# Faster Repetition-Aware Compressed Suffix Trees based on Block Trees

Manuel Cáceres / Gonzalo Navarro

SPIRE

09/09/2019

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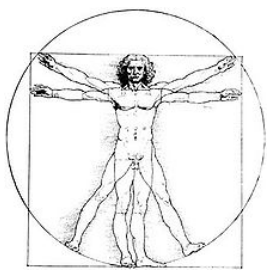
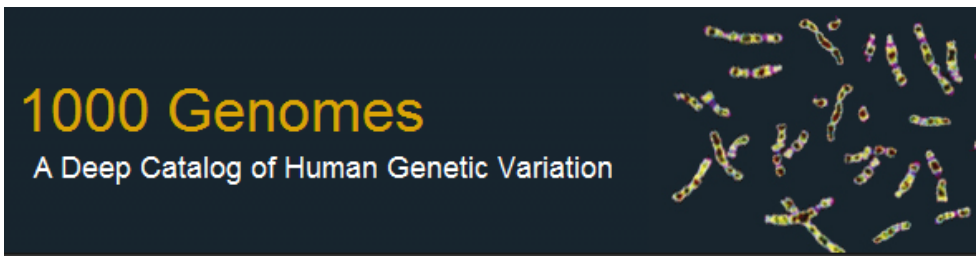
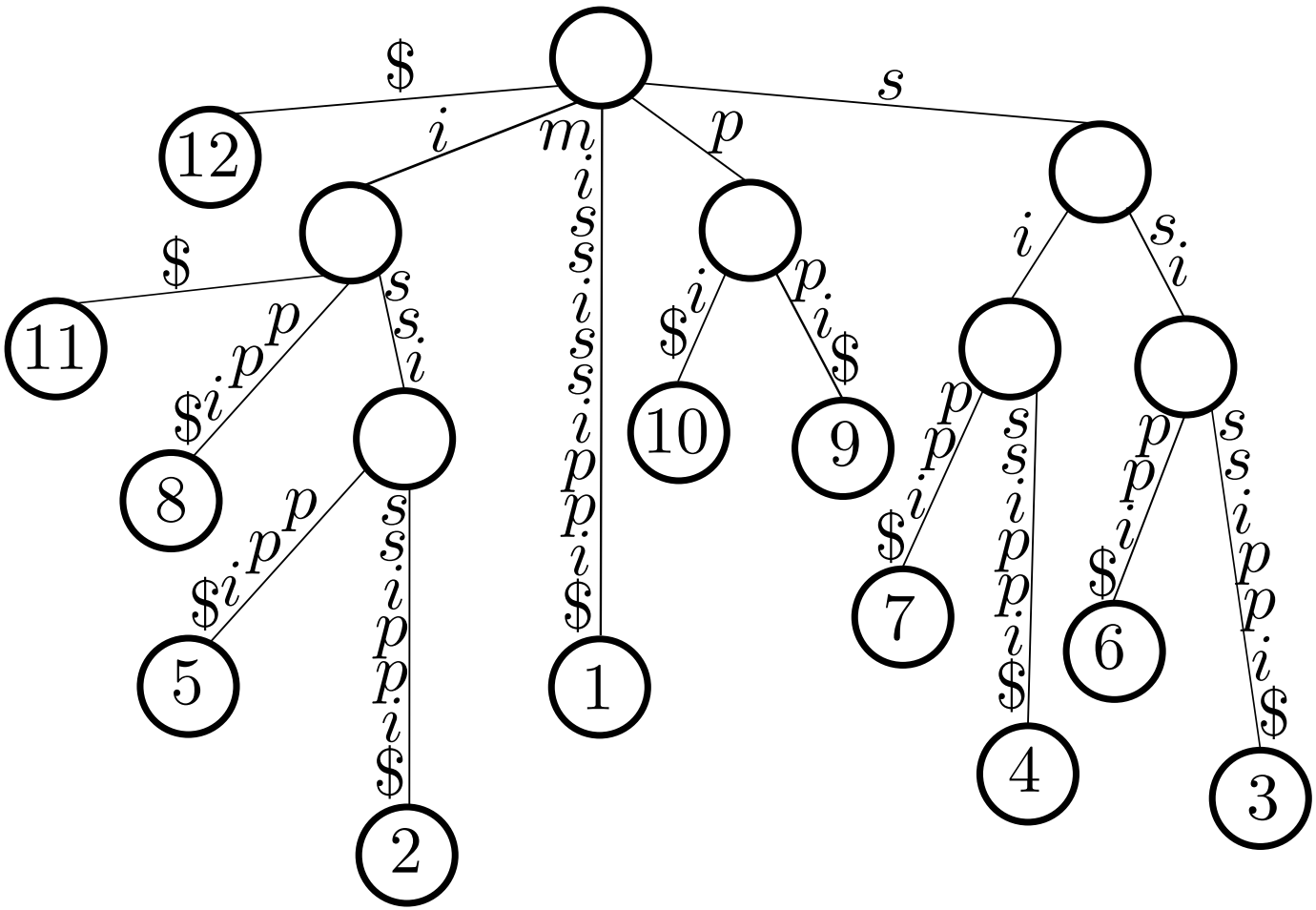





# Suffix Tree

$$T = mississippi\$$$



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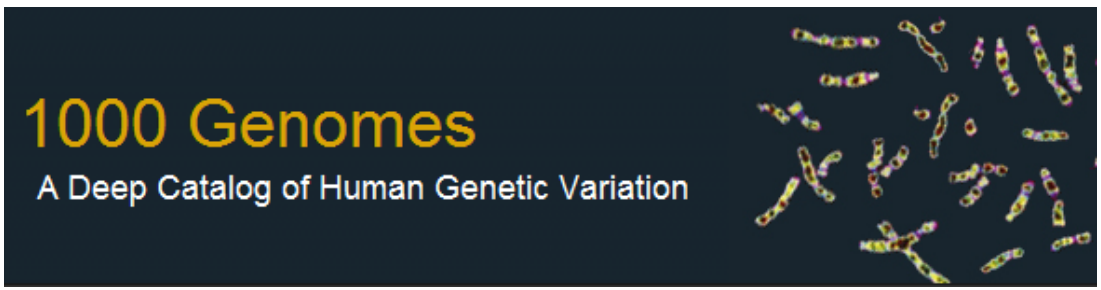


$\sim 30TB$

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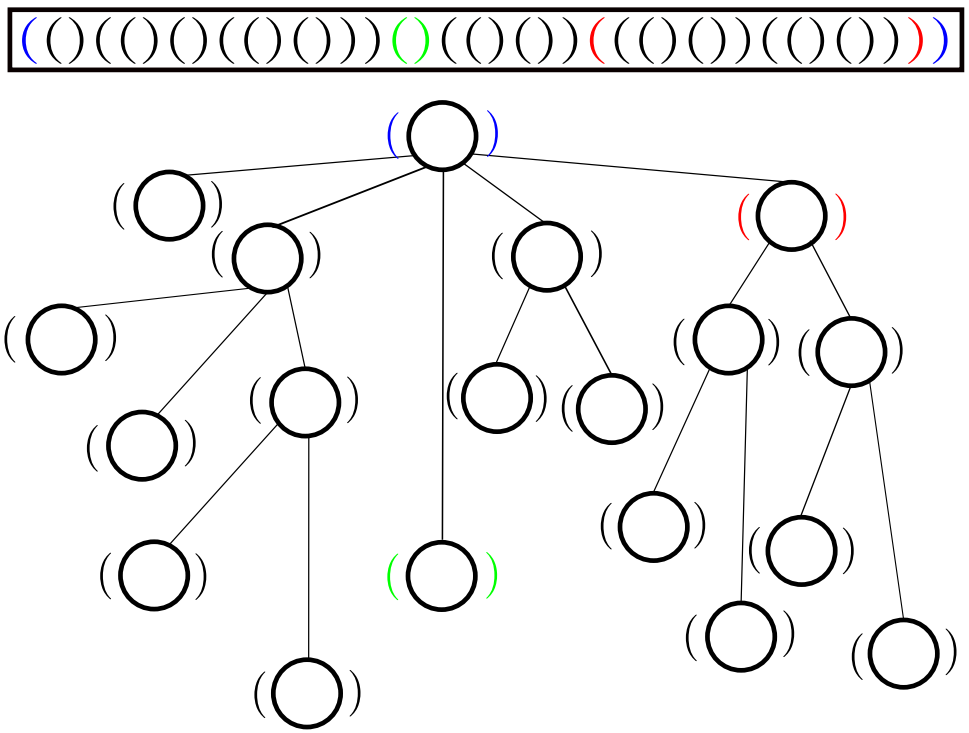
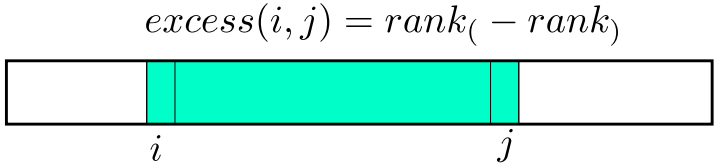
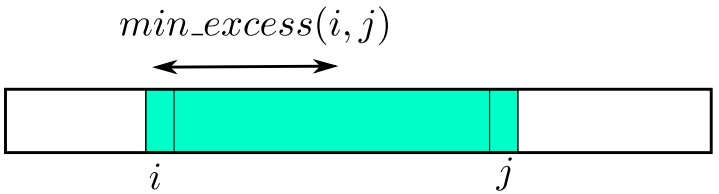
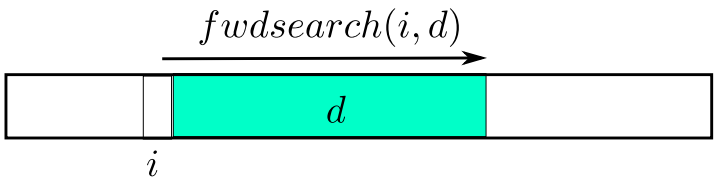
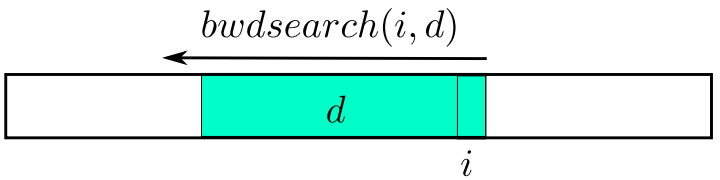


# Primitives

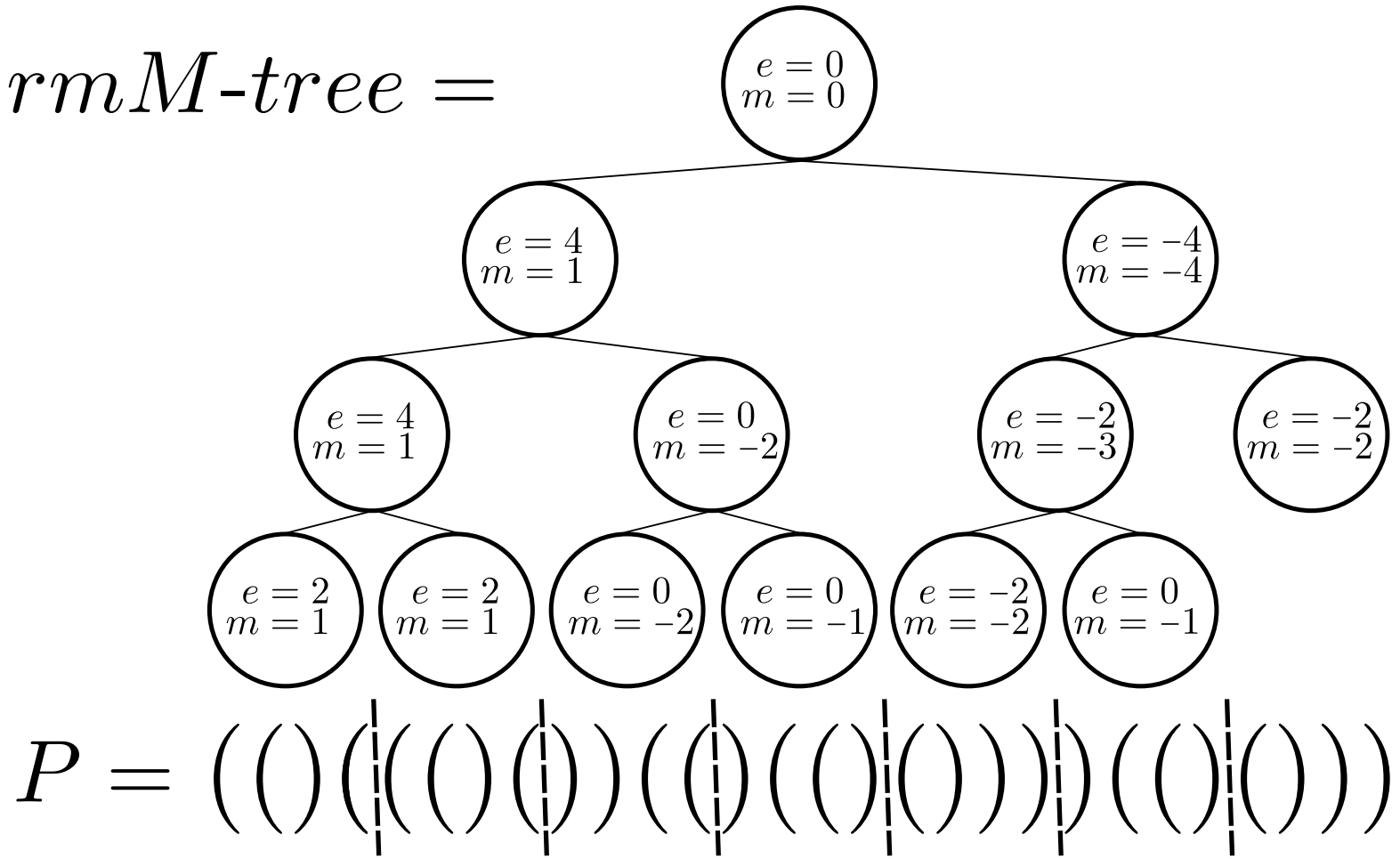

$excess(i,j) = rank_( - rank_)$
$i$
$j$


$min\_excess(i,j)$
$i$
$j$

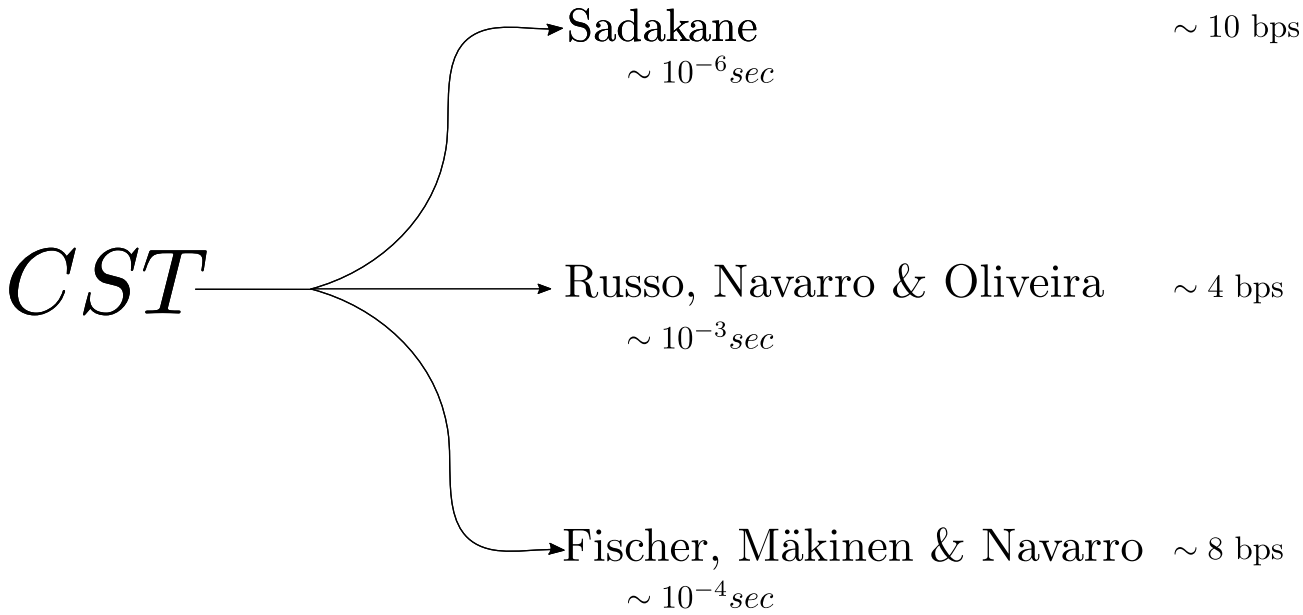

$fwdsearch(i,d)$
$d$
$i$


$bwdsearch(i,d)$
$d$
$i$

# Range min-Max Tree



# State of the Art



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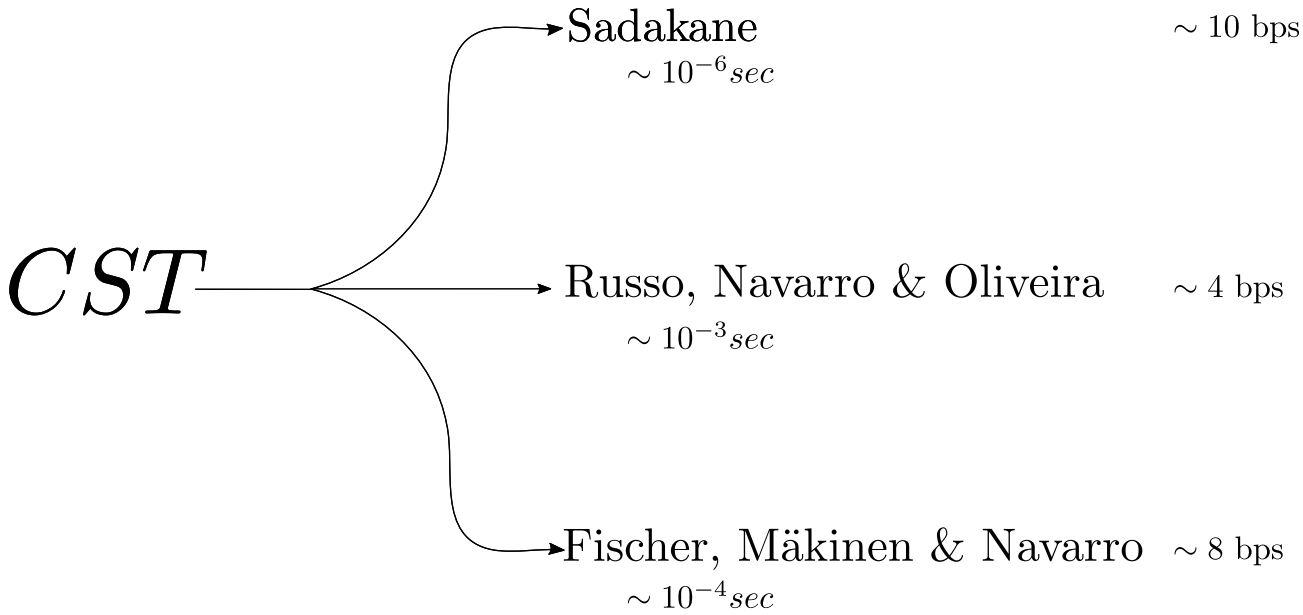


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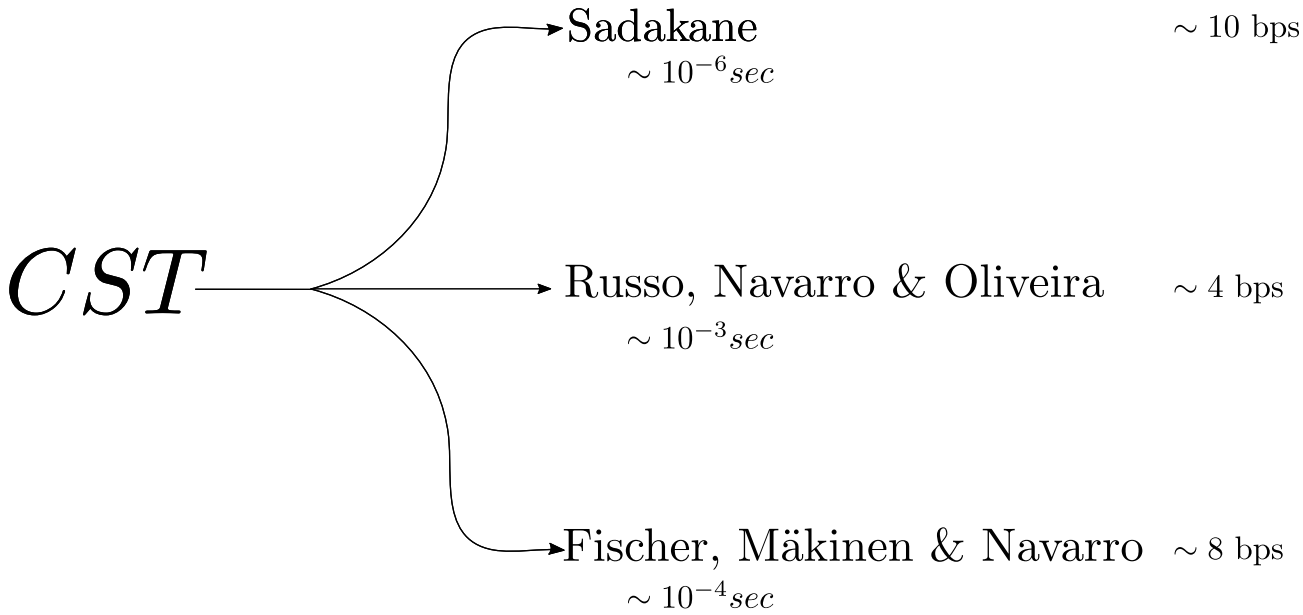


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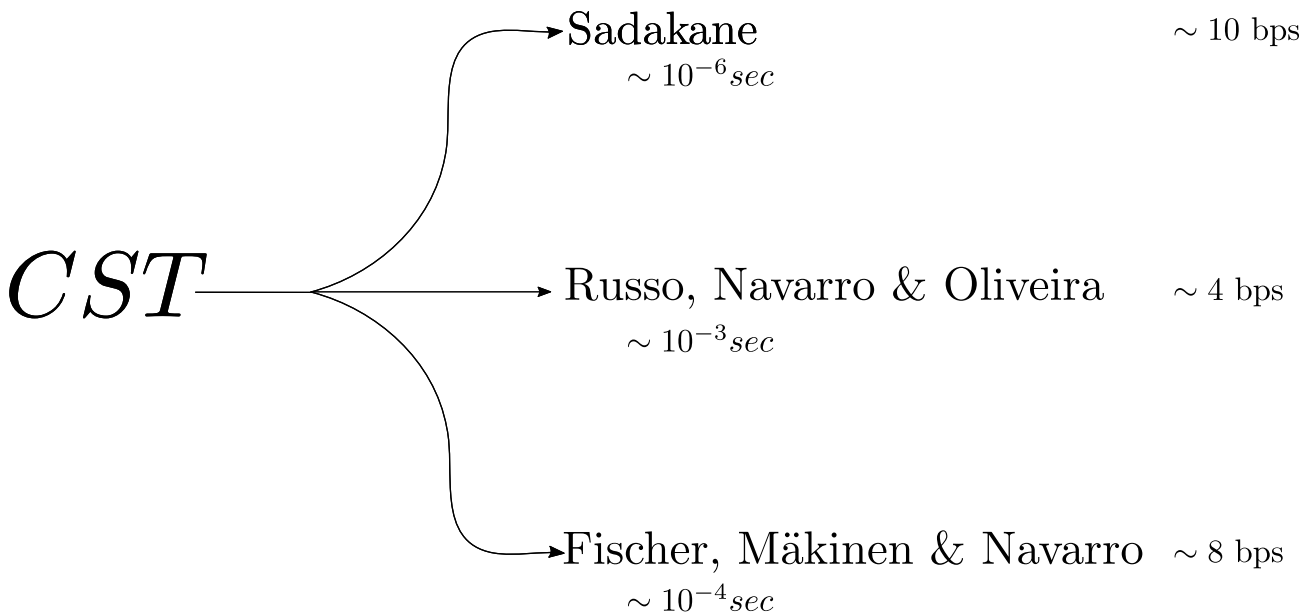


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- Many collections are highly repetitive
- BWT-Runs, Lempel-Ziv and Grammar based indexes

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It uses $\sim 2$ bps and operates in $10^{-5}$ sec.

# Block Tree

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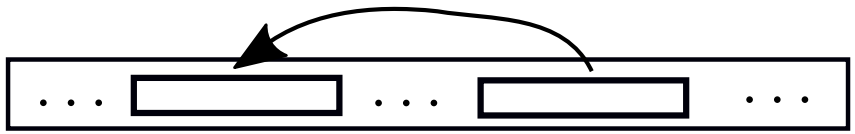
- *Lempel-Ziv* bounded structure

$T =$ 

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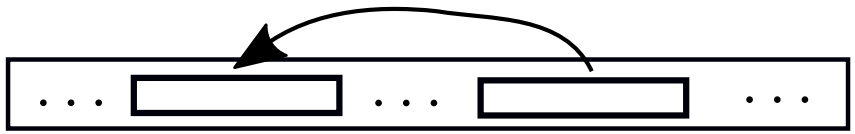
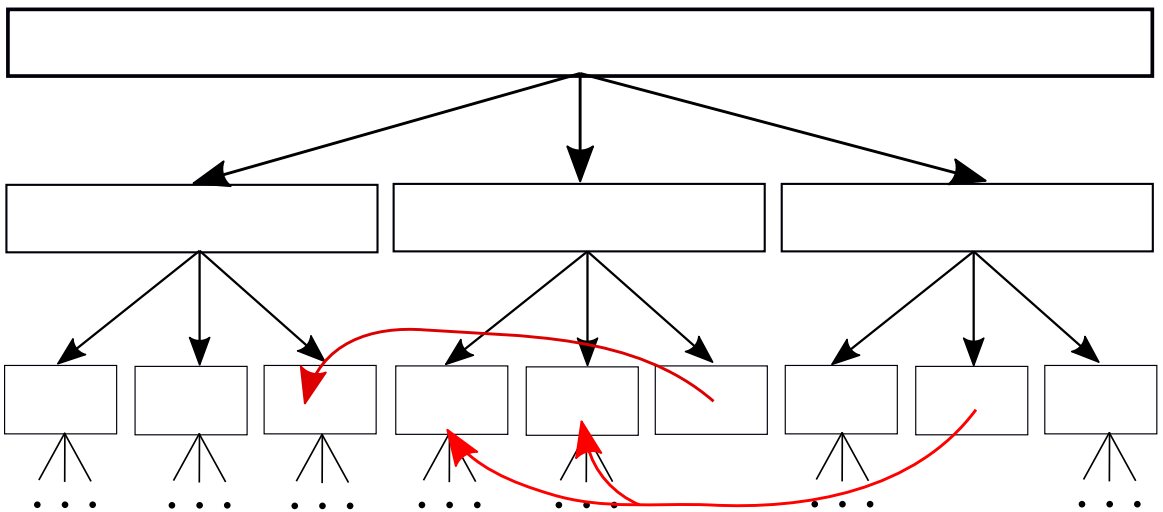
$T =$ 

- It divides the text into blocks and uses *back pointers* to previous occurrences

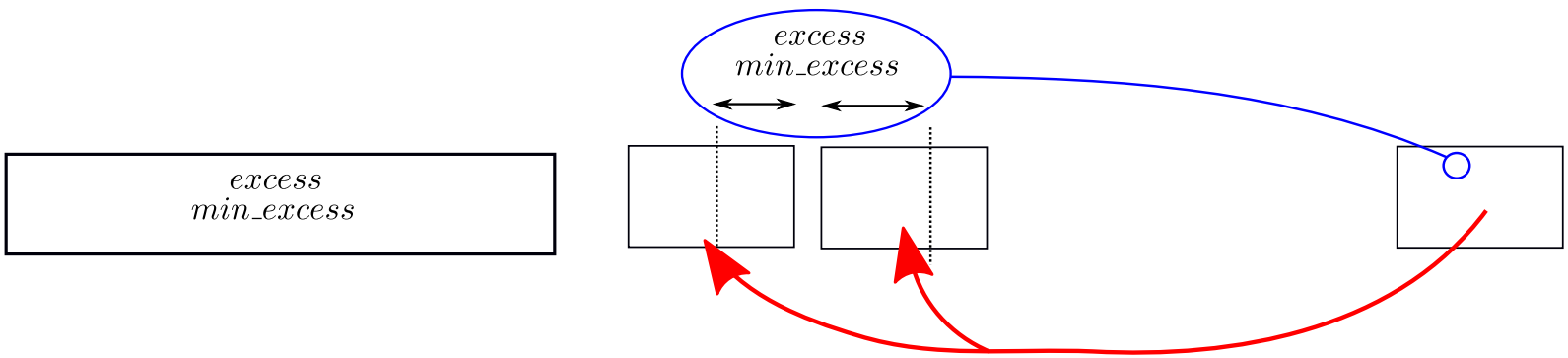
$T =$ 

# Main Idea

"Represent the balanced parentheses topology with a Block Tree and enhance its nodes with *excess* and *min_excess* information to answer the primitives efficiently "

# Block Tree Compressed Topology (BT-CT)

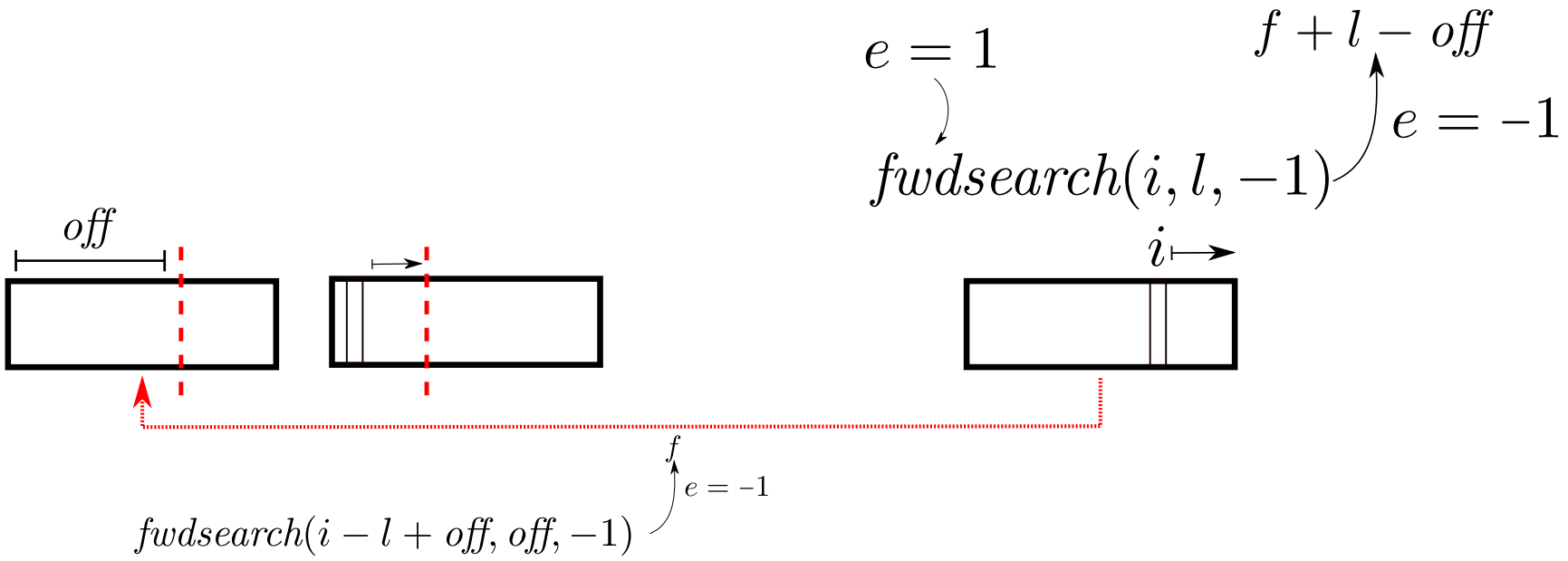
# Augmentation



# Operations

"The basic principle to solve the operations is to compute them recursively and used the stored fields to skip recursive computation"

# $fwd\text{-}search(i, d \leq 0)$



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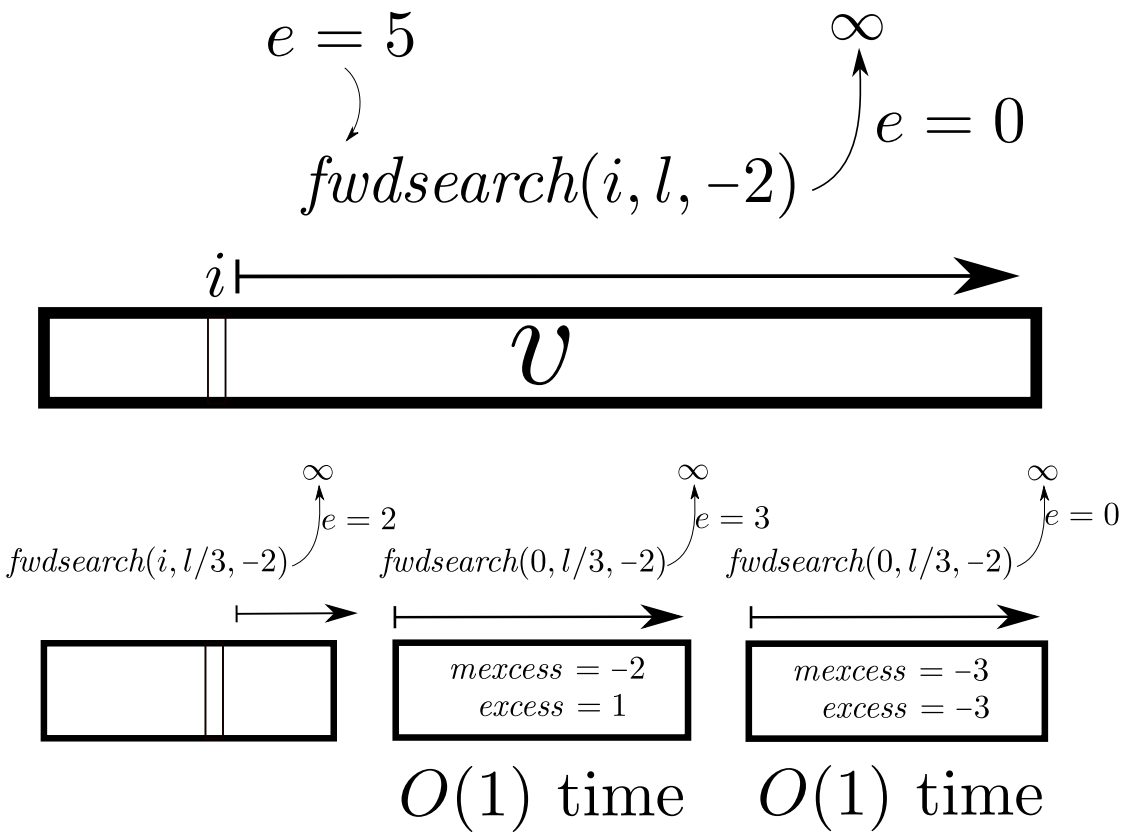
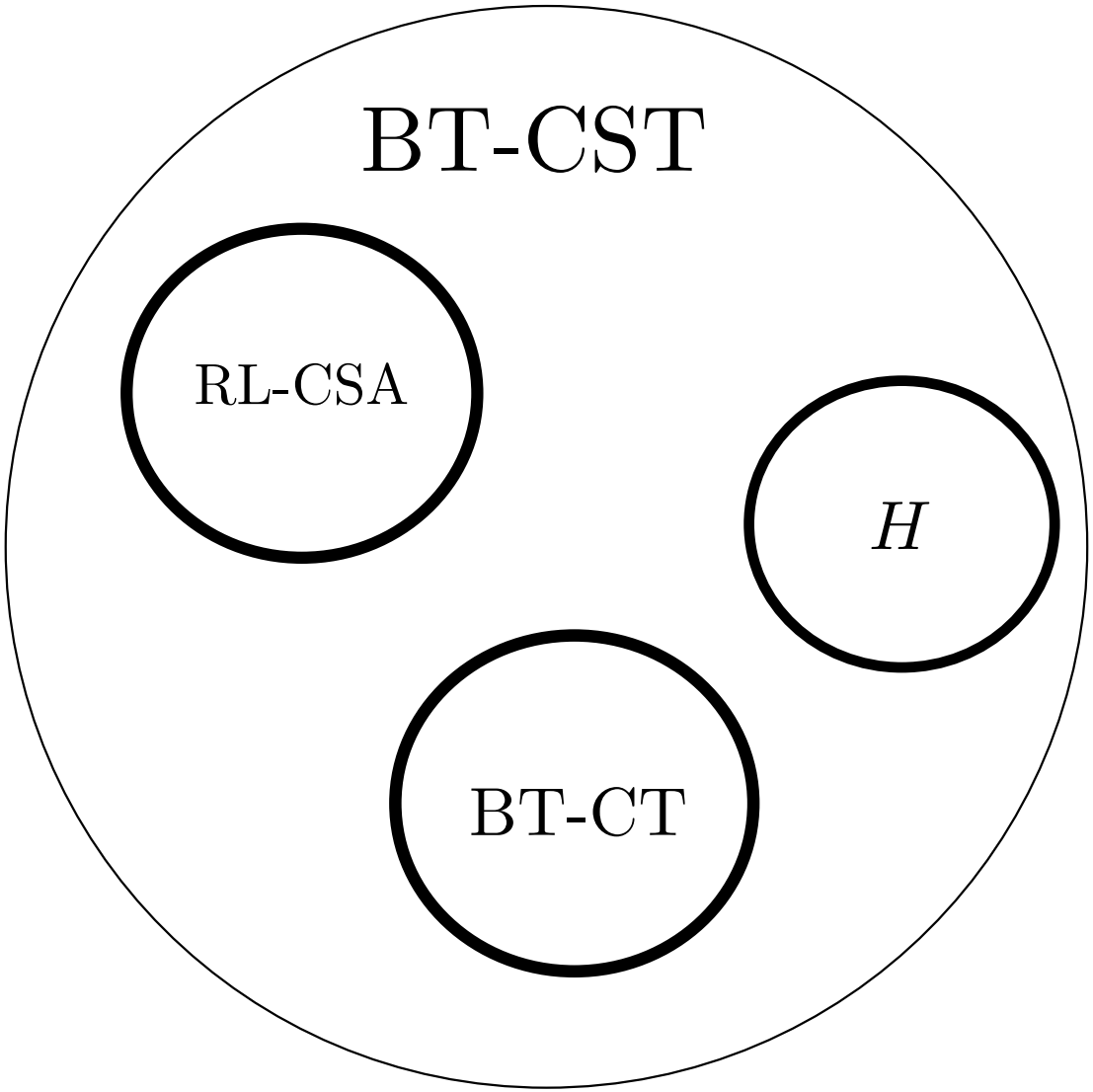


# BT-CST



# Results

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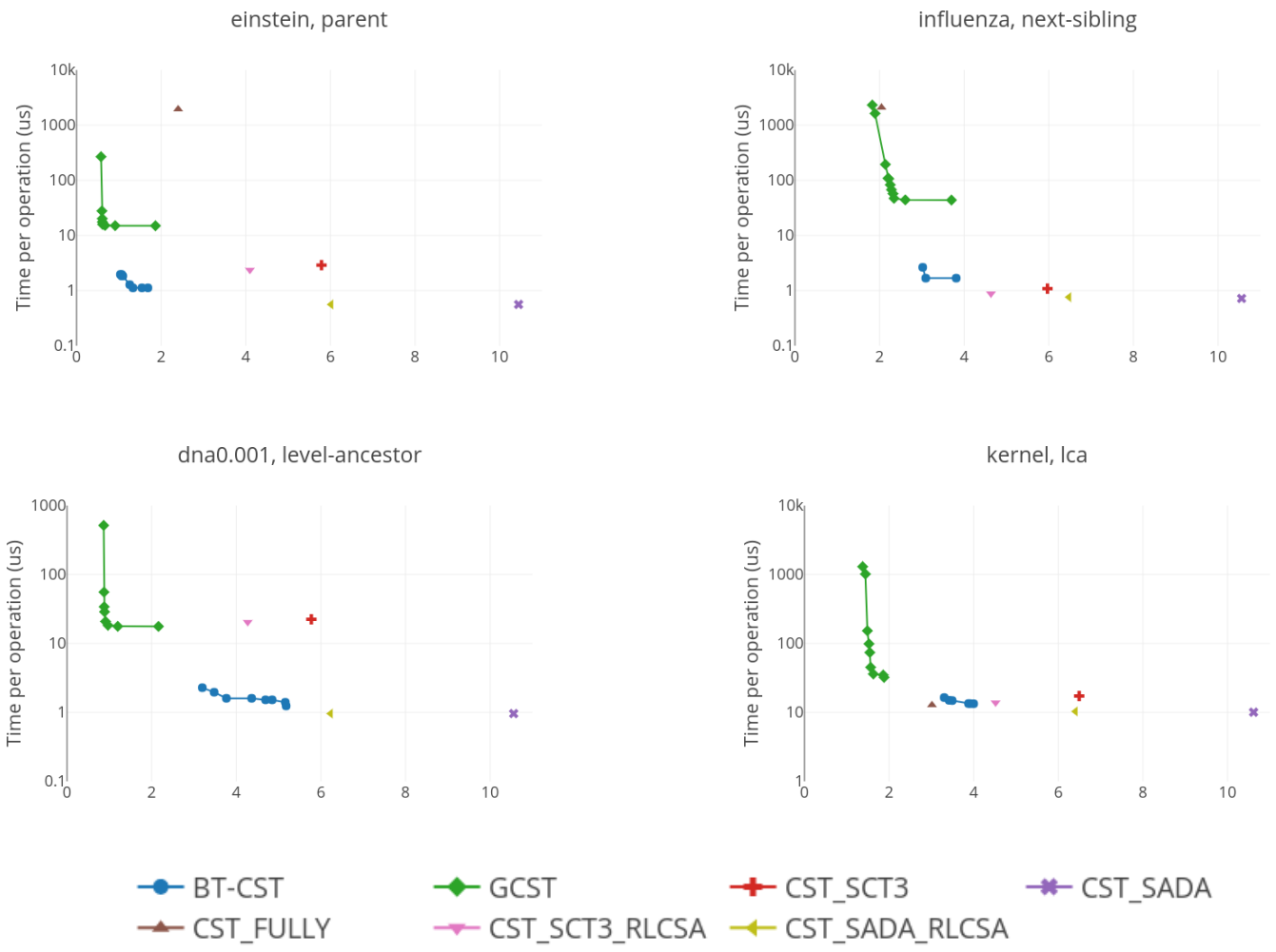
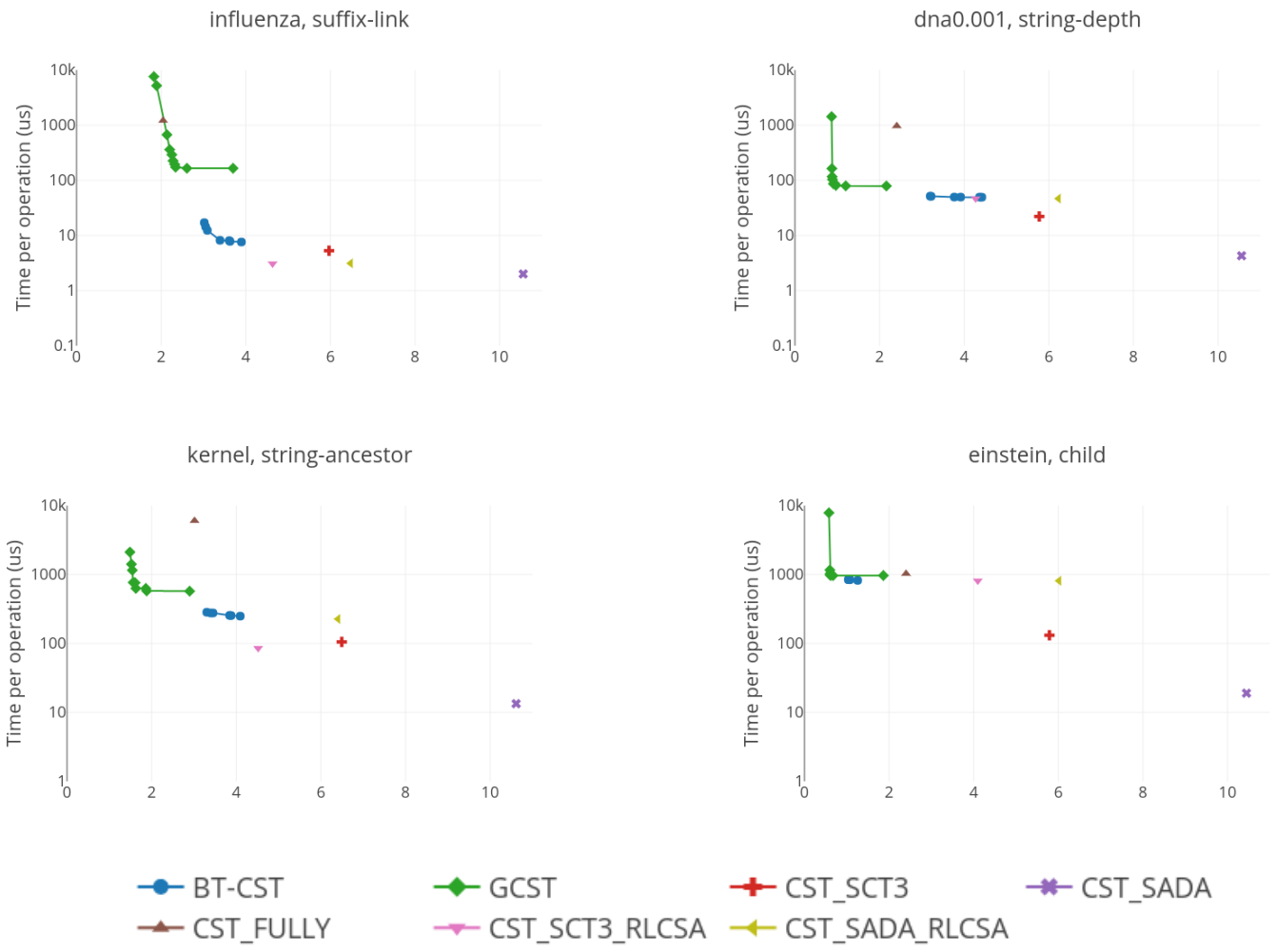
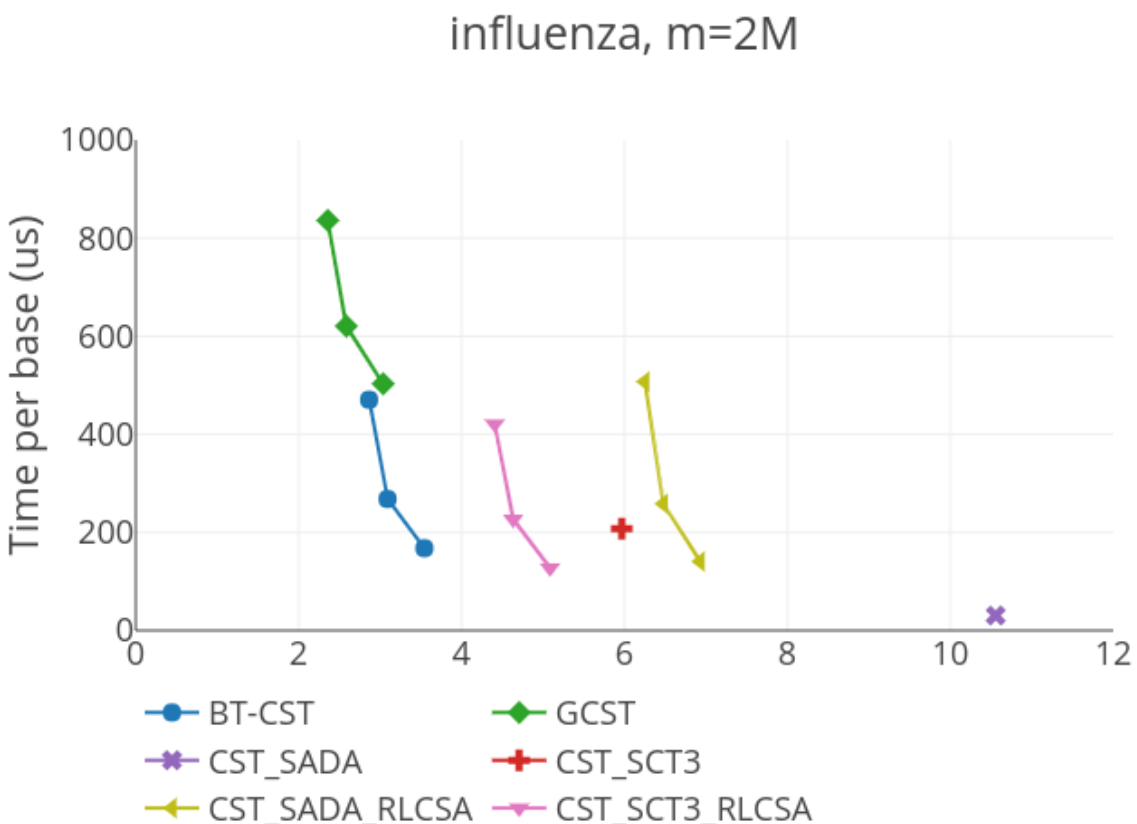


# Results – CSA Based Operations



# Results – Maximal Substrings



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- Public available code for researchers and practitioners
- Lack of worst-case time analysis or new algorithms for primitives
- Time improvement on CSA based operations (WCTA'19)

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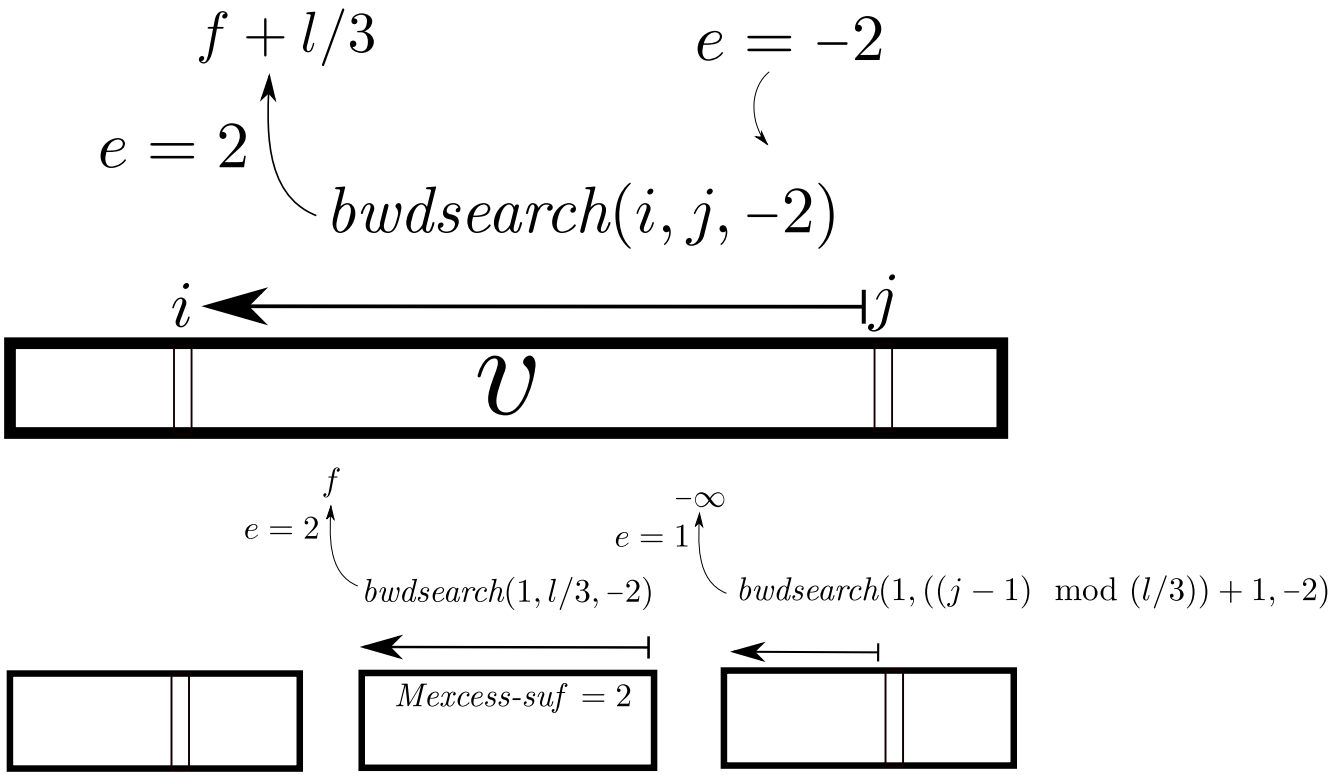

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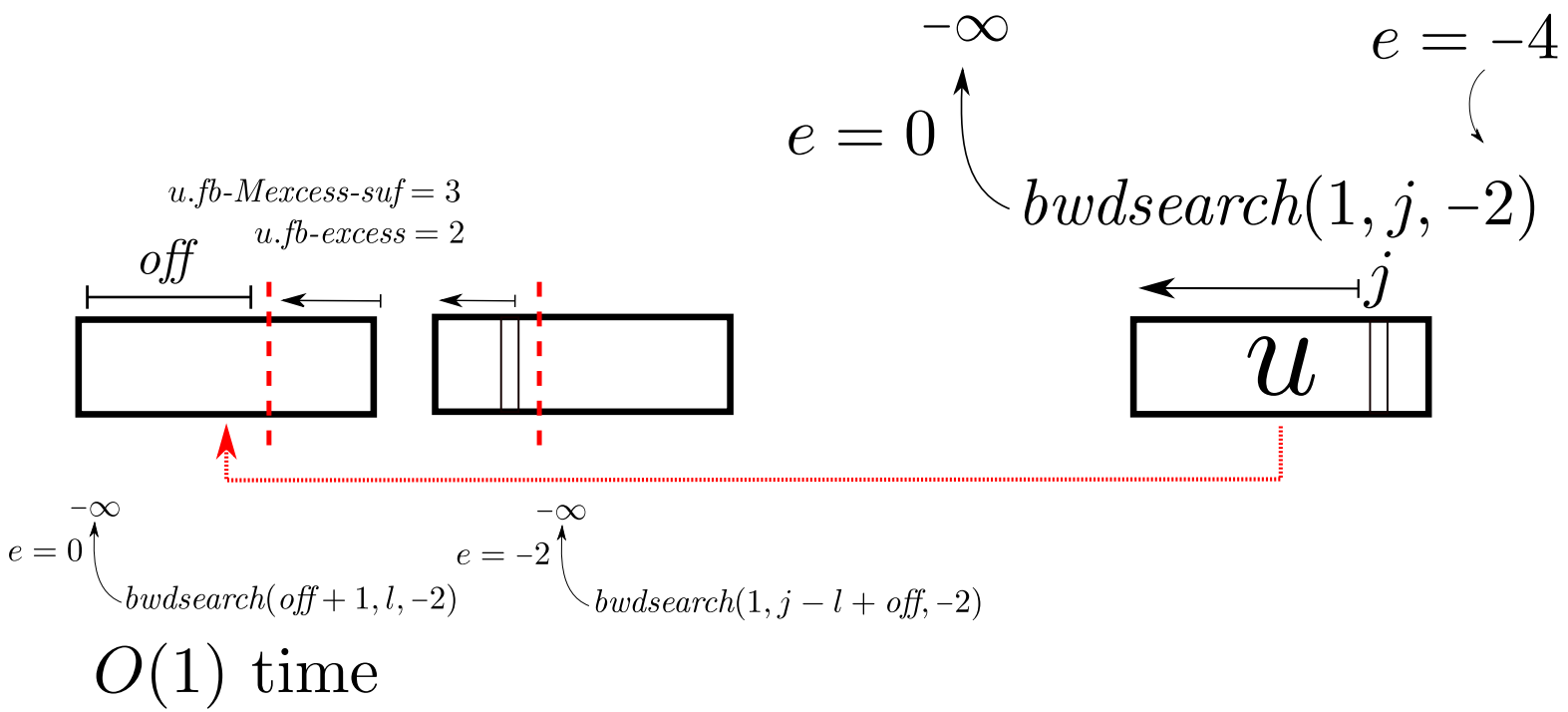
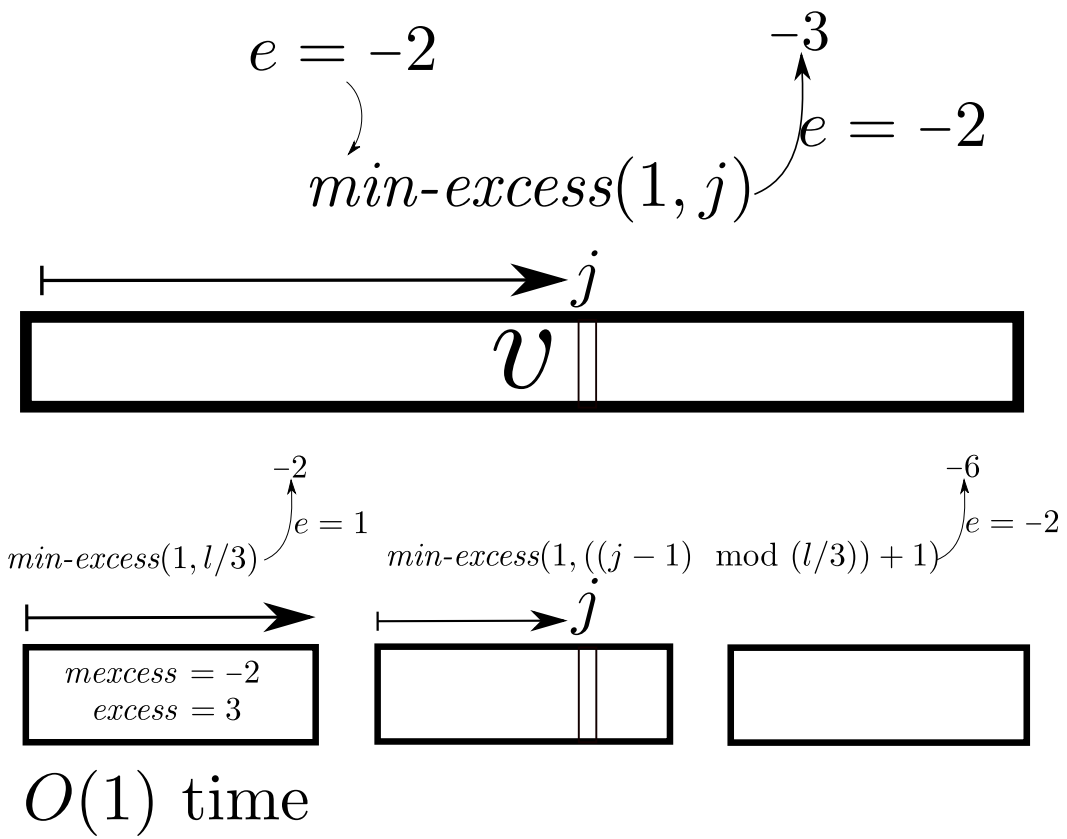



$O(1)$ time

# $min\text{-}excess(i, j)$



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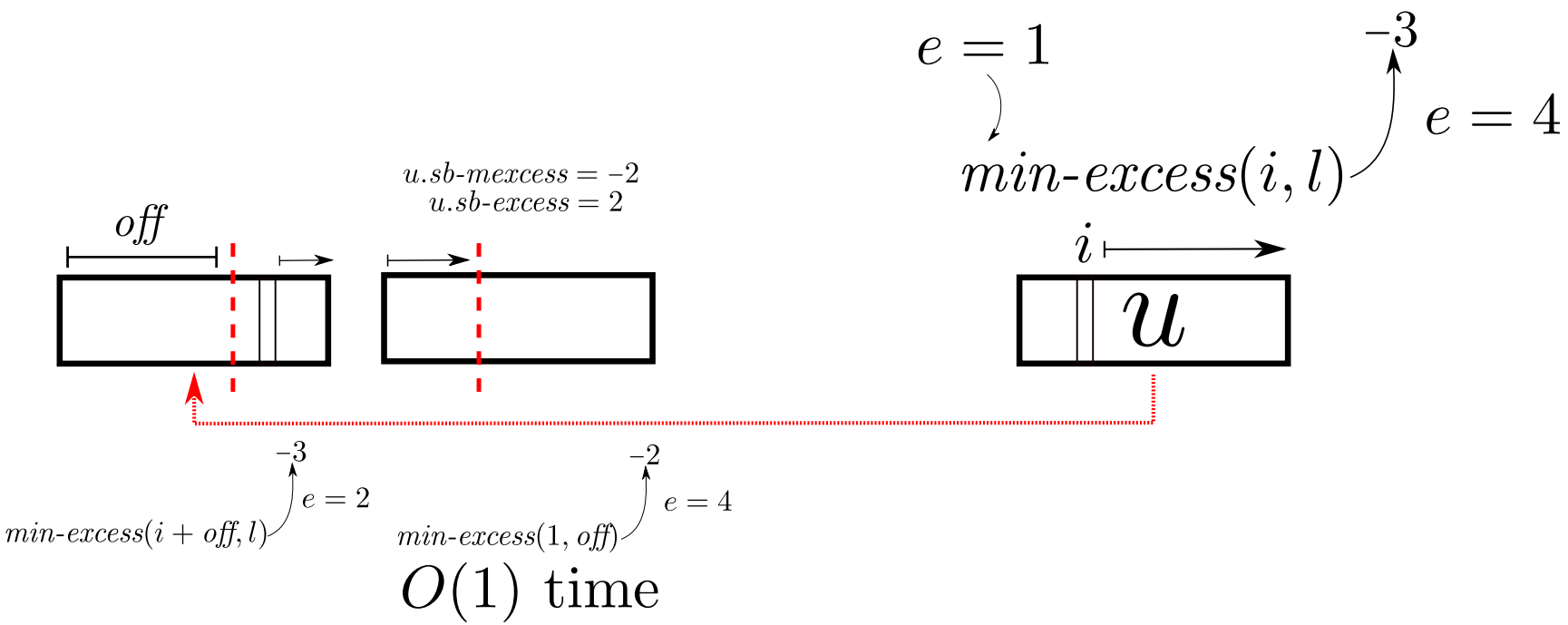
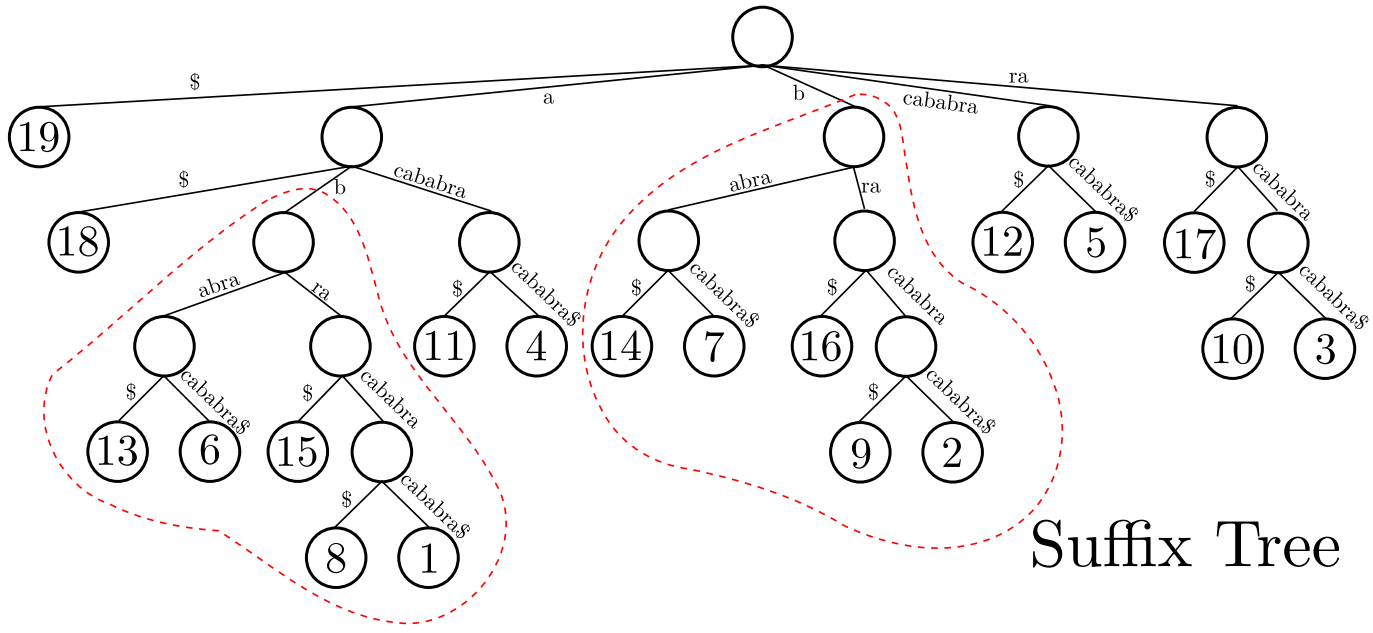


# Repetitiveness

$T = abracadabracadabra\$$




Suffix Tree

$P = (()(()(((())())(()(()())))(()()))((()())(()(()())))(()())(()(()())))$

$\Delta A =$

| 19 | −1 | −5 | −7 | 9 | −7 | −7 | 10 | −7 | 10 | −7 | 9 | −7 | −7 | 10 | −7 | 12 | −7 | −7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

$\Delta A^{-1} =$

| 7 | 7 | 5 | −10 | 7 | −12 | 7 | −5 | 7 | 5 | −10 | 7 | −12 | 7 | −5 | 7 | 5 | −15 | −1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

$\Delta LCP =$

| 0 | 0 | 1 | 5 | −4 | 2 | 7 | −10 | 7 | −8 | 5 | −4 | 2 | 7 | −10 | 7 | −7 | 2 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

# Maximal Substrings Problem

Find all maximal substrings of $S[1, m]$ that are also substrings of a text $T[1, n]$

- Solved in $O(m)$ using the *suffix tree* of $T$
  - The algorithm maintains two integers $i, j$ representing a substring $S[i, j]$
  - It uses *child* to advance $j$, when no possible outputs a maximal substring and starts applying *suffix-link* to advance $i$ until an application of *child* is possible again

# Block Tree definition

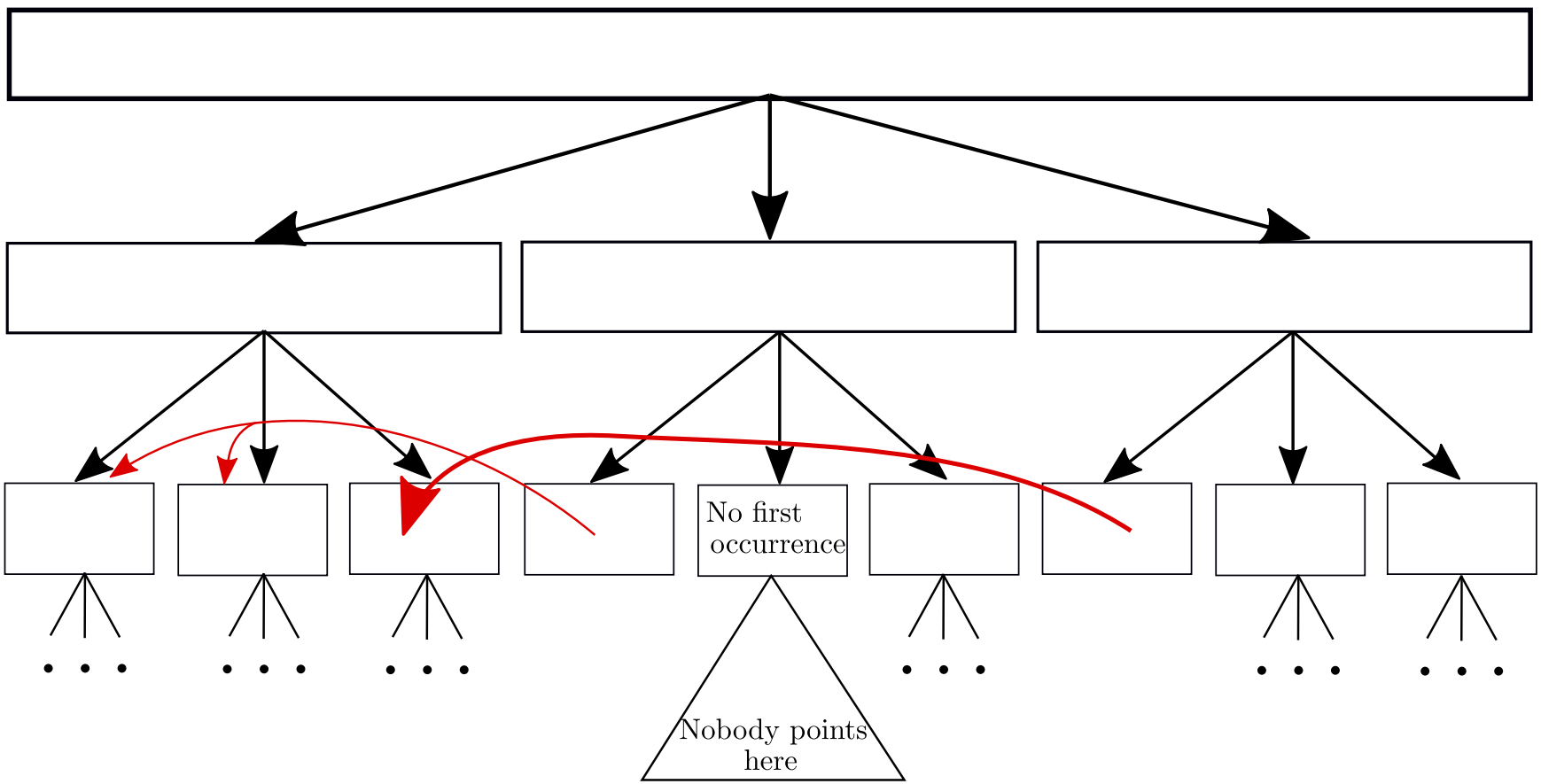
A node $v$, representing $v.blk = T[i, i + b - 1]$ can be of three types:

**LeafBlock:** If $b \leq mll$, where $mll$ is a parameter, then $v$ is a leaf of the Block Tree

**BackBlock:** Otherwise, if $T[i - b, i + b - 1]$ and $T[i, i + 2b - 1]$ are not their leftmost occurrences in $T$, then the block is replaced by its leftmost occurrence in $T$

**InternalBlock:** Otherwise, the block is split into $r$ blocks of size $\lceil \frac{b}{r} \rceil$ and $\lfloor \frac{b}{r} \rfloor$

# Pruning



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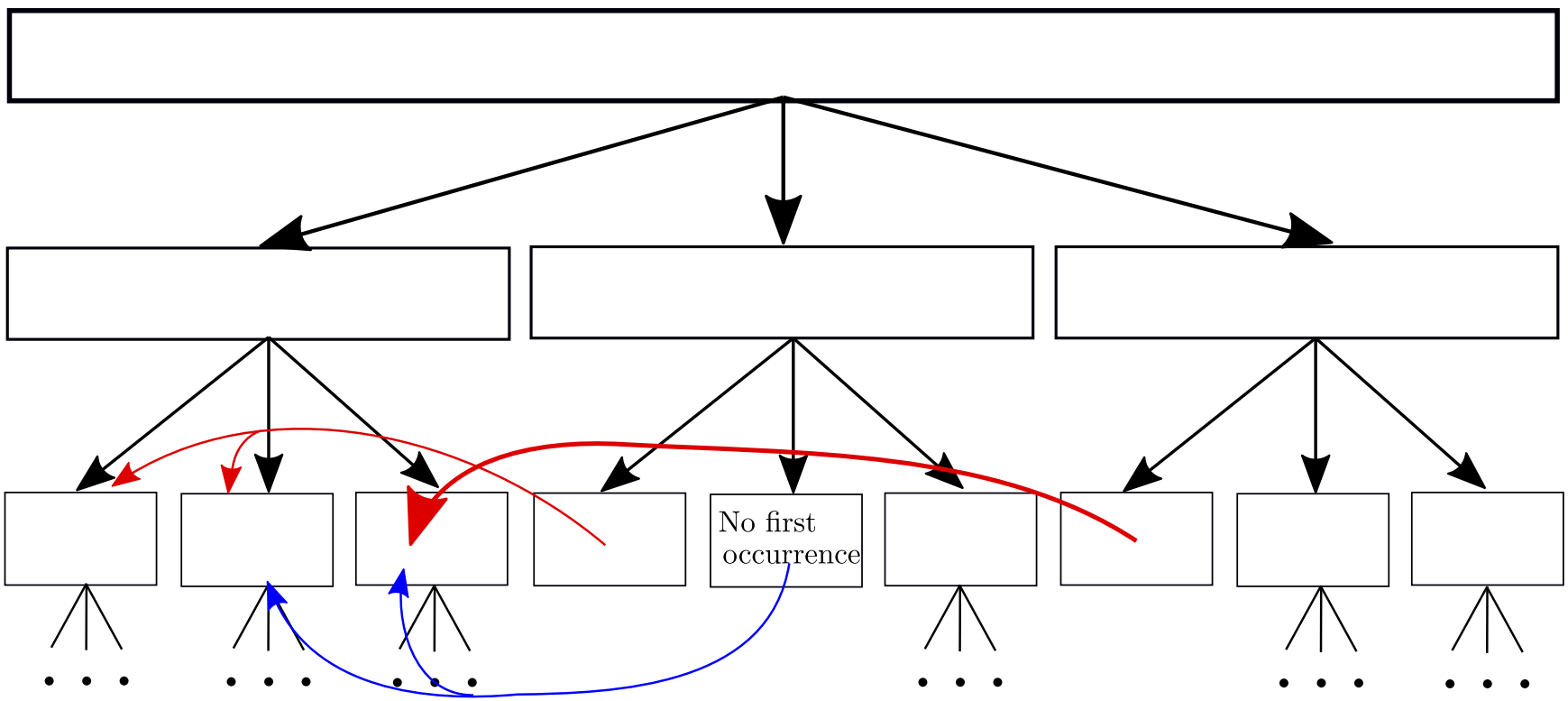
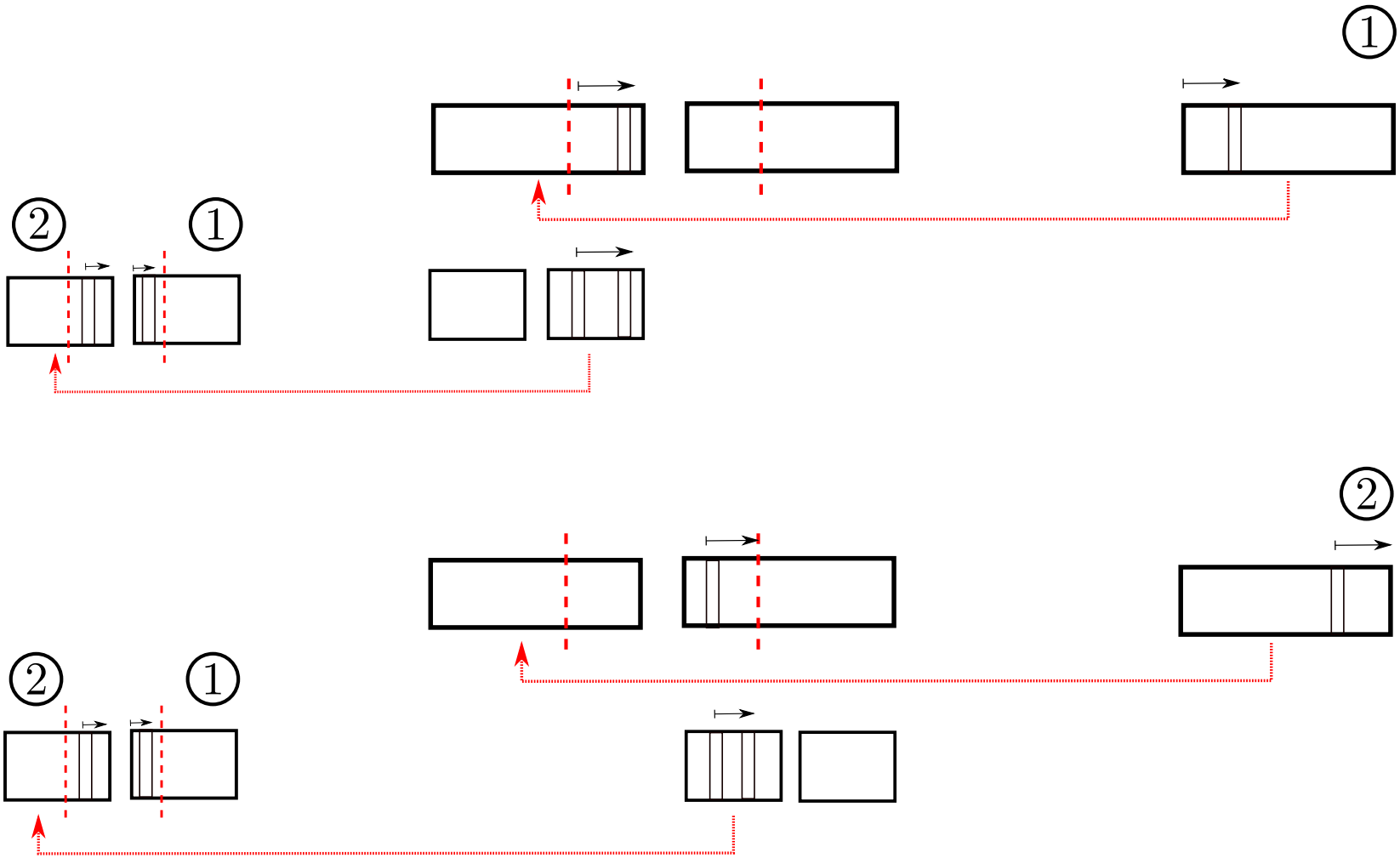


# Bad Instance



# Construction Time/Max Space