# Query Evaluation over SLP-Compressed Data

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HU Berlin

Forschungsvortrag
Magdeburg, 13.11.25

# Outline of My Recent Research Programme

DFG Project: "Query Evaluation over SLP-Compressed Data"

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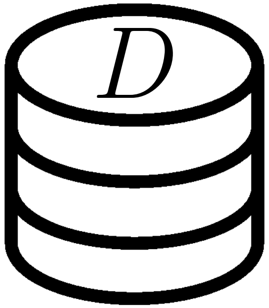


Data(base)

$q$

Query

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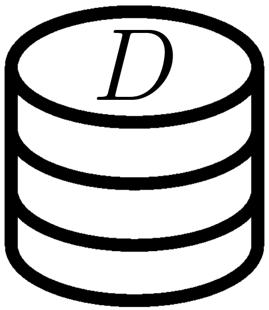

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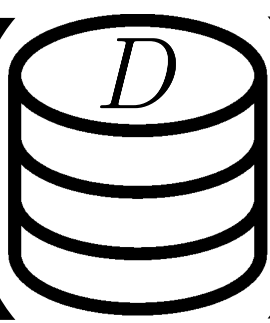
$q\Big($  $\Big) = \{\, t_1, \quad t_2, \quad t_3, \quad t_4, \ldots \,\}$

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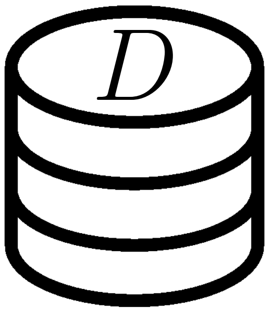


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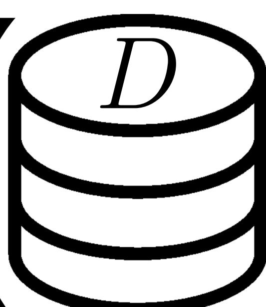
$q\Big($ 

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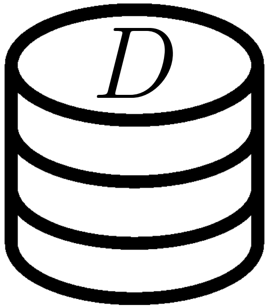


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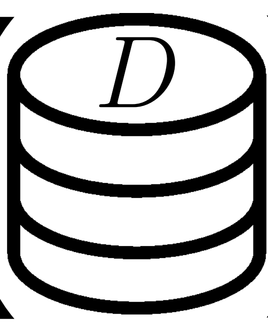
$q\Big($  $\Big) = \{ t_1, \quad t_2, \quad t_3, \quad t_4, \ldots \}$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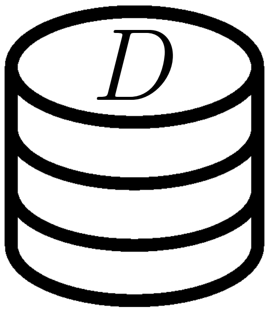


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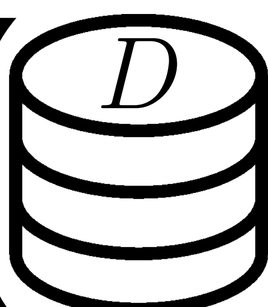
$q$ (   ) $= \{ t_1, \quad t_2, \quad t_3, \quad t_4, \ldots \quad \}$

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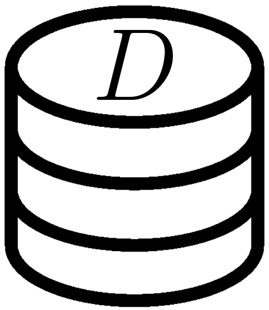


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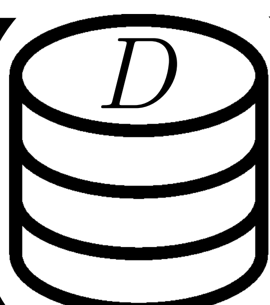
$q\Big($ 

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enumerate

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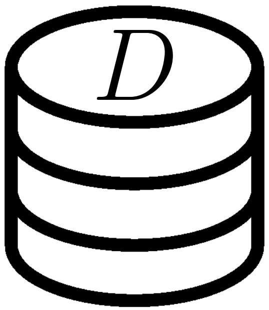


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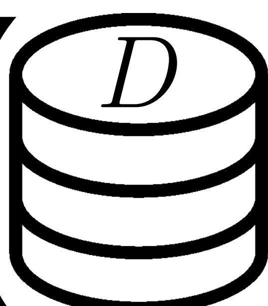
$q$(  )


Query result

Preprocessing

$= \{ t_1, \quad t_2, \quad t_3, \quad t_4, \ldots \}$

delay delay delay

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Preprocessing: linear in $|D|$ Delay: Independent from $|D|$

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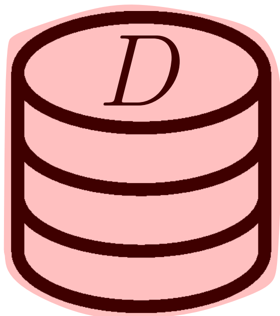


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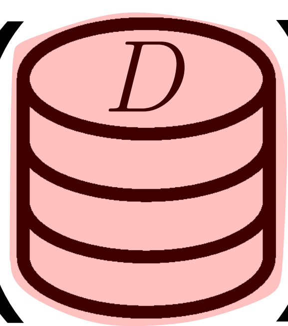
$q($

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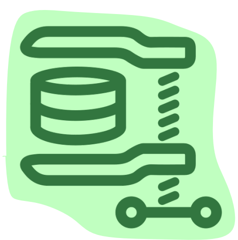

Compressed data

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Algorithm B

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Algorithm $B$ might outperform algorithm $A$ on strongly compressible instances!

We will survey three results about query enumeration over SLP-compressed data.

| | Query class | Data domain |
|---|---|---|
| (1) | Document spanners | Strings |
| (2) | MSO-queries | Node-labelled unranked forests |
| (3) | FO-queries | Relational structures of bounded degree |

## Querying Compressed Strings, Trees, and Relational Data

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Note: We measure algorithmic performance in data complexity. This means that the size of the query is constant.

# The Compression Scheme

We need a compression scheme that ...

- ... is lossless.
- ... is versatile, i.e., we can use it for different data domains.
- ... potentially achieves very strong compression.
- ... is suitable for algorithmics on compressed inputs.
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## Data Domain: Strings

Data: $\mathtt{a\,a\,b\,b\,a\,b\,a\,a\,b\,a\,a\,b\,b\,a\,b}$

Compression: $S \to C\,B\,C, \quad B \to \mathtt{a}\,A$

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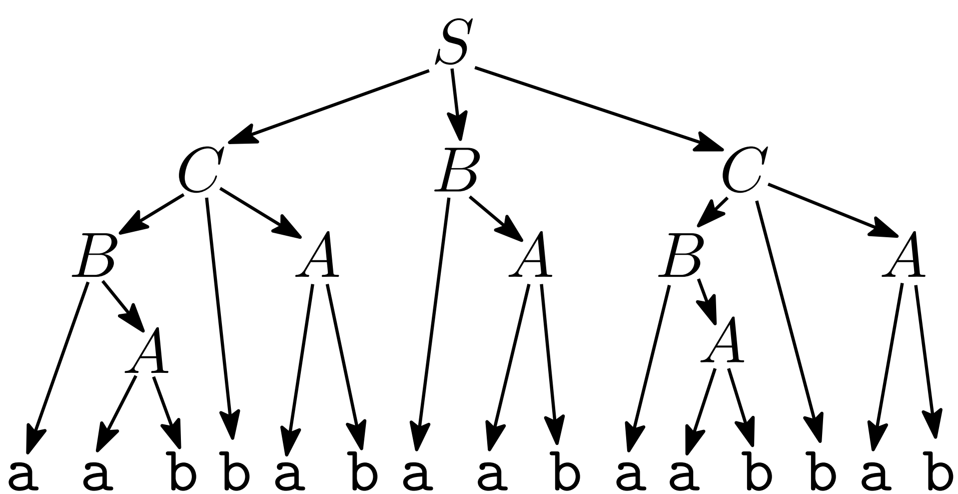

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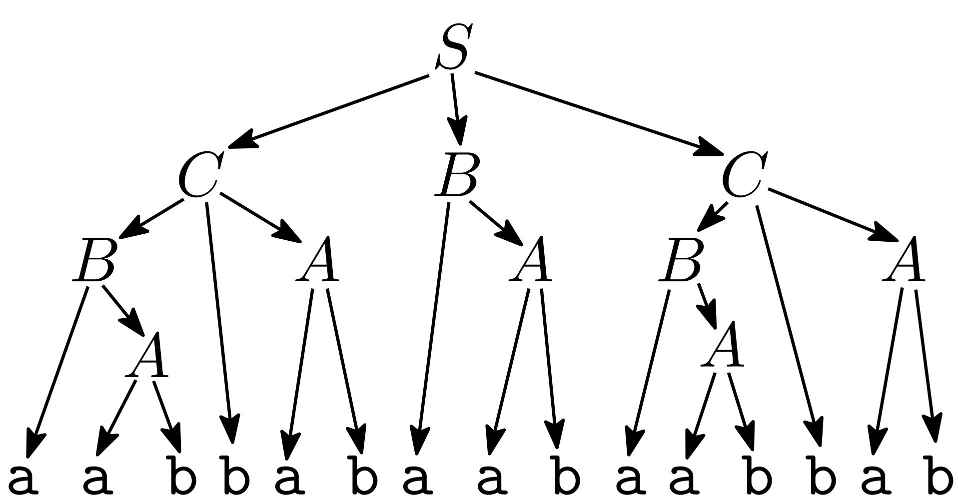


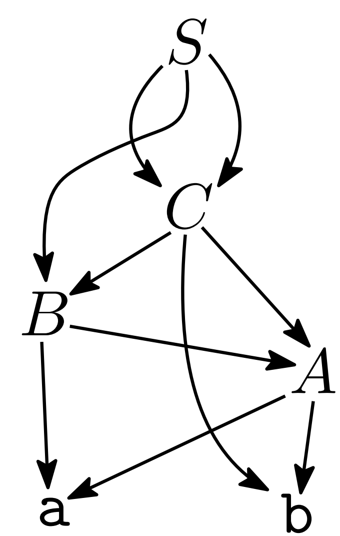

# String-SLPs - State of the Art

String-SLPs are very popular and have several good properties.

- exponential compression in the best case.
- tightly related to dictionary based compression, in particular LZ77 and LZ78.
- there are many fast compression algorithms that achieve excellent compression in practice.
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New angle and challenge: Extend known techniques ...

- ... to the query evaluation perspective.
- ... to the enumeration perspective.

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**Theorem:**

Given a document spanner $q$,
a string D,
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Given a document spanner $q$,
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## Data Domain: Trees and Forests

# Straight-Line Programs for Trees

Recall string-SLPs:
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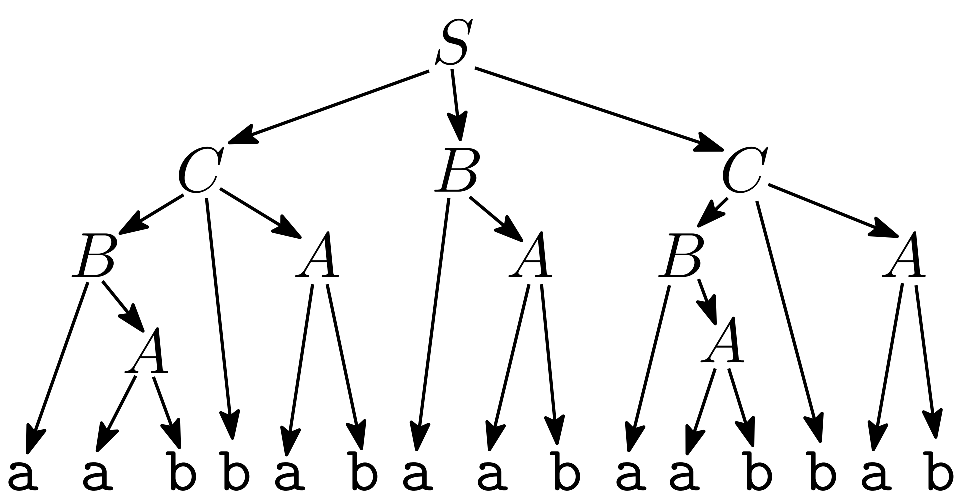


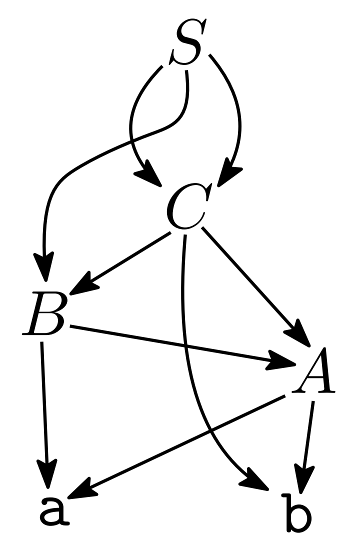

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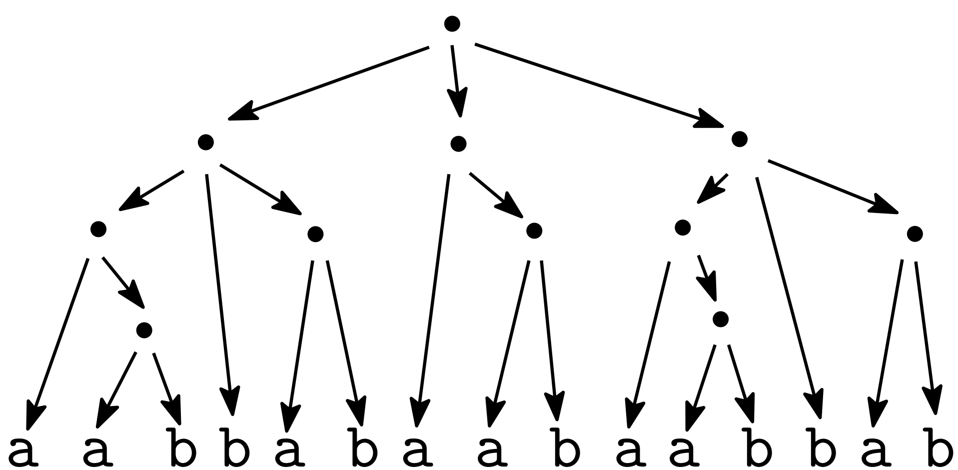


Expression over the monoid $(\Sigma^*, \cdot)$

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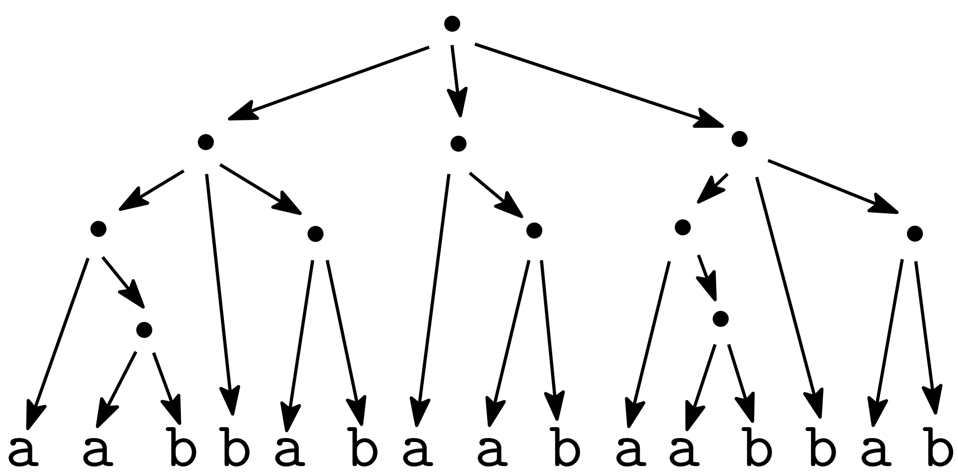
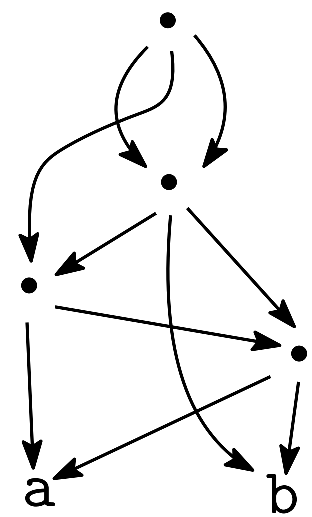



Expression over the monoid $(\Sigma^*, \cdot)$




Circuit over the monoid $(\Sigma^*, \cdot)$

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[Gascón et al., ToCS 2020]

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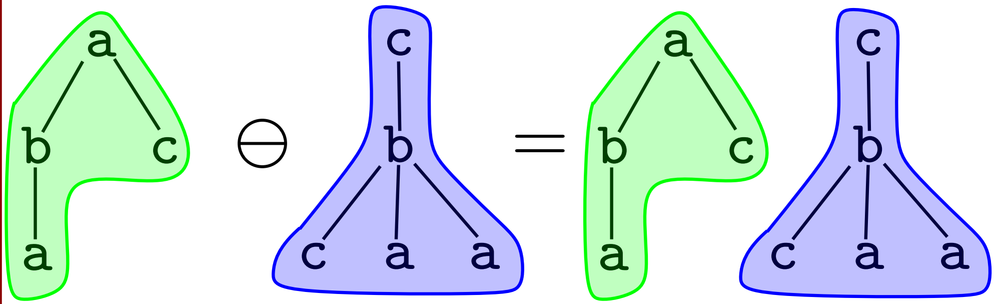
Horizontal concatenation $\ominus$



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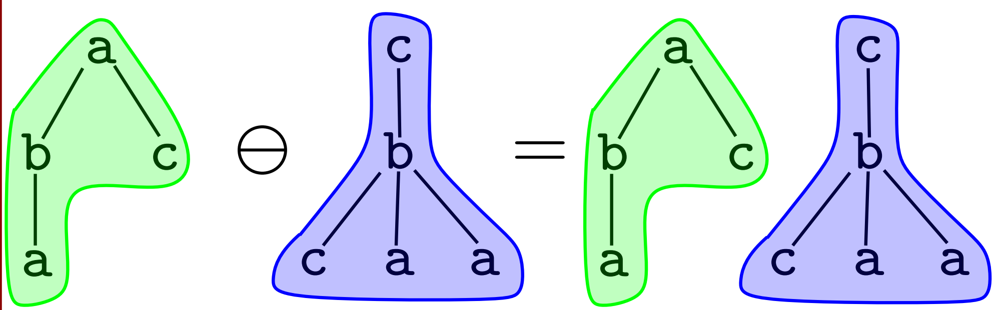
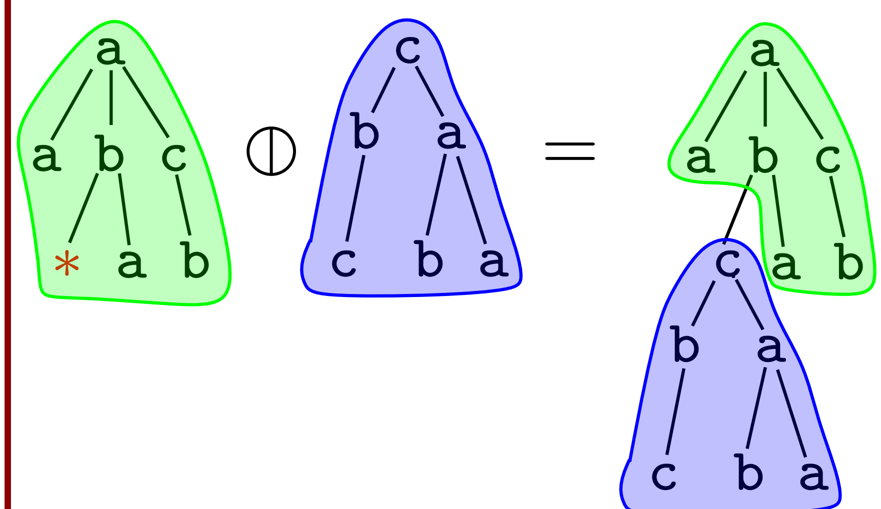


Vertical concatenation $\obar$



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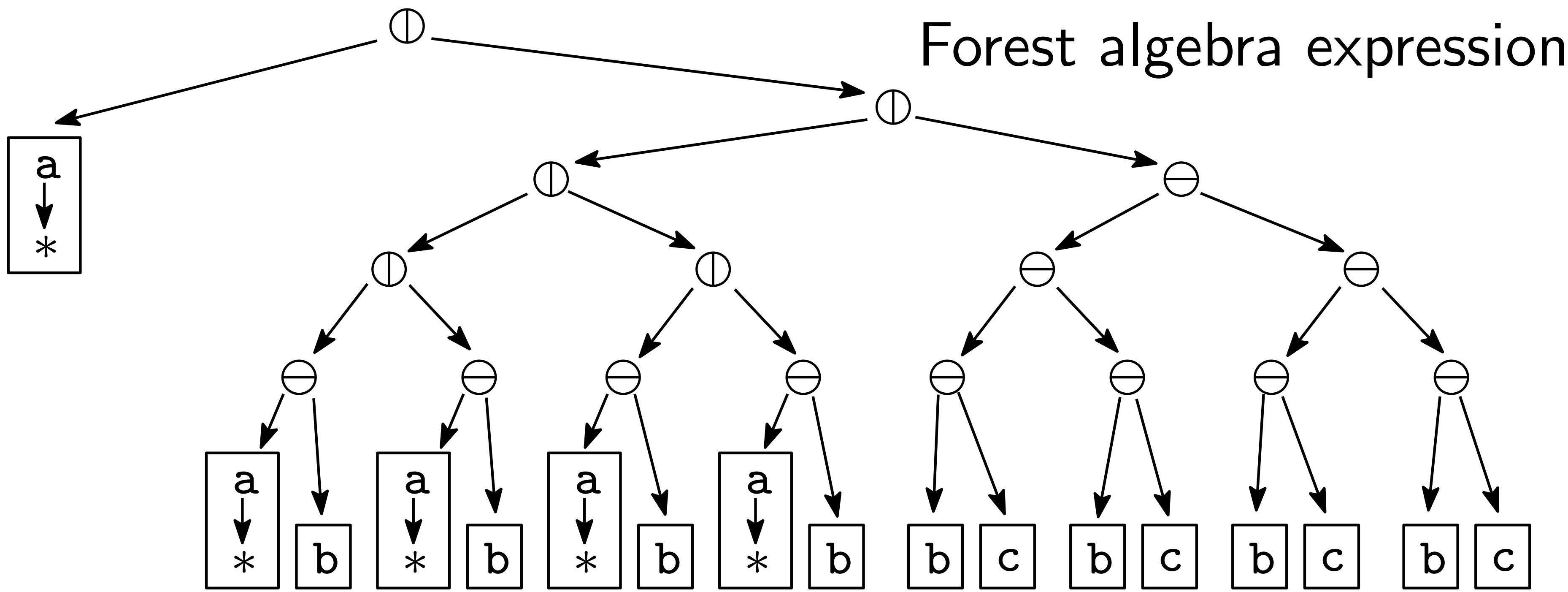

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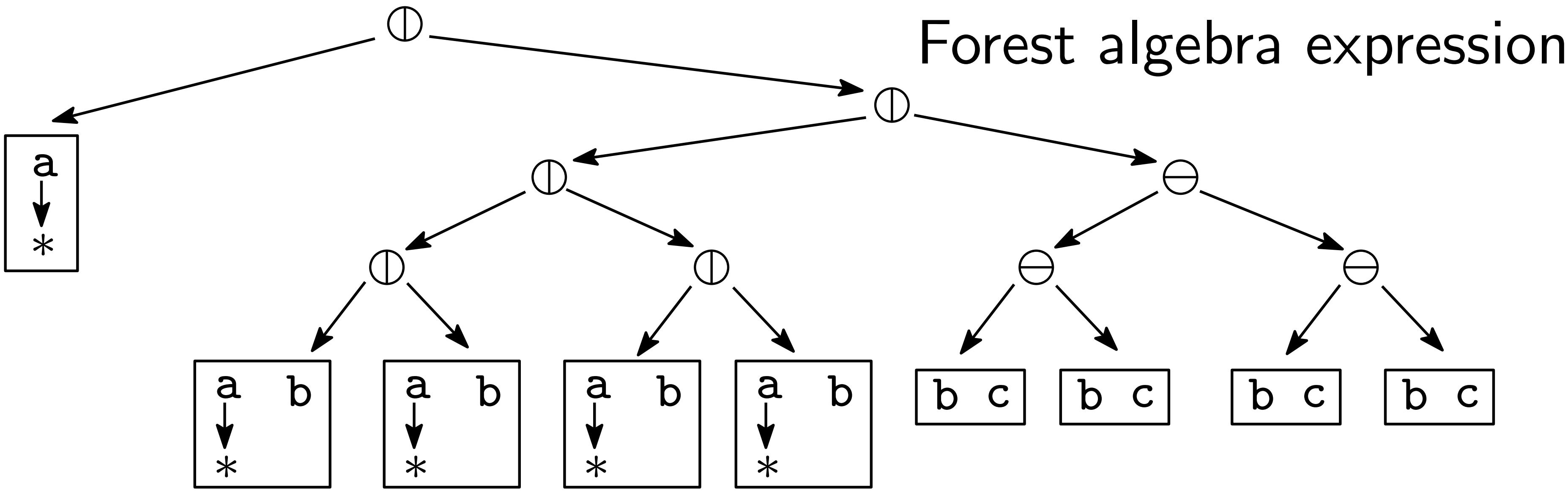

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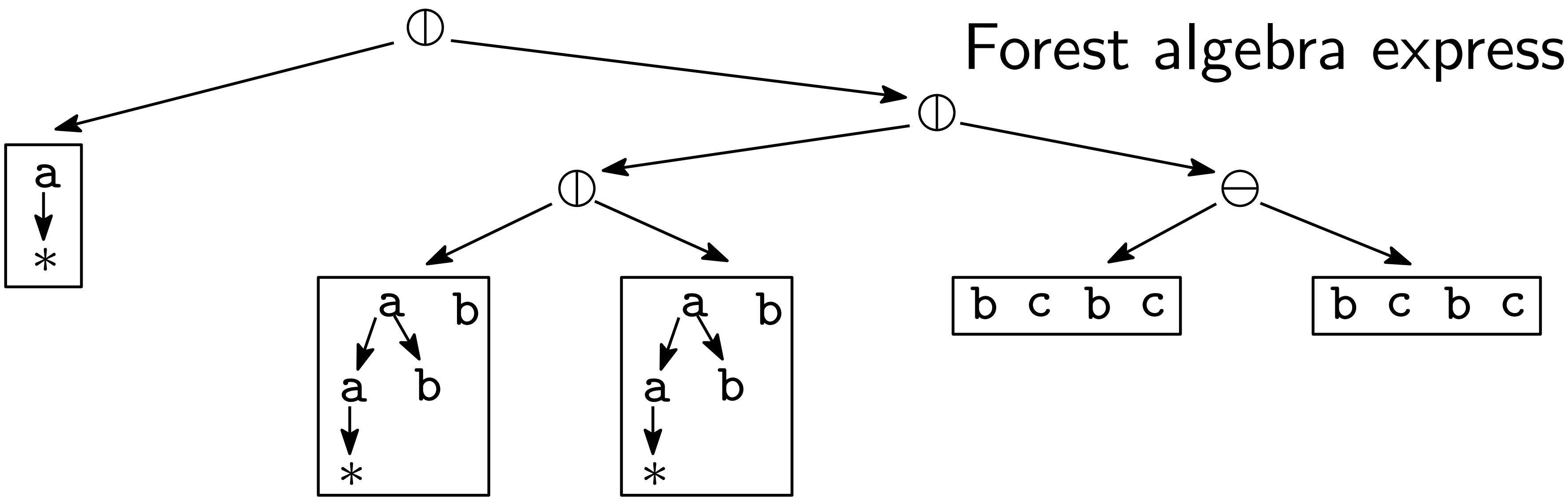
Forest algebra expression



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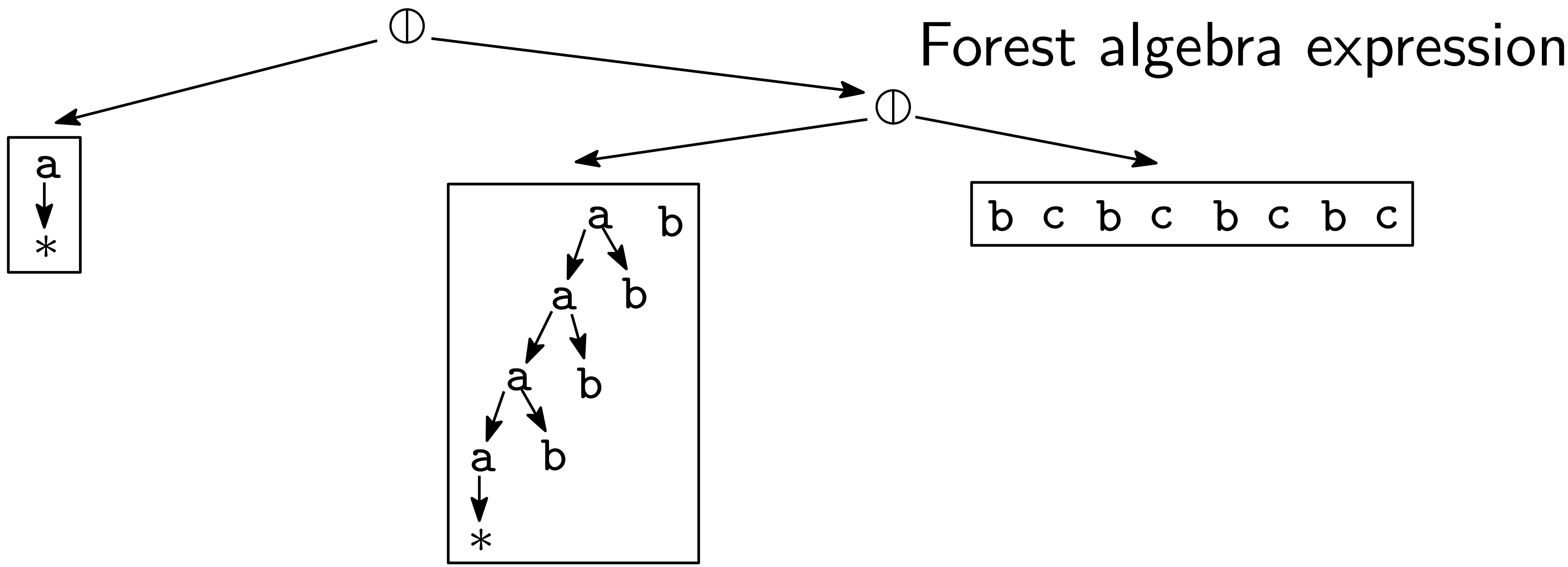

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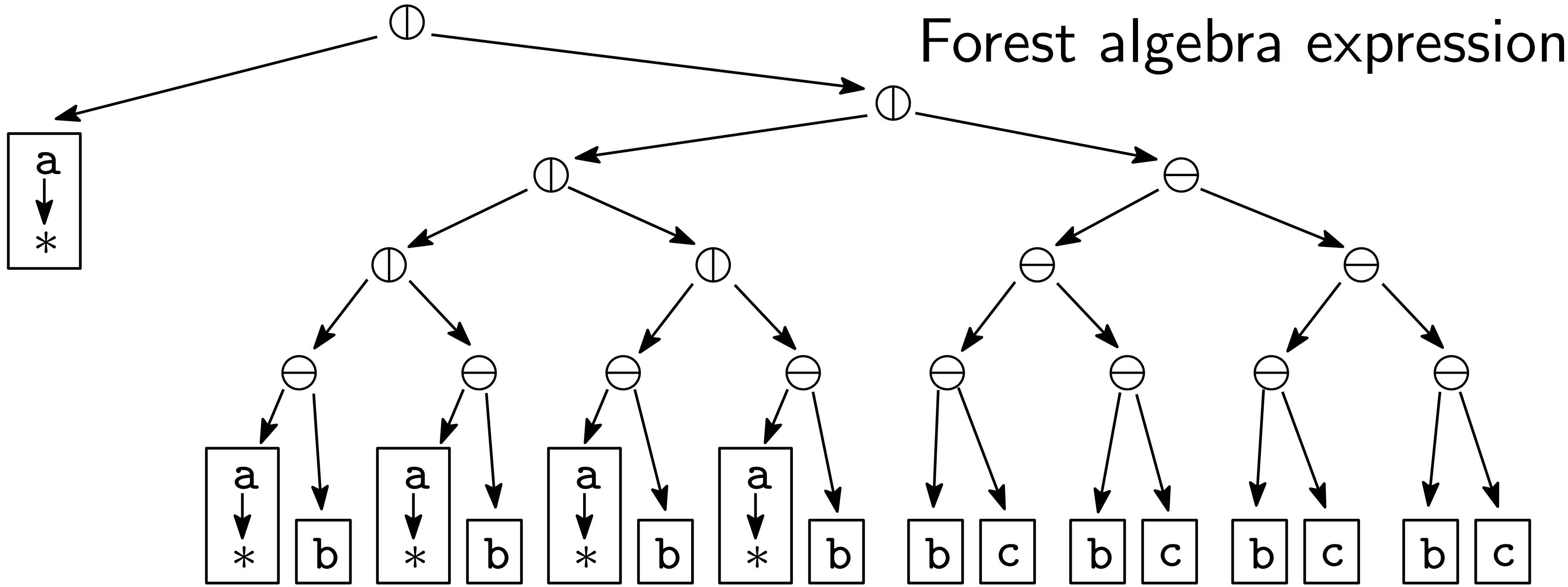

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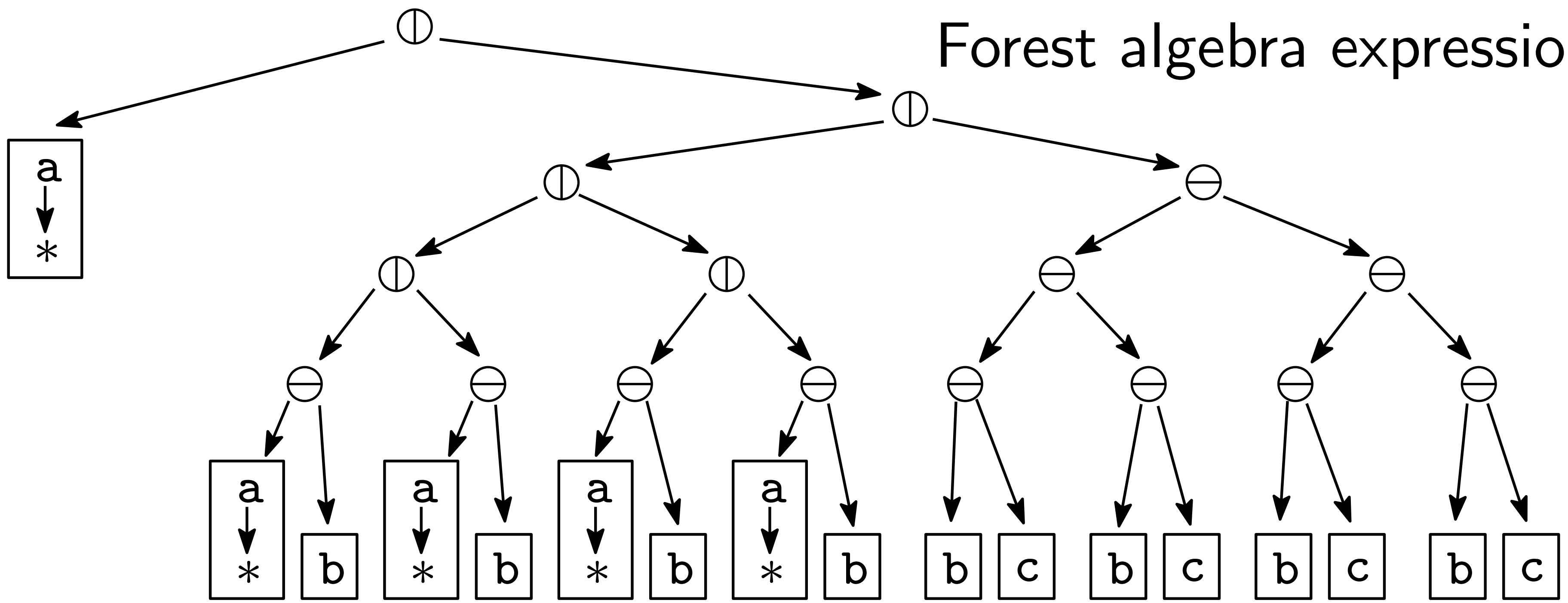


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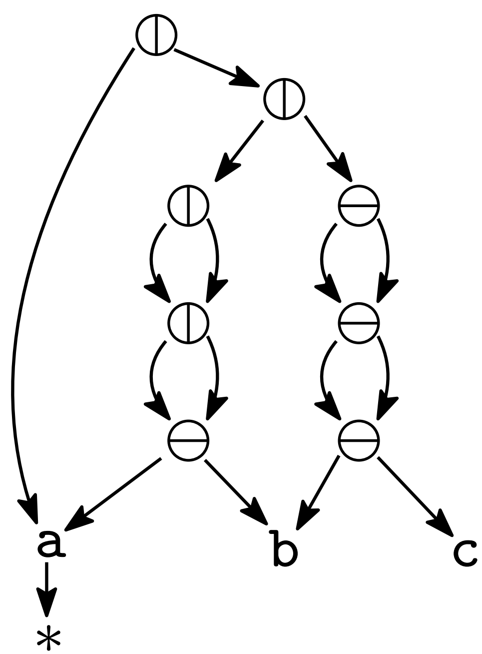


Forest SLP

# MSO Enumeration Over SLP-Compressed Forests

Queries in monadic second order logic (MSO-queries)

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Example: Query all $(x, Z)$ from a tree such that $x$ is a red node, $Z$ is the set of $x$'s children and all nodes of $Z$ are blue.

$$q(x, Z) = \mathsf{red}(x) \wedge (\forall y \in Z : \mathsf{blue}(y)) \wedge (\forall y : y \in Z \iff \mathsf{child}(x, y))$$

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Theorem:

Given an MSO query $q(X_1, \ldots, X_m)$,
a node-labelled unranked forest F,
after preprocessing $O(|F|)$, we can enumerate $q(F)$ with output linear delay.

[Bagan, CSL 2006]

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# Data Domain: Relational Data

# Straight-Line Programs for Relational Structures

Relational structure: $(\mathcal{U}, R_1, R_2, \ldots, R_m)$

finite universe

relations over $\mathcal{U}$

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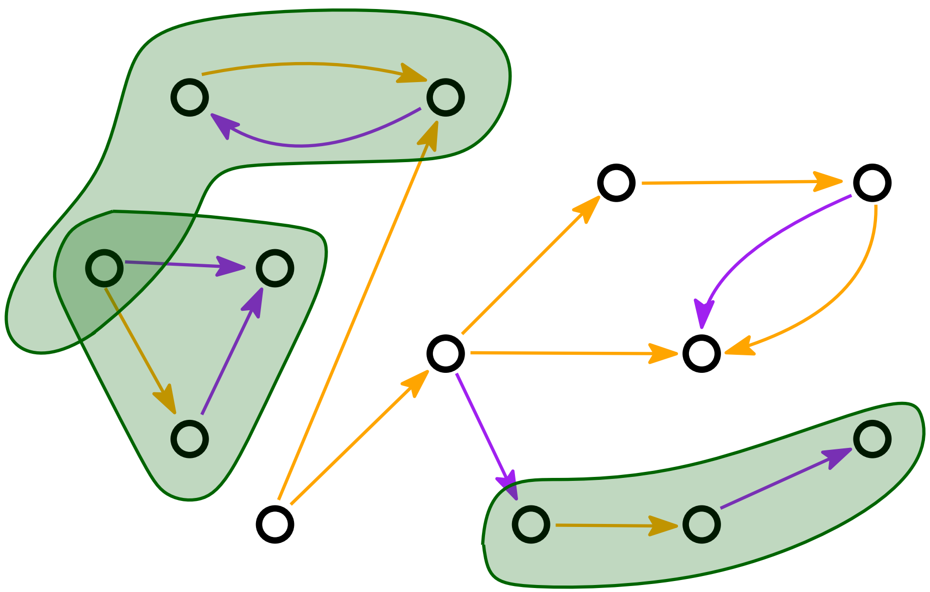

$\mathcal{U}$ has $13$ distinct elements.

$R_1$ has arity $2$.

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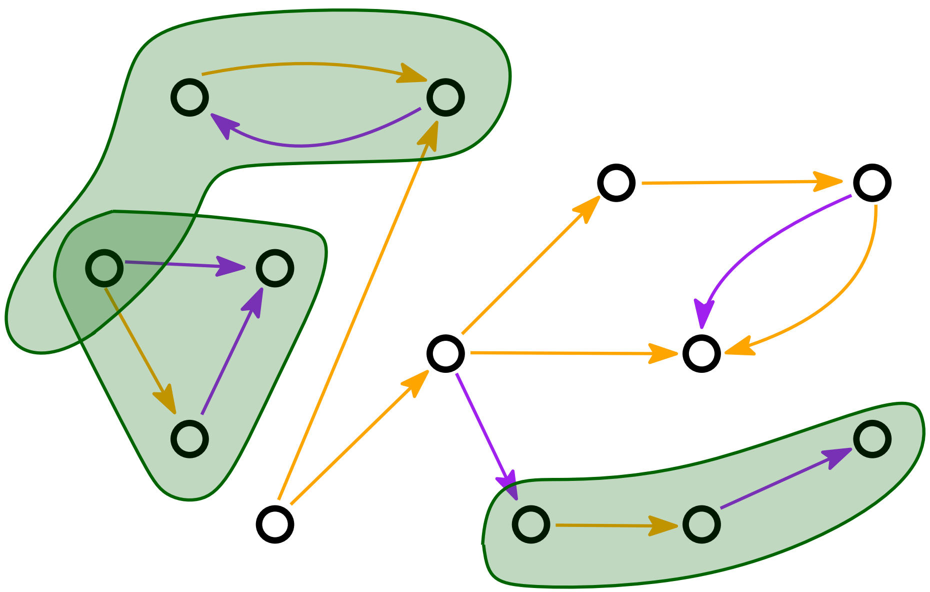

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Relational straight-line programs: SLPs based on hyper-edge replacement grammars.

[Lengauer, Wanke, SICOMP 1988]

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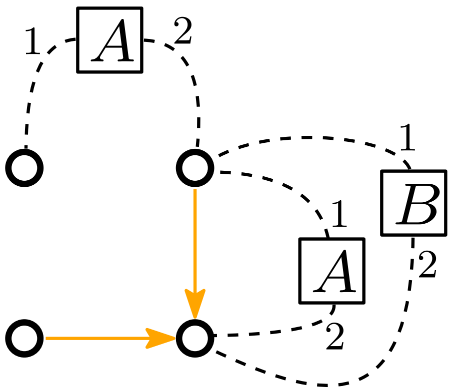
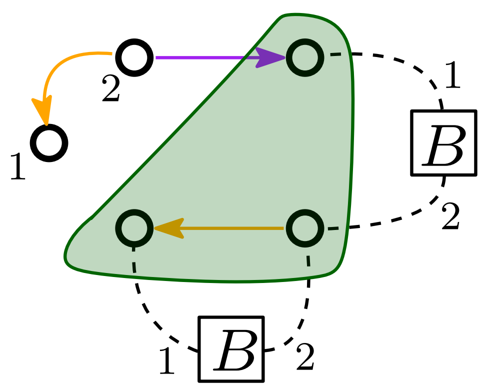
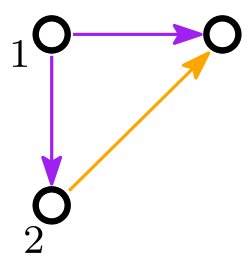
$S \longrightarrow$ 


$A \longrightarrow$ 


$B \longrightarrow$ 

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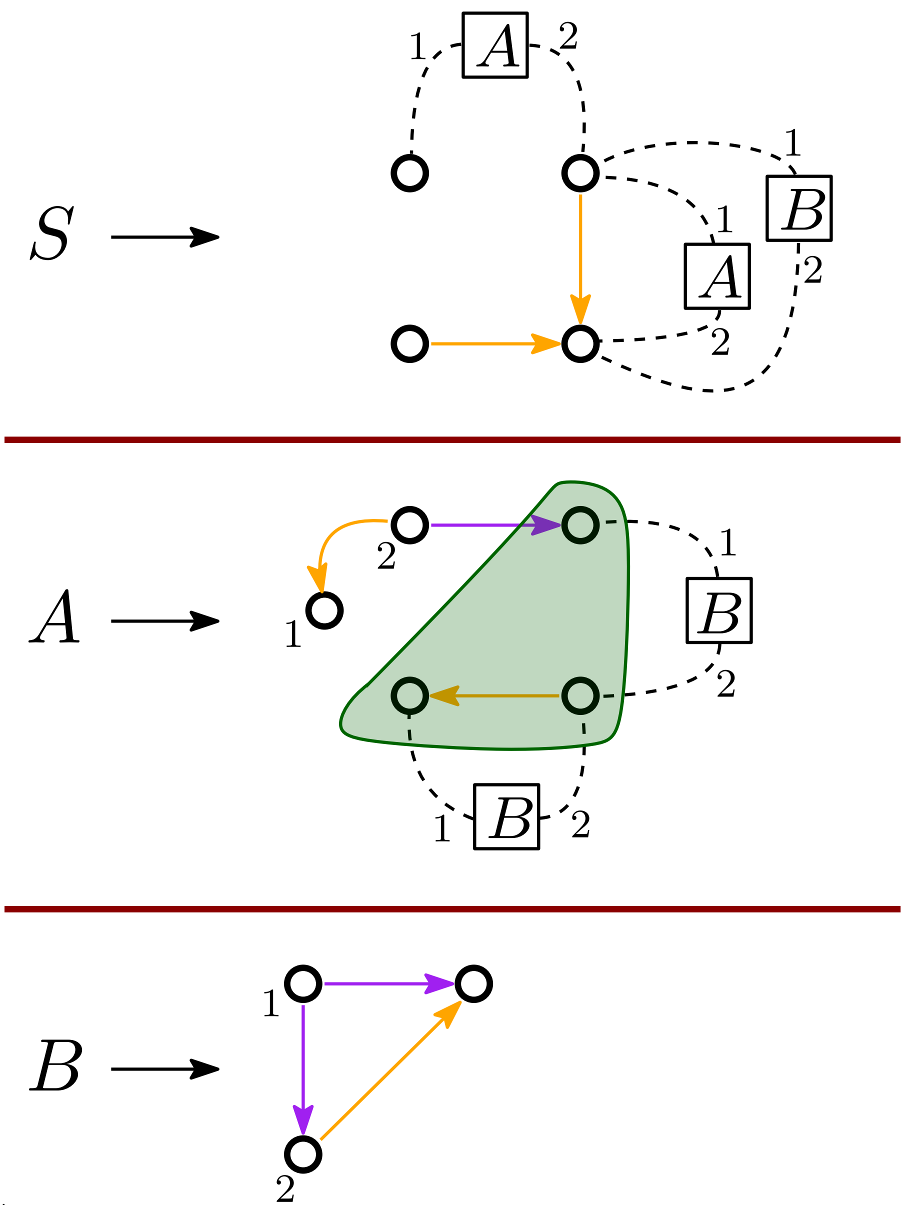


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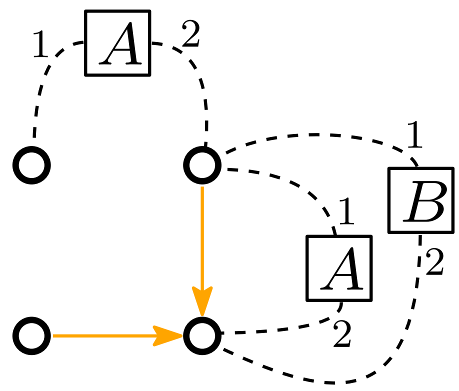

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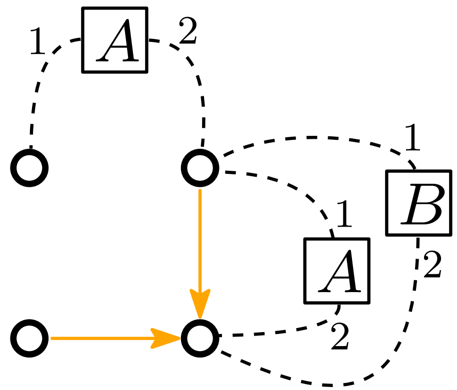


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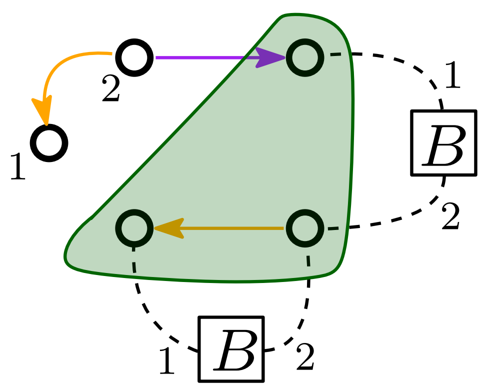


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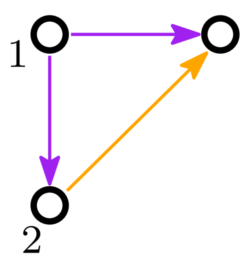


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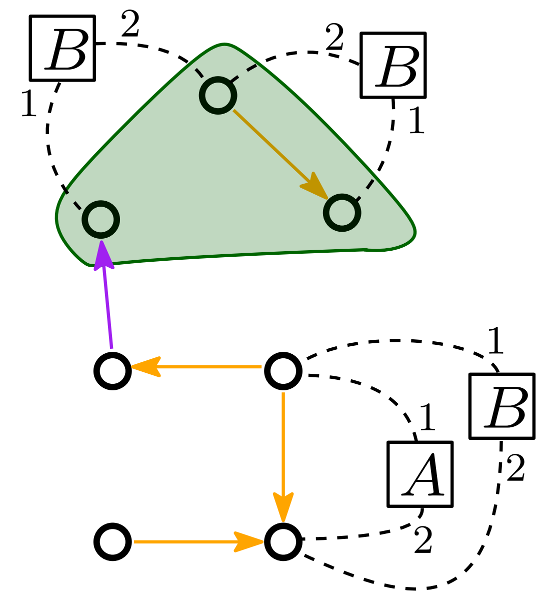

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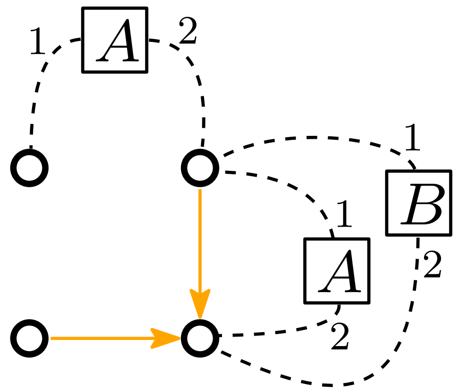


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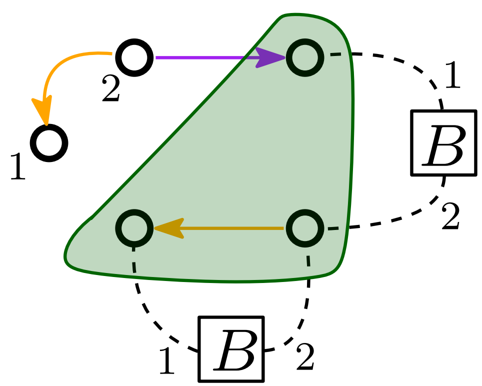


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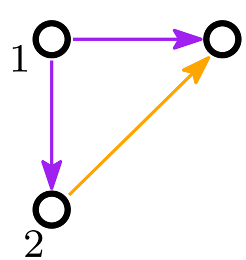


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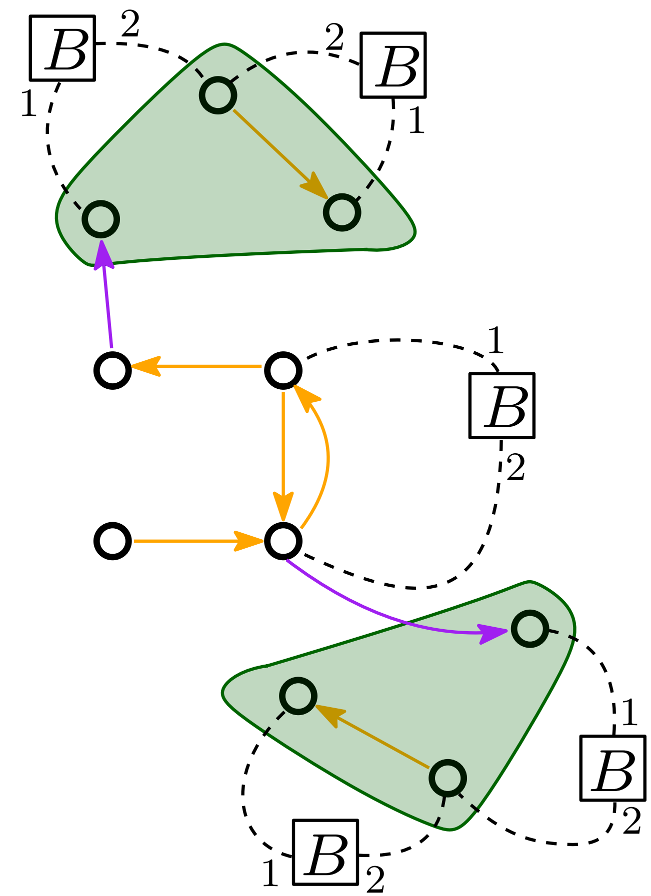

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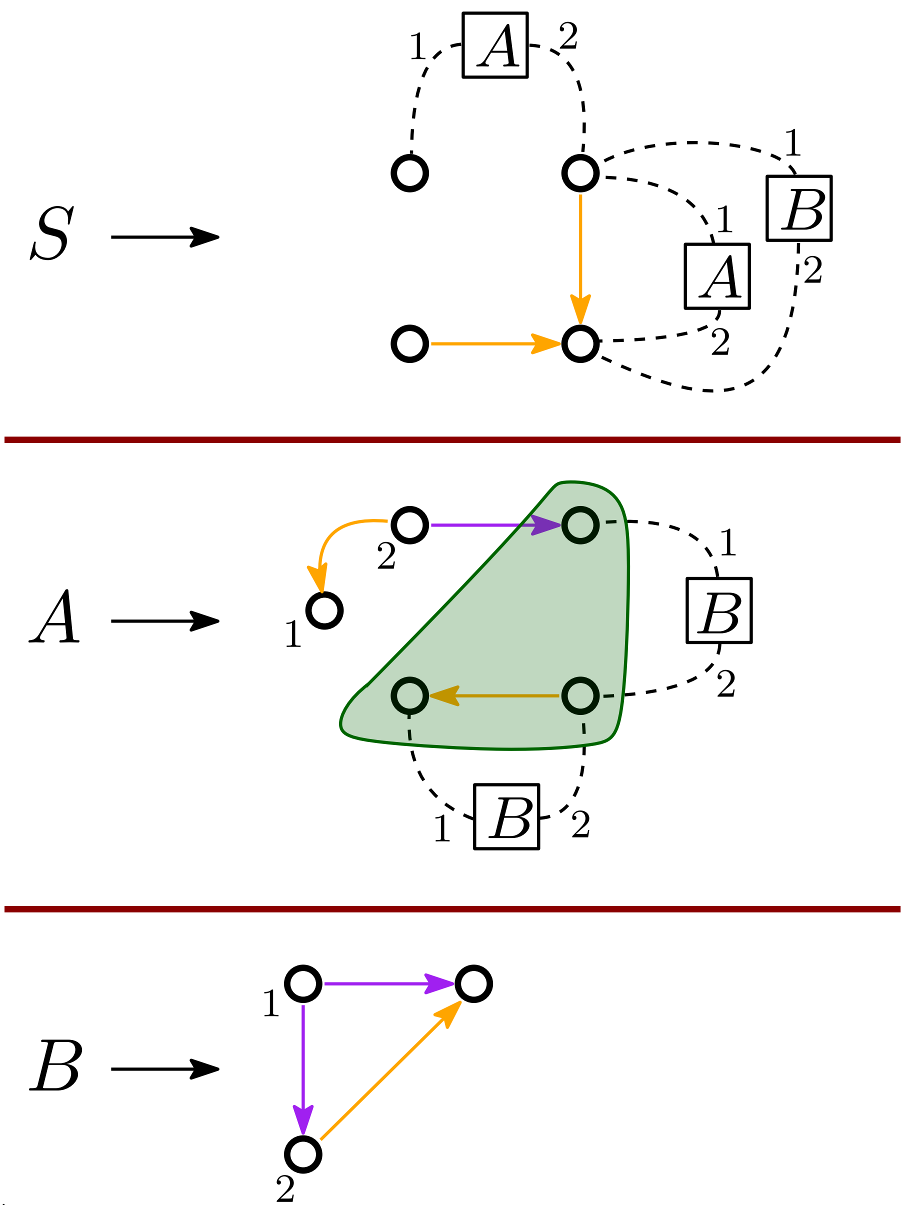


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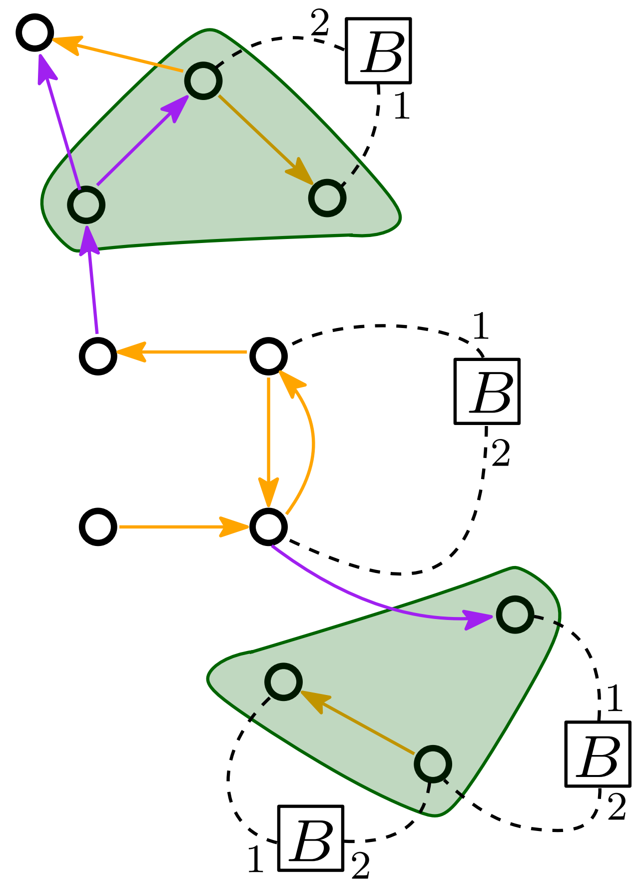

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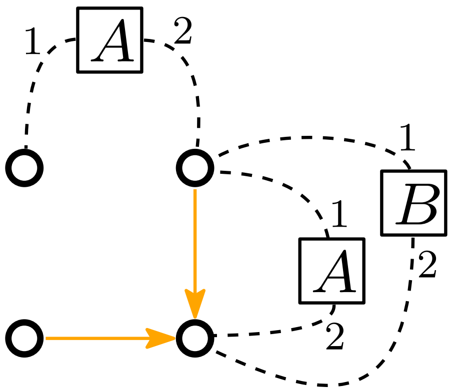


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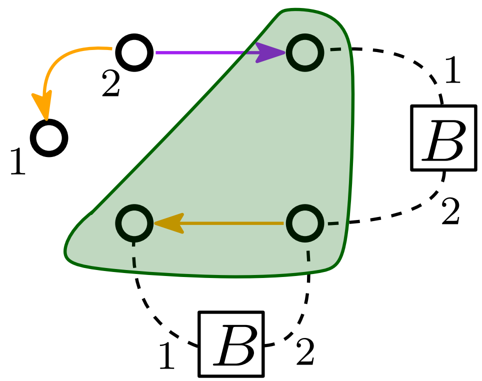


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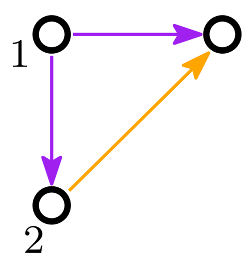


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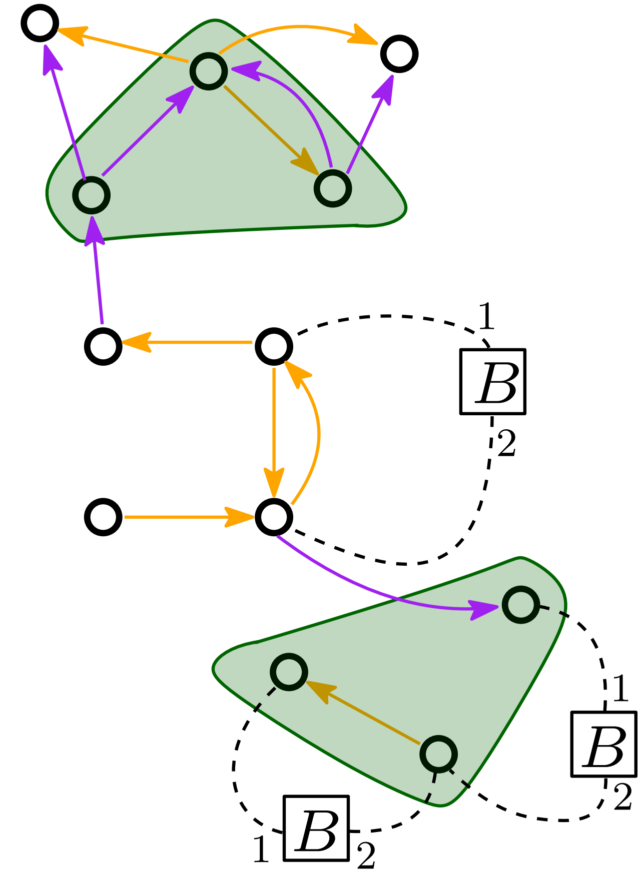

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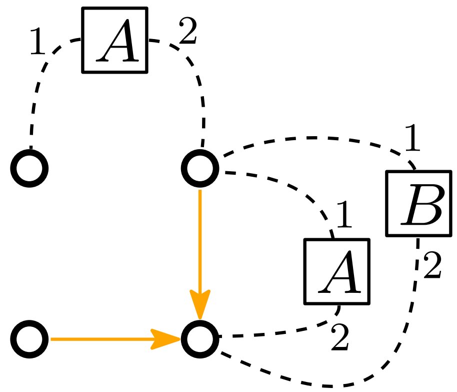


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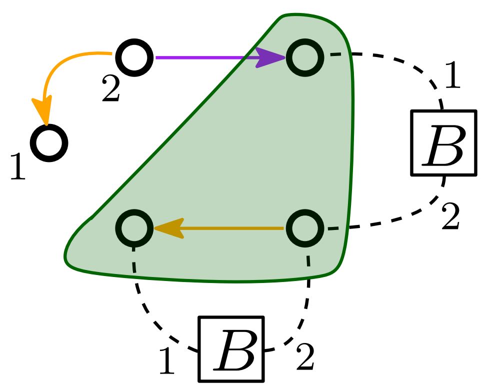


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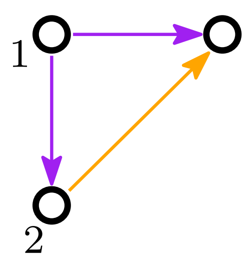


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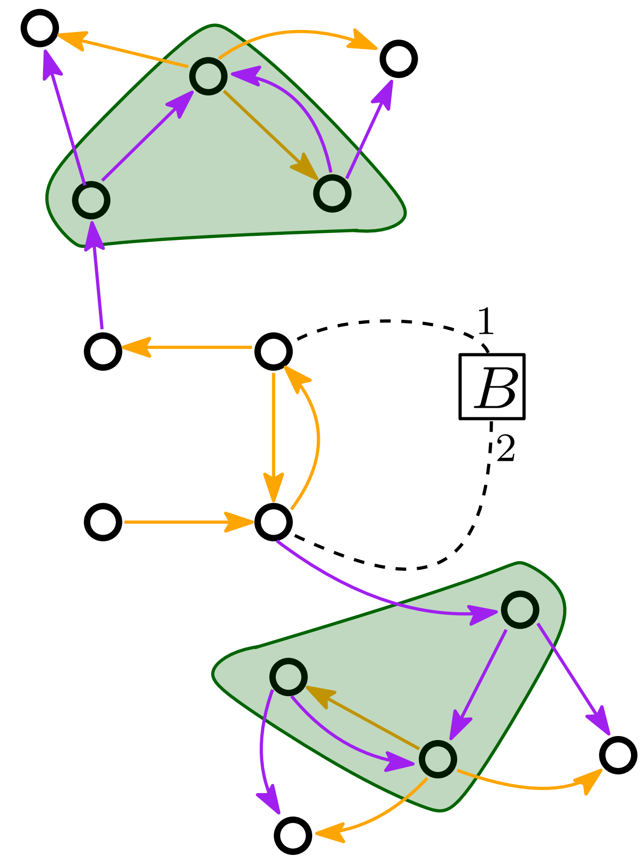

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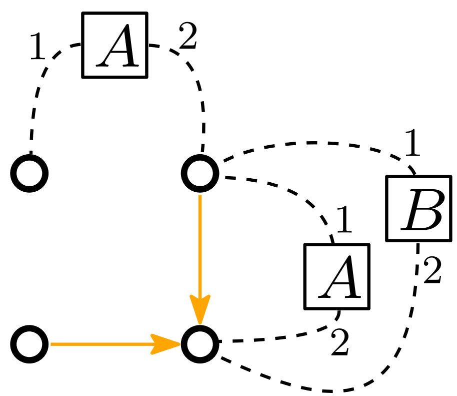


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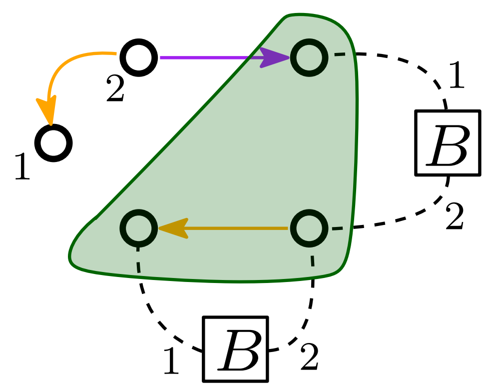


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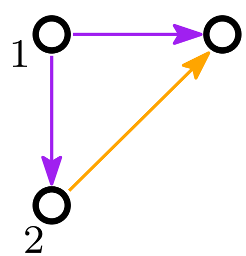


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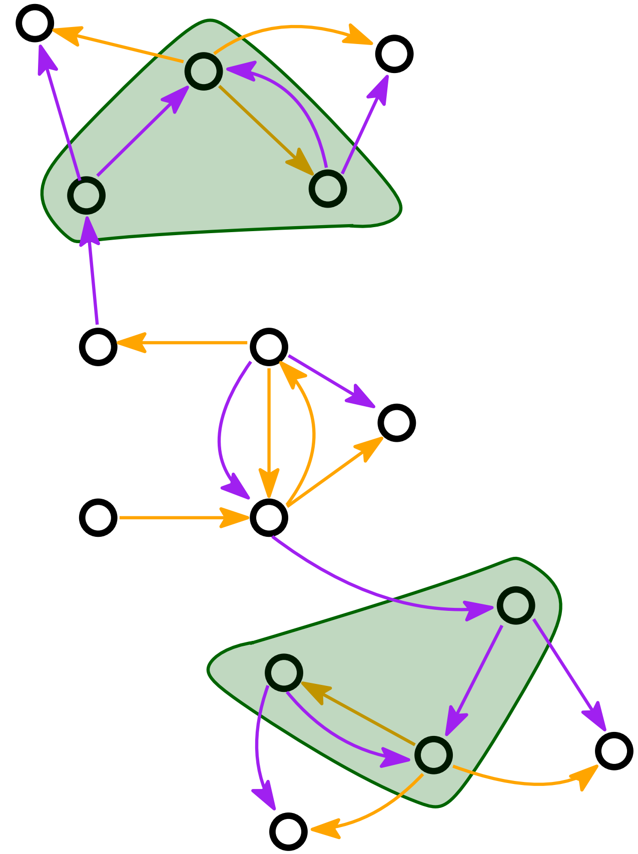

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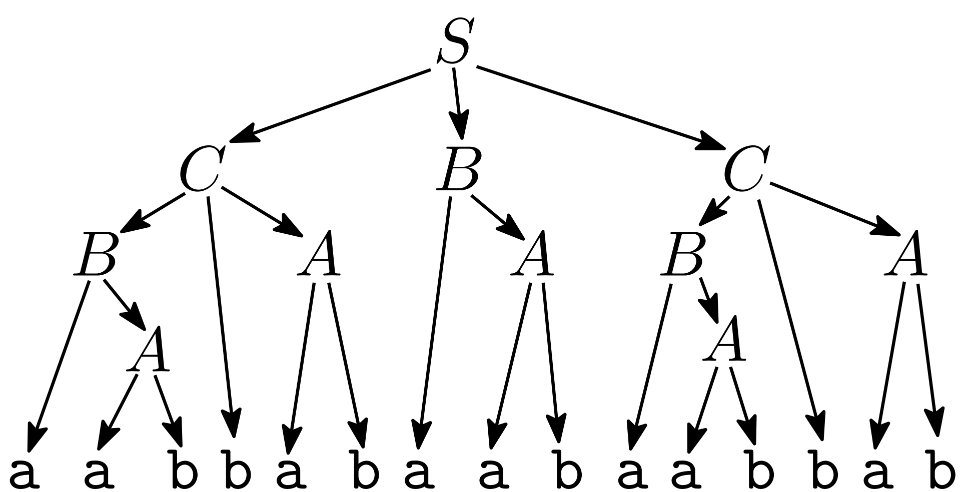


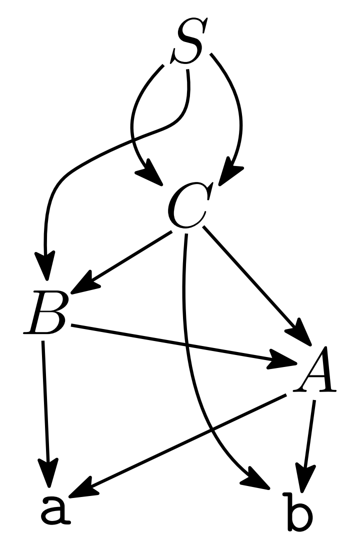

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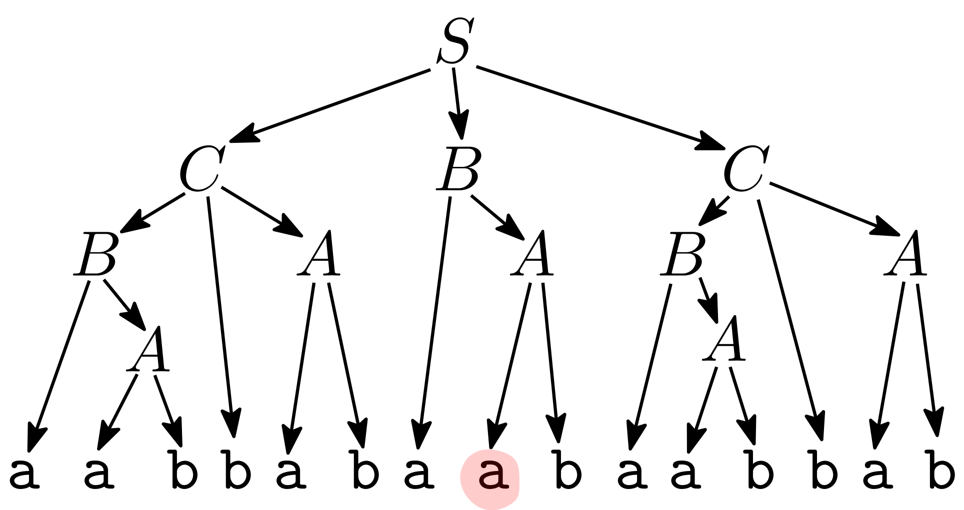


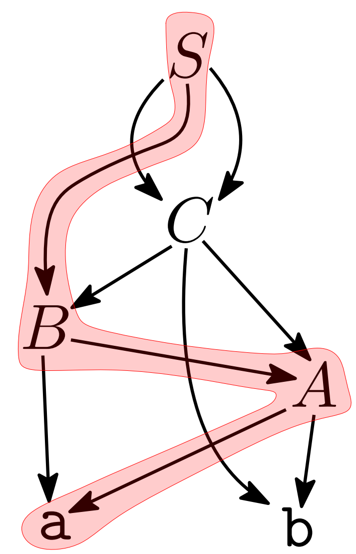

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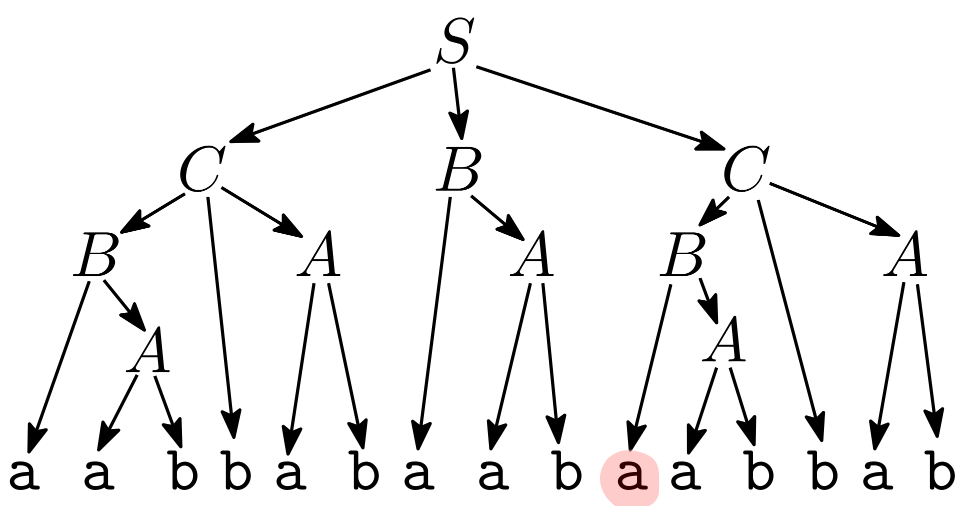


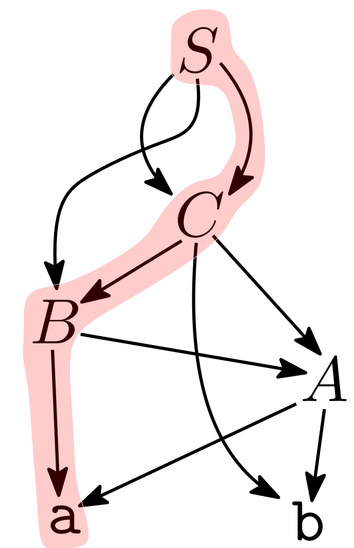

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