Mining Adaptively Frequent Closed Unlabeled Rooted Trees in Data Streams

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Data Streams

- Sequence is potentially infinite
- High amount of data: sublinear space
- High speed of arrival: sublinear time per example

Tree Mining

- Mining frequent trees is becoming an important task
- Applications:
  - chemical informatics
  - computer vision
  - text retrieval
  - bioinformatics
  - Web analysis.
- Many link-based structures may be studied formally by means of unordered trees

Introduction: Trees

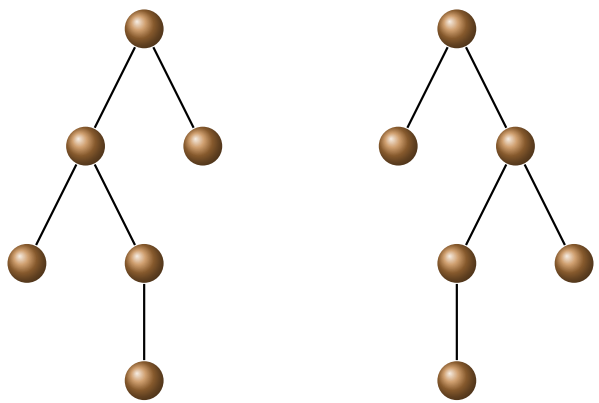
Our trees are:

- Rooted
- Unlabeled
- Ordered and Unordered

Our subtrees are:

- Induced

Two different ordered trees
but the same unordered tree



What Is Tree Pattern Mining?

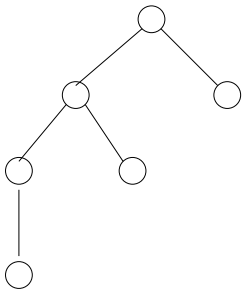
Given a dataset of trees, find the complete set of frequent subtrees

- Frequent Tree Pattern (FS):
  - Include all the trees whose support is no less than min_sup
- Closed Frequent Tree Pattern (CS):
  - Include no tree which has a super-tree with the same support
- $CS \subseteq FS$
- **Closed Frequent Tree Mining** provides a **compact** representation of frequent trees without loss of information

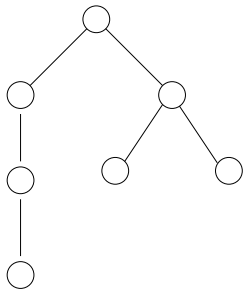
Introduction

Unordered Subtree Mining

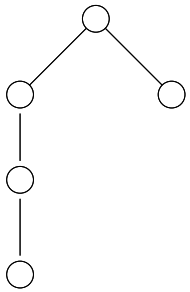
A:



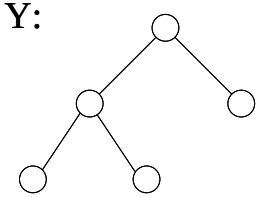
B:



X:



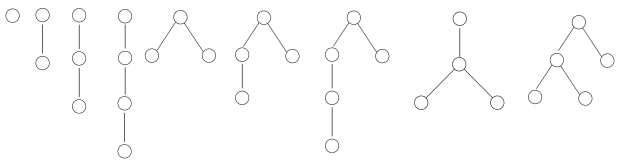
Y:



$$D = \{A, B\}, min\_sup = 2$$

Closed Subtrees : 2
Frequent Subtrees: 9

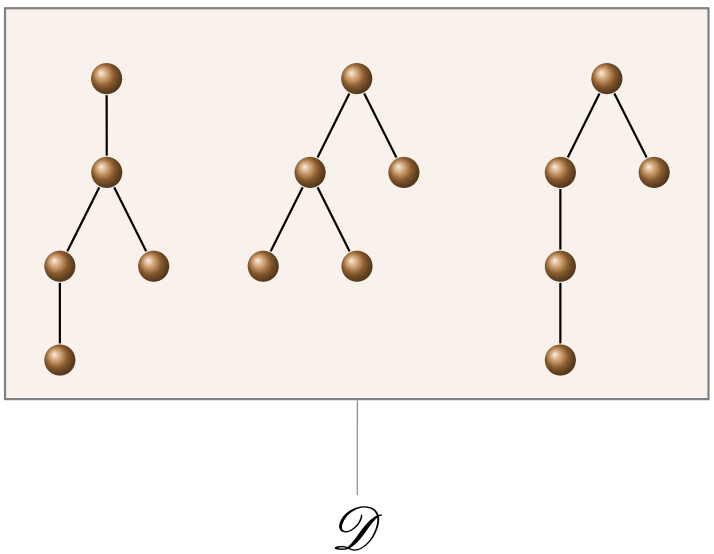
- Closed Subtrees: X, Y
- Frequent Subtrees:



Introduction

Problem

Given a data stream $\mathscr{D}$ of rooted, unlabelled and unordered trees, find frequent closed trees.



$\mathscr{D}$

We provide three algorithms, of increasing power

- Incremental
- Sliding Window
- Adaptive

Relaxed Support

Guojie Song, Dongqing Yang, Bin Cui, Baihua Zheng, Yunfeng Liu and Kunqing Xie.
CLAIM: An Efficient Method for Relaxed Frequent Closed Itemsets Mining over Stream Data

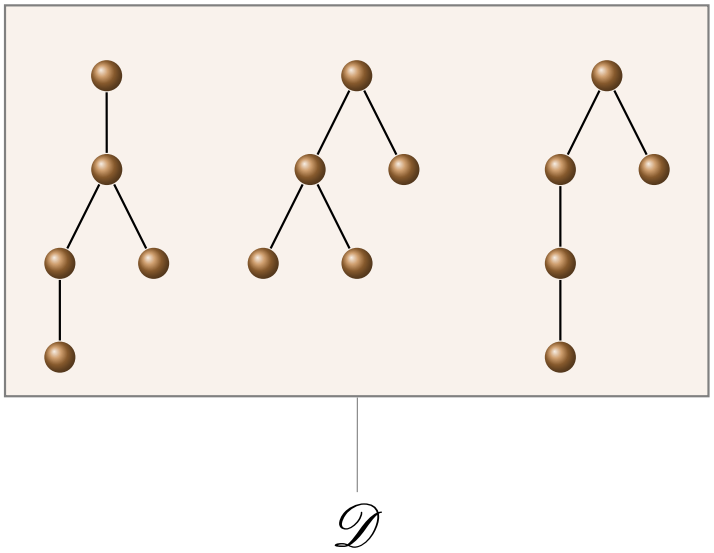
- **Linear Relaxed Interval**:The support space of all subpatterns can be divided into $n = \lceil 1/\varepsilon_r \rceil$ intervals, where ε_r is a user-specified relaxed factor, and each interval can be denoted by $\mathscr{I}_i = [l_i, u_i)$, where $l_i = (n-i) * \varepsilon_r \geq 0$, $u_i = (n-i+1) * \varepsilon_r \leq 1$ and $i \leq n$.
- **Linear Relaxed closed subpattern** t: if and only if there exists no proper superpattern t' of t such that their suports belong to the same interval $\mathscr{I}_i$.

Relaxed Support

As the number of closed frequent patterns is not linear with respect support, we introduce a new relaxed support:

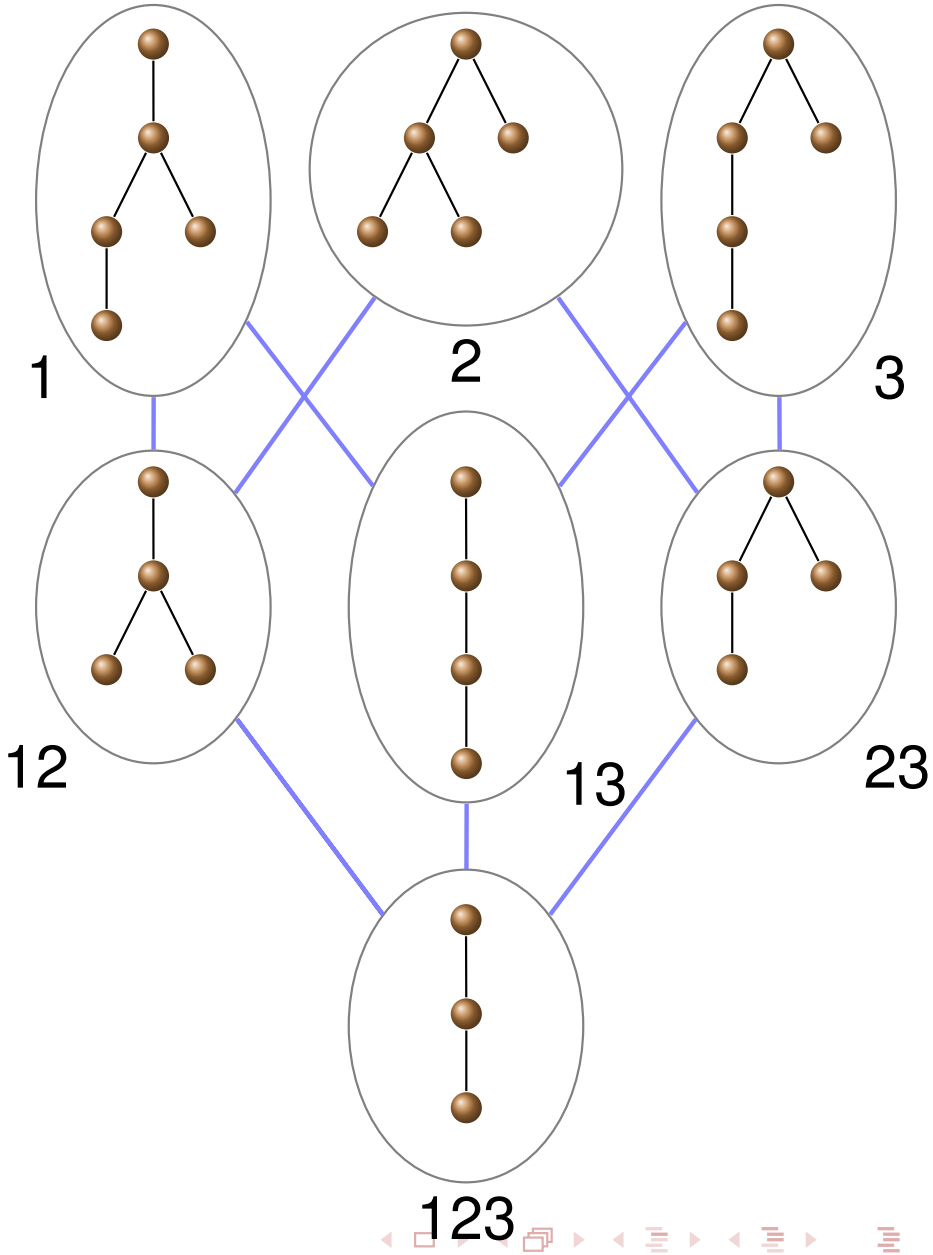
- **Logarithmic Relaxed Interval**:The support space of all subpatterns can be divided into $n = \lceil 1/\varepsilon_r \rceil$ intervals, where ε_r is a user-specified relaxed factor, and each interval can be denoted by $\mathscr{I}_i = [l_i, u_i)$, where $l_i = \lceil c^i \rceil$, $u_i = \lceil c^{i+1} - 1 \rceil$ and $i \leq n$.
- **Logarithmic Relaxed closed subpattern** t: if and only if there exists no proper superpattern t' of t such that their suports belong to the same interval $\mathscr{I}_i$.

Galois Lattice of closed set of trees



We need

- a Galois connection pair
- a closure operator



Algorithms

Algorithms

- Incremental: IncTreeNat
- Sliding Window: WinTreeNat
- Adaptive: AdaTreeNat Uses `ADWIN` to monitor change

`ADWIN`

An adaptive sliding window whose size is recomputed online according to the rate of change observed.

`ADWIN` has rigorous guarantees (theorems)

- On ratio of false positives and negatives
- On the relation of the size of the current window and change rates

Experimental Validation: TN1

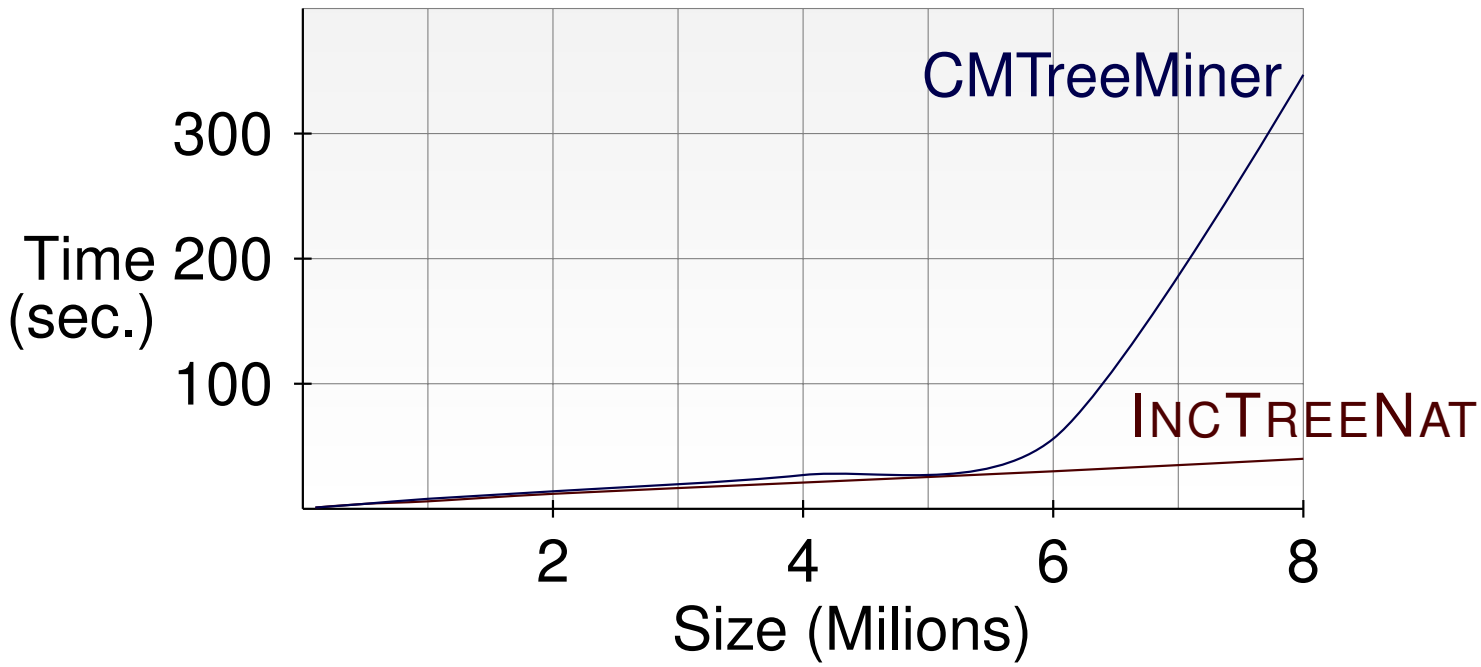


Figure: Time on experiments on ordered trees on TN1 dataset

Experimental Validation

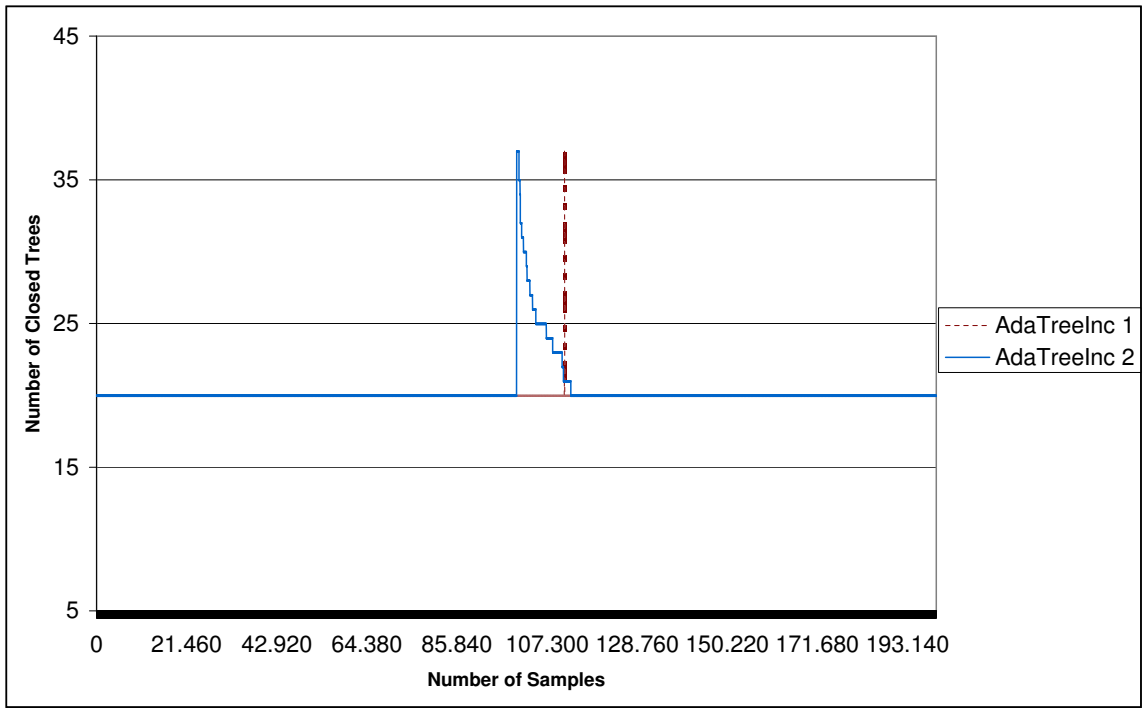


Figure: Number of closed trees maintaining the same number of closed datasets on input data

Summary

Conclusions

- New logarithmic relaxed closed support
- Using Galois Latice Theory, we present methods for mining closed trees
  - Incremental: IncTreeNat
  - Sliding Window: WinTreeNat
  - Adaptive: AdaTreeNat using ADWIN to monitor change

Future Work

Labeled Trees and XML data.