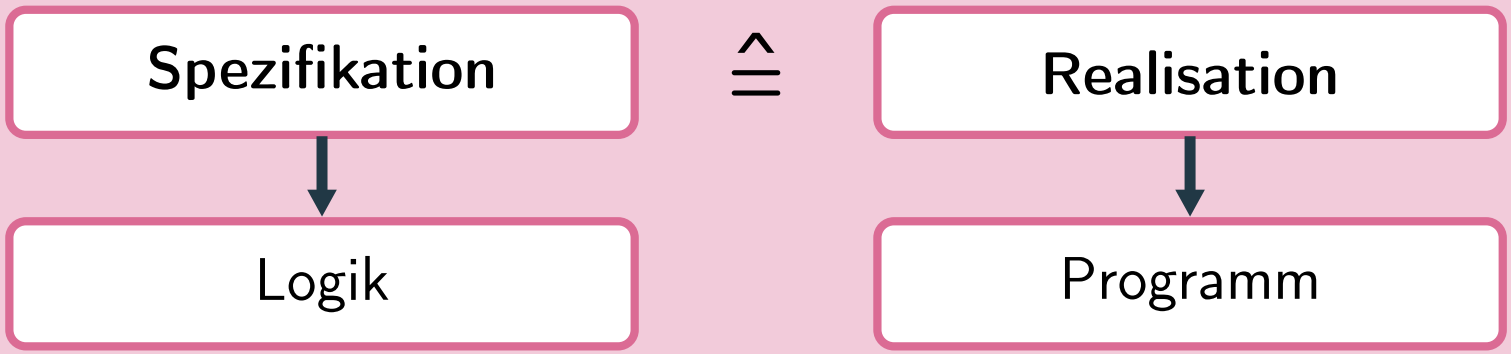

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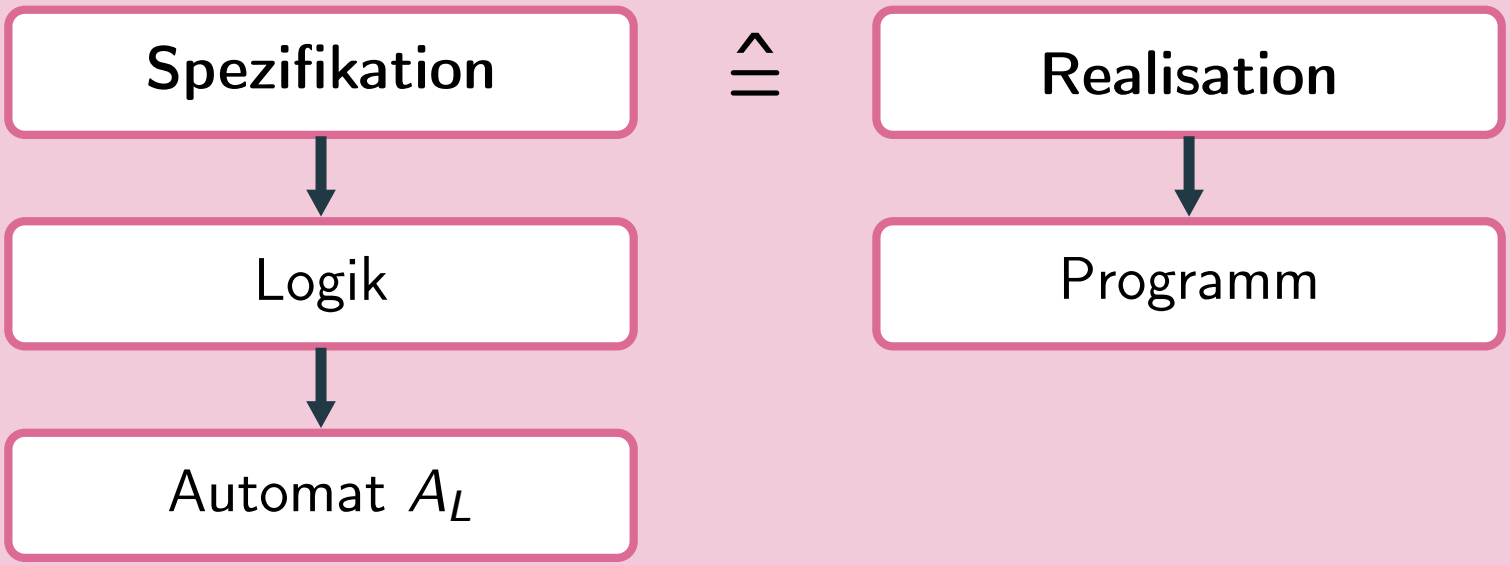

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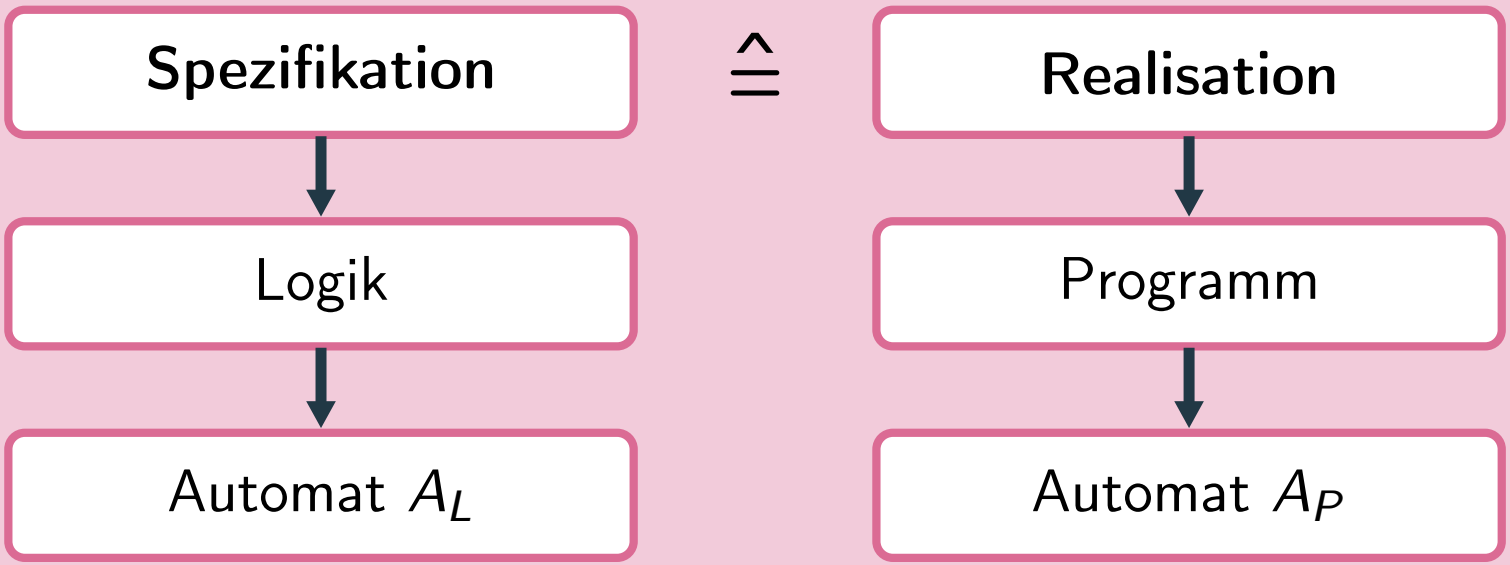

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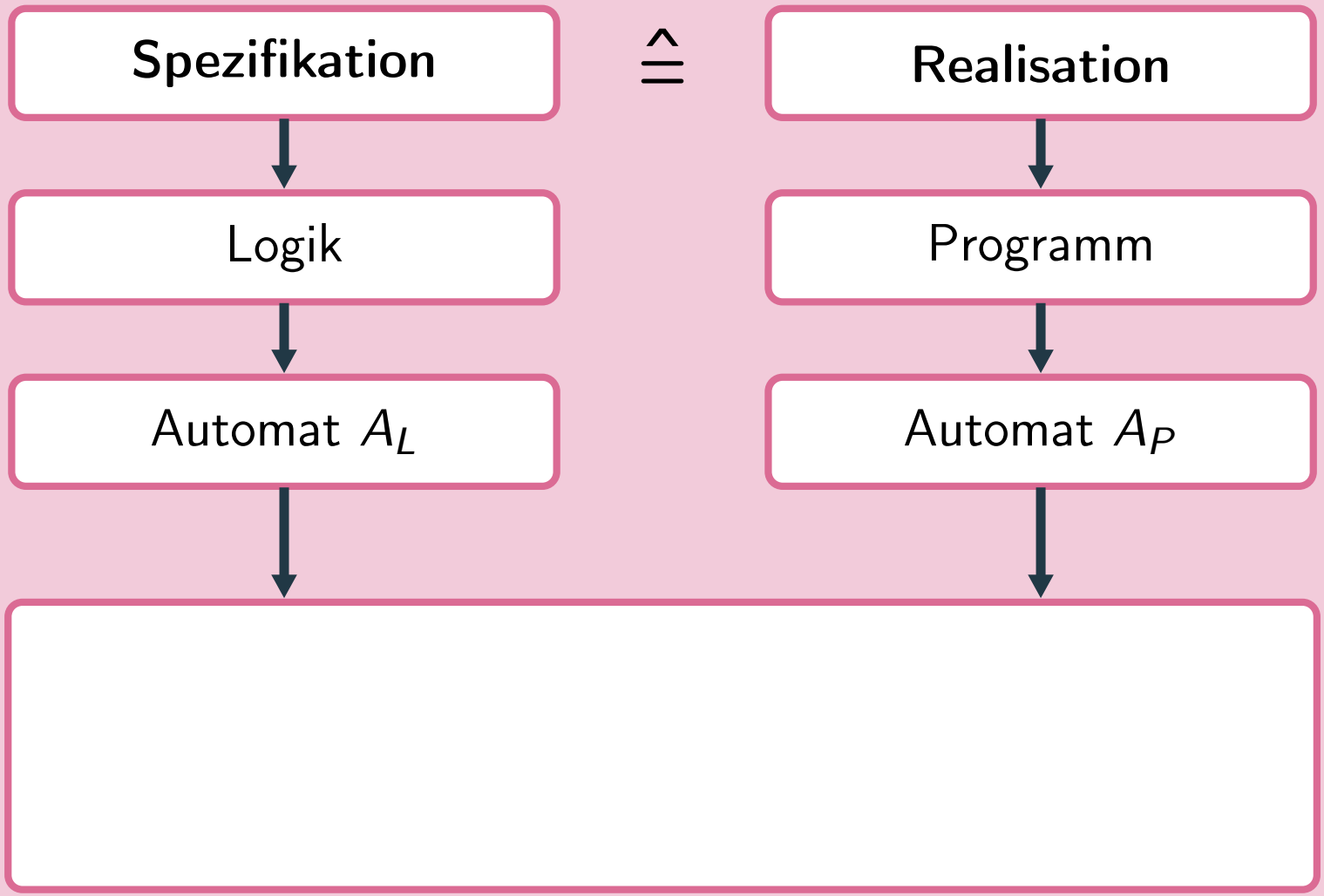

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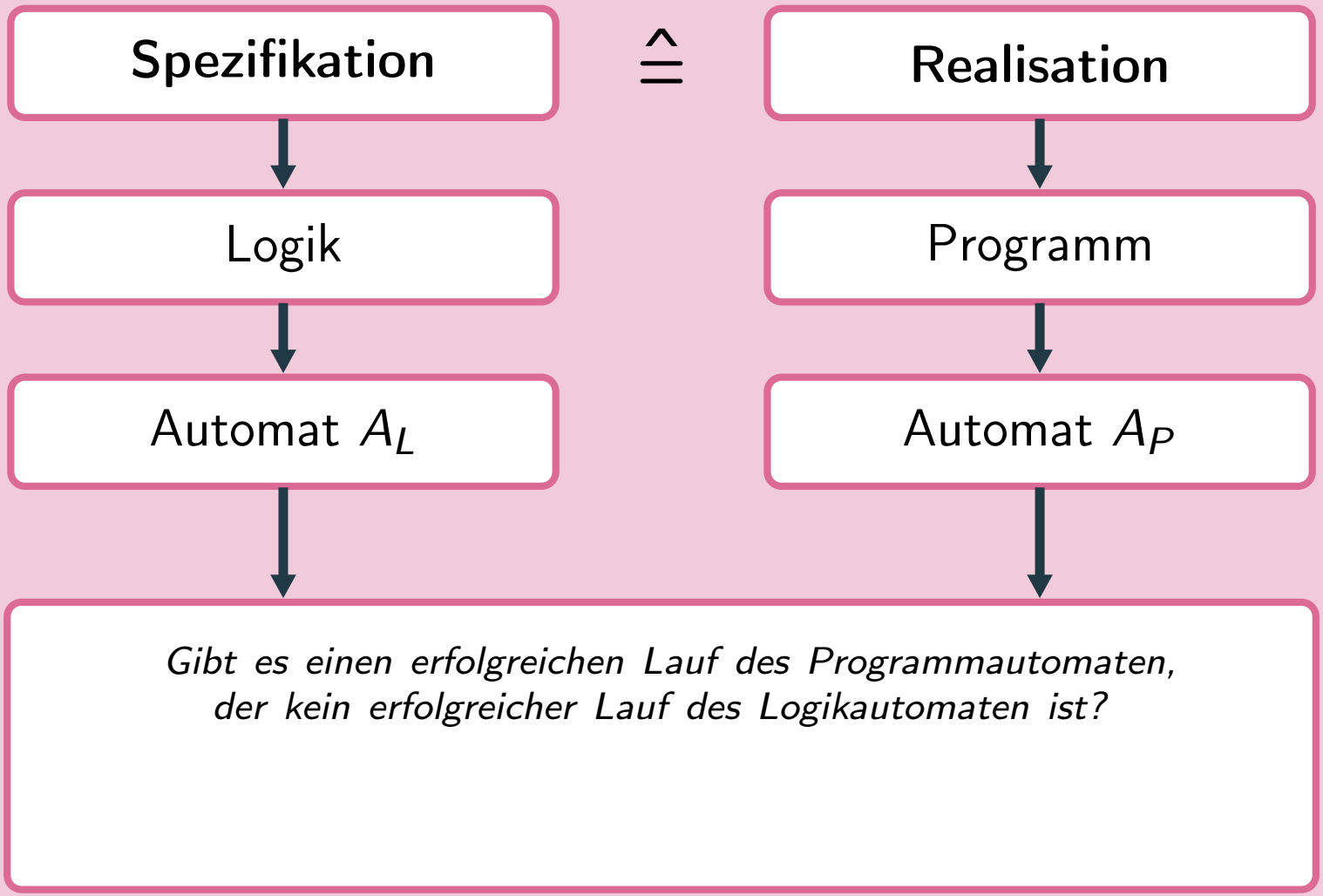

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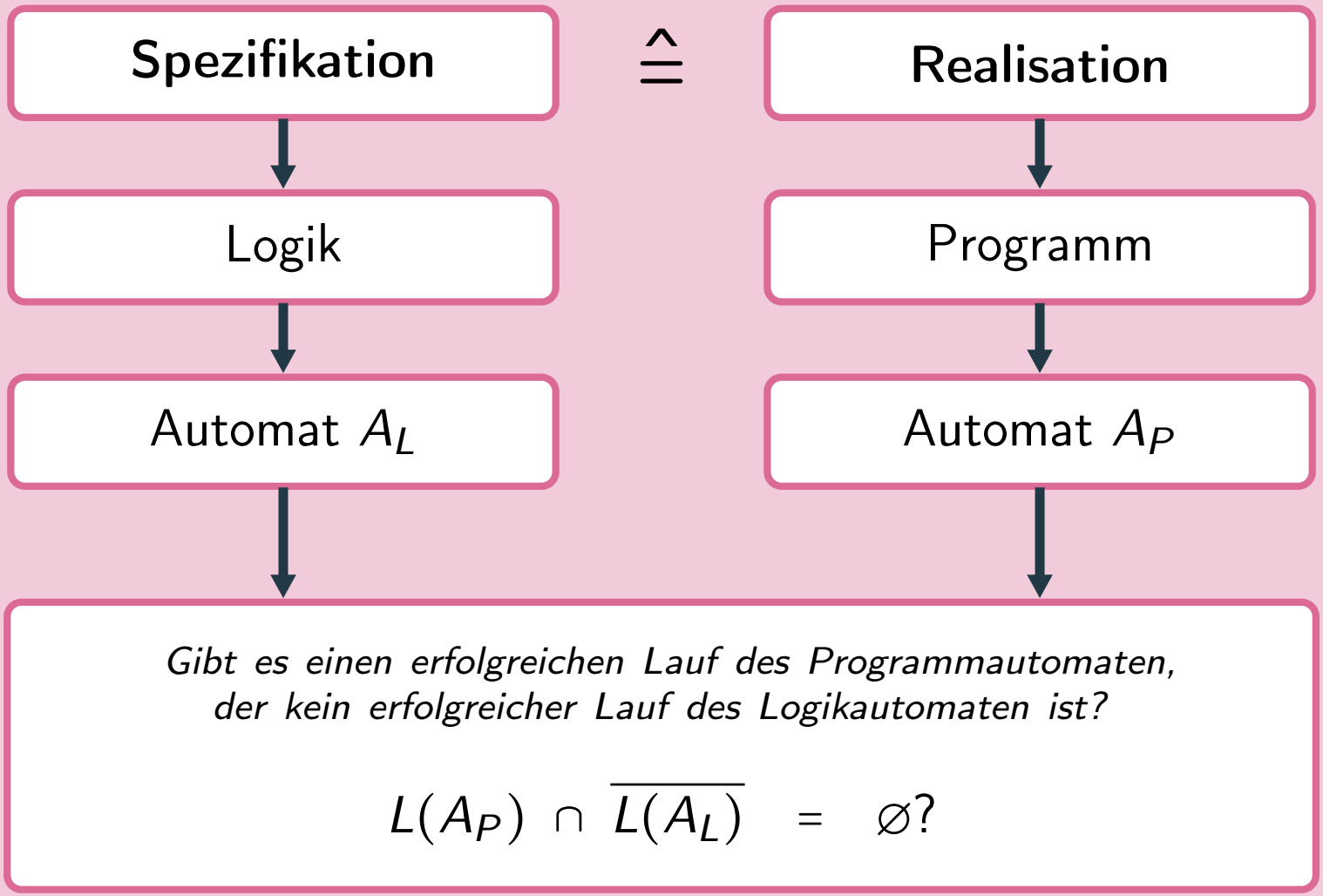

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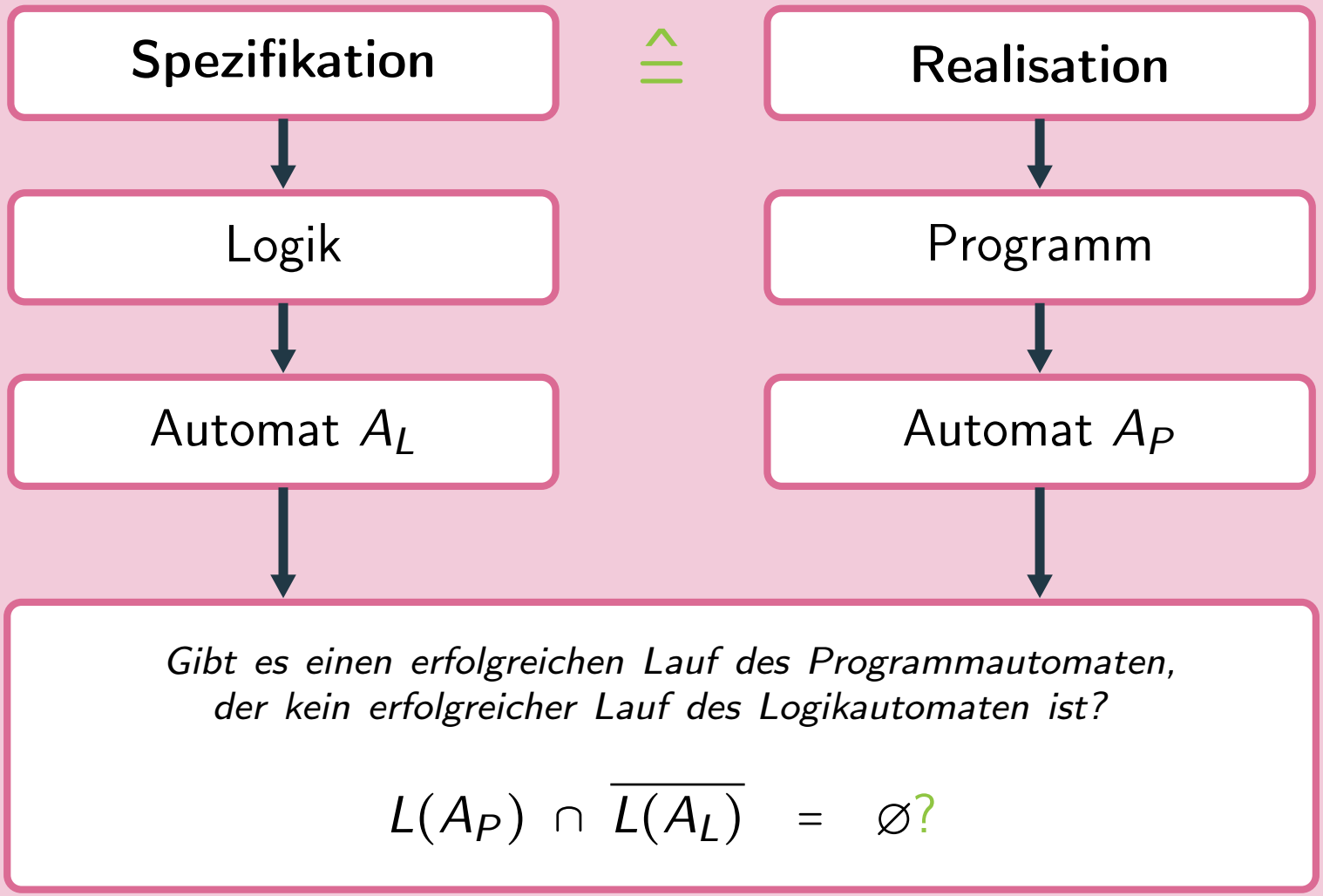

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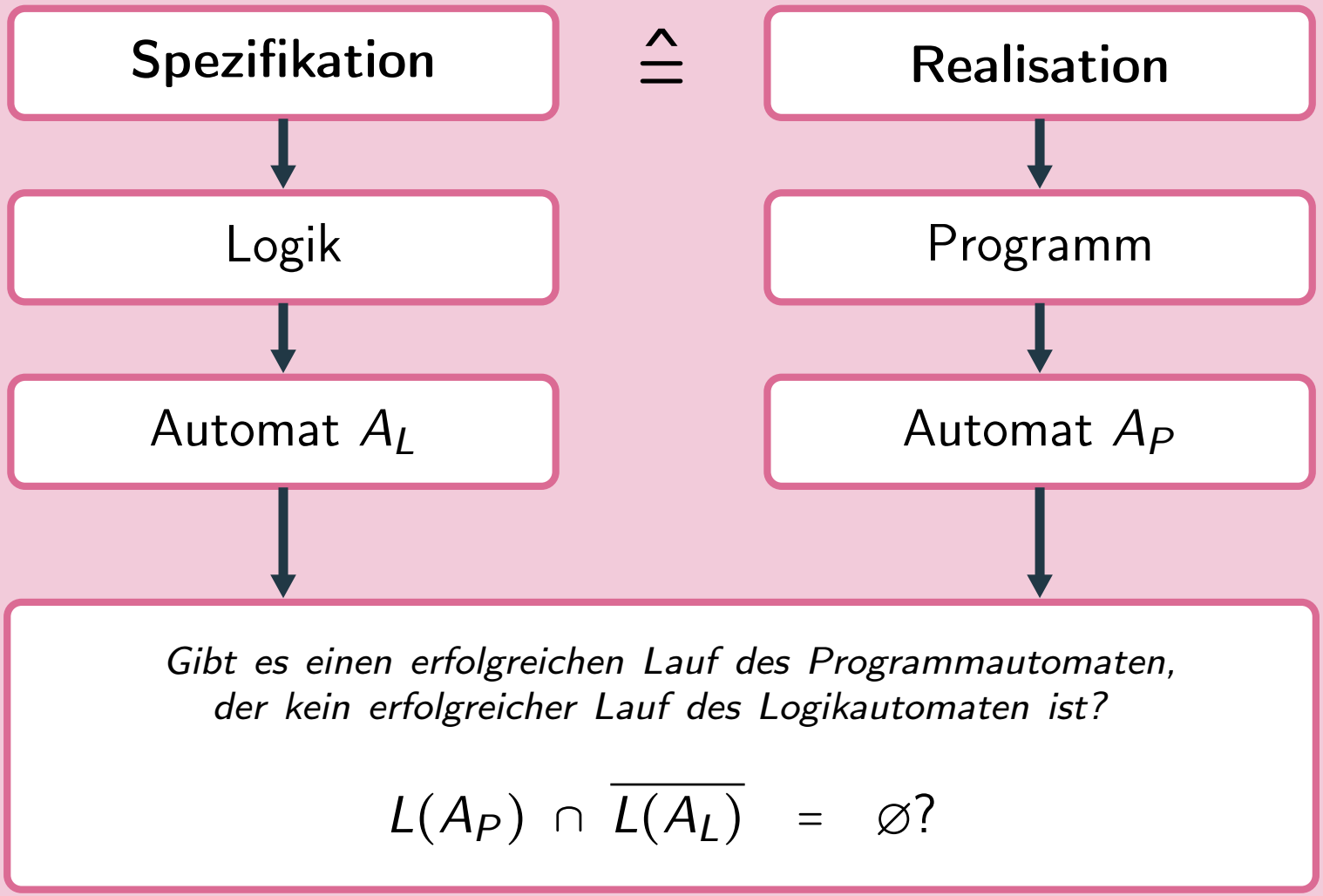

Modelchecking in Aktion: Promela+LTL+Spin

Modelchecking im Finanzwesen

Modelchecking im Finanzwesen

Model Checking and Verification of the Internet Payment System with SPIN

Wei Zhang et al., Journal of Software, Vol. 7, No. 9, September 2012.

Ergebnisse:

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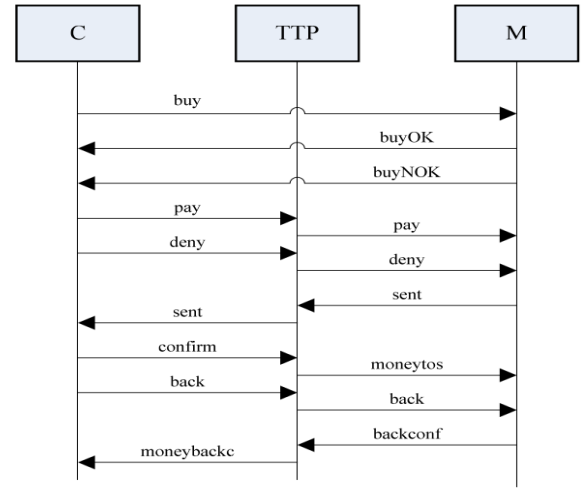

Figure 1. Massage flow in the Internet Payment Systems

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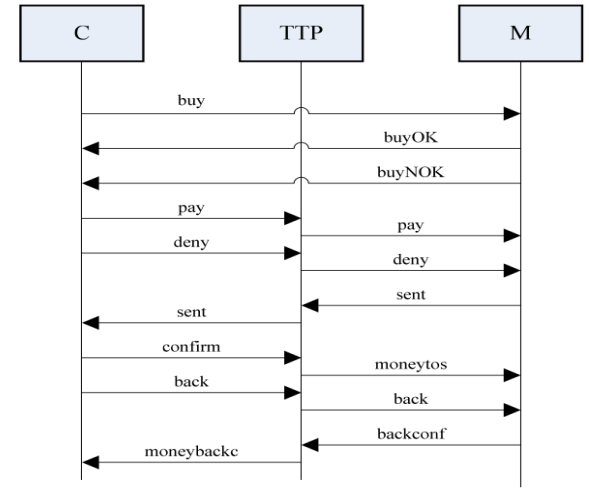

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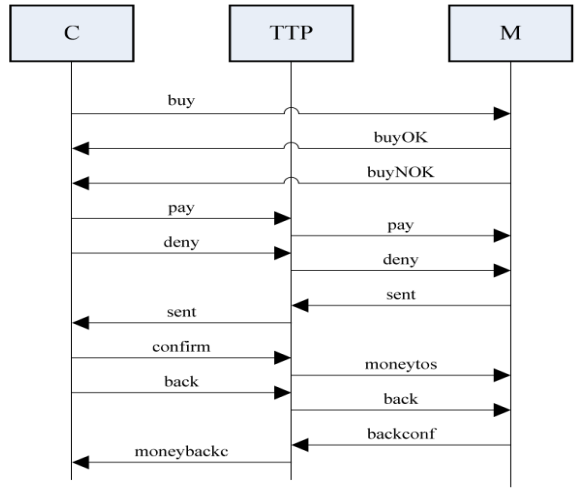

Figure 1. Massage flow in the Internet Payment Systems

Ergebnisse:

- Modell in Promela

```
.....
chan customer_netpay=[0] of {mtype};
chan customer_seller=[0] of {int};
chan seller_netpay=[0] of {mtype};
chan netpay_customer=[0] of {mtype};
chan seller_customer=[0] of {mtype};
chan netpay_seller=[0] of {mtype};
.....
```

Figure 5. Fragment of the channels' definition in PROMELA

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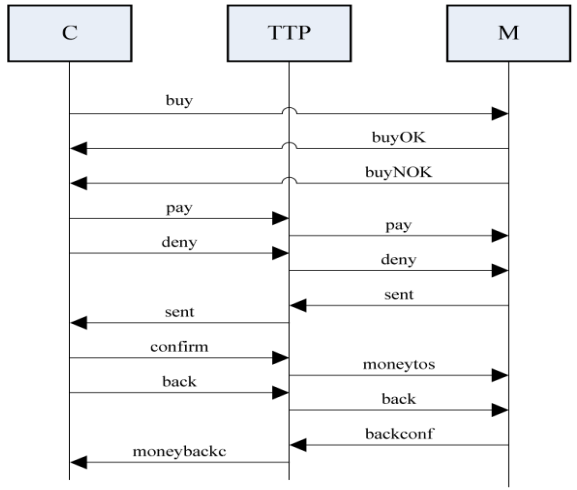

Figure 1. Massage flow in the Internet Payment Systems

Ergebnisse:

- Modell in Promela
- Spezifikation in LTL

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……
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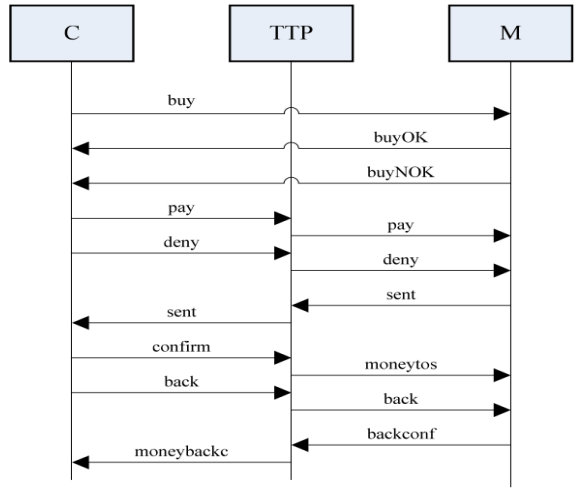

Figure 1. Massage flow in the Internet Payment Systems

Ergebnisse:

- Modell in Promela
- Spezifikation in LTL
- Erfolgreiche Verifikation des Modells

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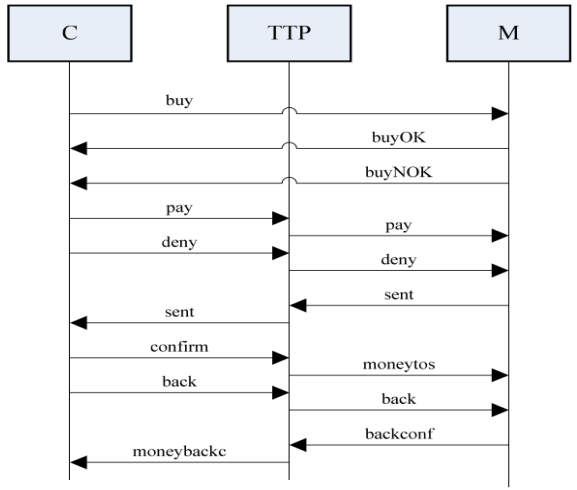

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- Modell in Promela
- Spezifikation in LTL
- Erfolgreiche Verifikation des Modells

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```

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Der Preis der Sicherheit

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Software

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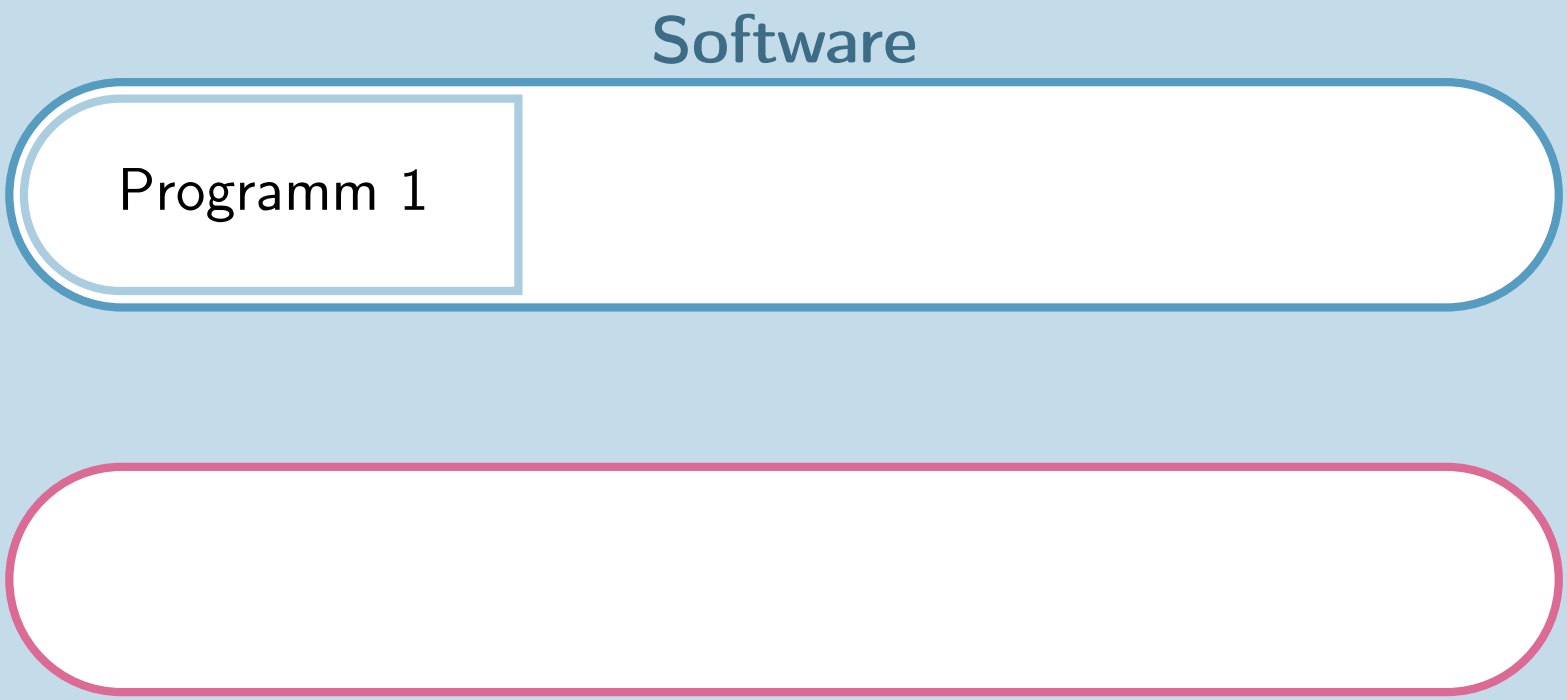
Software

Verifikation

Der Preis der Sicherheit



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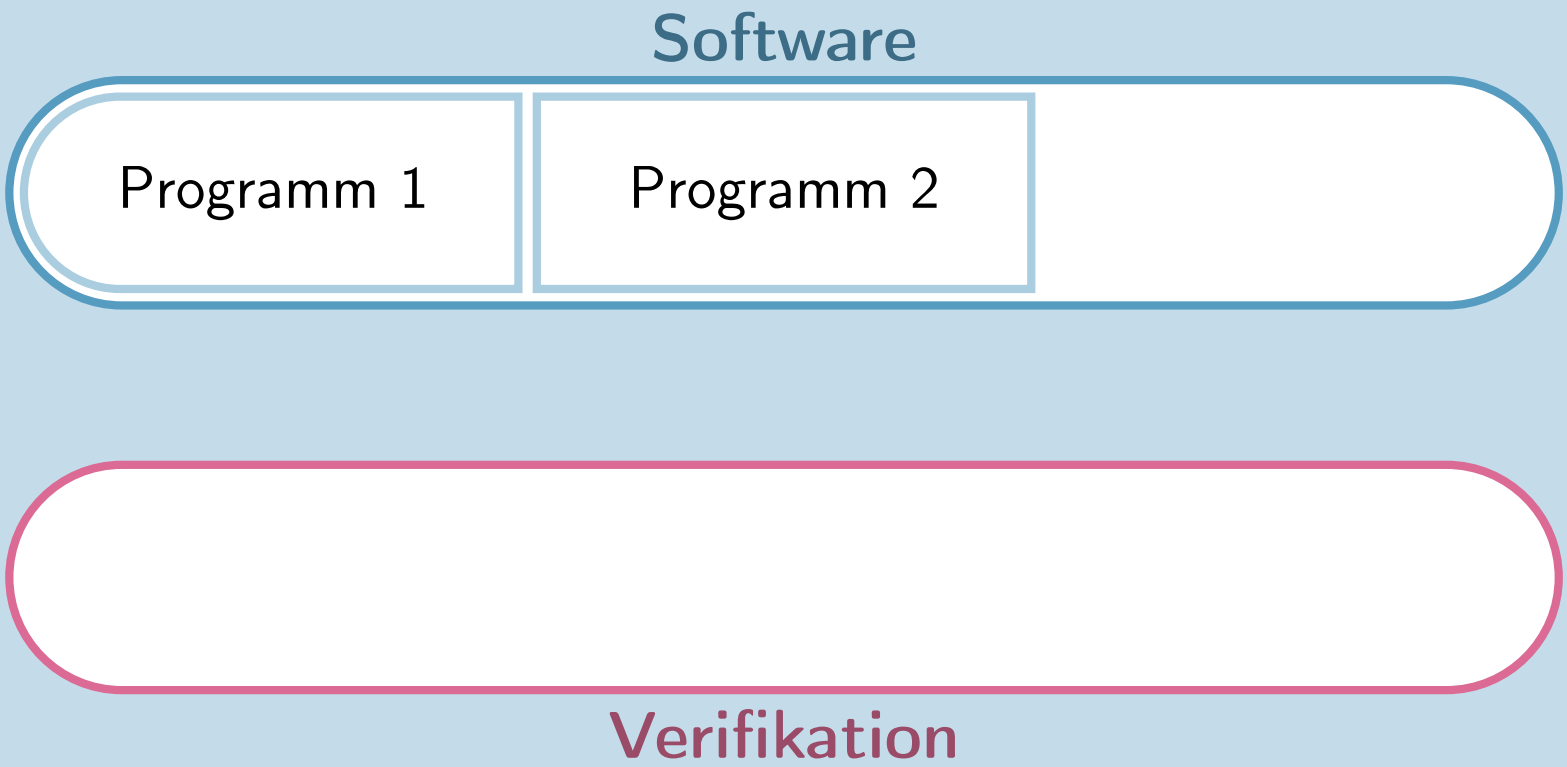

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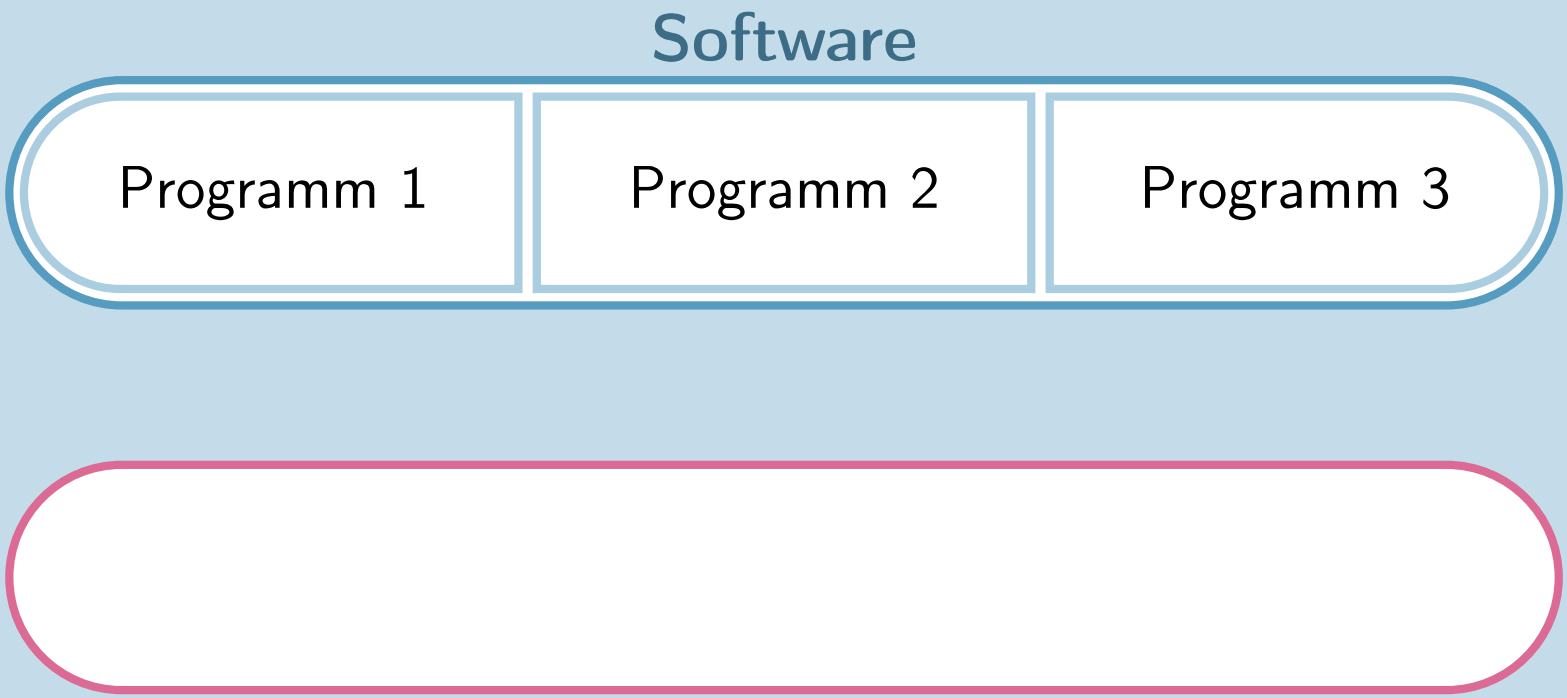

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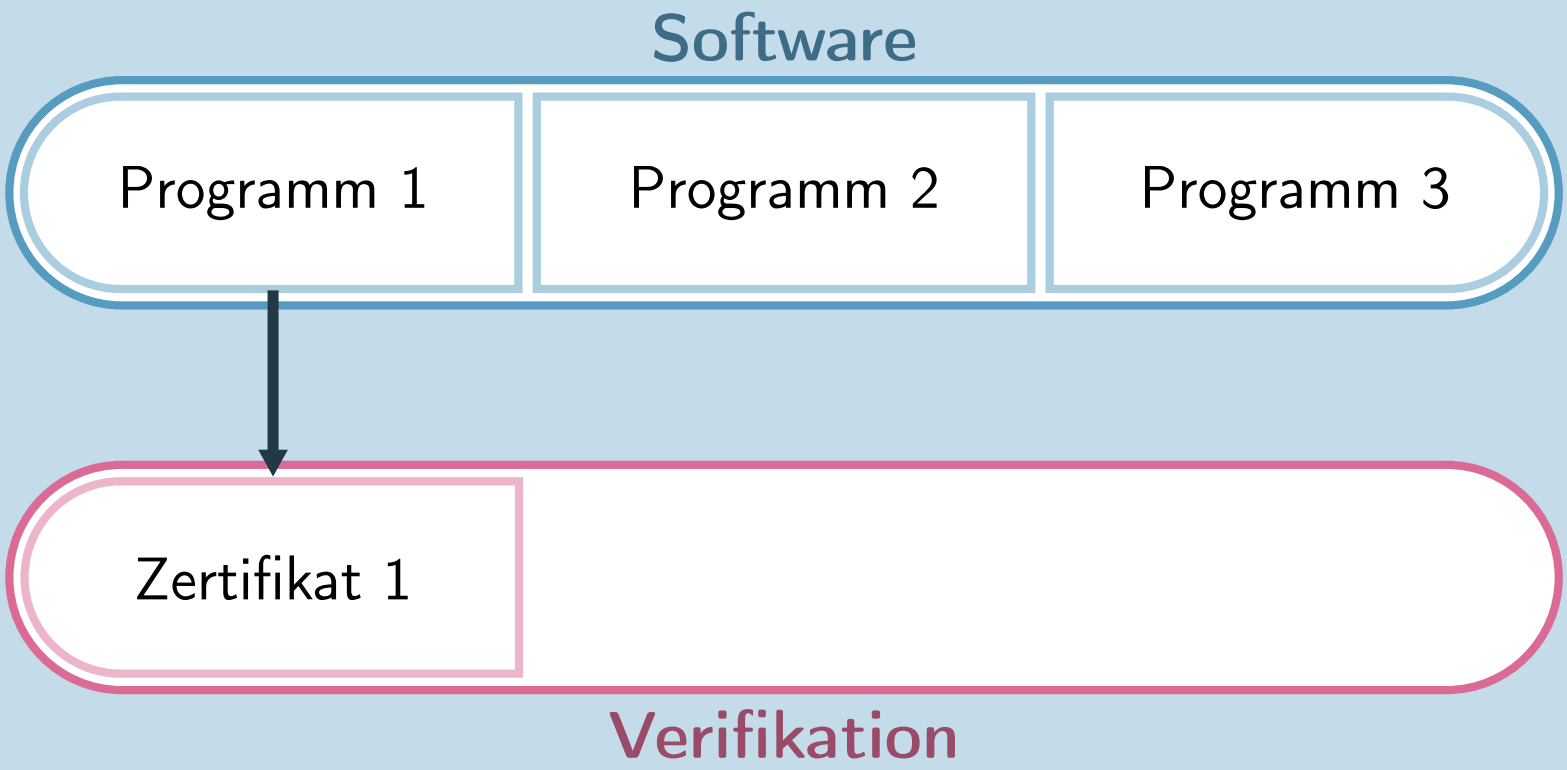

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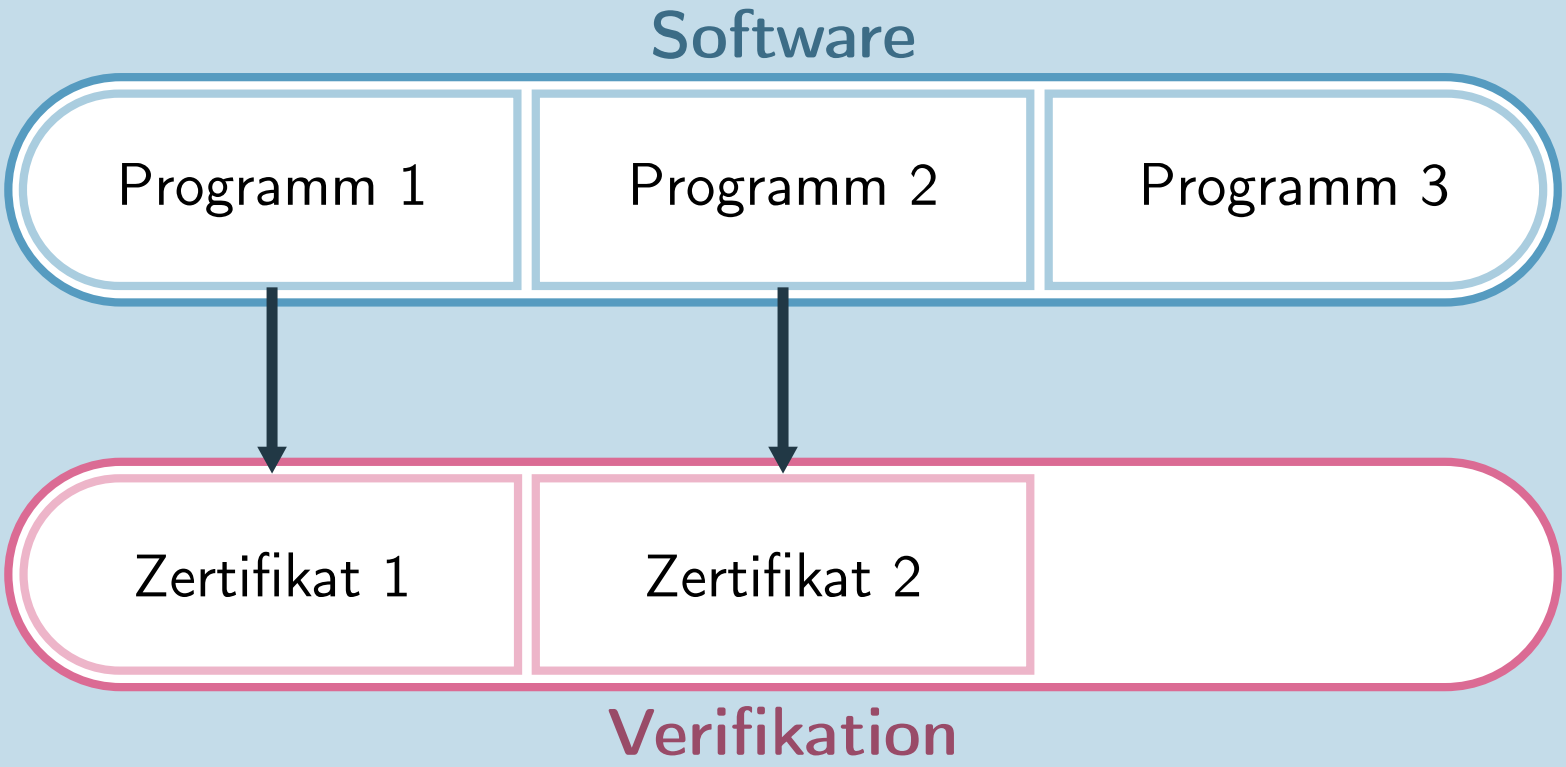

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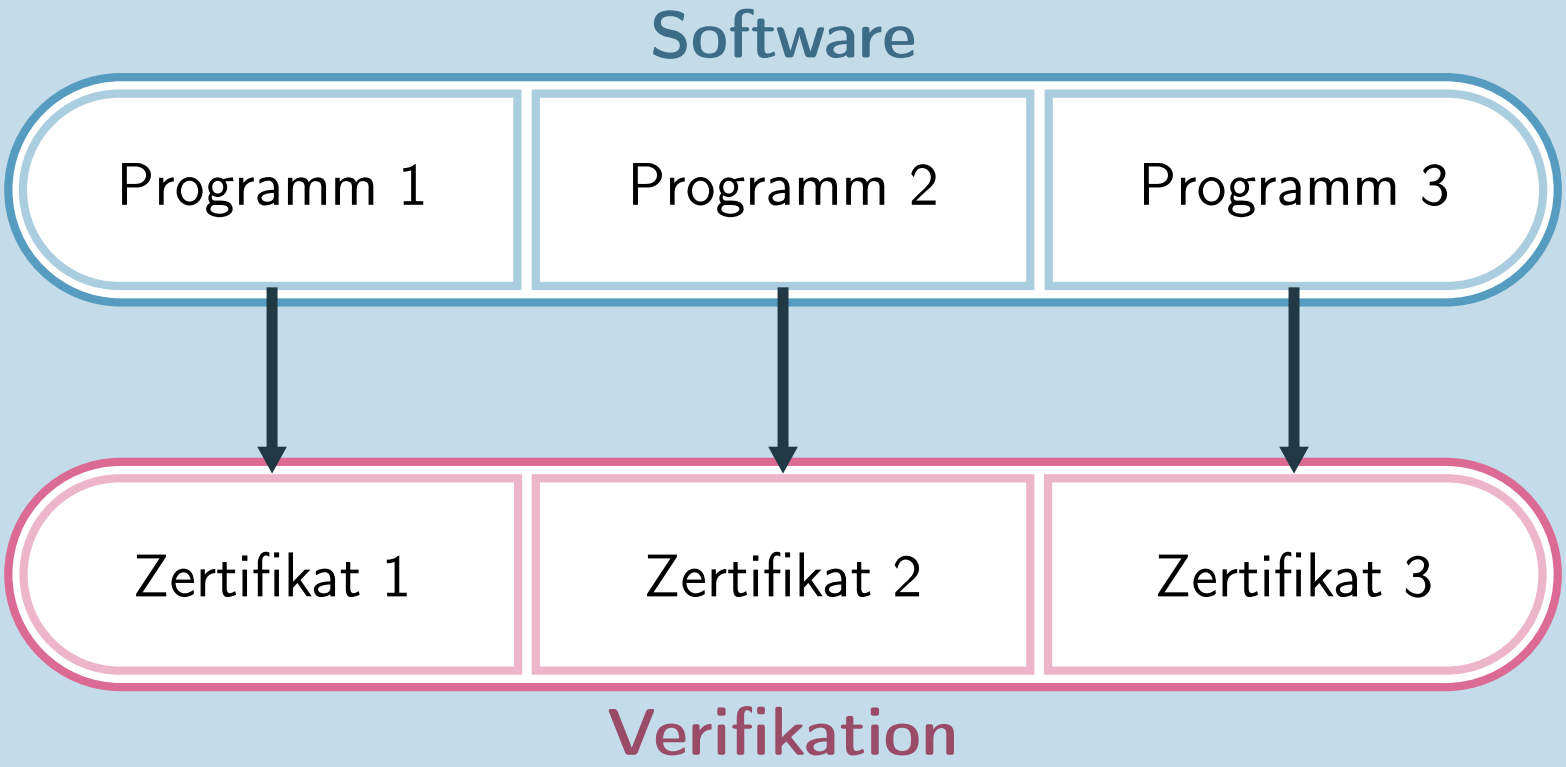

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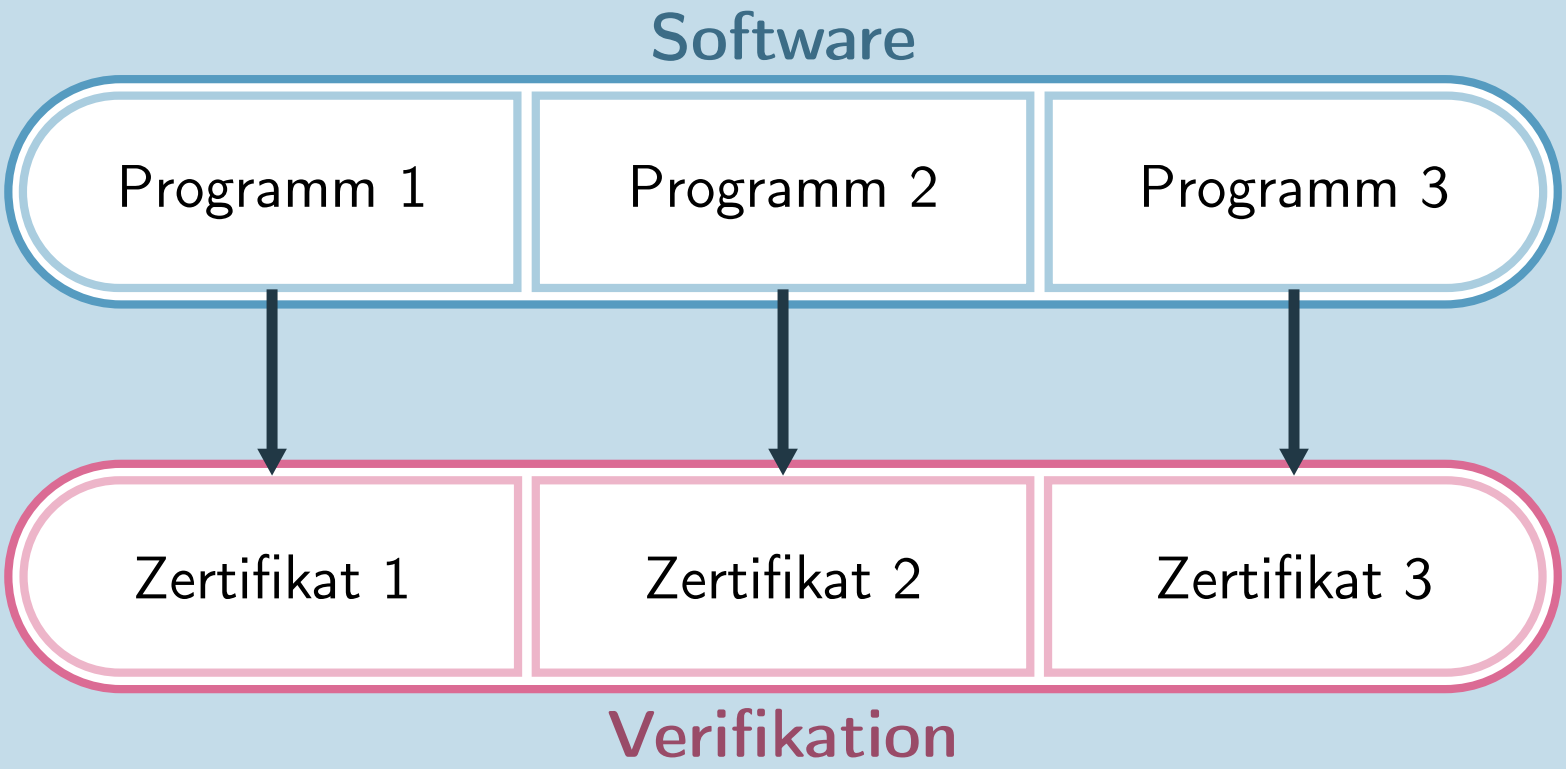
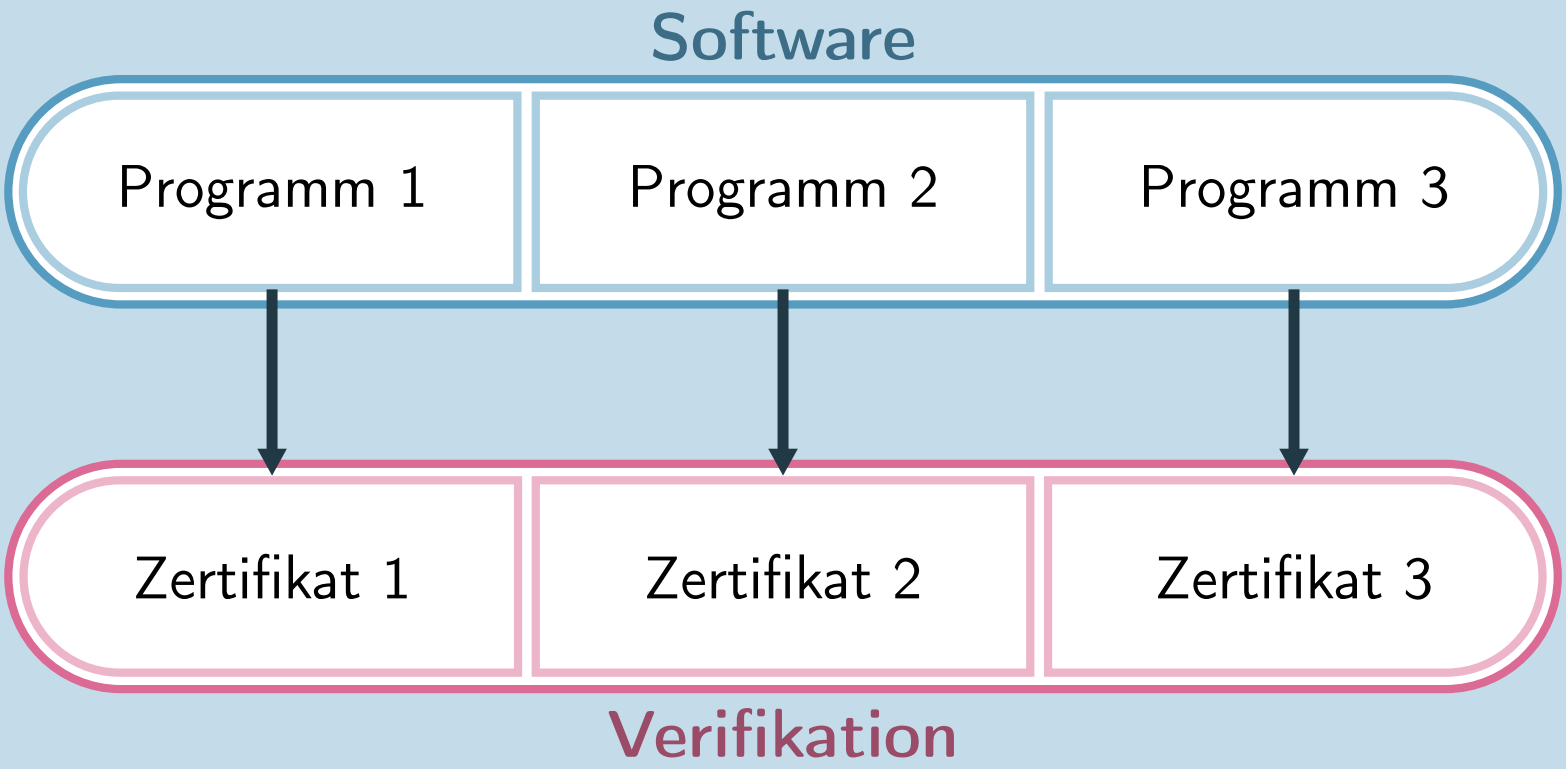


Kosten Verifikation

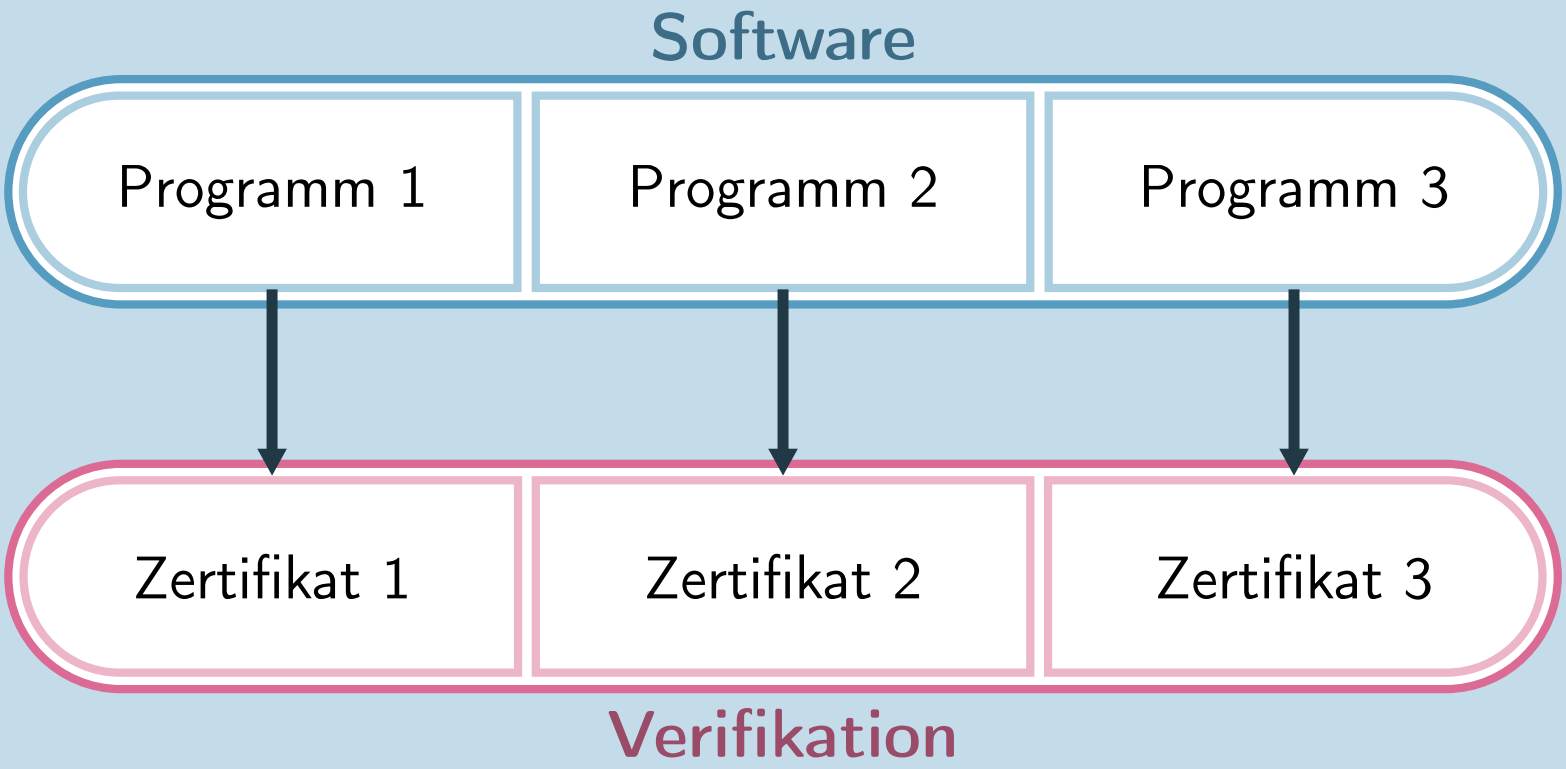
Kosten Systemausfall

Der Preis der Sicherheit



Kosten Verifikation $>$ Kosten Systemausfall

Der Preis der Sicherheit



Kosten Verifikation $<$ / $>$ Kosten Systemausfall

Modelchecking in Bahnsteuerungssystemen

Proving Completeness of Properties in Formal Verification of Counting Heads for Railways

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Kinder, Sebastian, and Rolf Drechsler, 10th Euromicro Conference on Digital System Design Architectures, Methods and Tools (DSD 2007). IEEE, 2007.

Modelchecking in Bahnsteuerungssystemen

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Kinder, Sebastian, and Rolf Drechsler, 10th Euromicro Conference on Digital System Design Architectures, Methods and Tools (DSD 2007). IEEE, 2007.

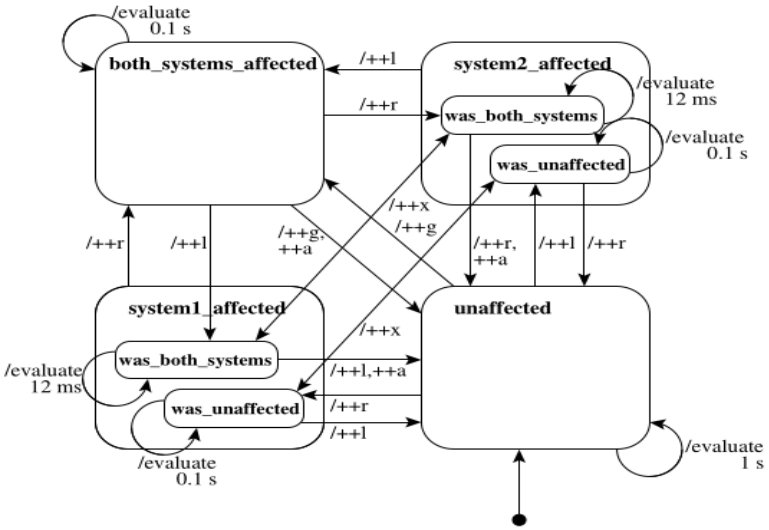

Figure 4. FSM of the Counting Head [8]

Modelchecking in Bahnsteuerungssystemen

Proving Completeness of Properties in Formal Verification of Counting Heads for Railways

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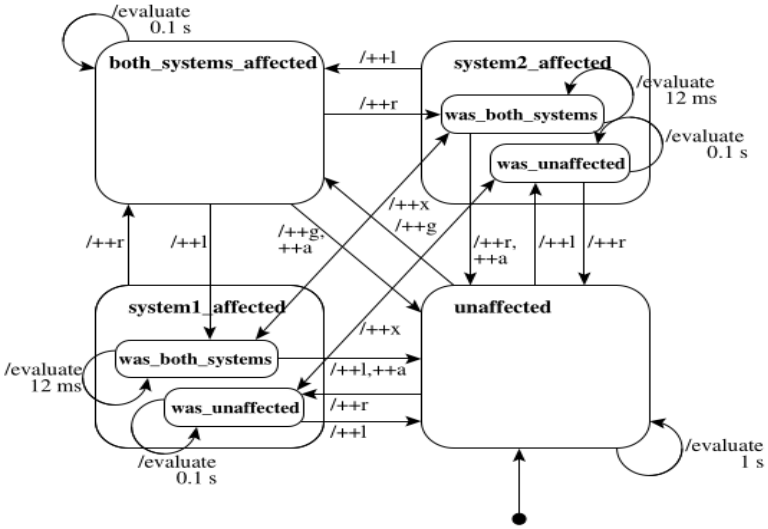
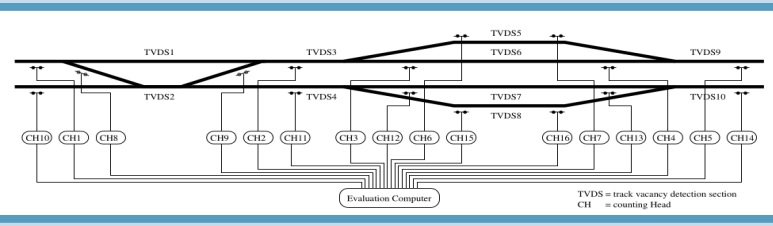


Figure 4. FSM of the Counting Head [8]



Modelchecking in Bahnsteuerungssystemen

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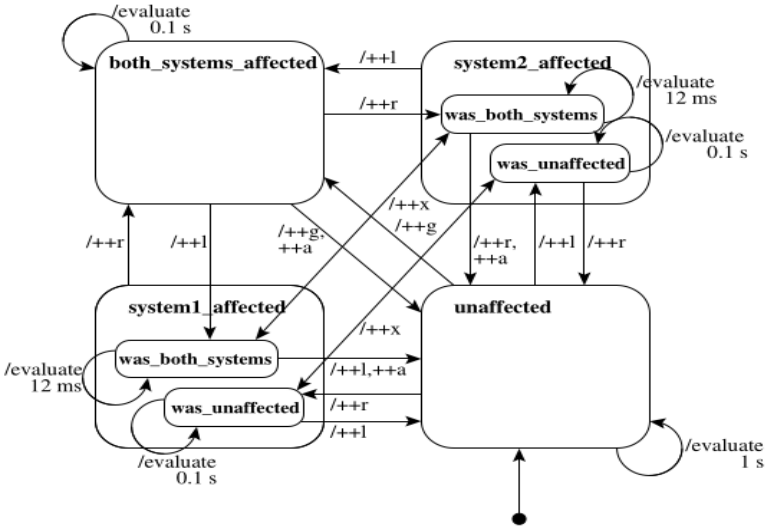
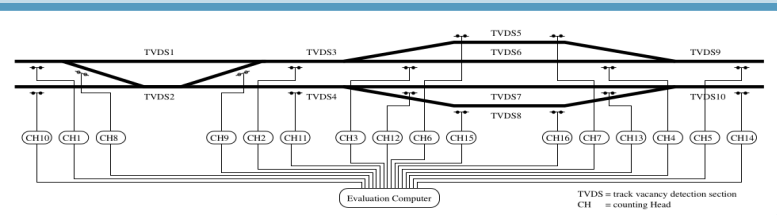


Figure 4. FSM of the Counting Head [8]

Verifikation in Minuten!



Who will check the checkmen?

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$$
\begin{aligned}
&\Box\,(\text{notfall} \rightarrow \Diamond\,(\text{alarm} \wedge \Box\,(\text{alarm} \rightarrow \bigcirc(\text{alarm}\ \mathcal{U}\ \text{quittierung}))) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \mathcal{P}(\text{alarm})) \\
&\wedge\ \Box\,(\text{alarm} \rightarrow \bigcirc(\neg\text{alarm}\ \mathcal{U}\ \text{quittierung})) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \bigcirc(\neg\text{alarm}\ \mathcal{U}\ \text{notfall})) \\
&\wedge\ \Diamond_{\leq 5}\,(\text{teamgerufen}) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \Diamond\,(\text{behebung} \wedge \text{grundzustand})))
\end{aligned}
$$

Who will check the checkmen?

$$
\begin{aligned}
&\Box\,(\text{notfall} \rightarrow \Diamond\,(\text{alarm} \wedge \Box\,(\text{alarm} \rightarrow \bigcirc(\text{alarm}\ \mathcal{U}\ \text{quittierung}))) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \mathcal{P}(\text{alarm})) \\
&\wedge\ \Box\,(\text{alarm} \rightarrow \bigcirc(\neg\text{alarm}\ \mathcal{U}\ \text{quittierung})) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \bigcirc(\neg\text{alarm}\ \mathcal{U}\ \text{notfall})) \\
&\wedge\ \Diamond_{\leq 5}\,(\text{teamgerufen}) \\
&\wedge\ \Box\,(\text{quittierung} \rightarrow \Diamond\,(\text{behebung} \wedge \text{grundzustand})))
\end{aligned}
$$

Wo ist der Fehler?