Mining Structures of Documents

CPS 296.1

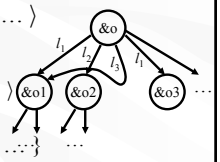
Topics in Database Systems

Overview

- Wang and Liu. "Discovering Typical Structures of Documents: A Road Map Approach." *SIGIR*, 1998
- Motivation: query/browsing tool, overview/summary, indexes, views, clustering, discovering access patterns, ...
- What is a "structure"?
  - Tree expression
- What is a "typical" structure?
  - Found in more than *MINSUP* documents
- How to discover typical structures?
  - Just like Apriori
  - Start from simple tree expressions to build more complex ones
  - Subexpressions of a typical tree expression must be typical

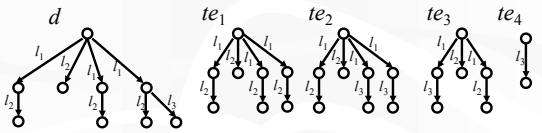
Data model

- OEM, but with list/bag instead of set
  - List example: val(&o) = $\langle\, l_1$:&o1, l_2:&o2, l_3:&o1, l_1:&o3, … $\rangle$
    - Order matters
    - Not equivalent to $\langle\, l_1$:&o1, l_3:&o1, l_2:&o2, l_1:&o3, … $\rangle$
  - Bag example: val(&o) = $\{\, l_1$:&o1, l_2:&o2, l_3:&o1, l_1:&o3, … $\}$
    - Order matters not
    - Equivalent to $\{\, l_1$:&o1, l_3:&o1, l_2:&o2, l_1:&o3, … $\}$
- We will ignore the case of bag in our discussion



Tree expression

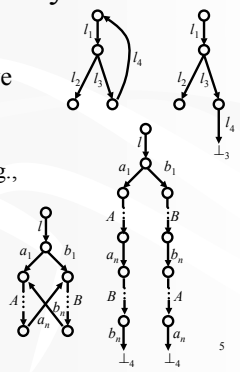
- A structure that may occur in a document



- *d* supports te_1, but not te_2, te_3, te_4
- Order of outgoing edges matters
- Number of duplicates matters
- Every path from the root in the tree expression must match a path from the root in the document

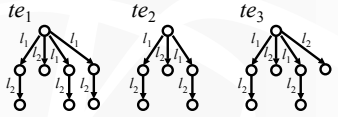
Dealing with cycles

- Use an alias $\perp_i$ to "point" back to the i-th node above the current one
  - A smart naming scheme—better than explicit id's (e.g., easy composition)
- Limitation: not a good representation for cycles with multiple entrances



Comparing tree expressions

- Some tree expressions are weaker than others
  - If *te* is weaker than *te'*, then a document that supports *te'* must support *te* as well
  - "Weaker than" is defined recursively on the structure of the trees being compared



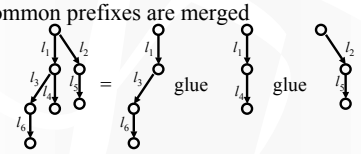
  - te_2 is weaker than both te_1 and te_3
  - te_1 and te_3 are incomparable

Discovering frequent tree expressions

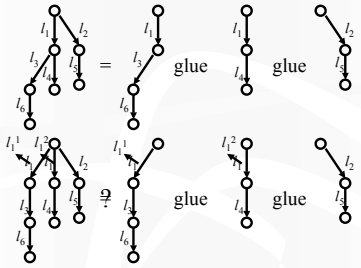
- Just like discovering frequent itemsets
  - Transaction = document
  - Itemset = tree expression
  - Transaction contains itemset = document supports tree expression
  - Itemset is in positive border = tree expression is frequent, and not weaker than any other frequent tree expression
- Question: item = ?
  - Or, from another perspective: How to "grow" tree expressions?

Item ≈ path expression

- A path expression represents a root-to-leaf path in a tree expression
- A tree expression with k leaves can be constructed (represented) by "gluing" a sequence of path expressions, one for each of the k leaves
  - Order matters
  - Common prefixes are merged



Dealing with duplicates



- Use superscripts to allows duplicate labels

Algorithm sketch

- Pass 1: Scan all documents to identify L_1, the set of frequent tree expressions with 1 leaf
  - That is, the set of frequent path expressions
- …
- Pass k
  - Generate C_k, the set of candidate tree expressions with k leaves, from L_{k-1}, the set of frequent tree expressions with $k-1$ leaves
    - Join and prune
  - Scan all documents to count each tree expression in C_k, and determine L_k
  - Stop if $L_k = \emptyset$
- …

Candidate generation: join

- Recall that a tree expression with k leaves can be represented by a sequence of k path expressions
- Given
  - $p_1 p_2 \cdots p_{k-2} p_{k-1} \in L_{k-1}$
  - $p_1 p_2 \cdots p_{k-2} p_k \in L_{k-1}$
- Generate $p_1 p_2 \cdots p_{k-2} p_{k-1} p_k$ in C_k

➢ Termed "extending p_{k-1} by p_k" in the paper

Candidate pruning

- Join alone does not enforce the Apriori property
- For each $p_1 p_2 \cdots p_{k-2} p_{k-1} p_k \in C_k$
  - $p_1 p_2 \cdots p_{k-2} p_{k-1}$ and $p_1 p_2 \cdots p_{k-2} p_k$ are frequent by construction
  - But we still should check other subsequence of length $k-1$; if any such subsequence is not frequent, prune $p_1 p_2 \cdots p_{k-2} p_{k-1} p_k$ from C_k

➢ Surprisingly, this strategy is not in the paper

Other pruning strategies (strategy 1)

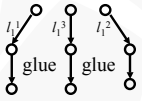
- Given $p_1\, p_2 \ldots p_{k-2}\, p_{k-1}$ and $p_1\, p_2 \ldots p_{k-2}\, p_k$ in L_{k-1}
- Do not extend p_{k-1} by p_k if the superscripts in $p_1\, p_2 \ldots p_{k-2}\, p_{k-1}$ do not occur in natural order (sorted and has no gap)
  - However, it is okay to have a gap between p_{k-2} and p_k, or between p_{k-1} and p_k

te_1: unnatural—do not extend

te_2: natural—can be extended by te_1

Other pruning strategies (strategy 2)

- For each $p_1\, p_2 \ldots p_{k-1}\, p_k \in C_k$, prune it if the superscripts for the some label do not occur in sorted order
  - Because no matter how we use this tree expression (to extend others or to be extended by others) these superscript will remain unsorted



Unsorted: prune

Summary

- First attempt at applying frequent itemset mining techniques to mining document structure
  - Mapping to the frequent itemset mining problem is fairly straightforward
- Patterns considered are restrictive
  - All paths start from the root
  - Cycles are not handled well
- Including subscripts in patterns really complicates things → two pruning strategies to deal with the complexity
  - Better idea: extend the notion of join instead?
- Repeated path expression matching is inefficient
  - How about building an index (like FP-tree)?

End-semester logistics

- Course project
  - In-class presentation: Thursday, May 2, 2pm – 5pm
    - Talk: 20 – 25 minutes; Q&A: 5 – 10 minutes
    - Slides/demos encouraged
  - Report due Thursday, May 2, 11:59pm
- Grading
  - Check CourseInfo for possible recording errors
    - Deadline for requesting a correction: May 2, 11:59pm
  - Final grades will be assigned on May 4
- Office hours during reading period
  - Regular office hours + class meeting time, or by appointment