Mining Frequent Patterns Without Candidate Generation

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(Part of the slides are due to Jiawei Han)

Is Apriori Efficient Enough? □Performance Bottlenecks!!

- Basic Idea: Candidate generation-and-test
  - Use frequent (*k* □ 1)-itemsets to generate candidate frequent *k*-itemsets
  - Use database scan and pattern matching to test (i.e., collect counts for the candidate itemsets)
- Bottleneck:
  - Generation may lead to huge candidate sets
    - n frequent 1-itemset will generate n(n-1)/2 candidate 2-itemsets
    - To discover a frequent pattern of length 100, e.g., $\{a_1, a_2, □, a_{100}\}$, we need to generate $2^{100} \approx 10^{30}$ candidates.
  - Test involves multiple scans of the entire database
    - Needs $(n+1)$ scans, n is the length of the longest pattern

Can We Do Better? □ Mining frequent patterns without candidate generation

- Database projection and compression
  - Project the database based on its frequent patterns
  - Compress a database into a compact, Frequent-Pattern tree (FP-tree)
    - condensed, but complete for frequent pattern mining
    - no candidate generation: test projected database only!
- ®Divide-and-conquer□
  - decompose both the task and DB according to the frequent patterns obtained so far

Construction of FP-tree from a Transaction Database

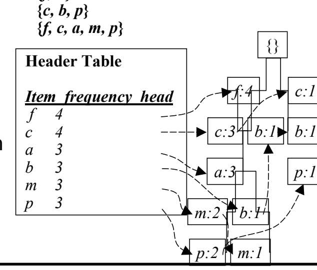
TID	*Items bought*	*(ordered) frequent items*
100	*{f, a, c, d, g, i, m, p}*	*{f, c, a, m, p}*
200	*{a, b, c, f, l, m, o}*	*{f, c, a, b, m}*
300	*{b, f, h, j, o, w}*	*{f, b}*
400	*{b, c, k, s, p}*	*{c, b, p}*
500	*{a, f, c, e, l, p, m, n}*	*{f, c, a, m, p}*

min_support = 3

1 Scan DB once, find frequent 1-itemset (single item pattern)

2 Order frequent items in frequency descending order

3 Scan DB again, construct FP-tree



Benefits of the FP-tree Structure

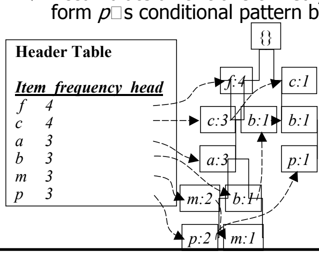
- Completeness
  - Preserves complete information for frequent pattern mining
- Compactness
  - Reducing irrelevant info□infrequent items are gone
  - Items in frequency descent order: the more frequently occurring, the more likely to be shared
  - Never be larger than the original database (not count node-links and the *count* field)
  - For Connect-4 DB, compression ratio could be over 100

Mining Frequent Patterns with FP-trees

- Idea: Frequent pattern growth
  - Recursively grow frequent patterns by pattern and database partition
- Method
  - For each frequent item, construct its conditional pattern-base, and then its conditional FP-tree
  - Repeat the process on each newly created conditional FP-tree
  - Until the resulting FP-tree is empty, or it contains only one path□single path will generate all the combinations of its sub-paths, each of which is a frequent pattern

From FP-tree to Conditional Pattern-Base

- Starting at the frequent item header table in the FP-tree
- Traverse the FP-tree by following the link of each frequent item *p*
- Accumulate all of *transformed prefix paths* of item *p* to form *p*□s conditional pattern base

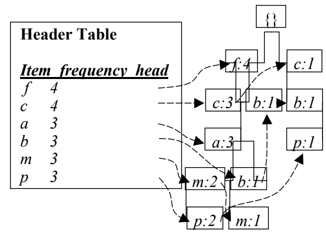


***Conditional* pattern bases**

item	cond. pattern base
c	f:3
a	fc:3
b	fca:1, f:1, c:1
m	fca:2, fcab:1
p	fcam:2, cb:1

Transformed Prefix Paths

- Derive the *transformed prefix paths* of item *p*
  - For each item *p* in the tree, collect *p*□s prefix path with count = *p*□s frequency



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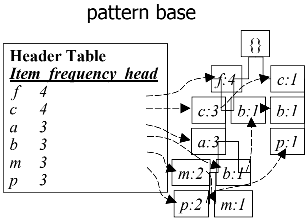
From Conditional Pattern-Bases to Conditional FP-trees

- For each pattern-base
  - Accumulate the count for each item in the base
  - Construct the FP-tree for the frequent items of the pattern base



***m-conditional* pattern base:**
fca:2, fcab:1

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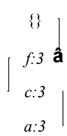

***m-conditional* FP-tree**

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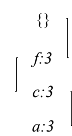
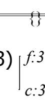
All frequent patterns relate to *m*
m,
fm, cm, am,
fcm, fam, cam,
fcam

Recursion: Mining Each Conditional FP-tree Until □



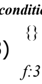
***m-conditional* FP-tree**

Cond. pattern base of ®am□: (fc:3)



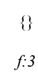
***am-conditional* FP-tree**

Cond. pattern base of ®cm□: (f:3)



***cm-conditional* FP-tree**

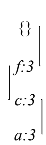
Cond. pattern base of ®cam□: (f:3)



***cam-conditional* FP-tree**

A Special Case: Single FP-tree Path

- Suppose a (conditional) FP-tree T has a single path P
- The complete set of frequent patterns of T can be generated by enumeration of all the combinations of the sub-paths of P



***m-conditional* FP-tree**

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All frequent patterns concerning *m*
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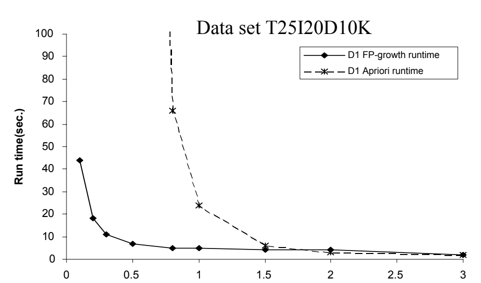
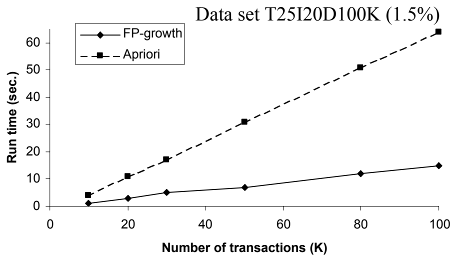
fm, cm, am,
fcm, fam, cam,
fcam

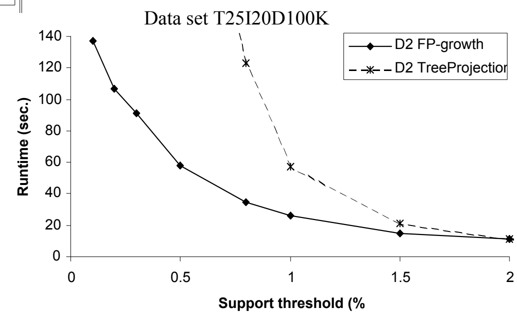
FP-Growth vs. Apriori: Scalability With the Support Threshold



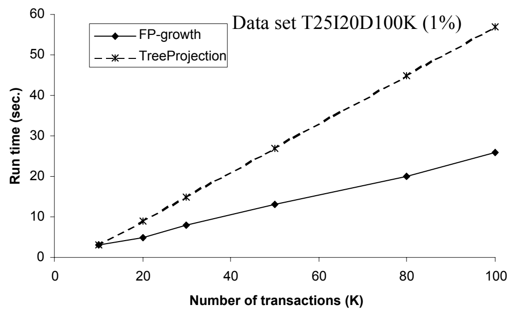
FP-Growth vs. Apriori: Scalability With the Number of Transactions



FP-Growth vs. Tree-Projection: Scalability with the Support Threshold



FP-growth vs. Tree-Projection: Scalability with the # of Transactions



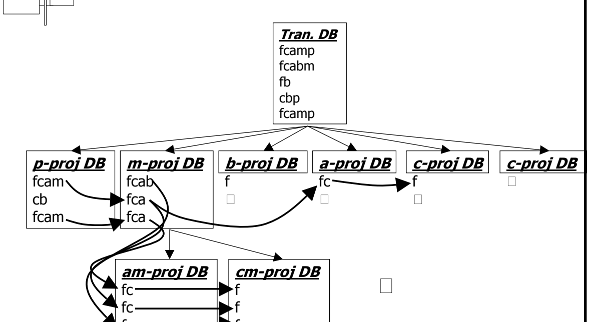
Why Is FP-Growth the Winner?

- decompose both the mining task and DB according to the frequent patterns obtained so far
- no redundant counting
- leads to focused search of smaller databases
- no candidate generation, no candidate test
- compressed database: FP-tree structure
- no repeated scan of entire database

I/O-Bound FP-Growth: Scaling FP-Growth by DB Projection

- FP-tree cannot fit in memory?□DB projection
  - first partition a database into a set of projected DBs
  - then construct and mine FP-tree for each projected DB
- Alternative methods
  - Construction of a disk-resident FP-tree
  - Materialization and incremental update of an FP-tree

Partition-Based Projection



Thank you !!!