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## Lossy compression of unordered rooted trees

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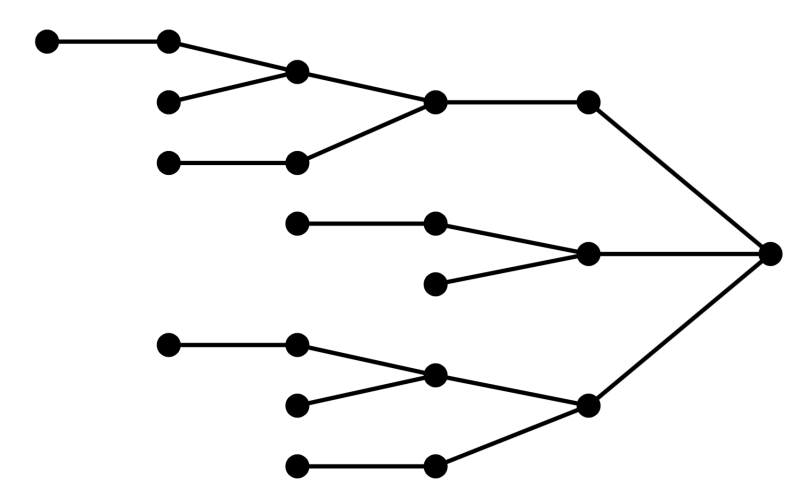
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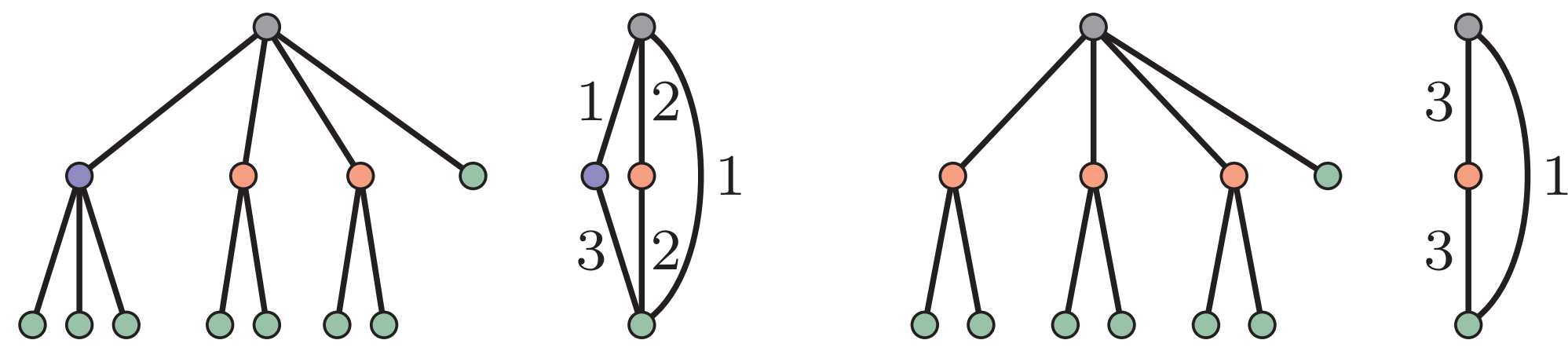
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## OBJECTIVES

DAG compression is a classical technique that consists in building a Directed Acyclic Graph (DAG) that represents an unordered tree without the redundancy of its subtrees.



Only trees with a high level of redundancy are efficiently compressed by this method. We introduce a **lossy compression method that consists in computing the DAG of a self-nested structure that both presents the highest level of redundancy and approximates the initial data to compress.**

## EDIT DISTANCE

This study requires to introduce a distance on the space of unordered trees in order to quantify the quality of a given self-nested estimate of a tree structure. We consider an editing distance defined from the following tree edit operations: **insertion and deletion of a leaf**. An edit script is a sequence of edit operations. The result of applying an edit script  $s$  to a tree  $\tau$  is the tree  $\tau^s$  obtained by applying the component edit operations to  $\tau$  in the order they appear in the script. The cost of an edit script is only the number of edit operations. Finally, given two trees  $\tau_1$  and  $\tau_2$ , the edit distance  $\delta(\tau_1, \tau_2)$  is the **length of the minimum edit script** that transforms  $\tau_1$  into a tree that is isomorphic to  $\tau_2$ .

## EXAMPLE

The tree data to compress and its DAG version (top) and the solutions provided by the lossy compression algorithms NEST (middle) and LP-RFC (bottom). The NEST solution has too many nodes for looking like the initial tree (107 nodes added to obtain a self-nested tree). The LP-RFC solution is **visually close to the initial tree**, which is confirmed by the error rate of 35%. Both algorithms achieve a compression rate greater than 80%.

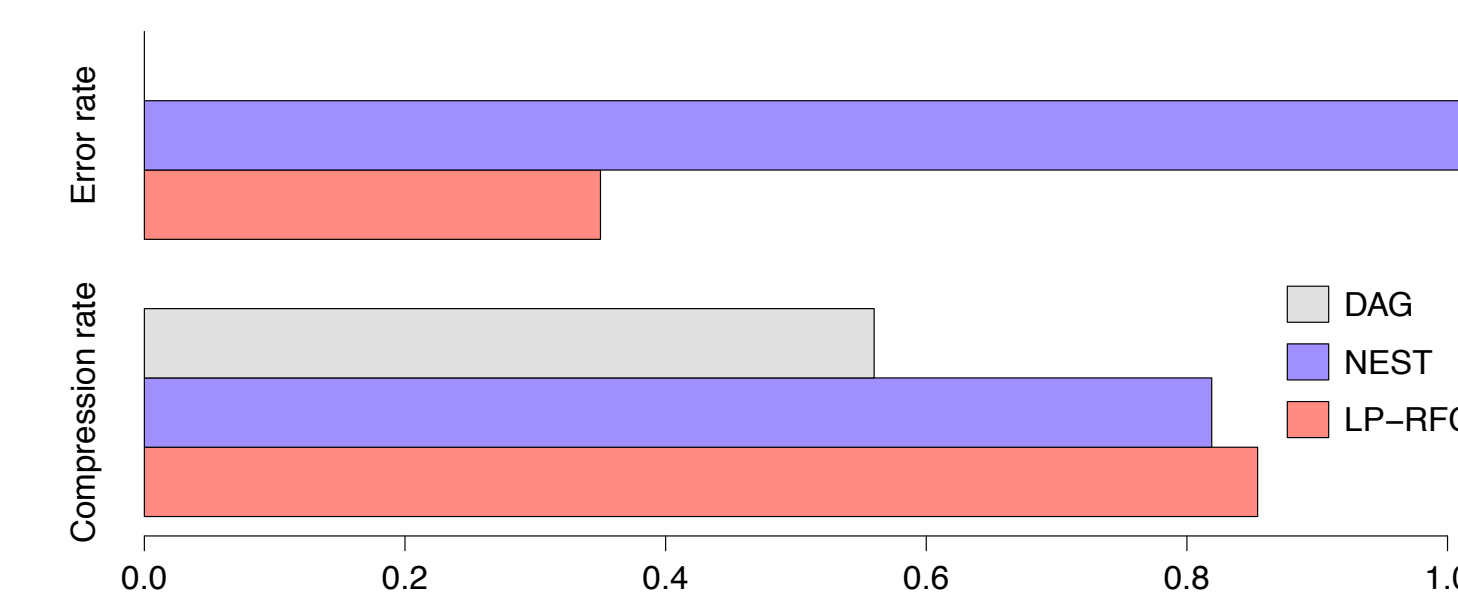
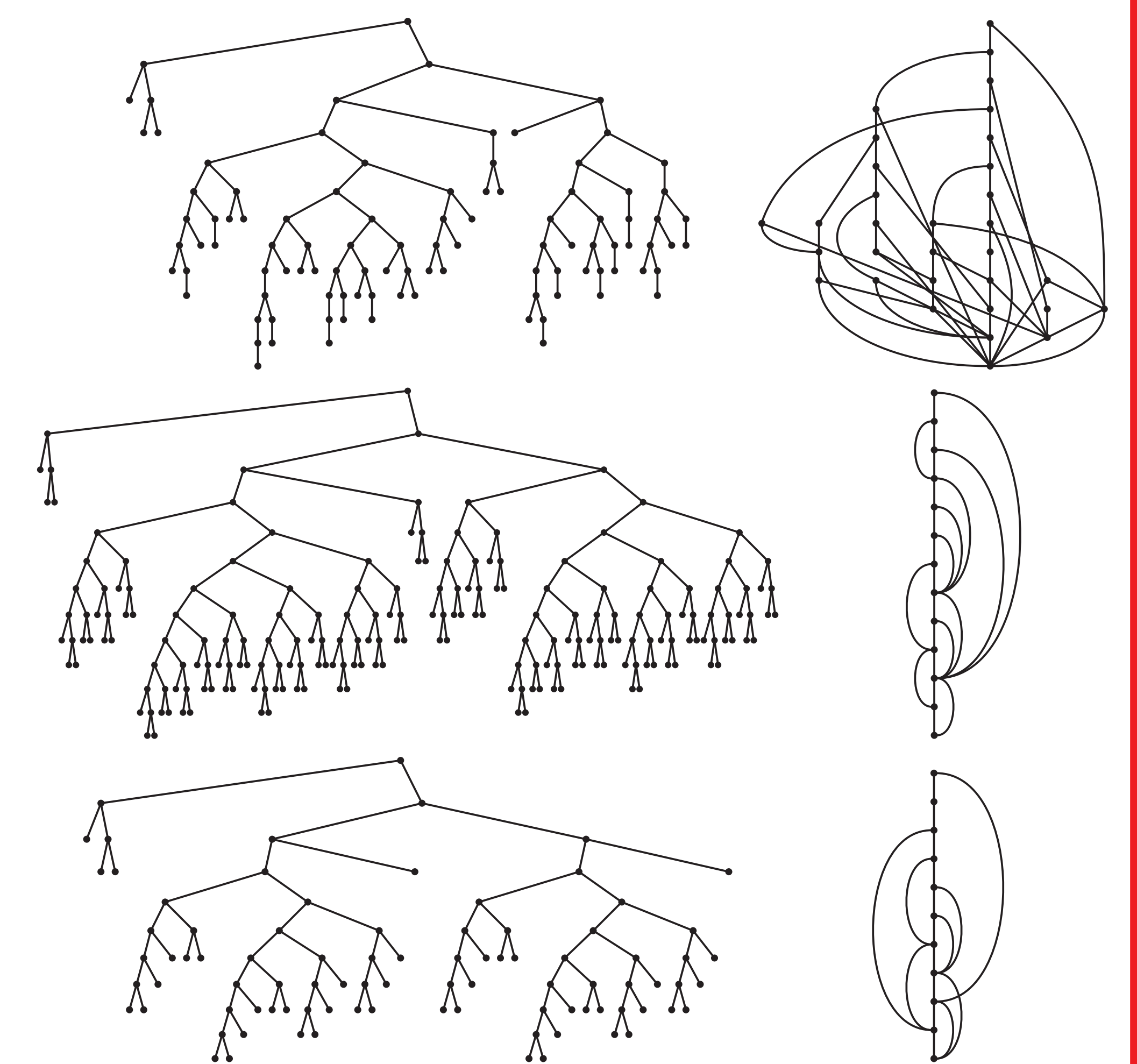


Figure 1: Error and compression rates on the example.



## SELF-NESTED TREES

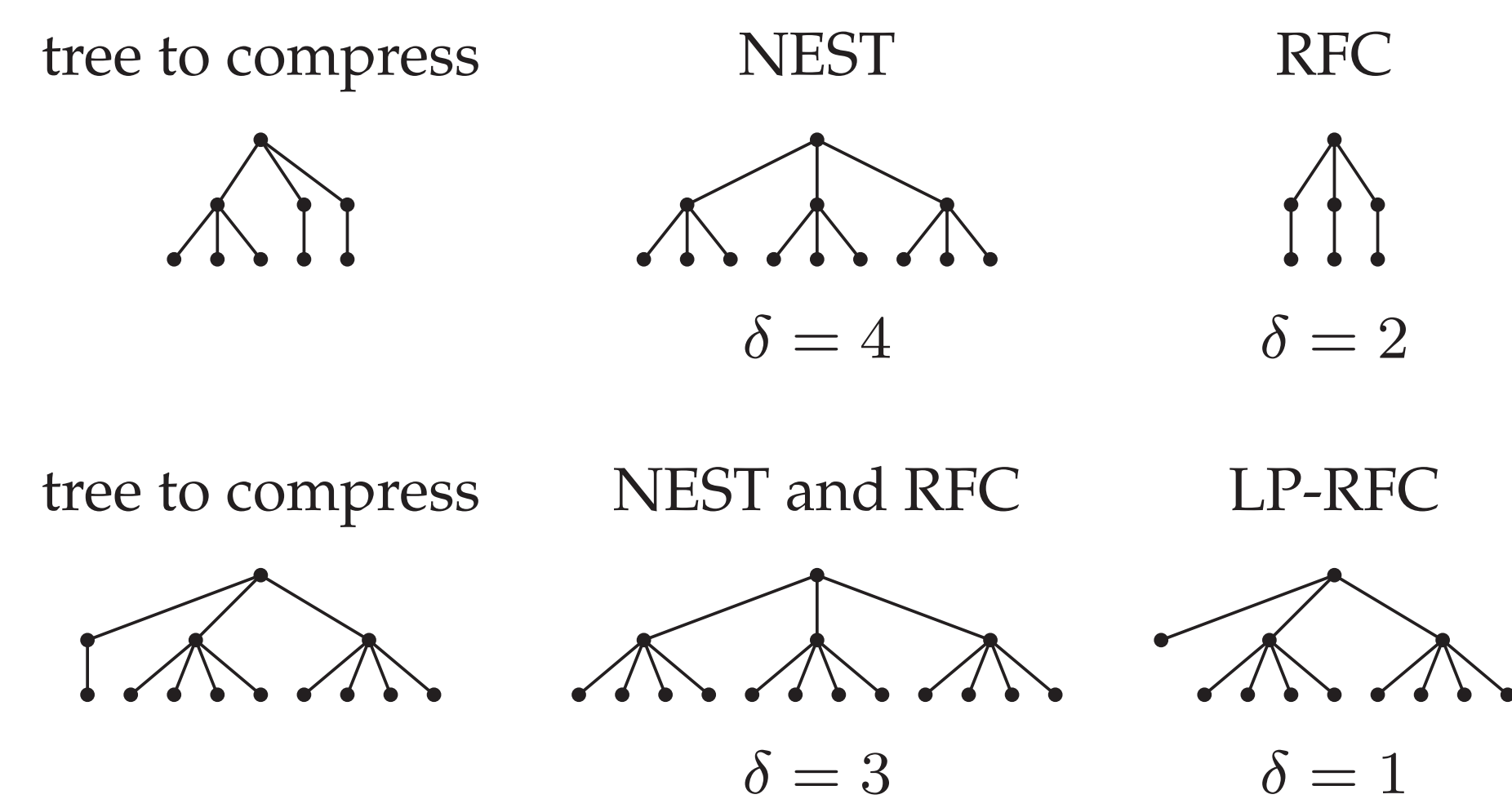
Self-nested trees present remarkable compression properties because of the **systematic repetition of subtrees**. They are defined as trees such that all the subtrees of a given height are isomorphic. The DAG related to a self-nested tree  $\tau$  is linear (there exists a path going through all its vertices) and has thus height( $\tau$ ) + 1 nodes. In other words, **self-nested trees achieve maximum compression rates**. In addition, self-nested trees are very rare, while still being quite close to any unordered tree.

	deg $\leq 2$	deg $\leq 3$	deg $\leq 4$
$h \leq 2$	0.88	$6.18 \cdot 10^{-1}$	$3.52 \cdot 10^{-1}$
$h \leq 3$	0.49	$3.38 \cdot 10^{-2}$	$7.43 \cdot 10^{-5}$
$h \leq 4$	0.07	$2.90 \cdot 10^{-8}$	$4.16 \cdot 10^{-23}$
$h \leq 5$	$3.36 \cdot 10^{-4}$	$3.56 \cdot 10^{-28}$	$1.66 \cdot 10^{-100}$

Table 1: Frequency of self-nested trees with given maximal height and ramification number with respect to unordered trees under the same constraint.

## ALGORITHM

The preexisting algorithm (NEST) only adds nodes to a tree  $\tau$  to transform it into a self-nested structure. Instead of adding nodes, we propose to **replace some internal structures of  $\tau$  by their centroid (RFC)**. In particular, this allows us to delete some nodes and thus gives flexibility. These self-nested estimates may be computed in polynomial time. Nevertheless, this procedure can only modify subtrees and not delete them. That is why we introduce a **new algorithm that exploits local pruning of  $\tau$  (LP-RFC)**.



## SIMULATION STUDY

Our simulations are performed on 500 small binary trees generated from a stochastic model. The three algorithms are equivalent in terms of compression rates. The key parameter is thus **the error rate that is much better for RFC and LP-RFC algorithms than for NEST procedure (substantial gain of 20%)**. Local pruning is useful in RFC 24.2% of the time and makes the error decrease of 1.8% (7.3% when useful).

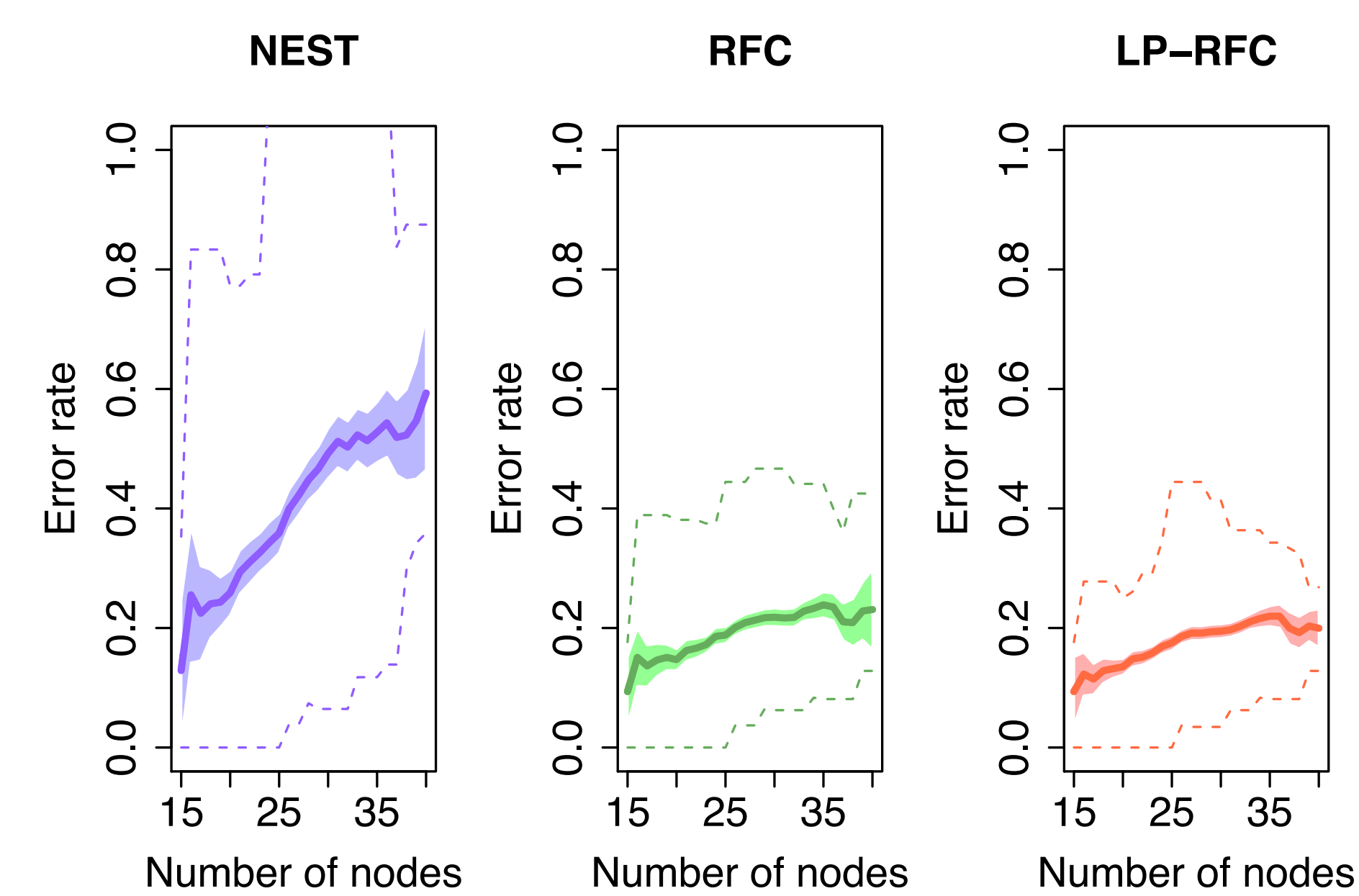


Figure 2: Error rates on the simulated dataset.

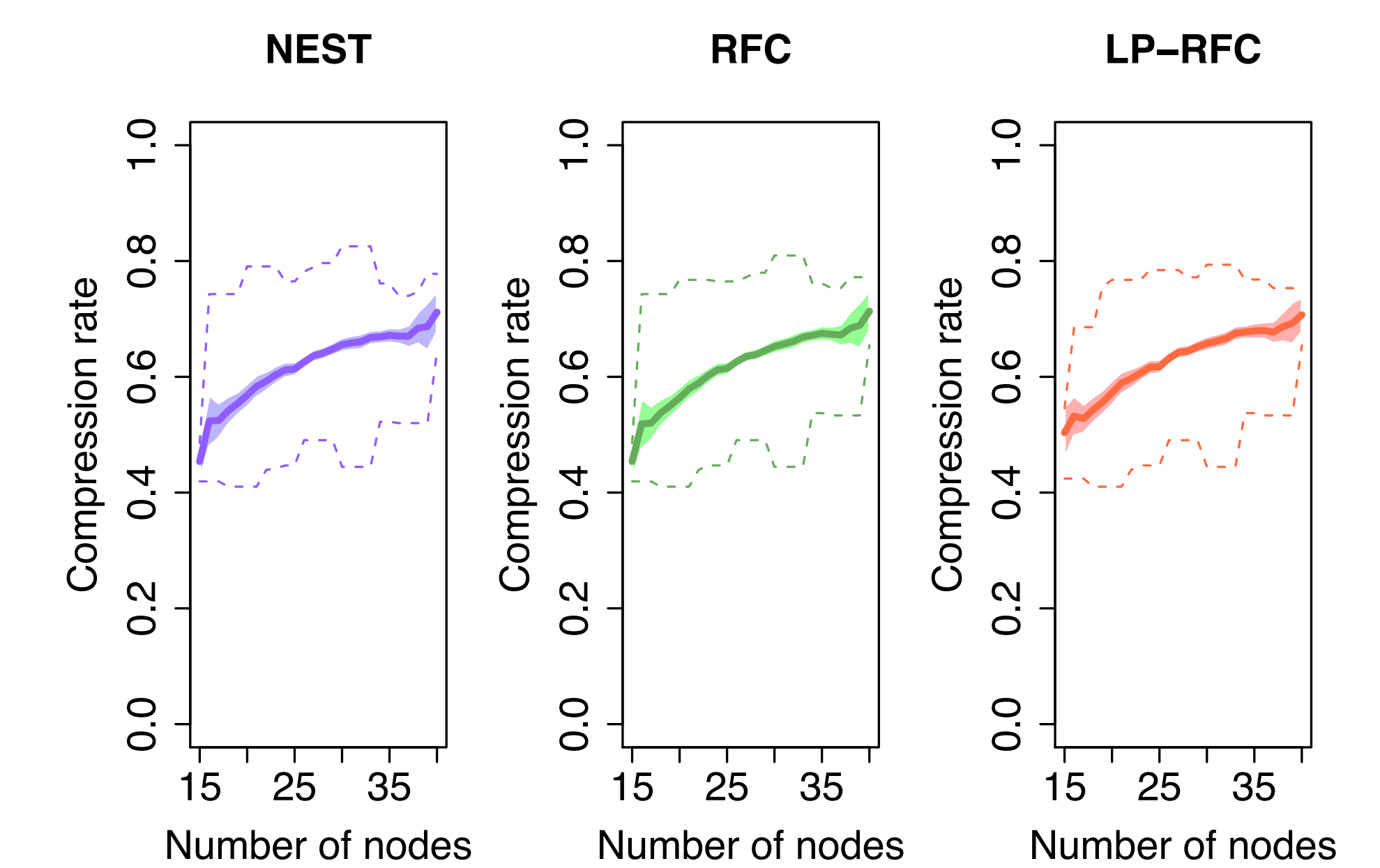


Figure 3: Compression rates on the simulated dataset.

## WORST-CASE APPROXIMATION ERROR

Among trees of height  $h$  and outdegree less than  $m$ , the tree that is the farthest to a self-nested tree may be identified. The editing distance to its best self-nested approximation is of order  $0.25 m^h$ . The diameter of the space of unordered trees being of

order  $m^h$ , it follows that **the largest area without any self-nested tree is of relative radius 0.25**. In addition, the error rate for this tree (and thus the worst error rate that must be expected from any lossy compression algorithm) is of order 0.33.

## REFERENCES

- [1] Azais, Durand, and Godin. Lossy compression of trees via linear DAGs. *Preprint*, 2016.
- [2] Godin and Ferraro. Quantifying the degree of self-nestedness of trees. Application to the structural analysis of plants. *IEEE TCBB*, 2010.

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