CTL May Be Ambiguous when Model Checking Moore Machines

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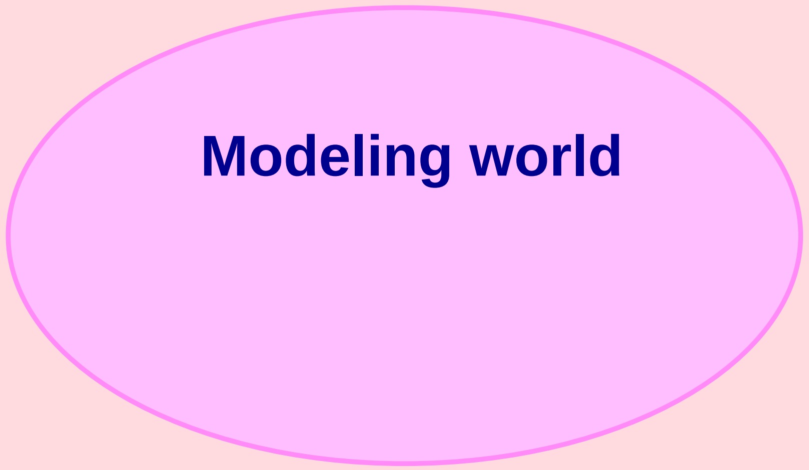
Modeling versus Verification

Modeling versus Verification



Modeling versus Verification

Modeling world

Moore or Mealy machines

Modeling versus Verification

Verification world

Modeling world

Moore or Mealy machines

Modeling versus Verification

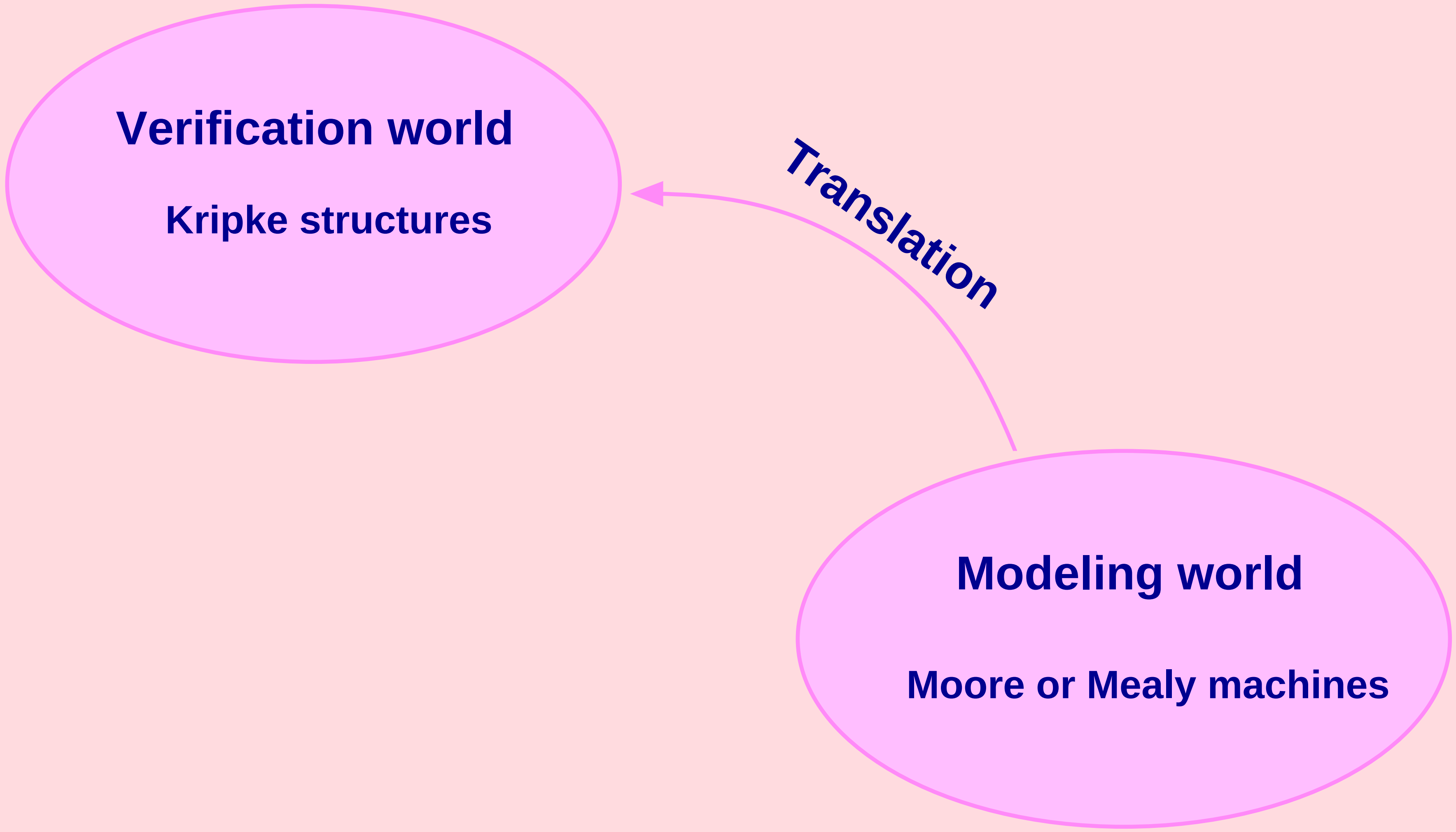
Verification world

Kripke structures

Modeling world

Moore or Mealy machines

Modeling versus Verification



From Moore to Kripke

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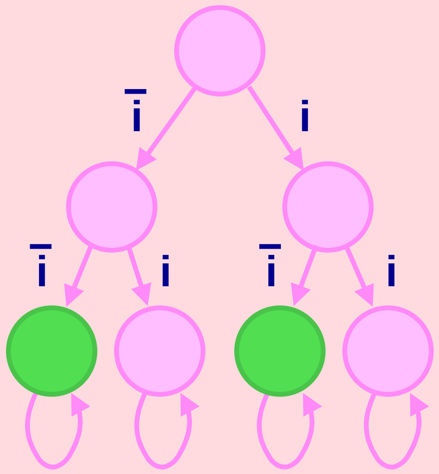
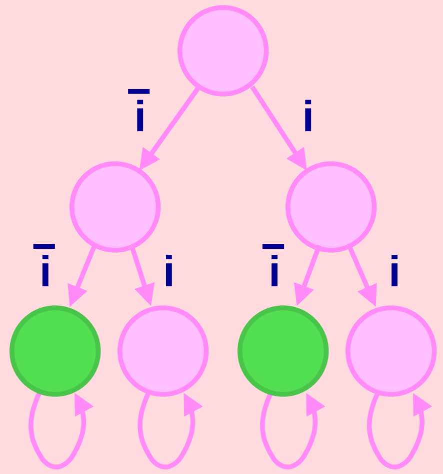


From Moore to Kripke

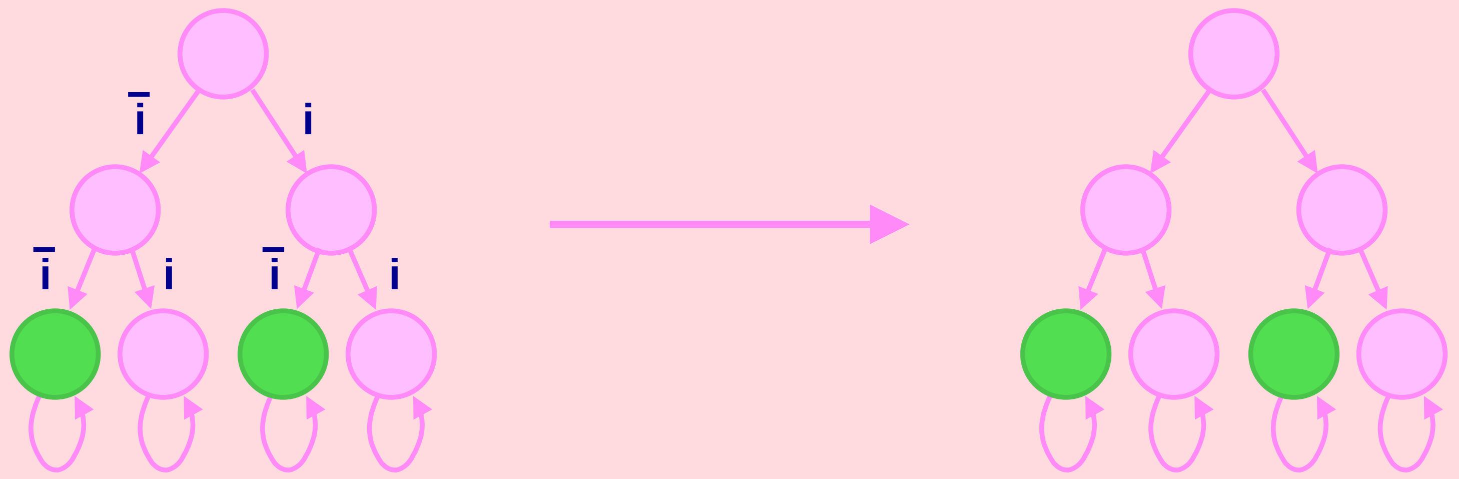
First translation scheme



From Moore to Kripke

First translation scheme

Remove the input signals



From Moore to Kripke

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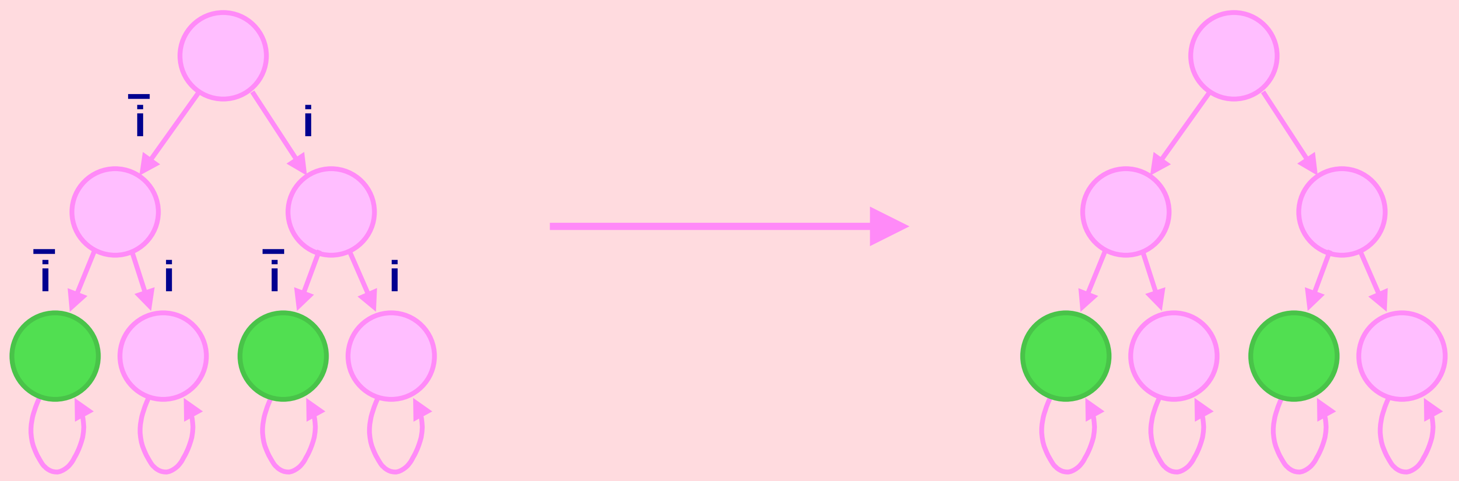

Simple

From Moore to Kripke

First translation scheme

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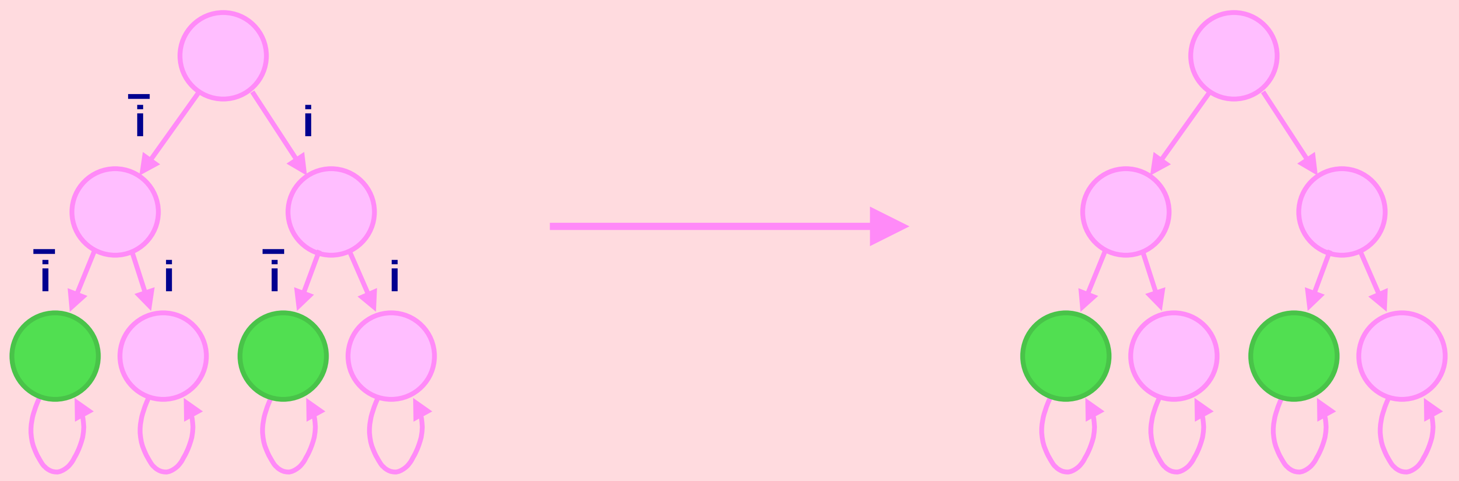
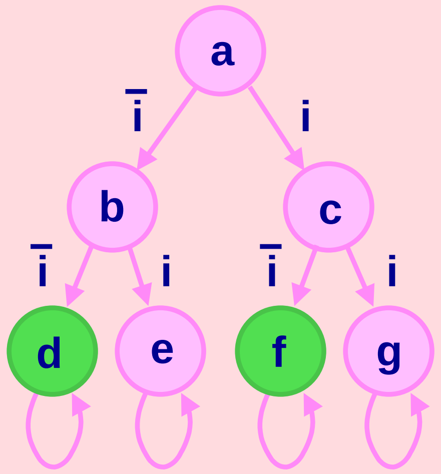


Simple

Impossible to express properties including input signals

From Moore to Kripke

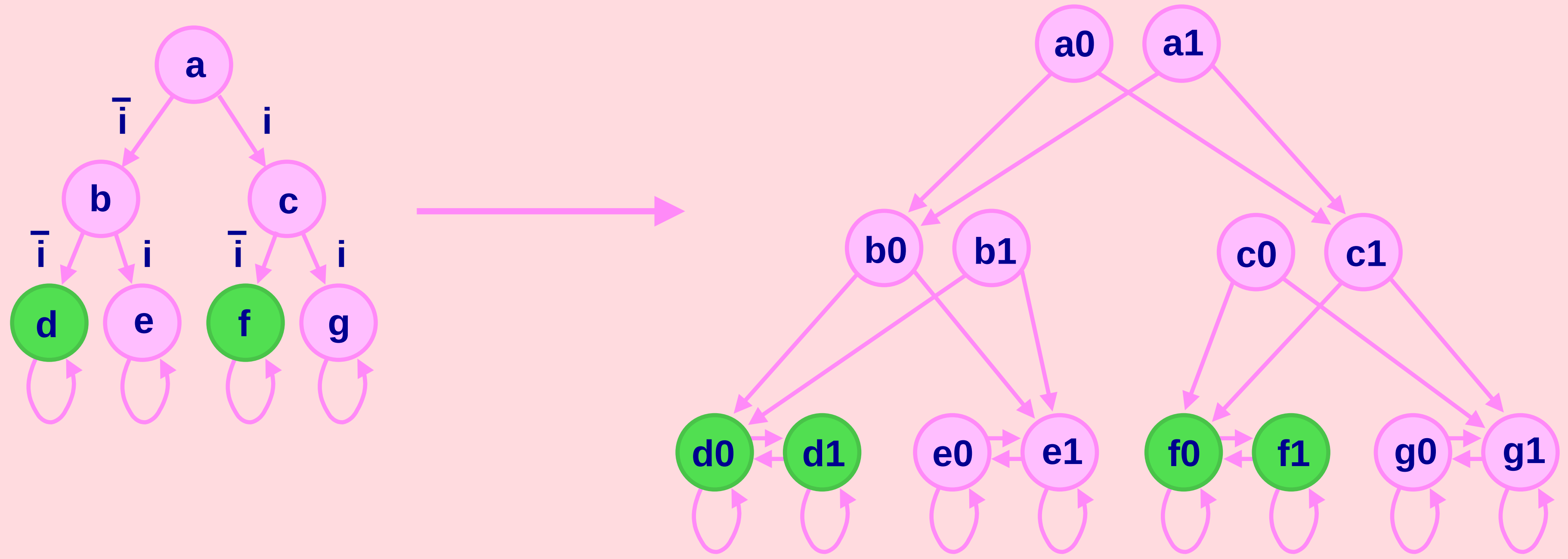
Second translation scheme



From Moore to Kripke

Second translation scheme

Input signals into target state of transitions



From Moore to Kripke

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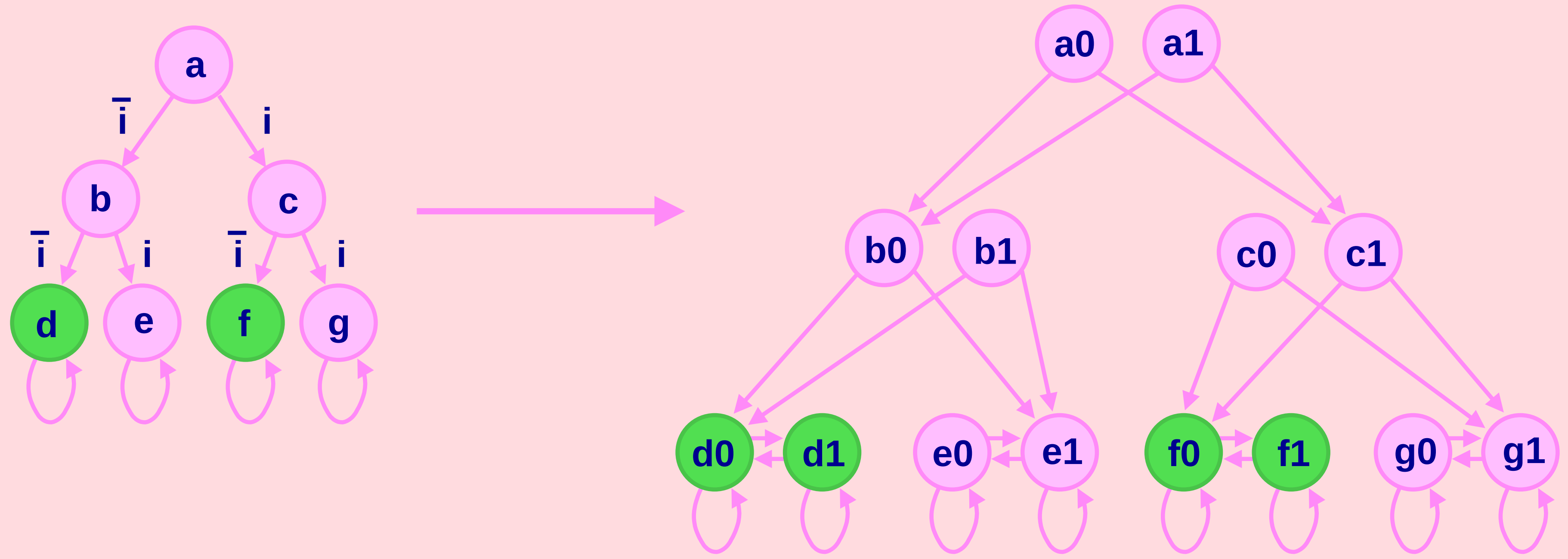
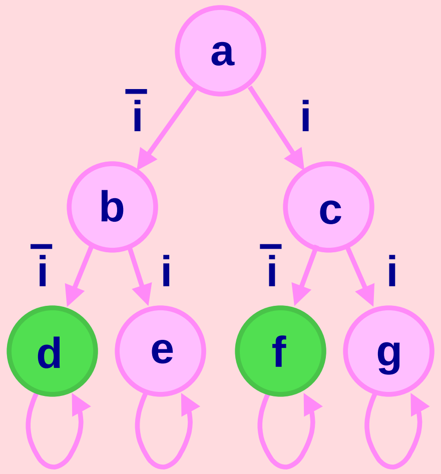


Composition of Moore machines lost

From Moore to Kripke

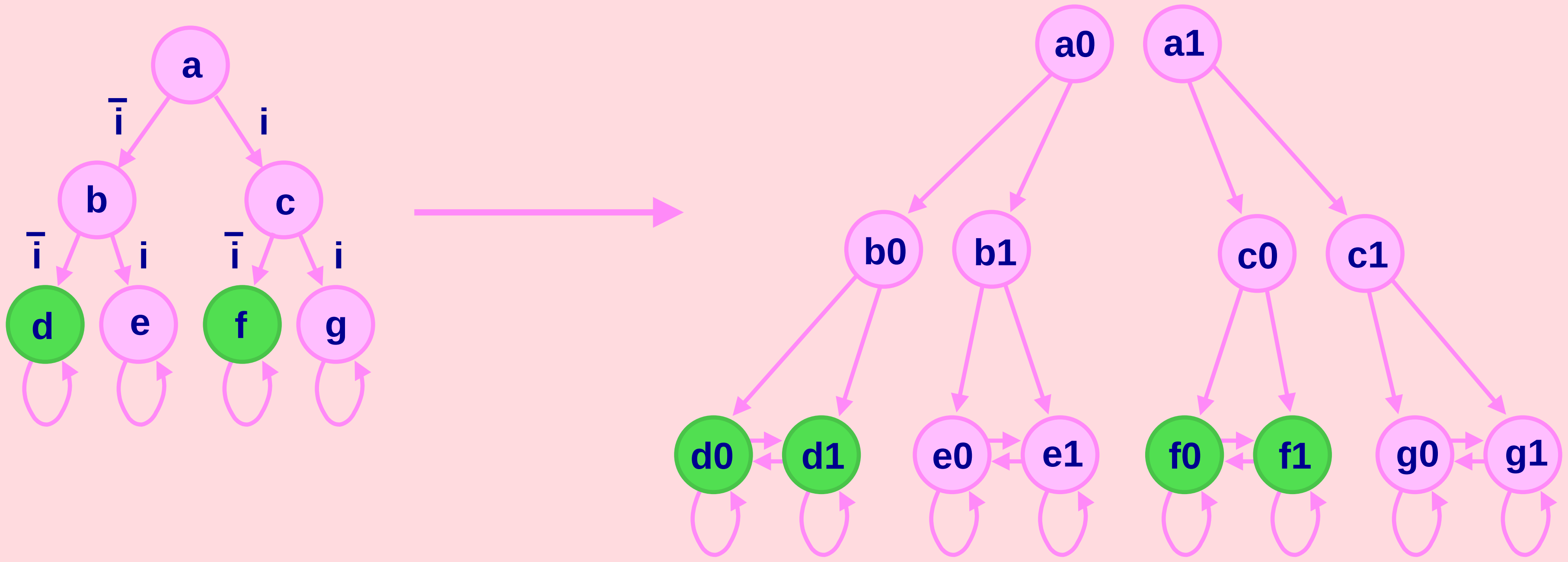
Third translation scheme



From Moore to Kripke

Third translation scheme

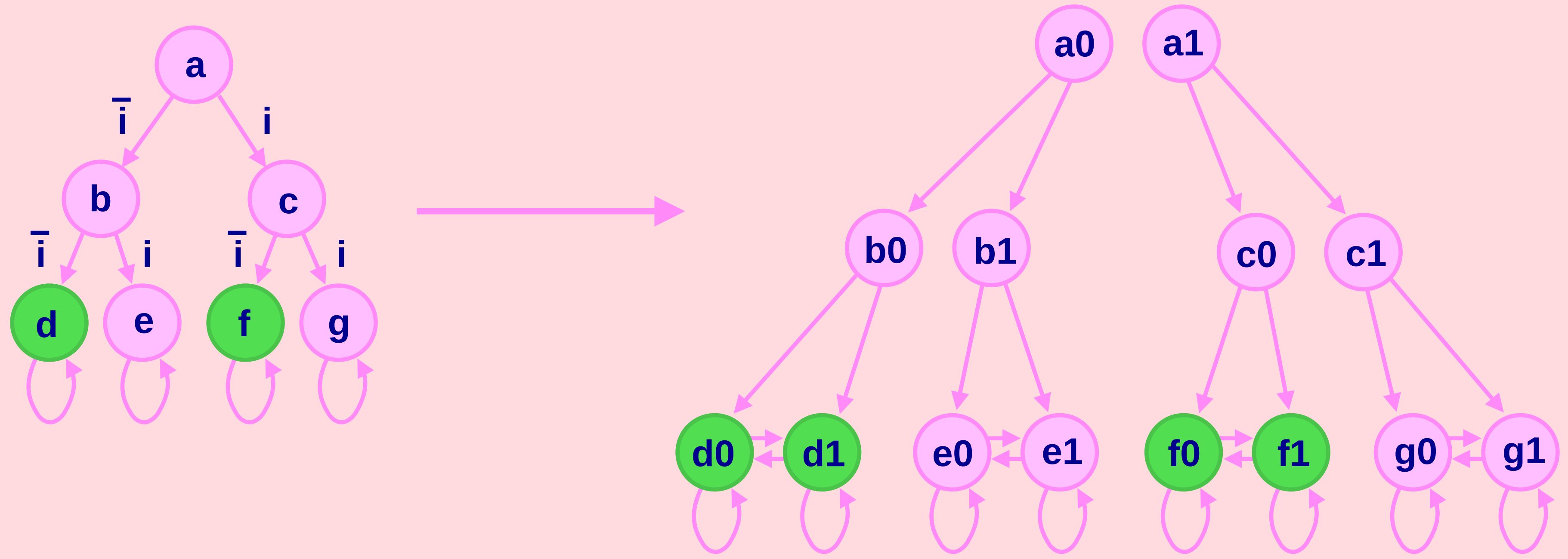
Input signals into source state of transitions



From Moore to Kripke

Third translation scheme

Input signals into source state of transitions

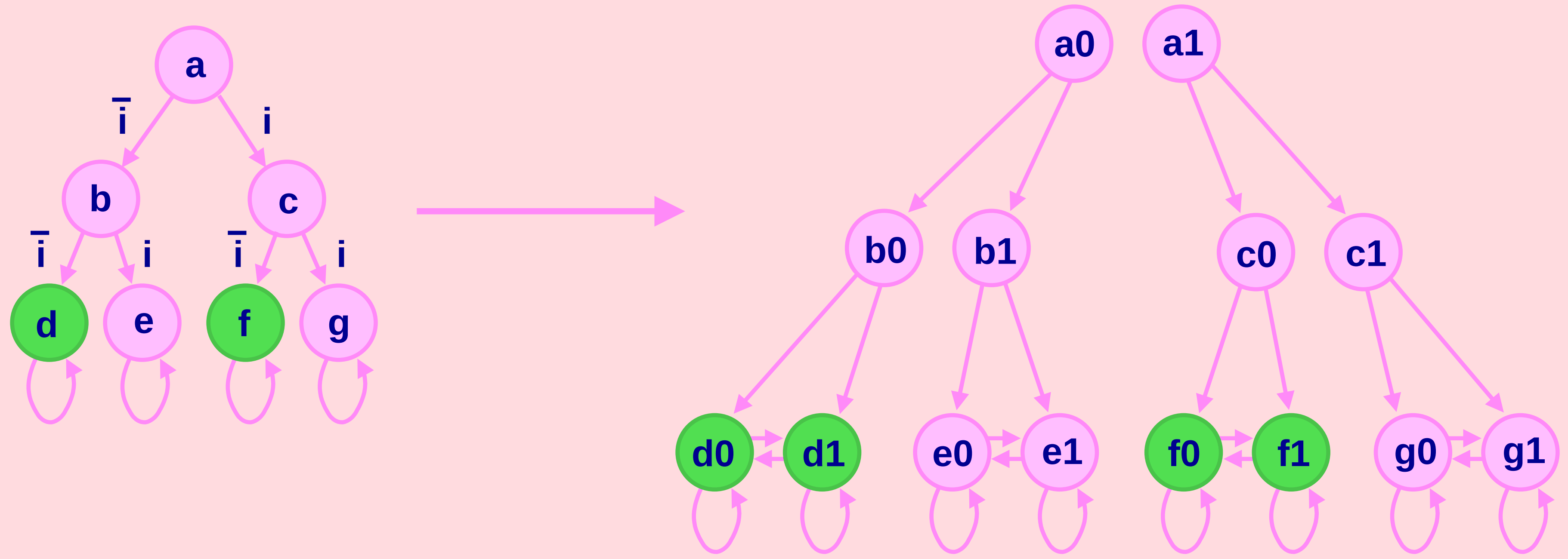


We can compose Moore machines

From Moore to Kripke

Third translation scheme

Input signals into source state of transitions



We can compose Moore machines

This may introduce ambiguities when using CTL

Possible CTL ambiguities

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Checking the property AX EX p

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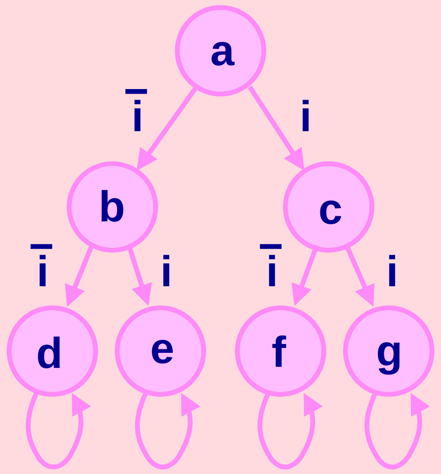
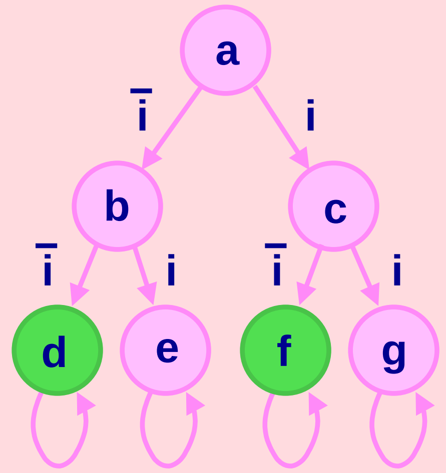


Possible CTL ambiguities

Checking the property AX EX p

🟢 states verifying p



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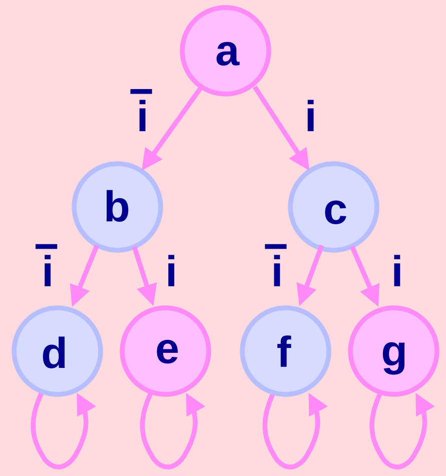

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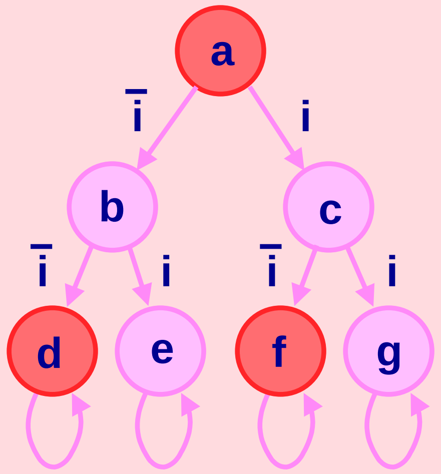

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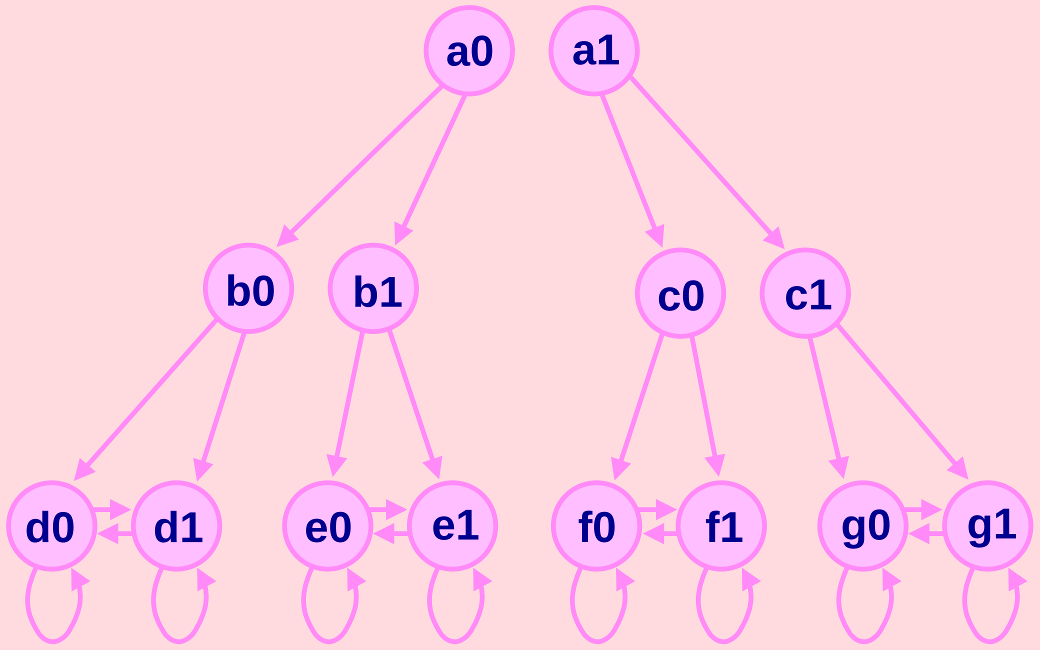

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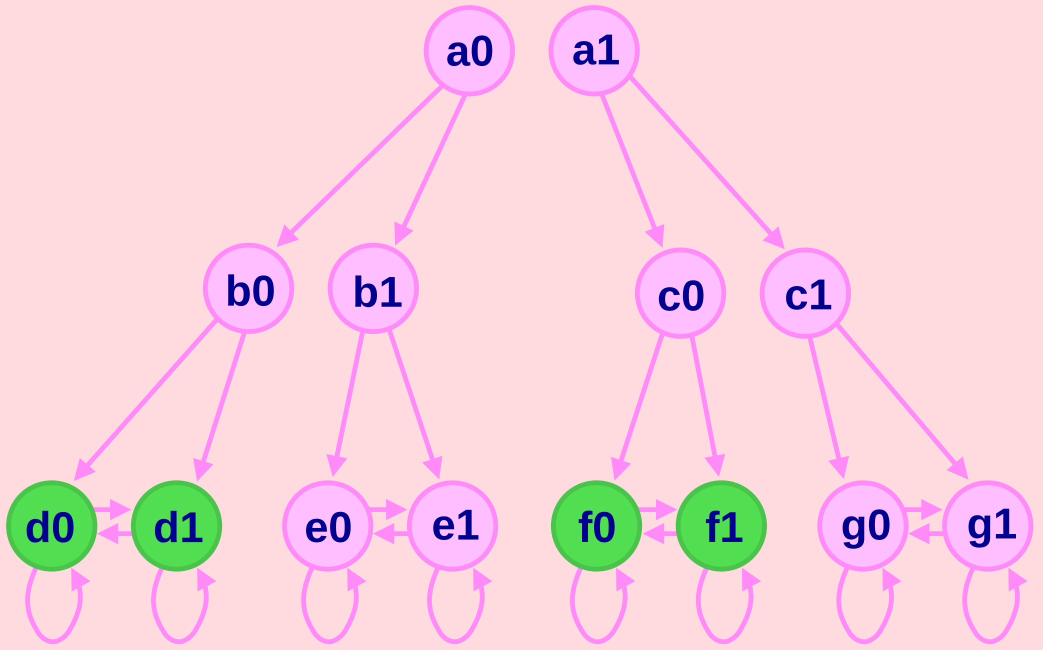

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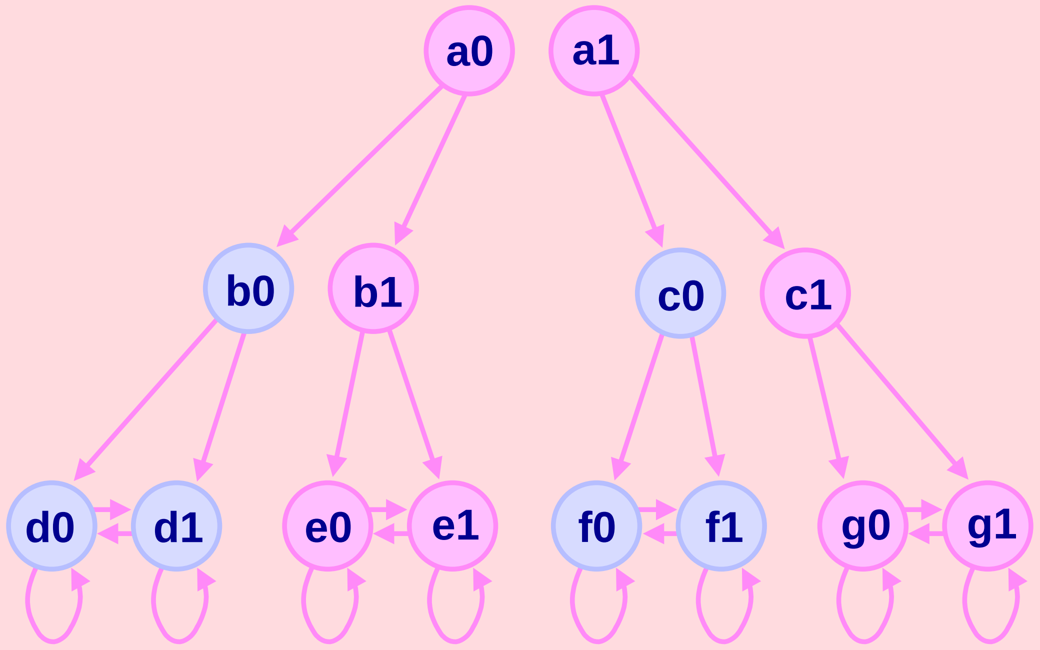

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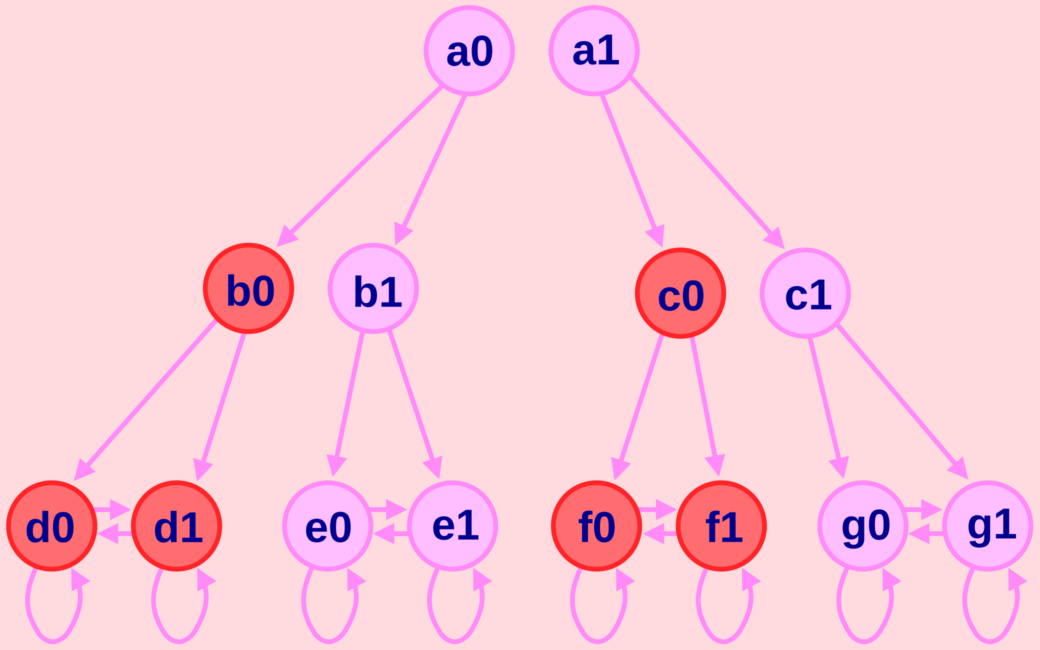

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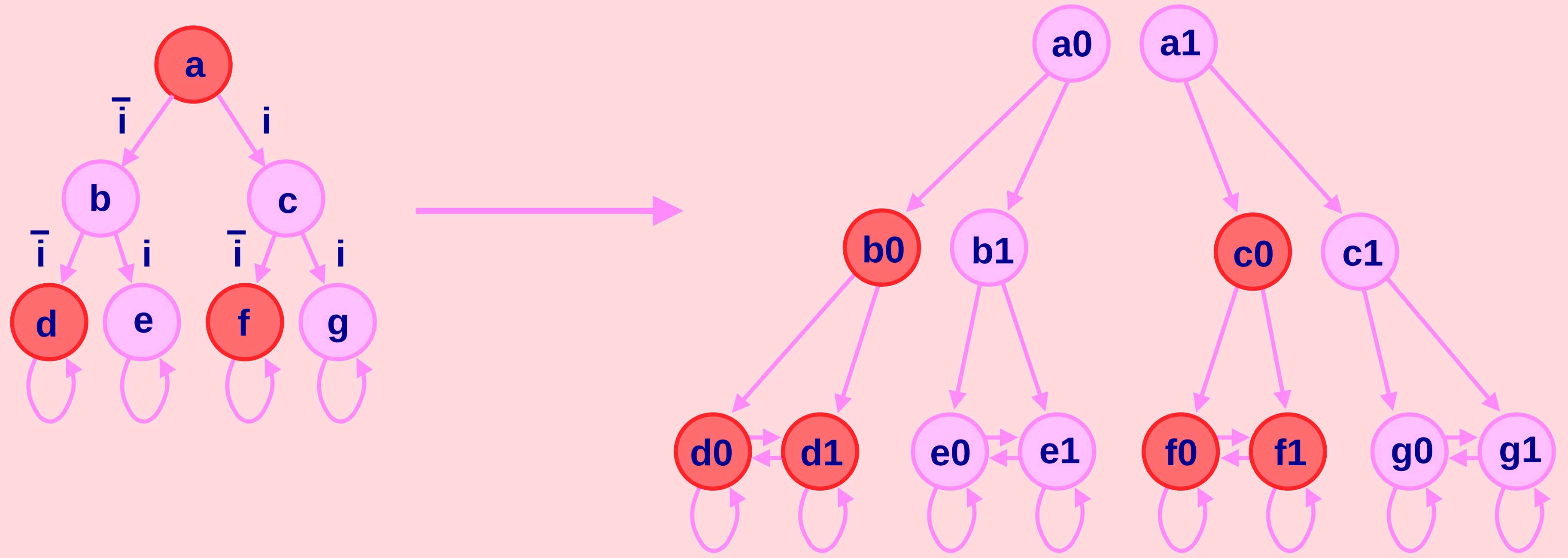

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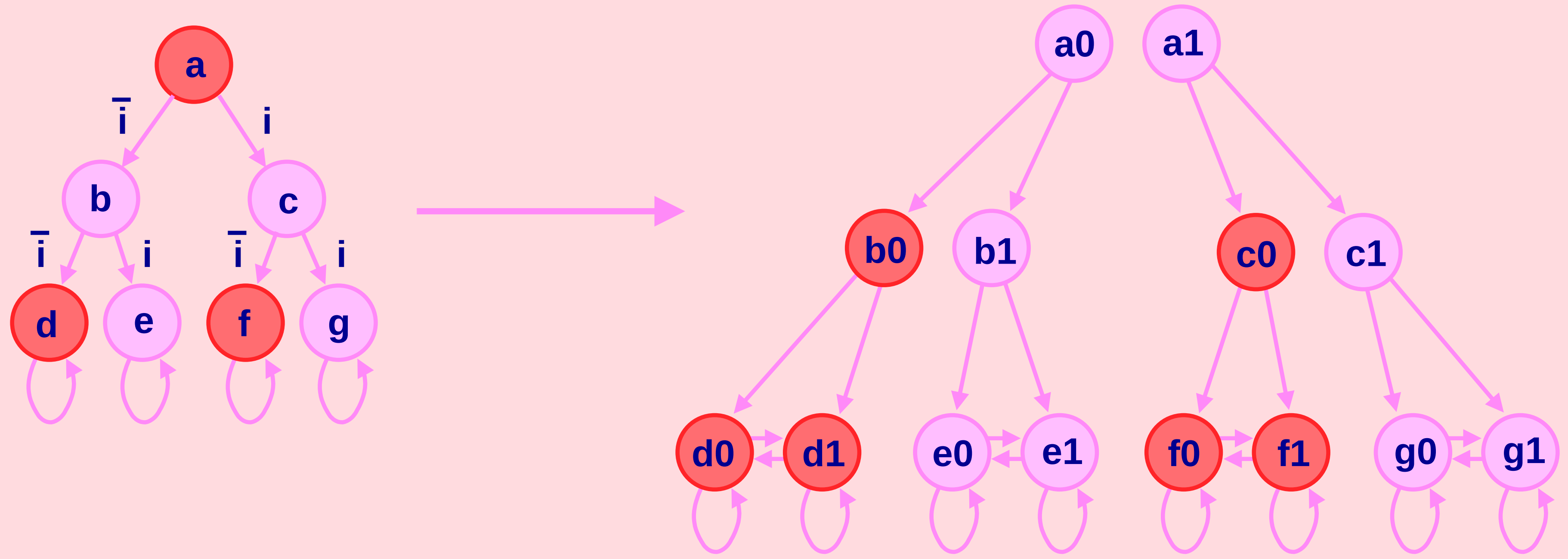

«AX EX p does not have the same truth value in both structures»

Possible CTL ambiguities

A first ambiguity

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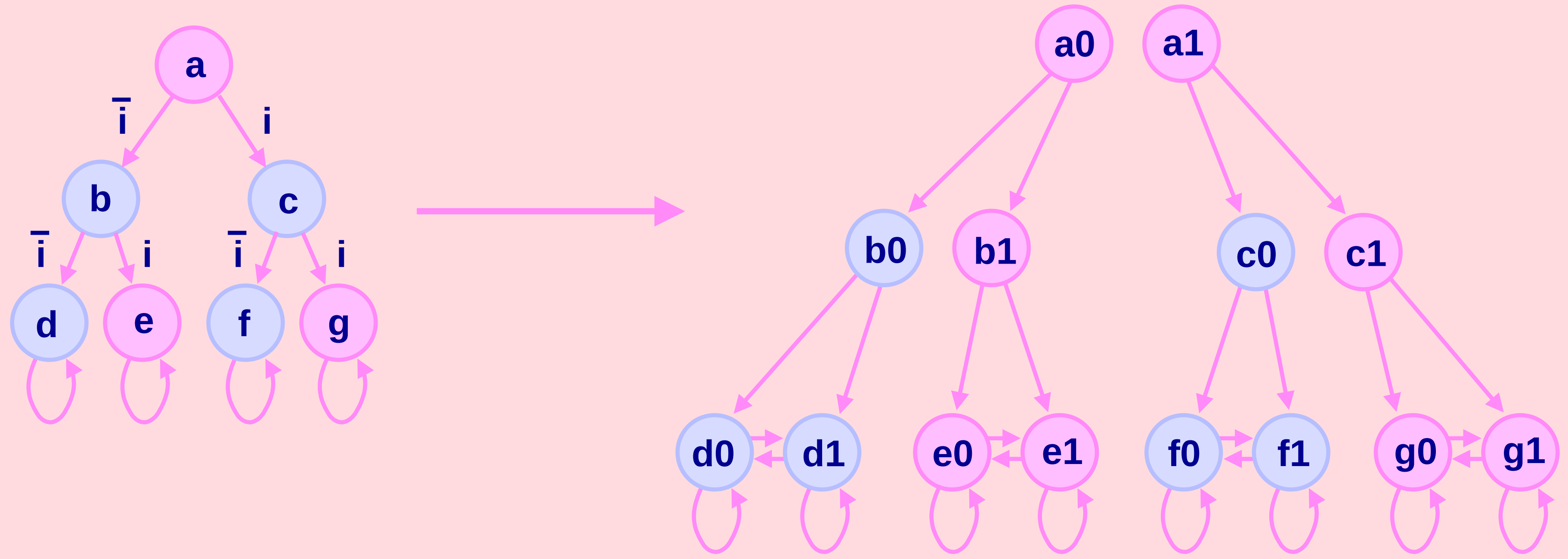
A first ambiguity

● states verifying EX p



Possible CTL ambiguities

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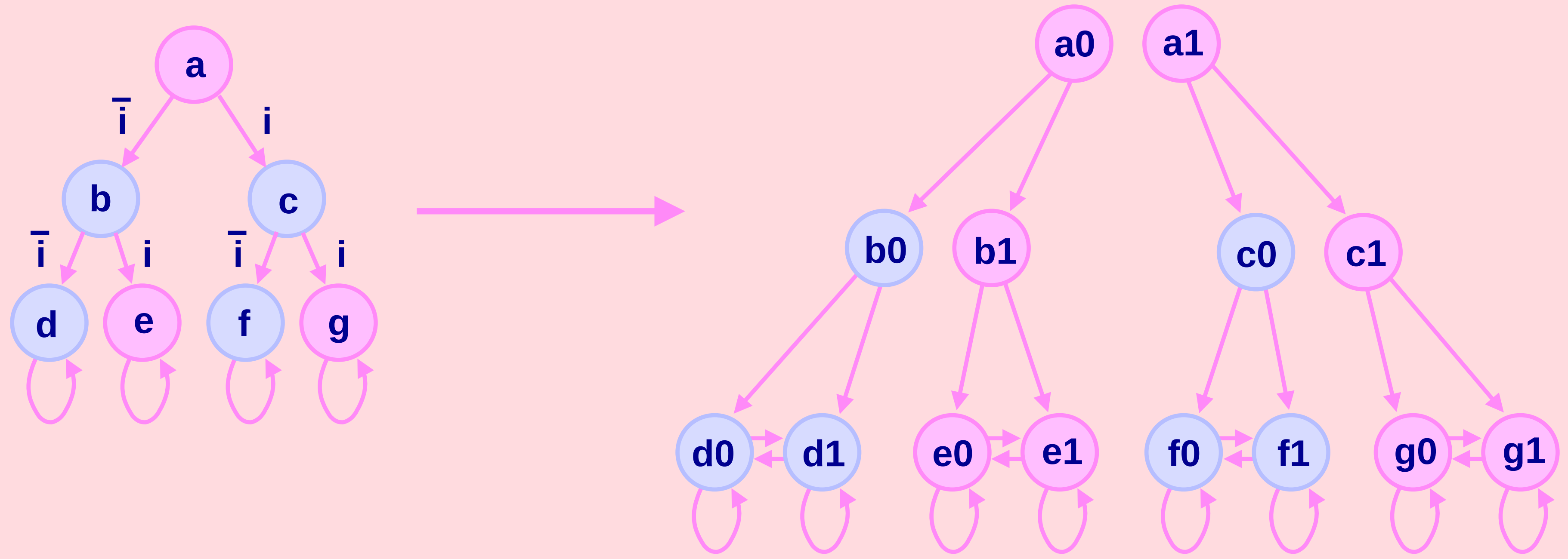


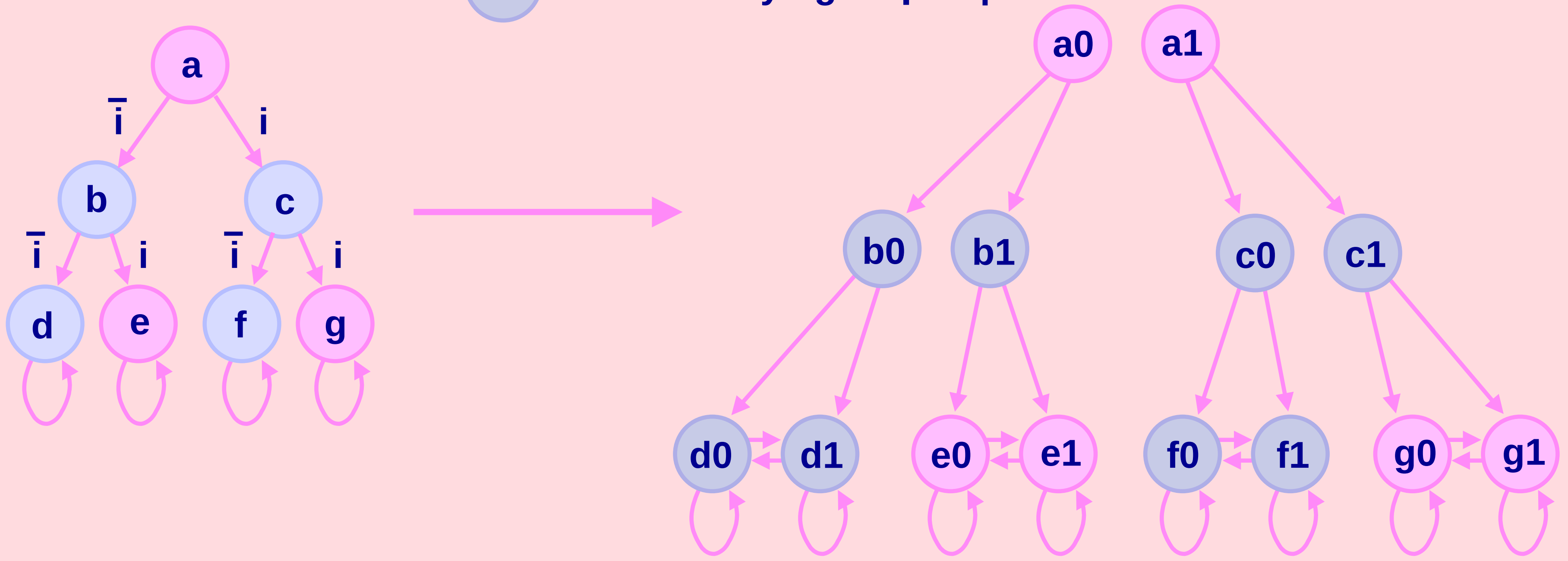
States b0 and b1 should verify EX p, as state b does

Possible CTL ambiguities

A first ambiguity

● states verifying EX p

● states verifying $\exists_i$ EX p



States b0 and b1 should verify EX p, as state b does

We introduce $\exists_i$ to remove this ambiguity

Possible CTL ambiguities

A second ambiguity

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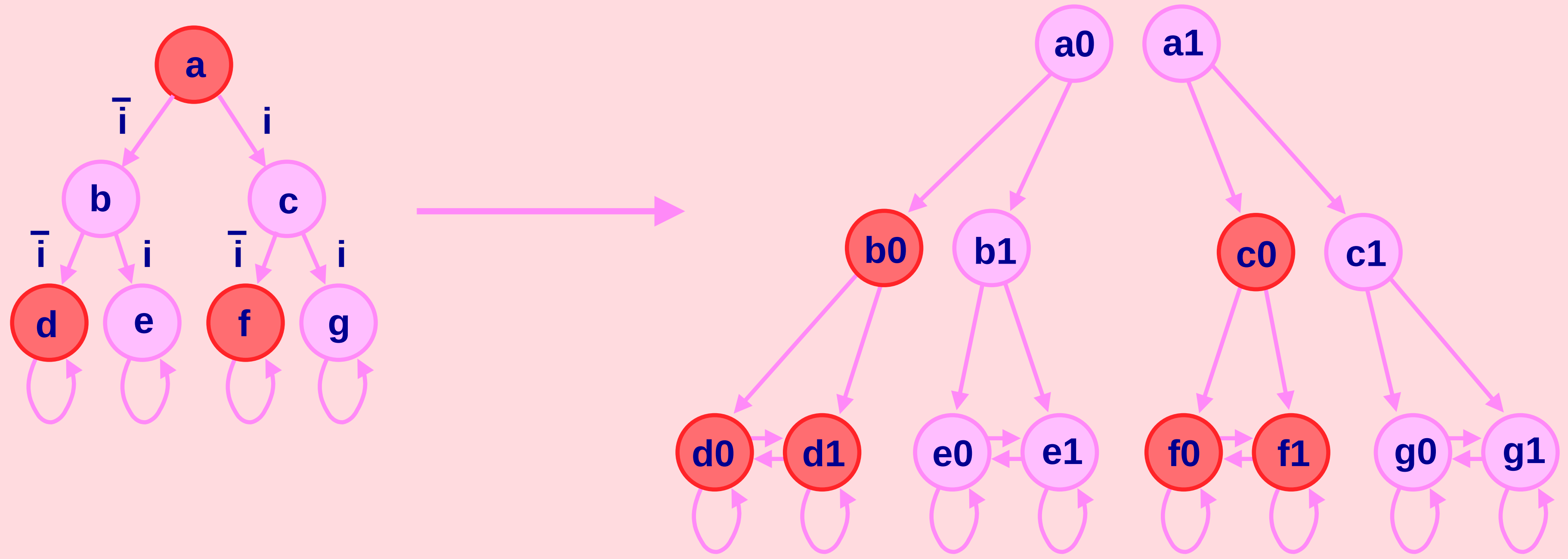
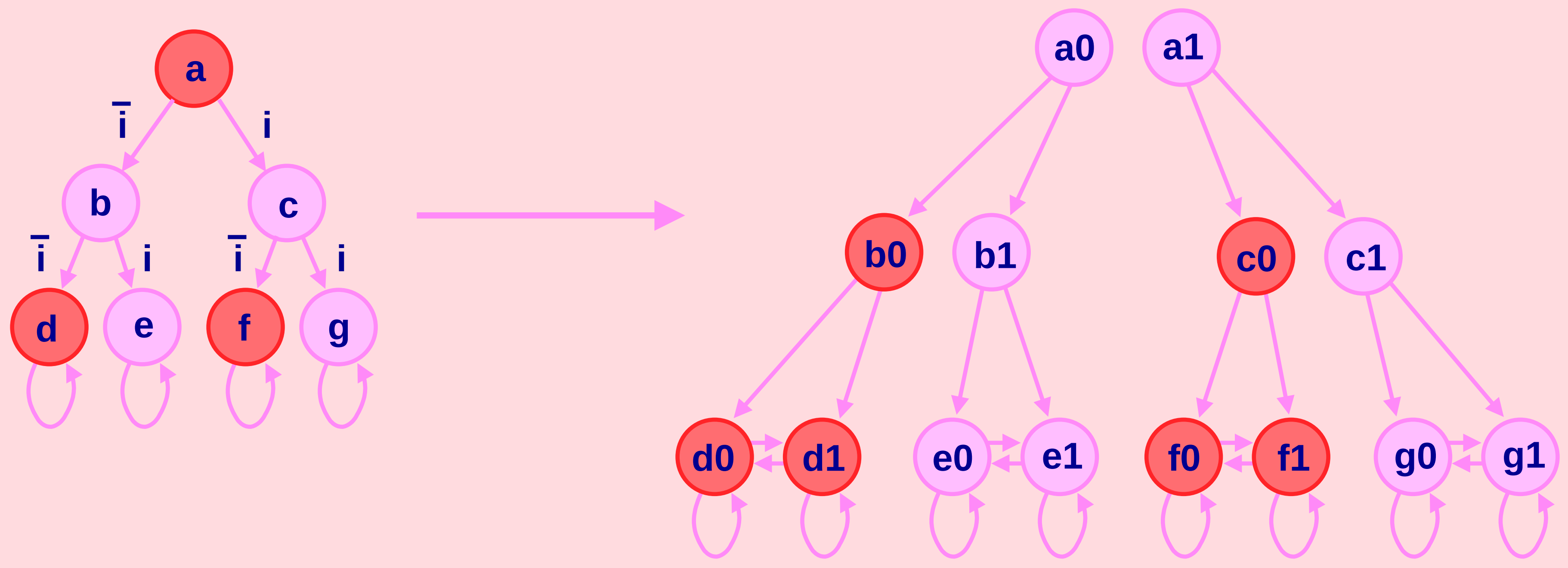
🔴 states verifying AX EX p



Possible CTL ambiguities

A second ambiguity

● states verifying AX EX p



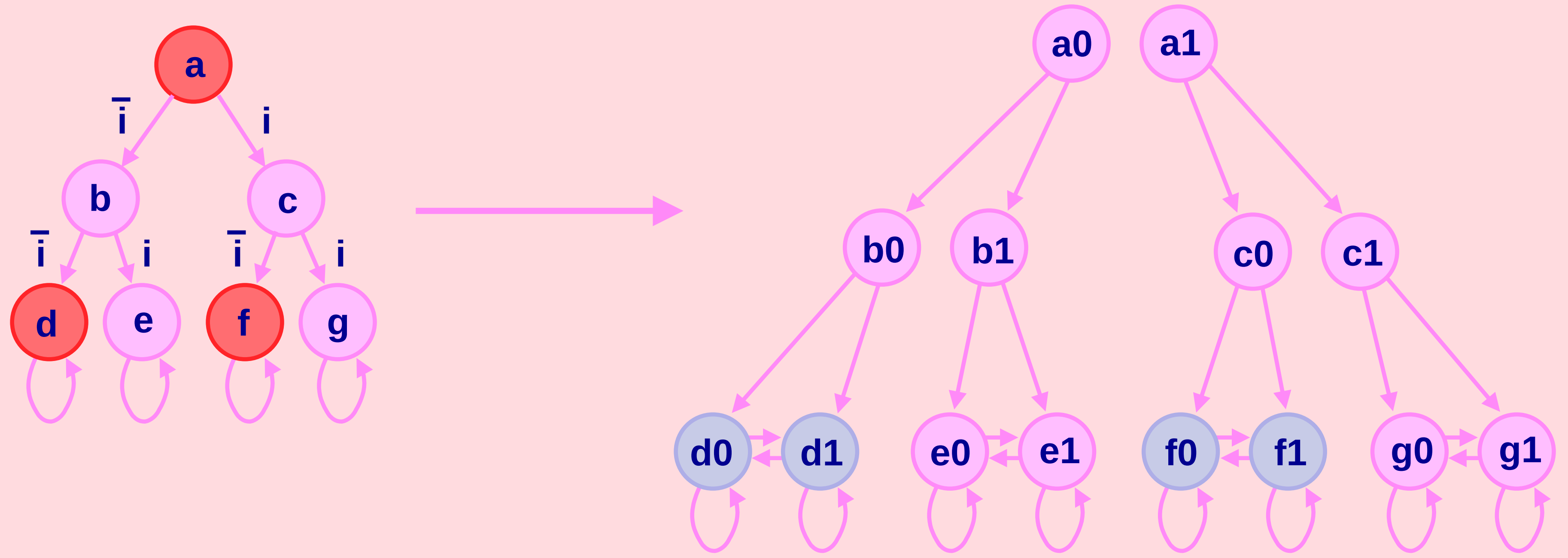
b0 (and b1) should not verify AX EX p, and a0 and a1 should

Possible CTL ambiguities

A second ambiguity

🔴 states verifying AX EX p

⚪ states verifying $\forall_i$ AX EX p



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We introduce $\forall_i$ to remove this ambiguity

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Checking the property $\forall_i AX \exists_i EX\ p$

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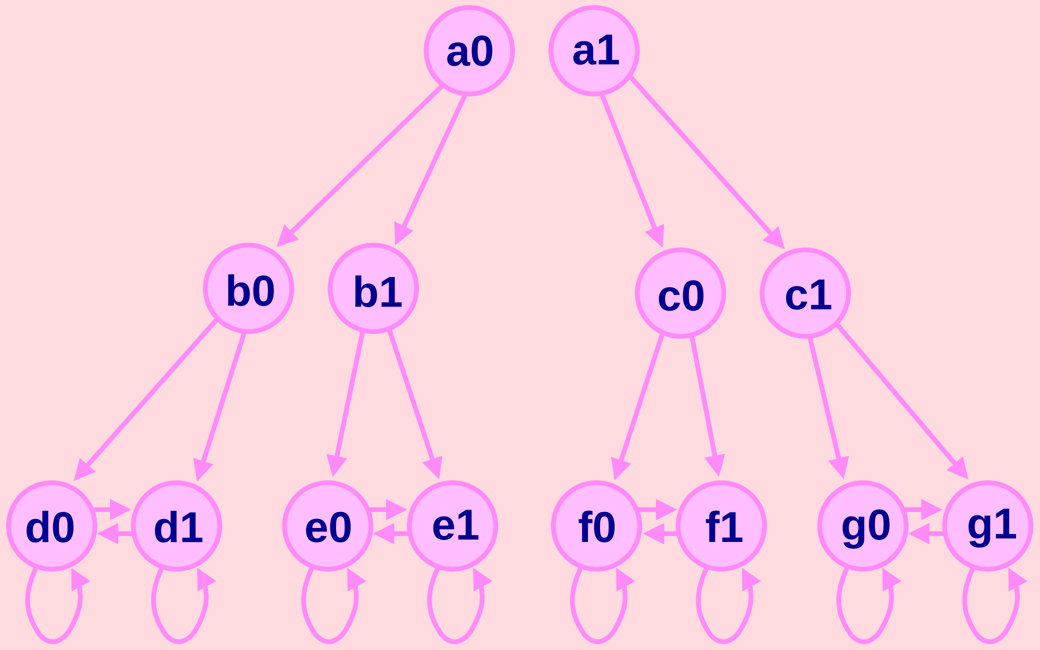
Checking the property $\forall_i \, AX \, \exists_i \, EX \, p$



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Checking the property $\forall_i AX \exists_i EX p$

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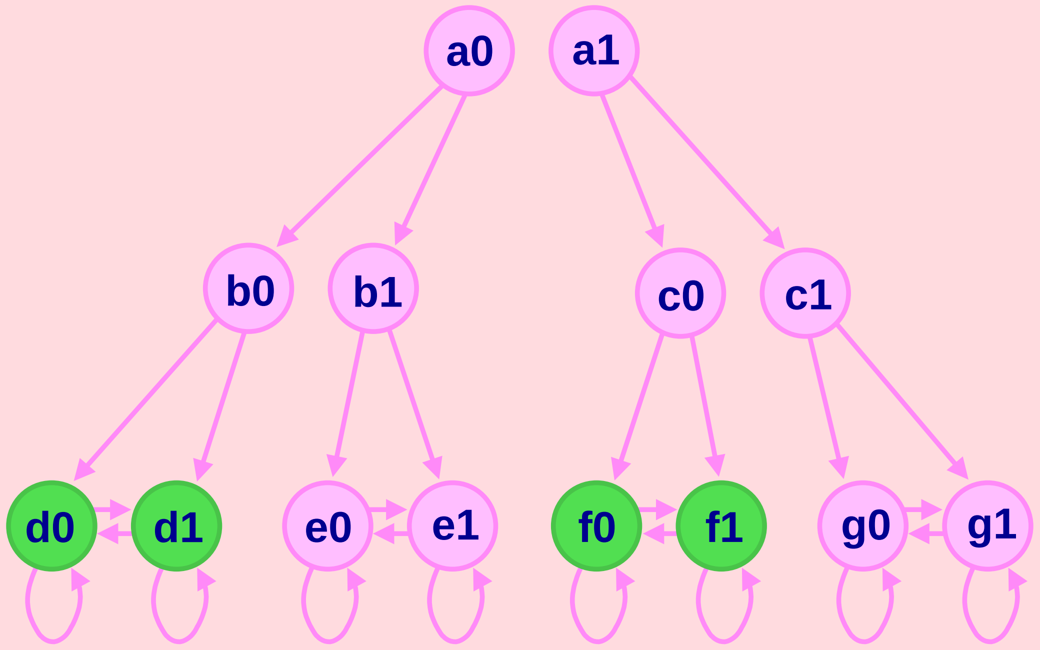

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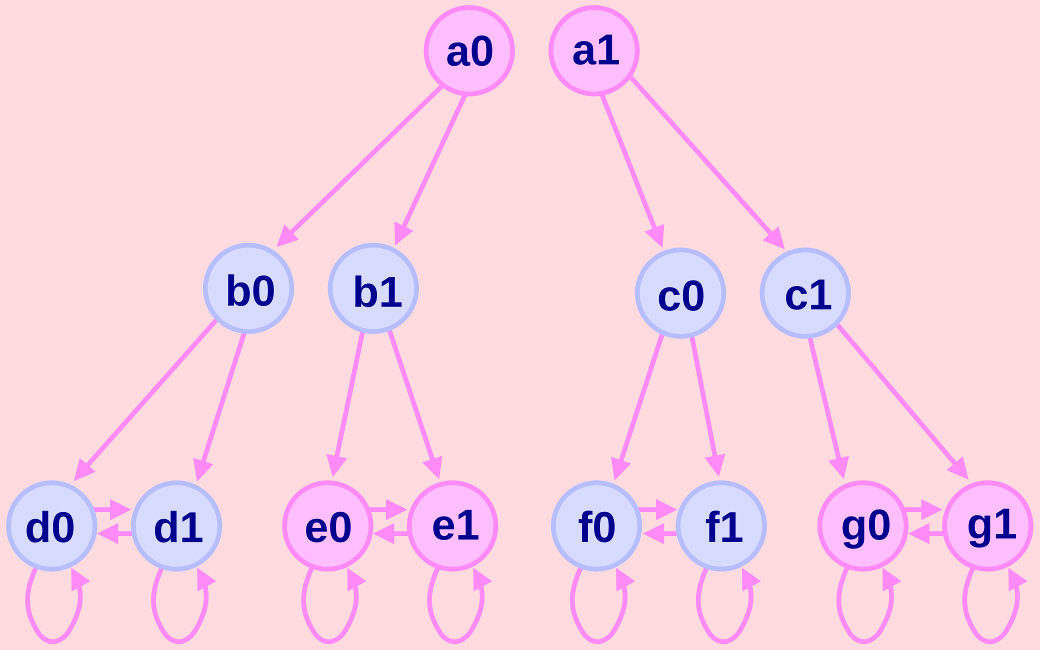

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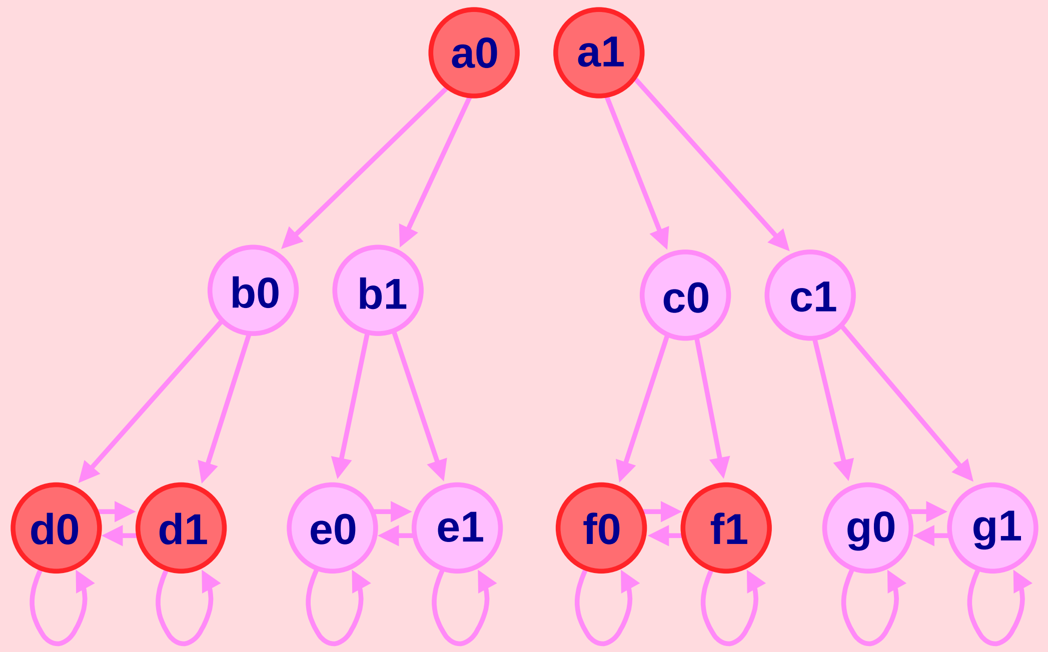

Possible CTL ambiguities

Comparison with AX EX p

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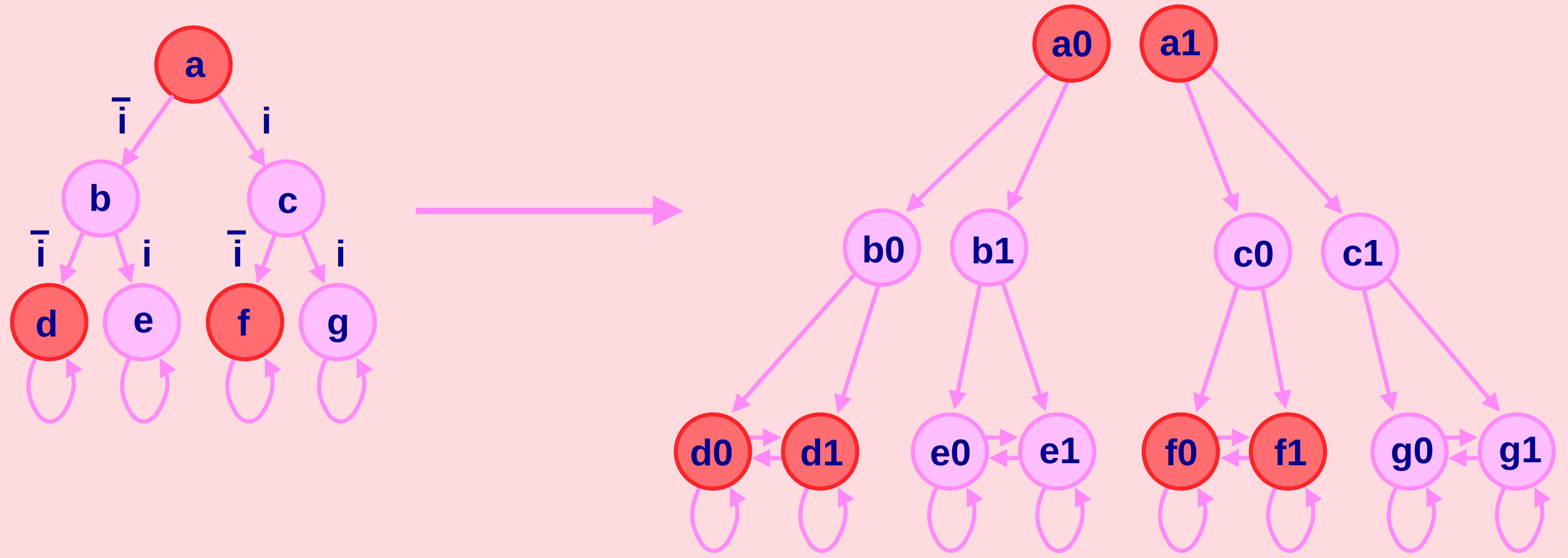
Comparison with AX EX p

🟥 states verifying AX EX p

🟥 states verifying $\forall_i$ AX $\exists_i$ EX p



Possible CTL ambiguities

Comparison with AX EX p

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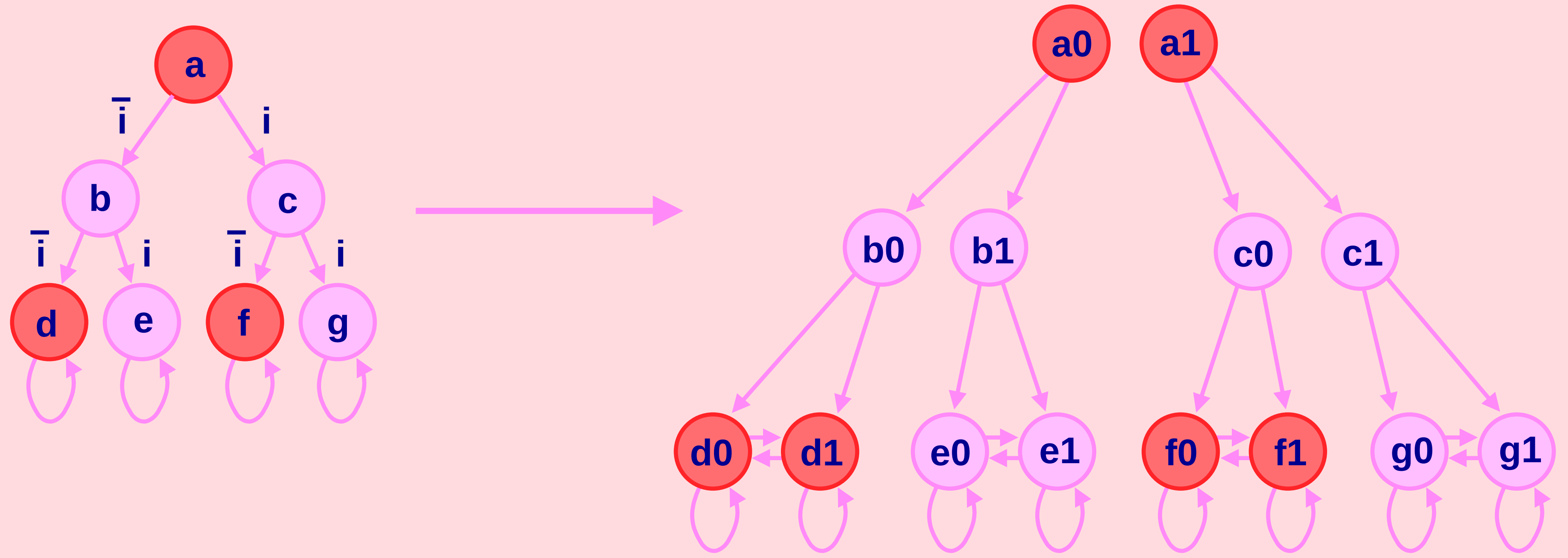
🟥 states verifying $\forall_i$ AX $\exists_i$ EX p



The ambiguities have been removed

iCTL

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Extends CTL with $\forall_i$ and $\exists_i$

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More expressive than CTL

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Easily integrable in a symbolic model−checker
(univ_abstract, exist_abstract)

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$\forall_i$ AX and $\exists_i$ EX seem similar to [*] and <*> of the mu−calculus

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$\forall_i$ AX and $\exists_i$ EX seem similar to [*] and <*> of the mu−calculus

but what about $\forall_i$ EX ?

Thank you