universität freiburg

eSLIM: Using Exact Synthesis for Circuit Minimization

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IWLS 2025 Programming Contest

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Exact Synthesis

i_1	i_2	i_3	o_1	o_2
0	0	0	0	0
0	0	1	0	1
0	1	0	0	0
0	1	1	0	1
1	0	0	0	0
1	0	1	0	1
1	1	0	1	1
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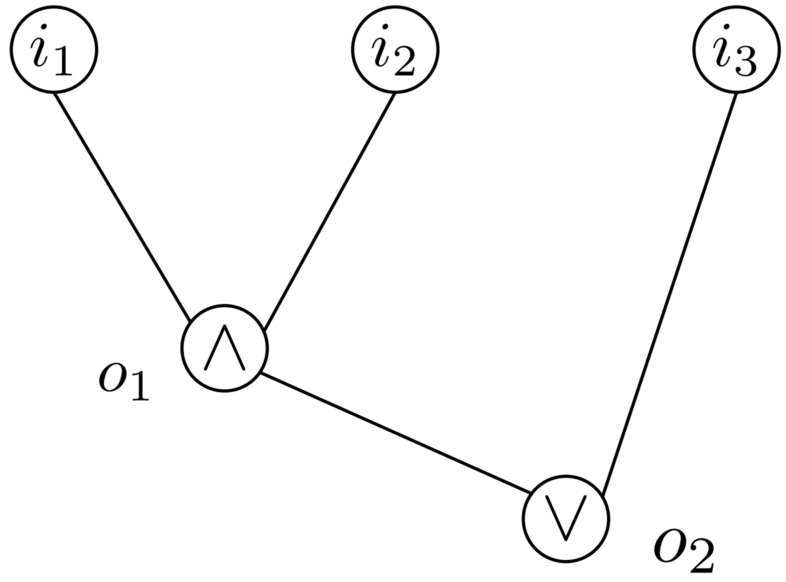
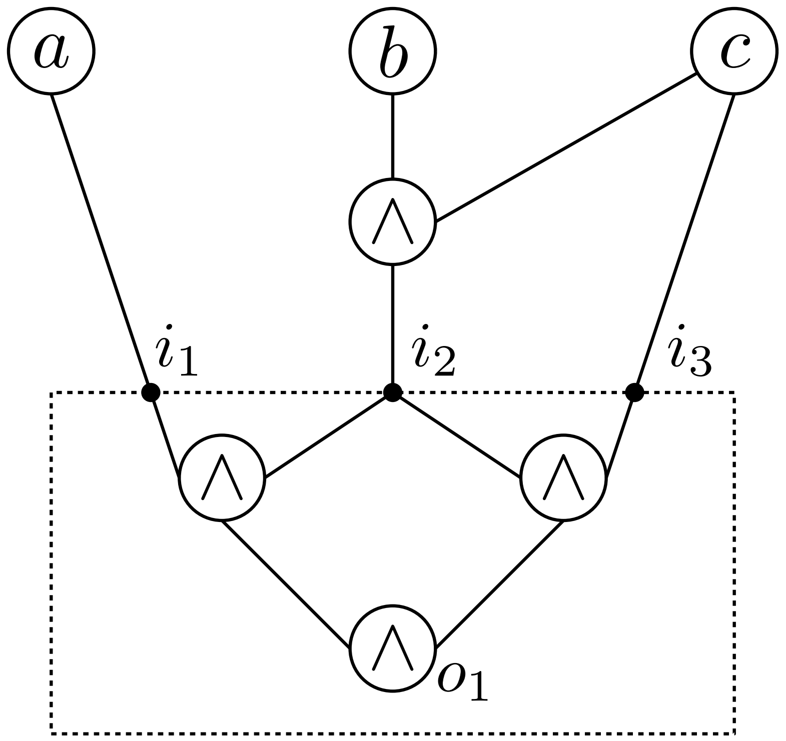


Exact Synthesis of Subcircuits



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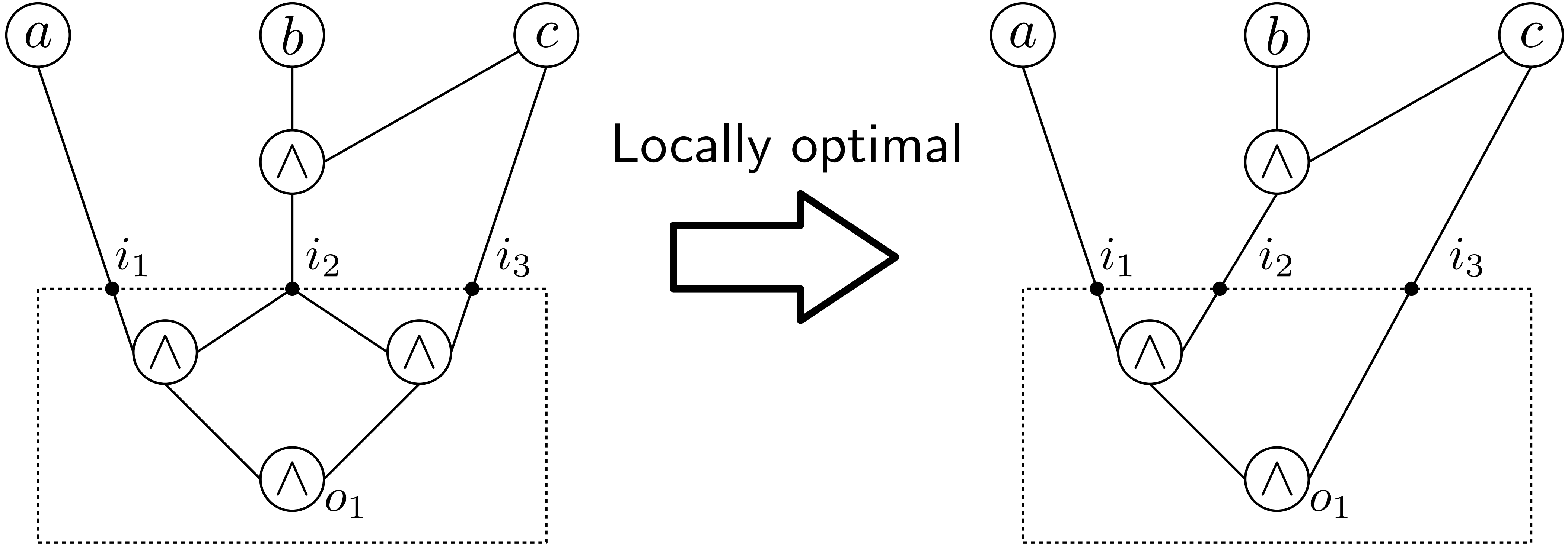

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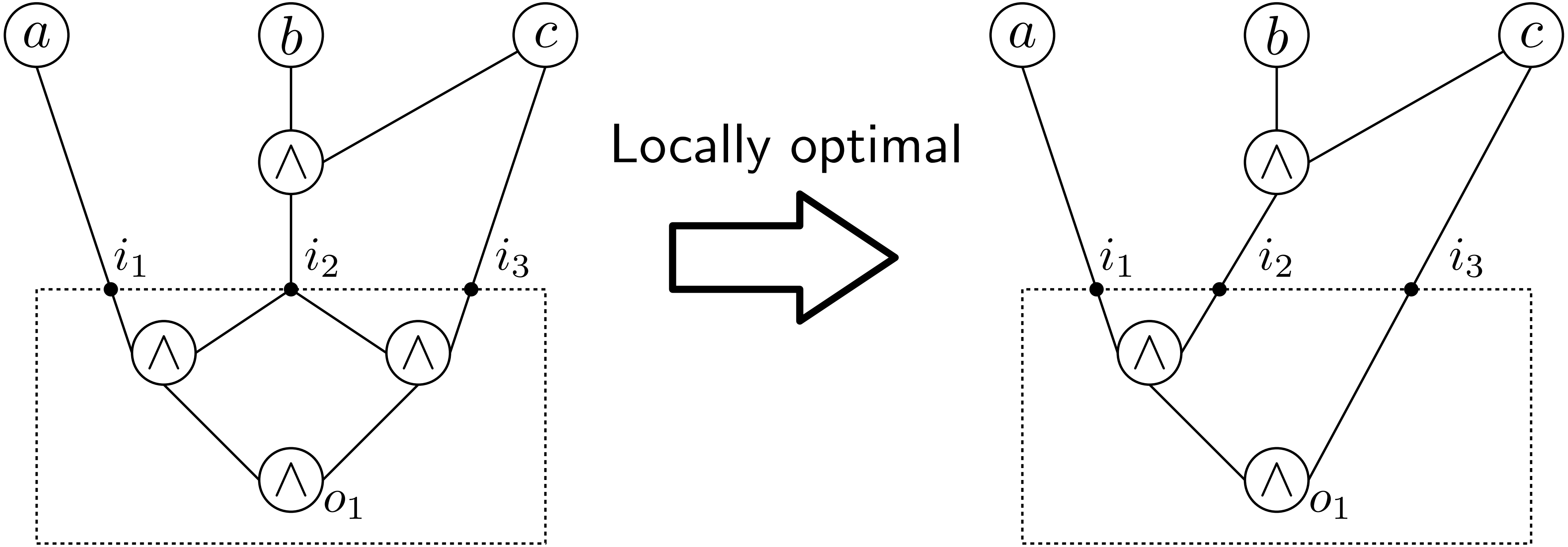

Not limited to equivalent replacements
$\rightarrow$ Make use of don't cares

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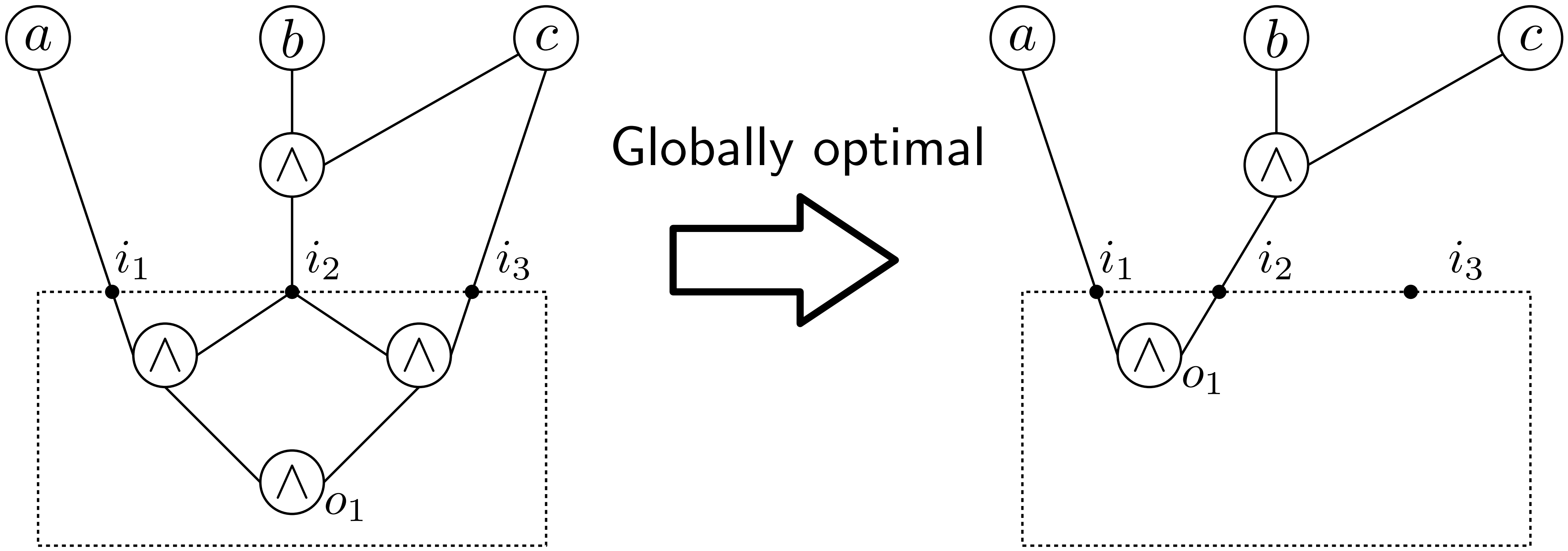

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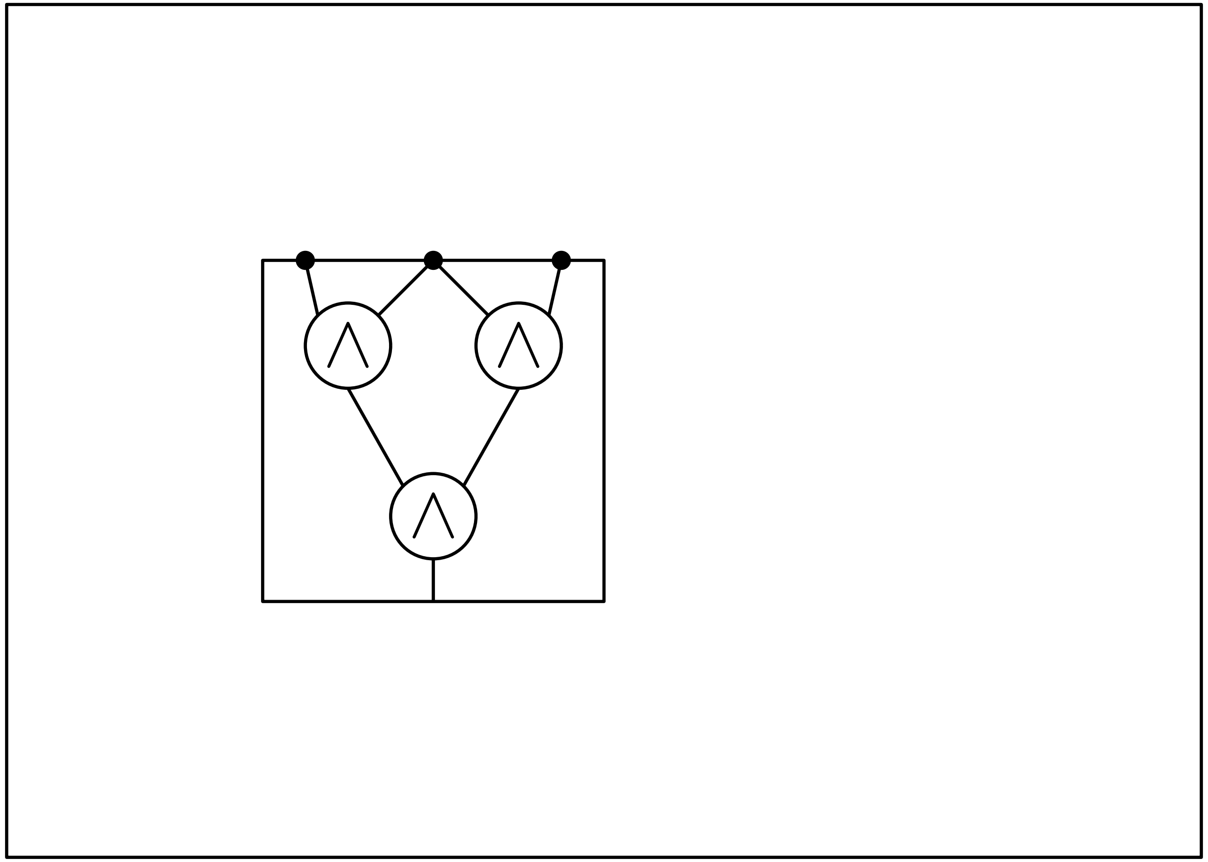
Workflow

1. Initial circuit

Workflow



1. Initial circuit
2. Select subcircuit

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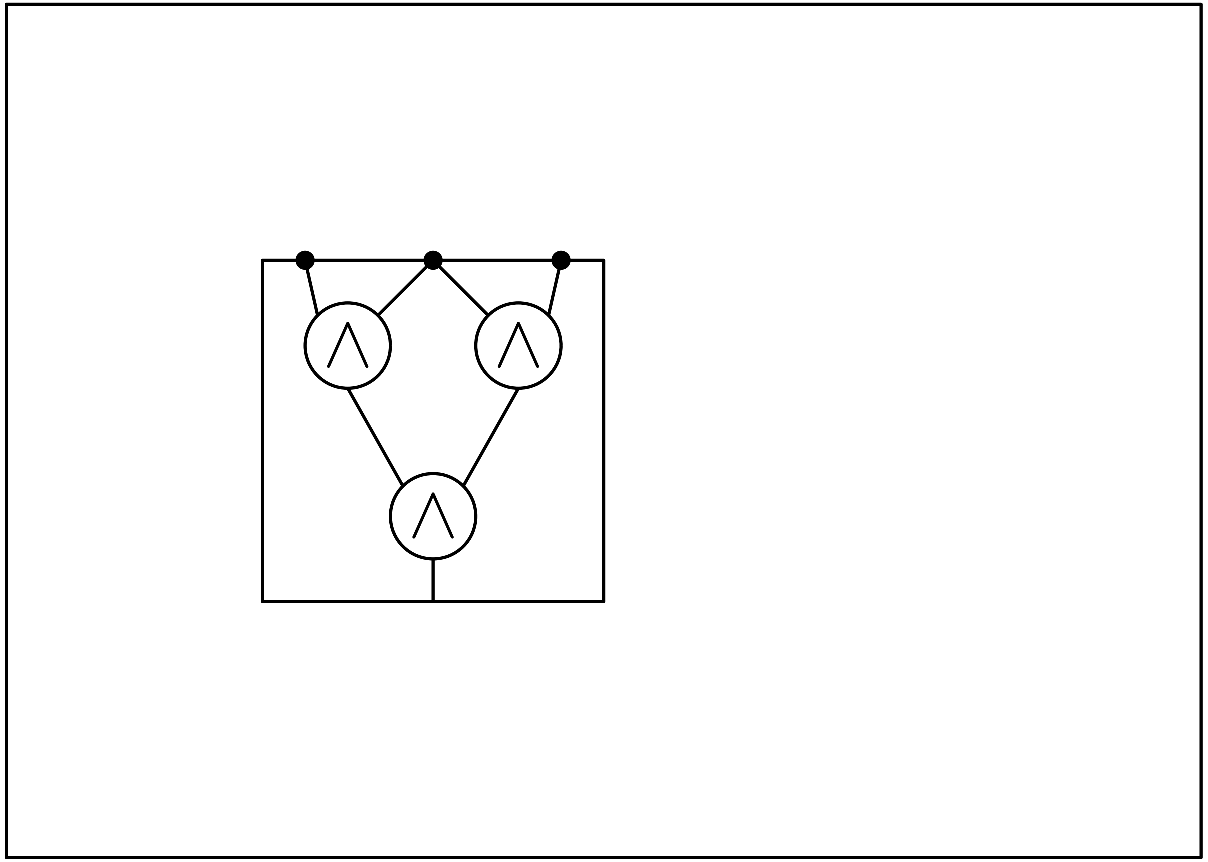

1. Initial circuit
2. Select subcircuit
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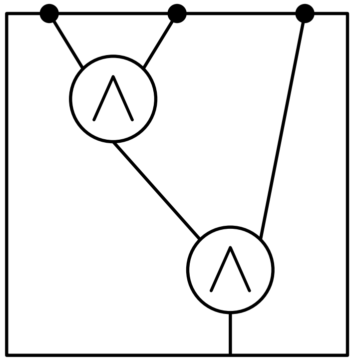

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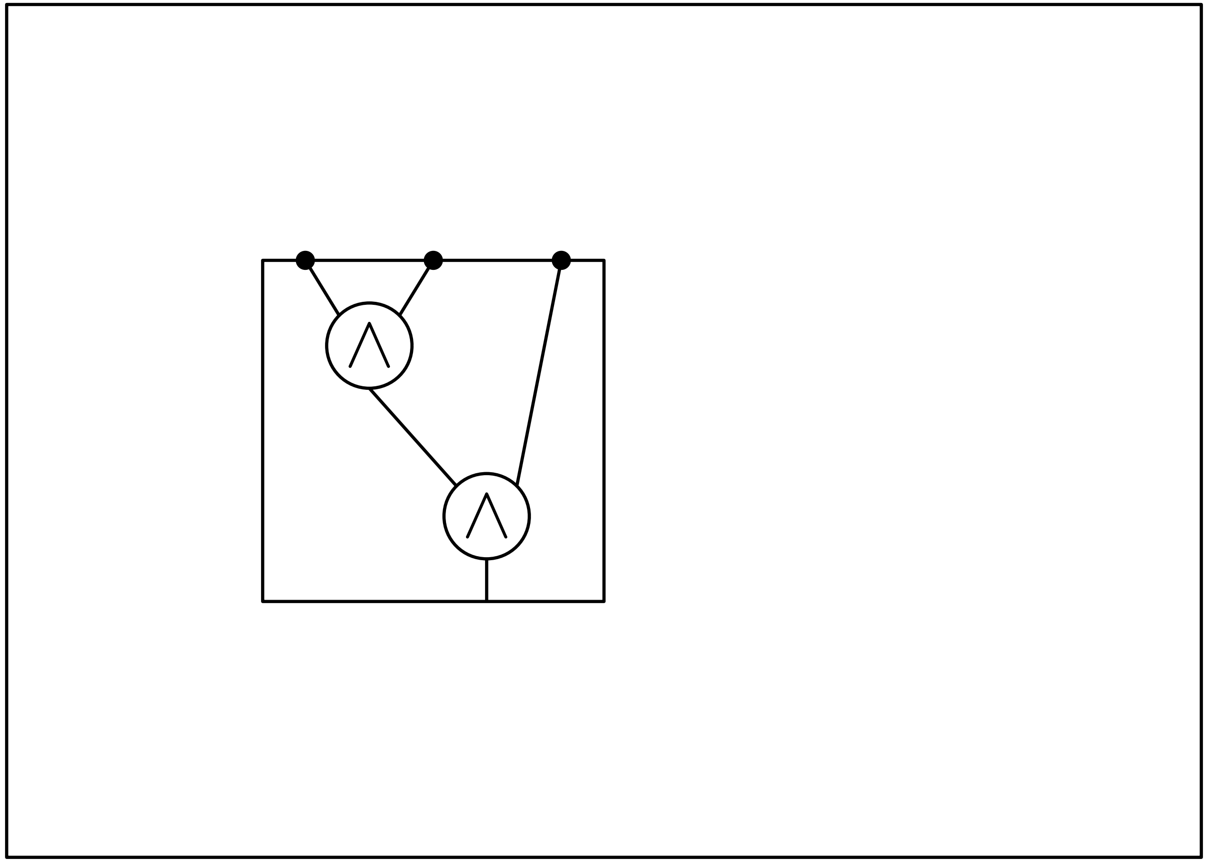

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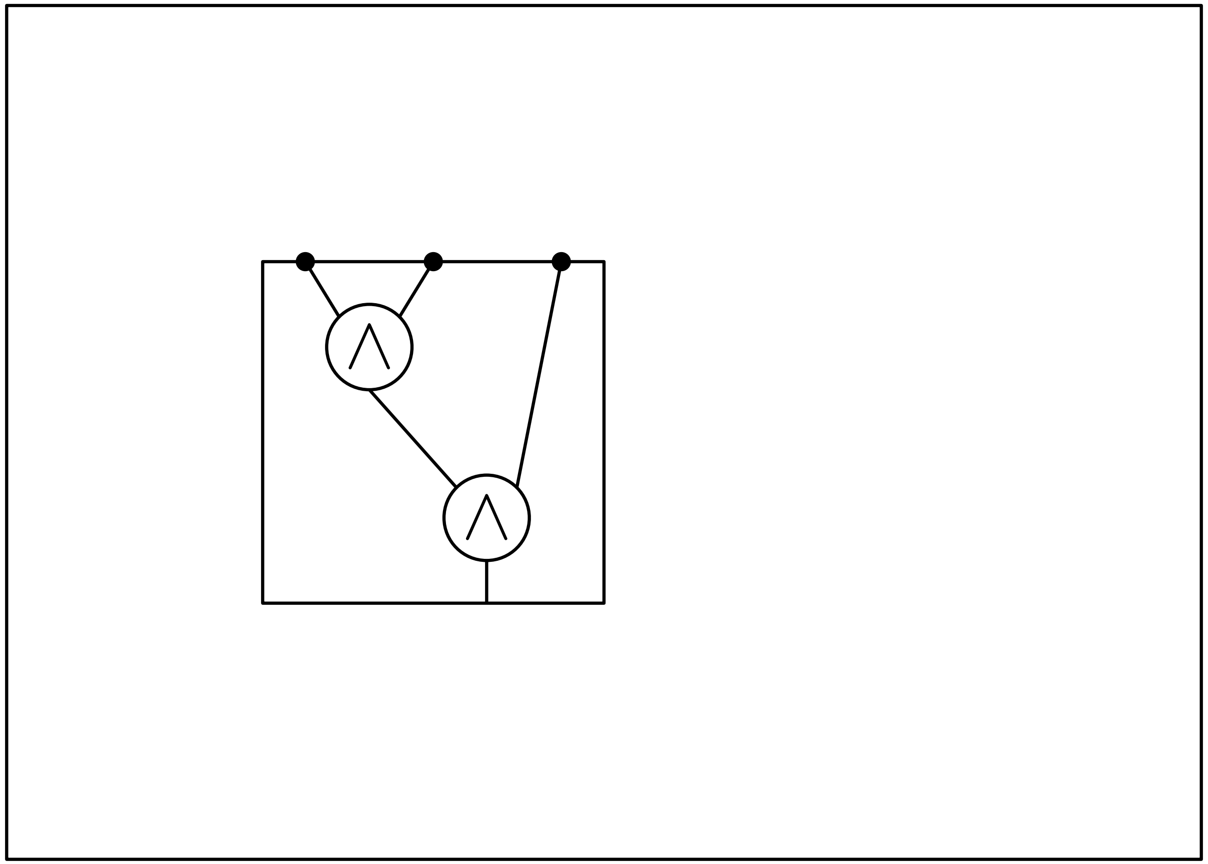
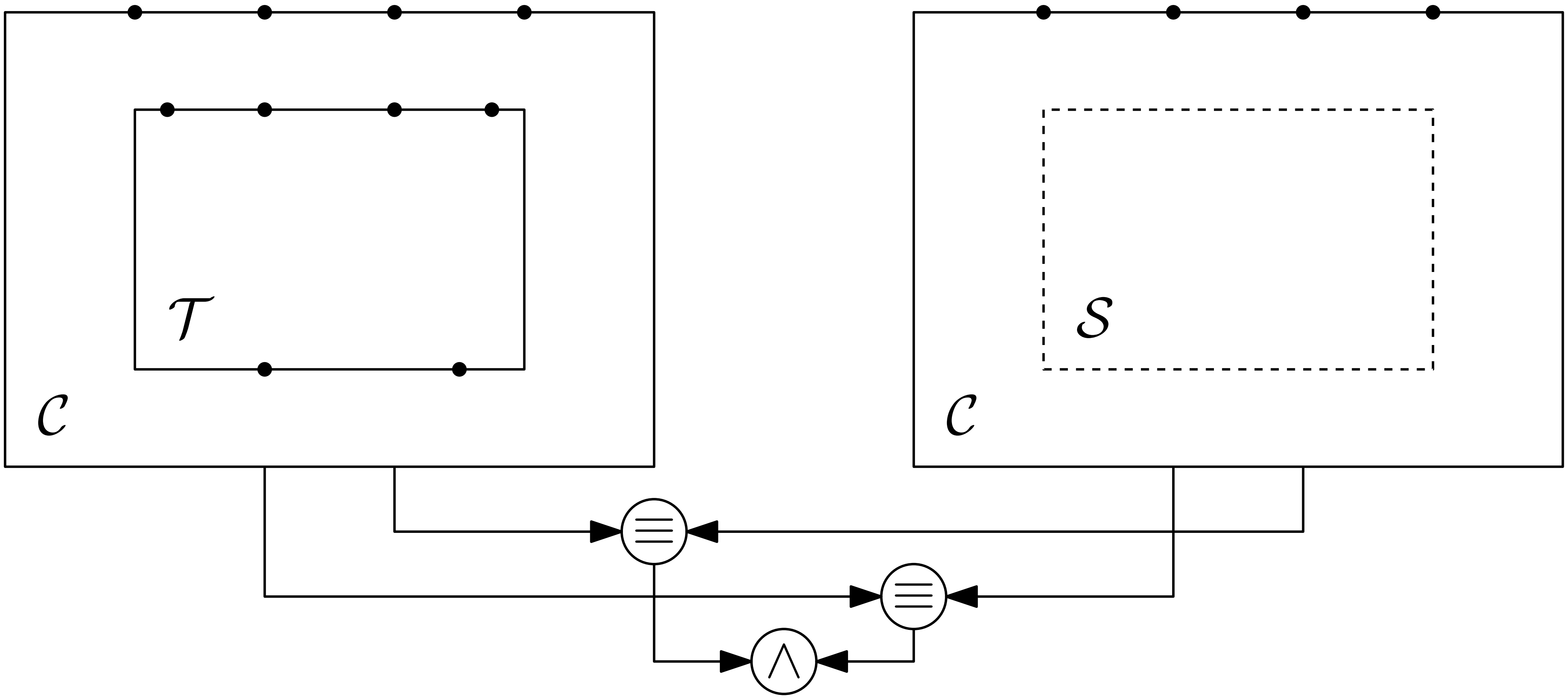


1. Initial circuit
2. Select subcircuit
3. Synthesise replacement
4. Insert Replacement
5. Repeat

QBF-based Synthesis

$$\exists \mathcal{T}\, \forall I\, \exists G . \mathcal{C}[\mathcal{S} \leftarrow \mathcal{T}] \equiv \mathcal{C}$$



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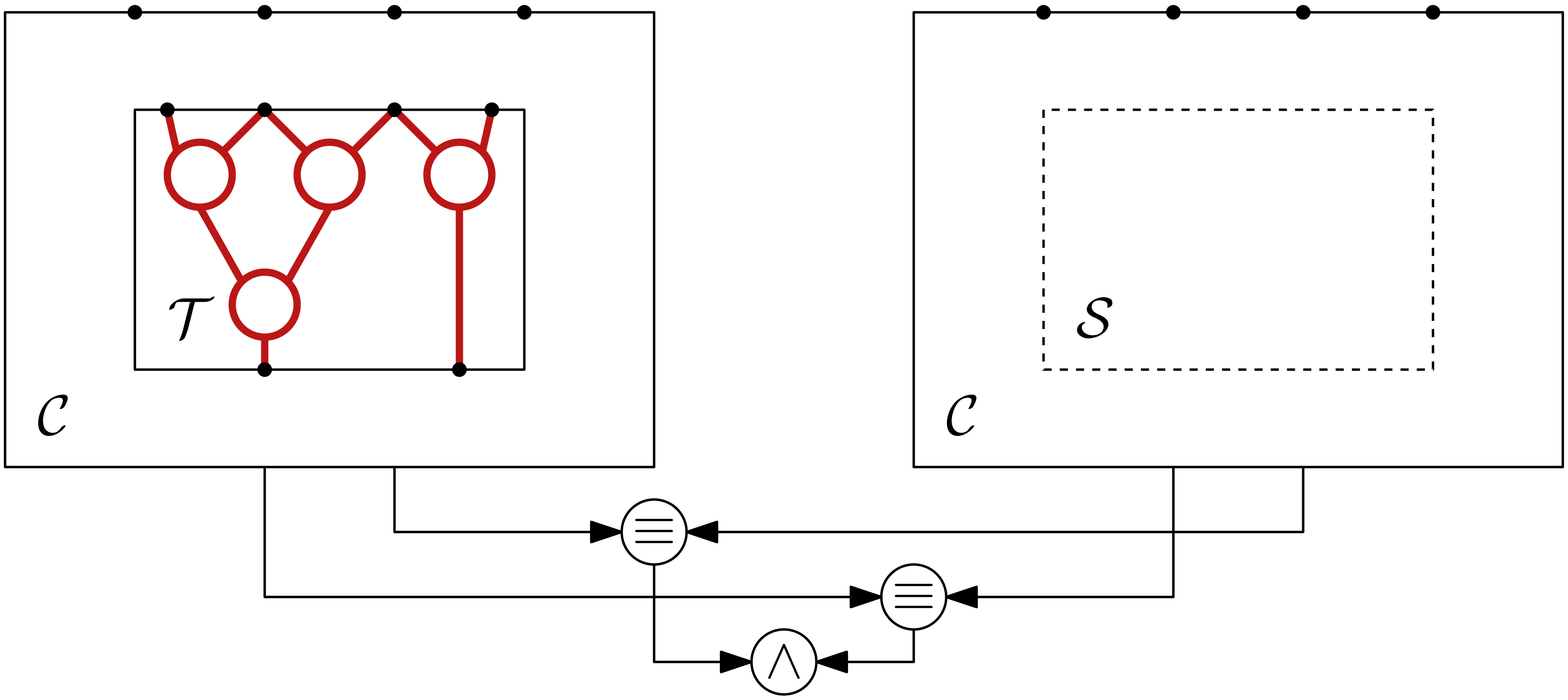

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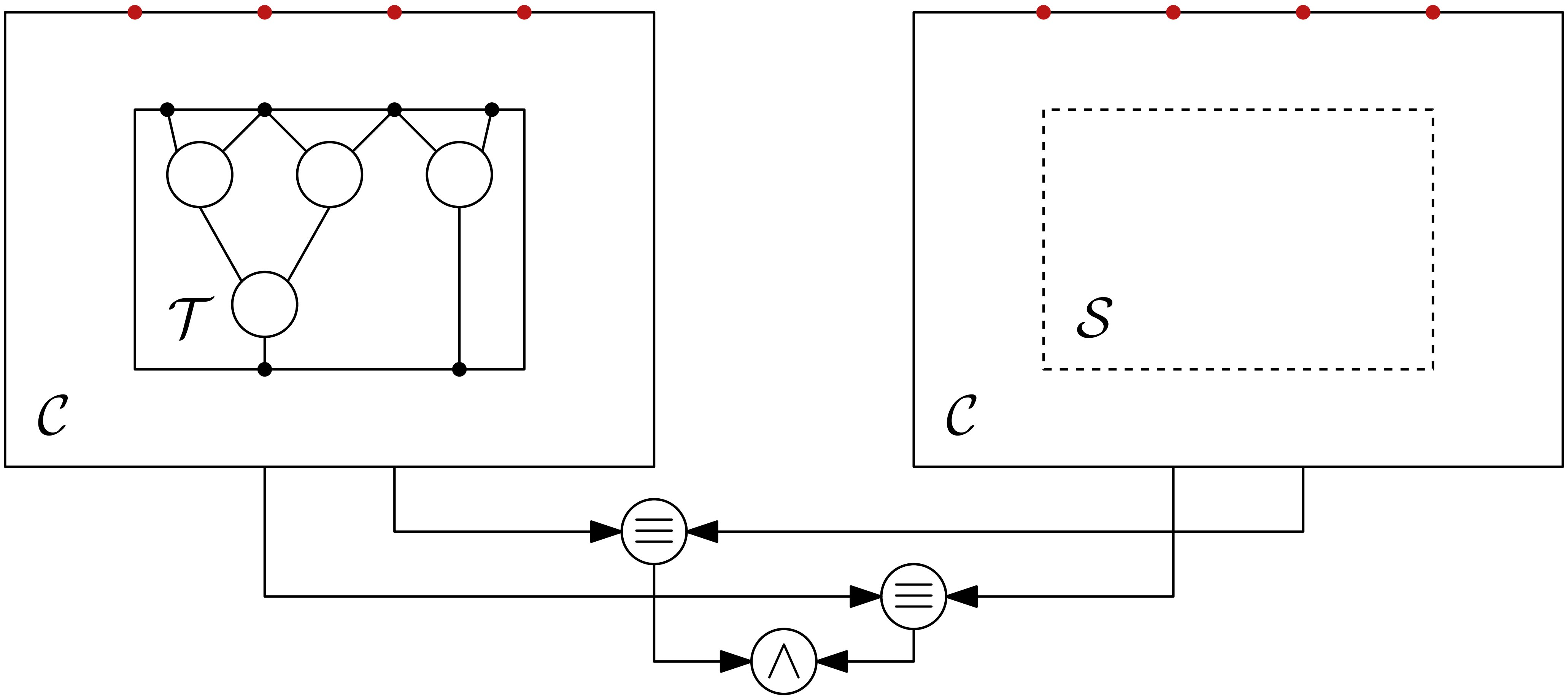

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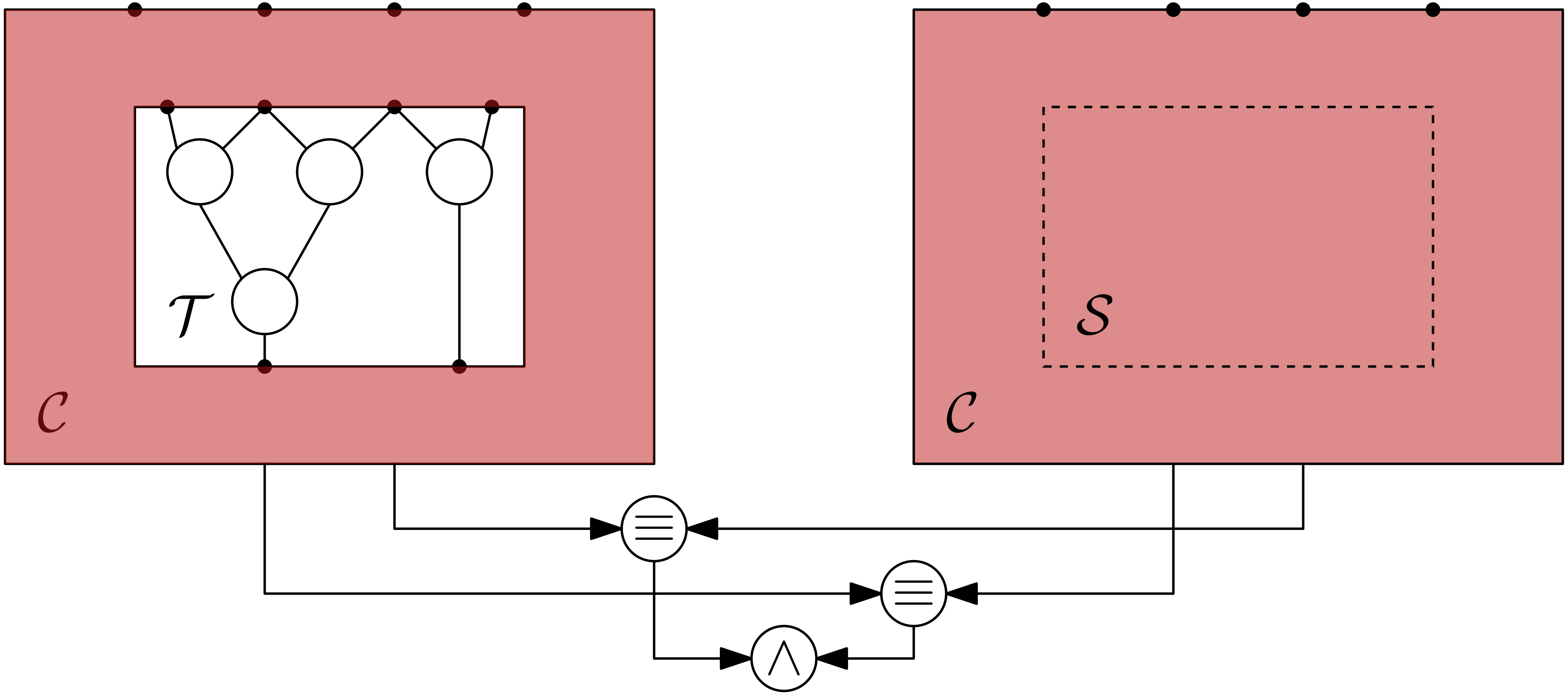

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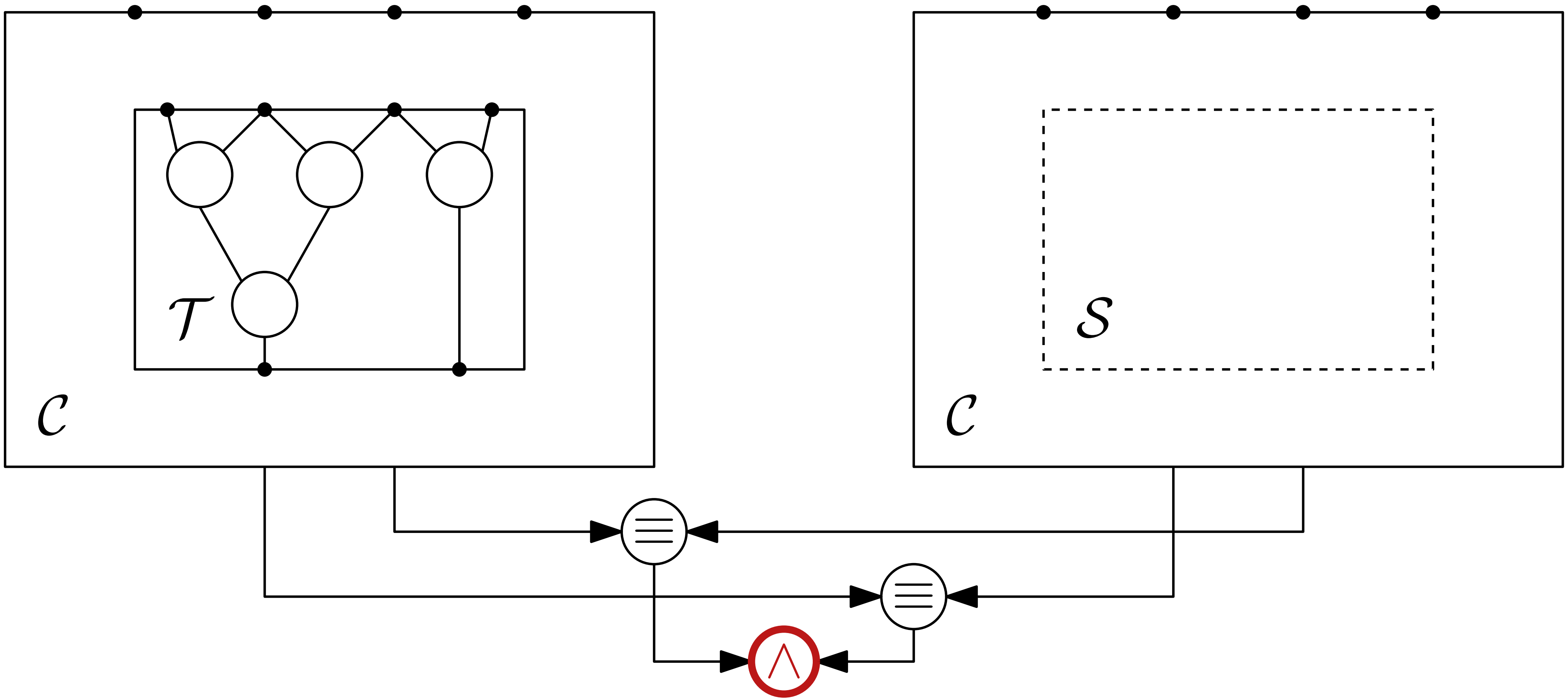

Boolean Relations

- Assign inputs to permitted outputs

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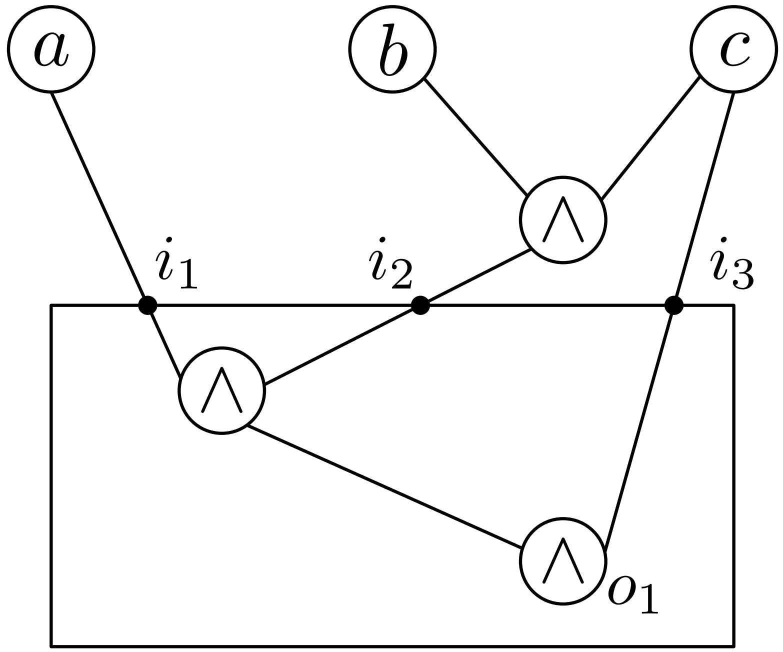

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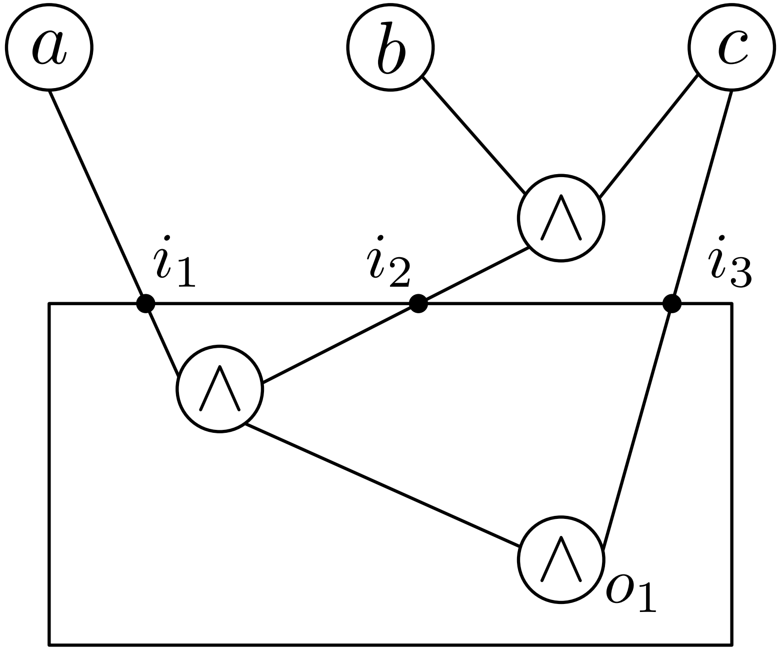
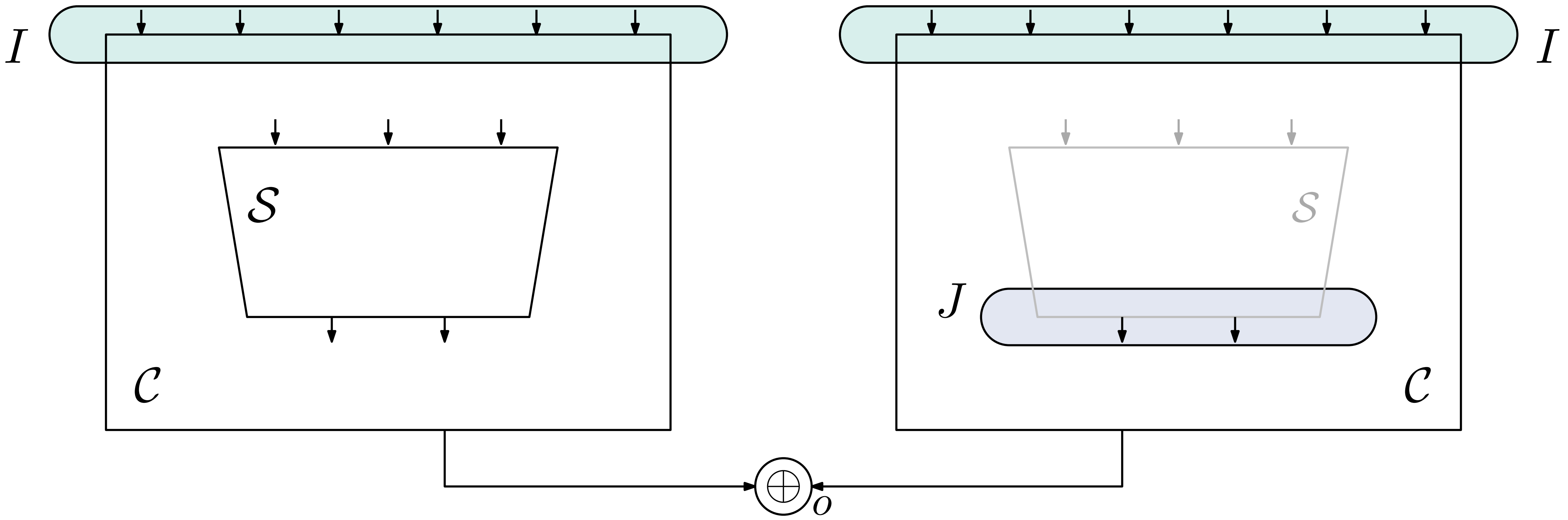


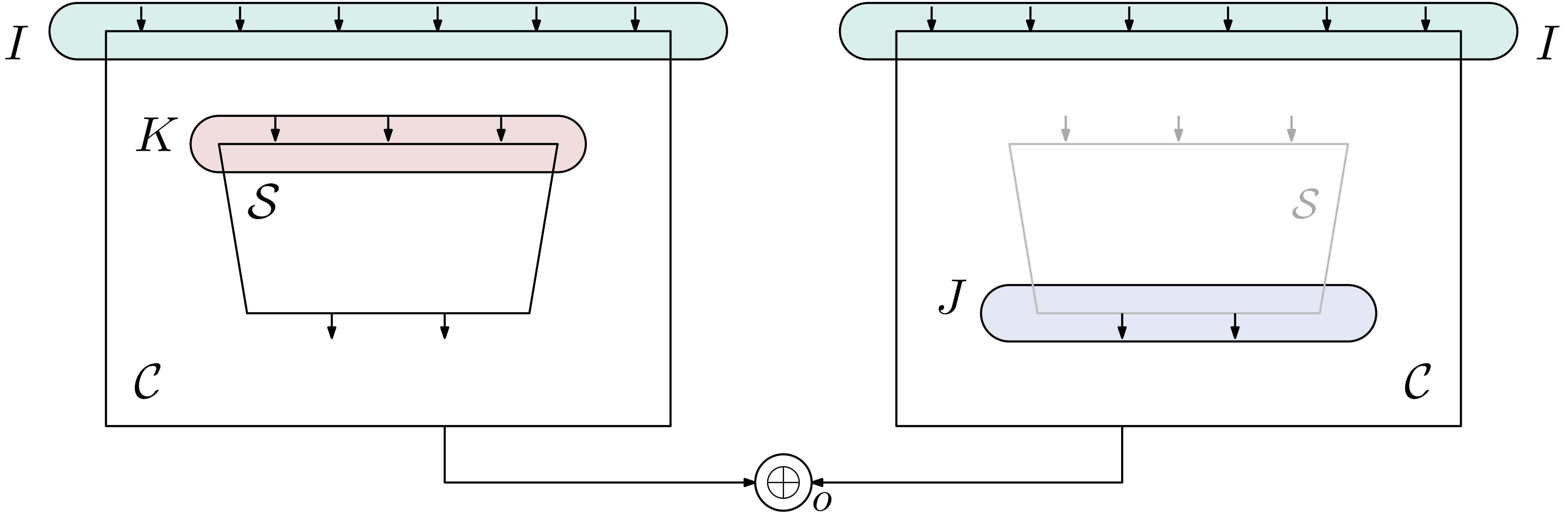
i_1	i_2	i_3	
0	0	0	$\{\neg o_1\}$
0	0	1	$\{\neg o_1\}$
0	1	0	$\{o_1, \neg o_1\}$
0	1	1	$\{\neg o_1\}$
1	0	0	$\{\neg o_1\}$
1	0	1	$\{\neg o_1\}$
1	1	0	$\{o_1, \neg o_1\}$
1	1	1	$\{o_1\}$

Computing Boolean Relations



Find assignments for I and J such that o is true

Computing Boolean Relations



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Under the assignment K, the subcircuit $\mathcal{S}$ must not attain J

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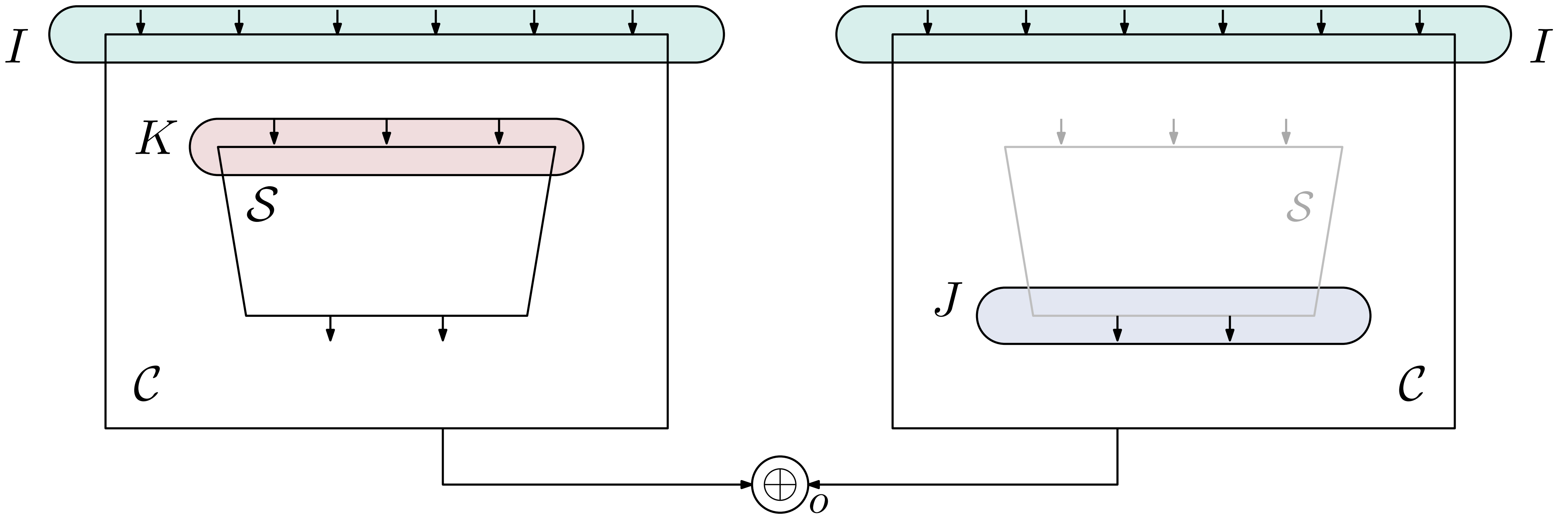


Find assignments for I and J such that o is true

Under the assignment K, the subcircuit $\mathcal{S}$ must not attain J

Iteratively compute assignments I, J, K by assumption based SAT solving

SAT-based Synthesis

Exact Synthesis

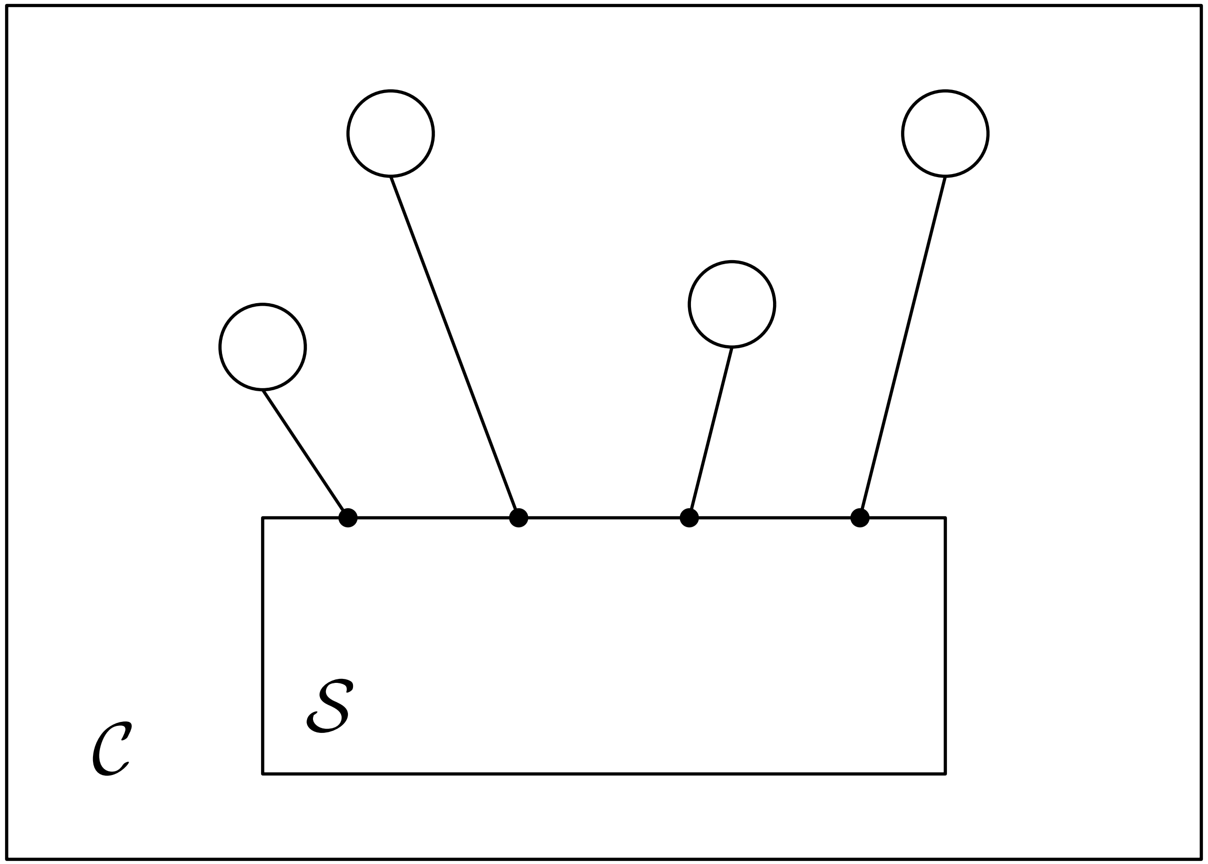
i_1	i_2	i_3	
0	0	0	$\neg o_1 \wedge \neg o_2$
0	0	1	$\neg o_1 \wedge o_2$
0	1	0	$\neg o_1 \wedge \neg o_2$
0	1	1	$\neg o_1 \wedge o_2$
1	0	0	$\neg o_1 \wedge \neg o_2$
1	0	1	$\neg o_1 \wedge o_2$
1	1	0	$o_1 \wedge o_2$
1	1	1	$o_1 \wedge o_2$

SAT-based Synthesis

Synthesising a relation

i_1	i_2	i_3	
0	0	0	$\neg o_1$
0	0	1	$(\neg o_1 \vee \neg o_2) \wedge (o_1 \vee o_2)$
0	1	0	$\neg o_1 \vee \neg o_2$
0	1	1	o_2
1	0	0	$(\neg o_1 \vee o_2) \wedge (o_1 \vee \neg o_2)$
1	0	1	$(\neg o_1 \vee \neg o_2) \wedge (o_1 \vee o_2)$
1	1	0	$\neg o_1 \vee \neg o_2$
1	1	1	o_1

Additional Inputs



$\mathcal{C}$ can contain nodes with functionality used in $\mathcal{S}$

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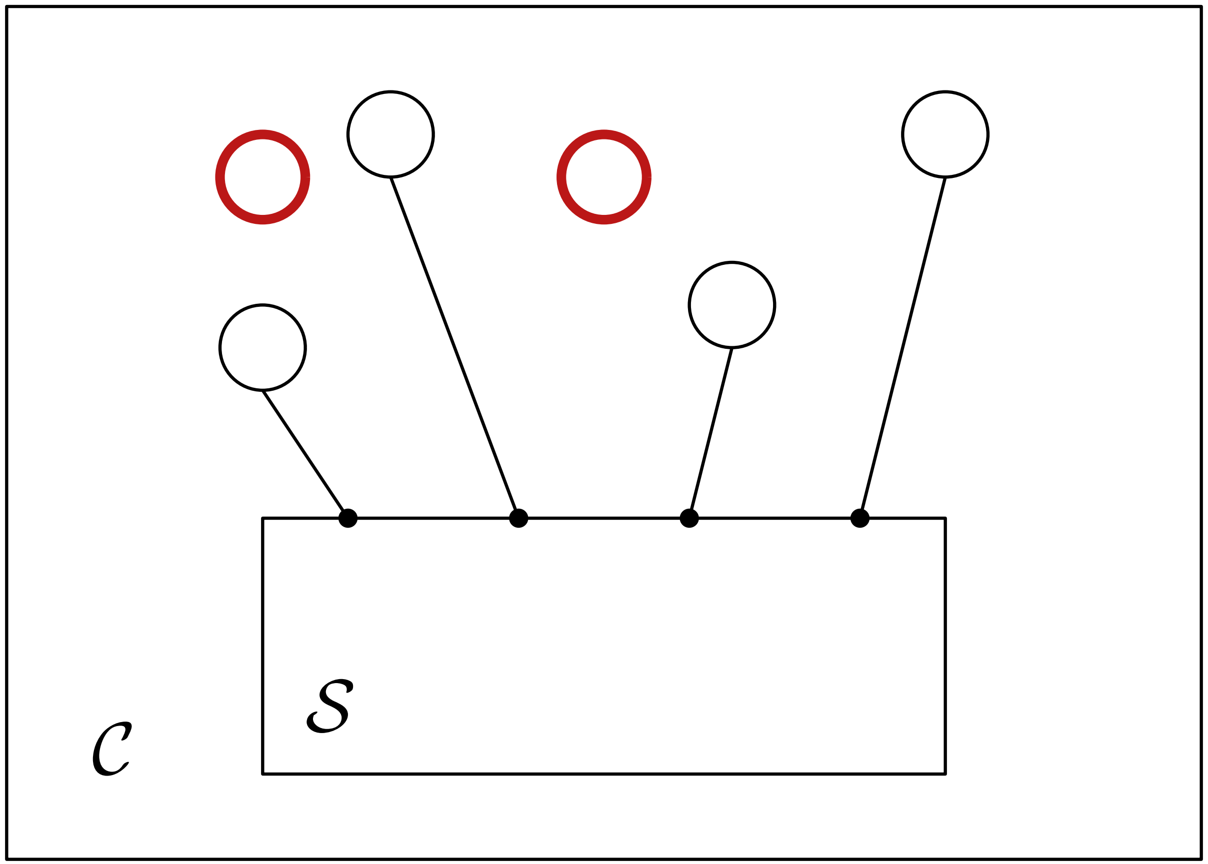

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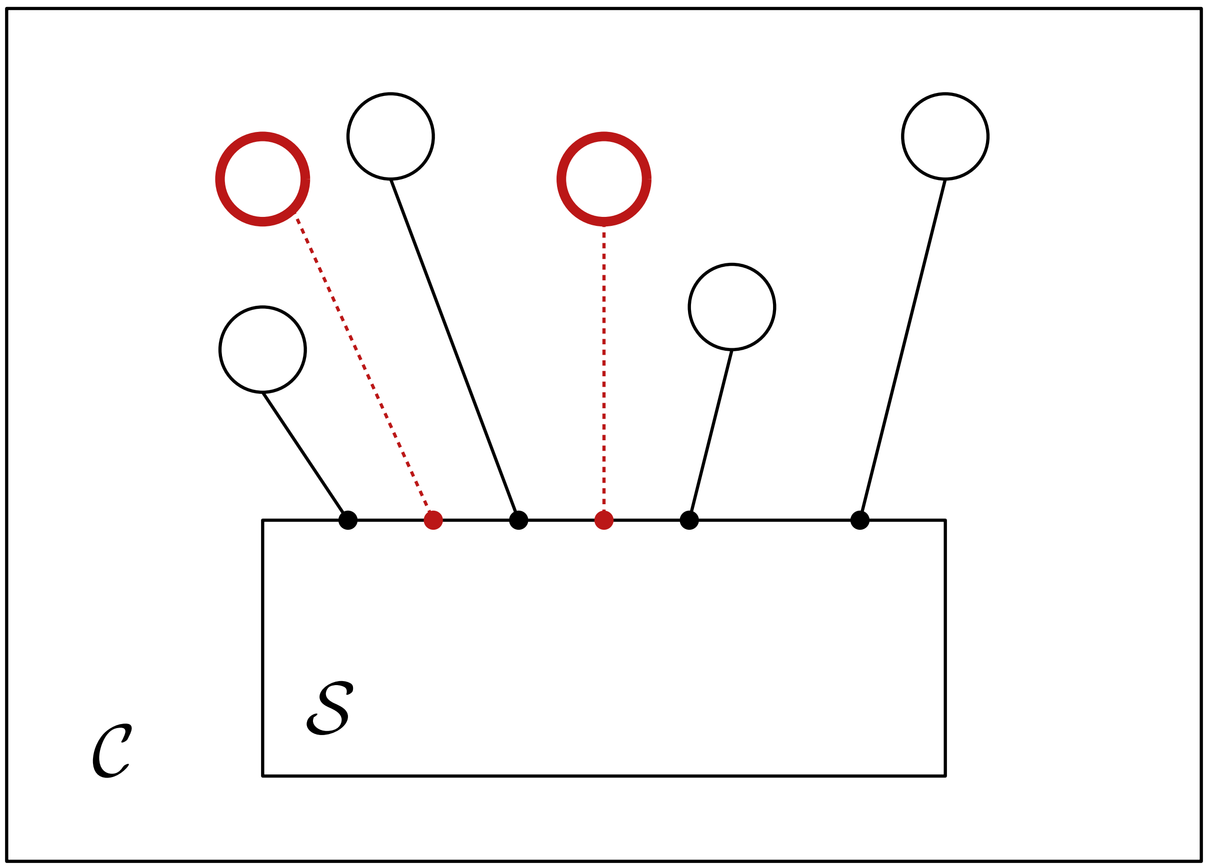

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Allow these nodes as inputs when synthesing replacement

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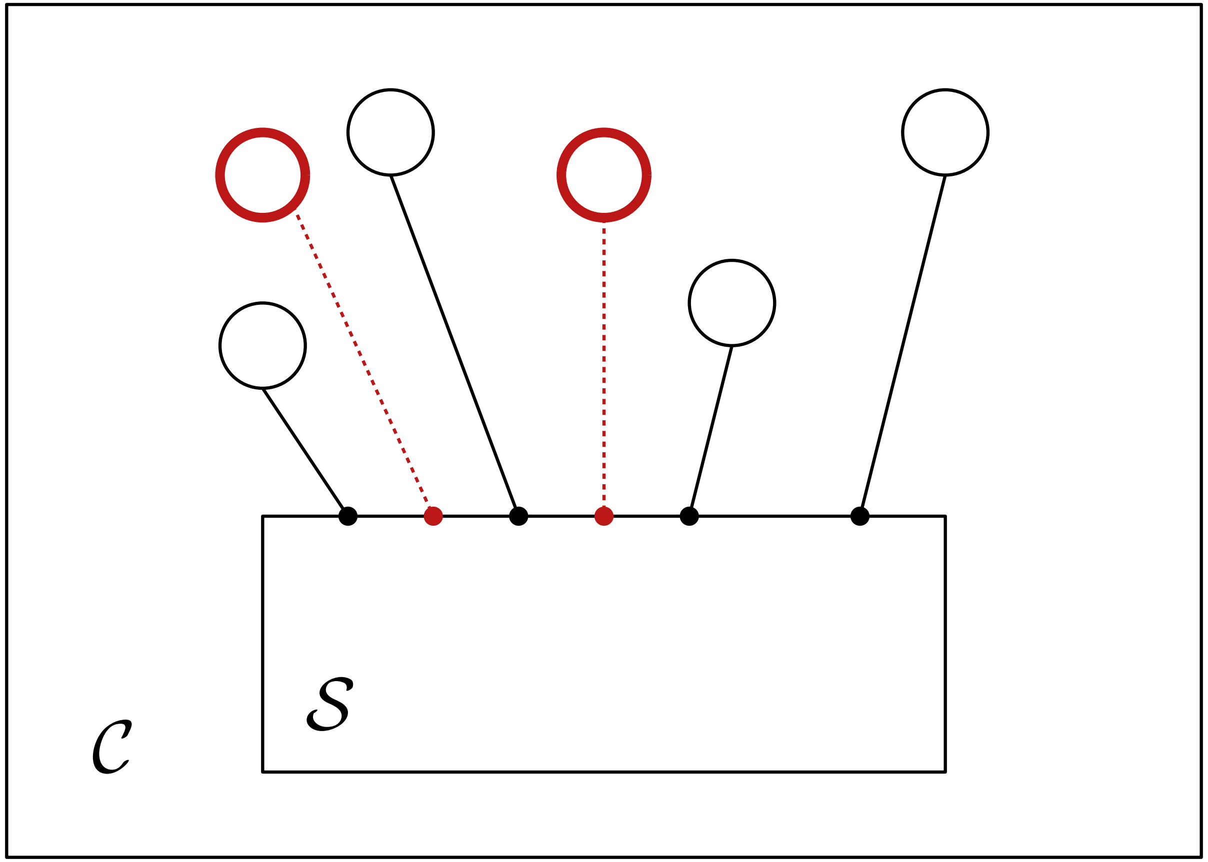

$\mathcal{C}$ can contain nodes with functionality used in $\mathcal{S}$

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Works better with QBF-based synthesis

Availability

- Implemented in our tool eSLIM

  `https://github.com/fxreichl/eSLIM`

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  `https://github.com/fxreichl/eSLIM`

- Integrated within ABC

  Available with the `&eslim` command

  Currently limited to SAT-based approach