C | A | U Christian-Albrechts-Universität zu Kiel Technische Fakultät

# Inf-KDDM: Knowledge Discovery and Data Mining

Winter Term 2020/21

## Lecture 4: Frequent Itemset Mining II

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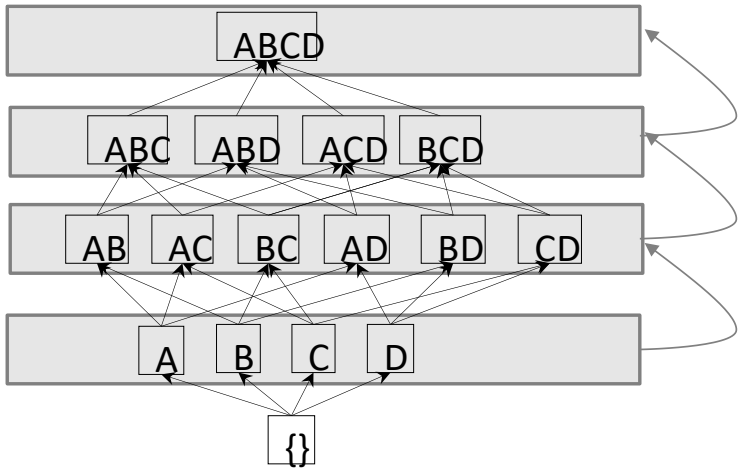
Exercises: Steffen Strohm

# Outline

- Apriori improvements
- Closed frequent itemsets (CFI) & Maximal frequent itemsets (MFI)
- Beyond FIM for binary data

# Apriori improvements

- Major computational challenges in Apriori:
  - Multiple scans of the DB: For each level *k* (i.e., *k*-itemsets), a database scan is required
  - Huge number of candidates (first generate, then test)
  - Tedious workload of support counting for candidates
    - Too many candidates.
    - One transaction may contain many candidates.
- Improving Apriori directions:
  - Reduce passes of transaction database scans
  - Shrink number of candidates
  - Facilitate support counting of candidates
  - In this lecture:
    - (FPGrowth), Partition, Sampling, ECLAT




level –wise search (breadth-first search)

# FPGrowth (Han, Pei & Yin, SIGMOD'00)

- The FPGrowth (frequent pattern growth) approach
  - Compresses the database using FP-tree, an extension of prefix-tree
    - It retains the transactions information
    - Never breaks a long pattern of any transaction
  - Depth-first search (DFS)
  - Avoids explicit candidate generation
    - Frequent itemsets are generated directly from the FP-tree.

# FP-tree

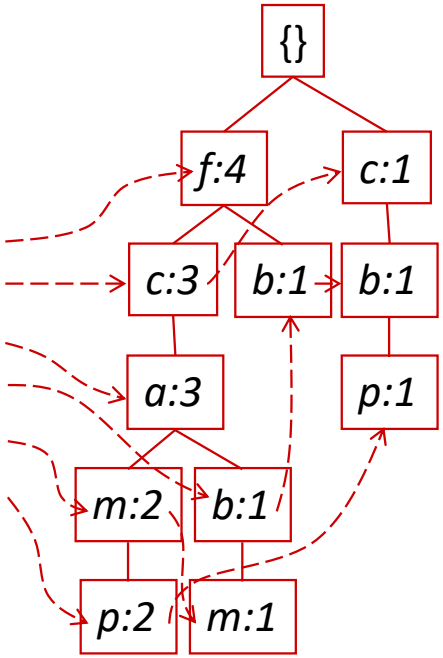
| TID | Items bought | (ordered) frequent items |
|---|---|---|
| 100 | {f, a, c, d, g, i, m, p} | {f, c, a, m, p} |
| 200 | {a, b, c, f, l, m, o} | {f, c, a, b, m} |
| 300 | {b, f, h, j, o, w} | {f, b} |
| 400 | {b, c, k, s, p} | {c, b, p} |
| 500 | {a, f, c, e, l, p, m, n} | {f, c, a, m, p} |

*minSupport* = 3

*f*-list = f-c-a-b-m-p

**Header Table**

| *Item* | *frequency* | *head* |
|---|---|---|
| *f* | 4 | |
| *c* | 4 | |
| *a* | 3 | |
| *b* | 3 | |
| *m* | 3 | |
| *p* | 3 | |




- Each transaction is mapped into a path in the FP-tree
- To facilitate tree traversal, each item in the header table points to its occurrences in the tree via a chain of node-links
- Most common items appear close to the root

# FP-tree construction 1/2

**Method:**

1. Scan DB once and find the frequent 1-itemsets. Scan 1
2. Discard infrequent items
3. Sort frequent items in frequency descending order → *f*-list

| 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} |

*minSupport* = 3

in our example:
a-b-c-f-m-p

in our example:
*f*-list = f-c-a-b-m-p

4. Scan DB again, construct FP-tree

Transaction items are accessed in *f*-list order!!!

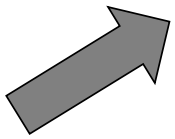
# FP-tree construction 2/2

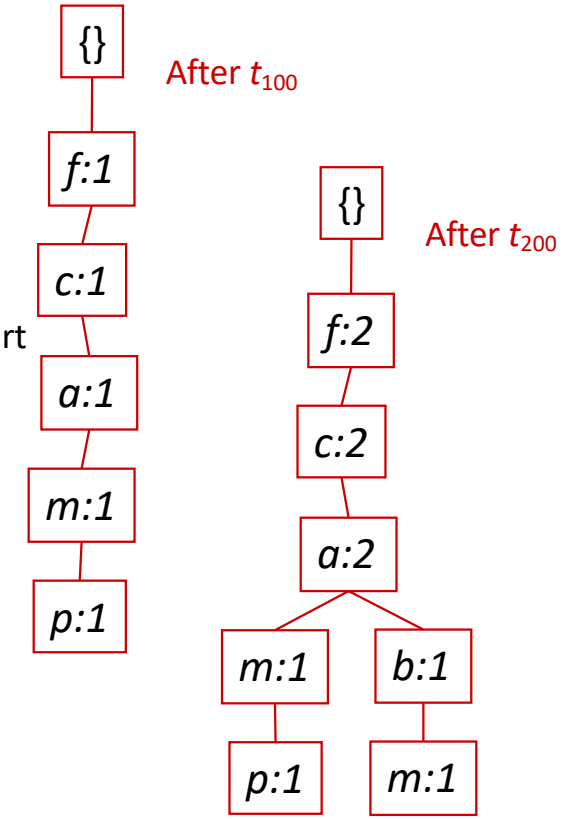
4. (Cont') Scan DB again, construct FP-tree Scan 2

- Create the root of the tree, labeled with "*null*"
- Insert first transaction ($t_{100}$) in the tree
- Insert the next transaction ($t_{200}$) in the tree
  - If they are identical, just update the nodes along the path
  - If they share a common prefix (in our case *fca*), update nodes in the shared part

  (i.e., fca) and create a new branch for the rest of the transaction $t_{200}$ (i.e., (bm)).
  - If nothing in common, start a new branch from the root
- Repeat for all transactions

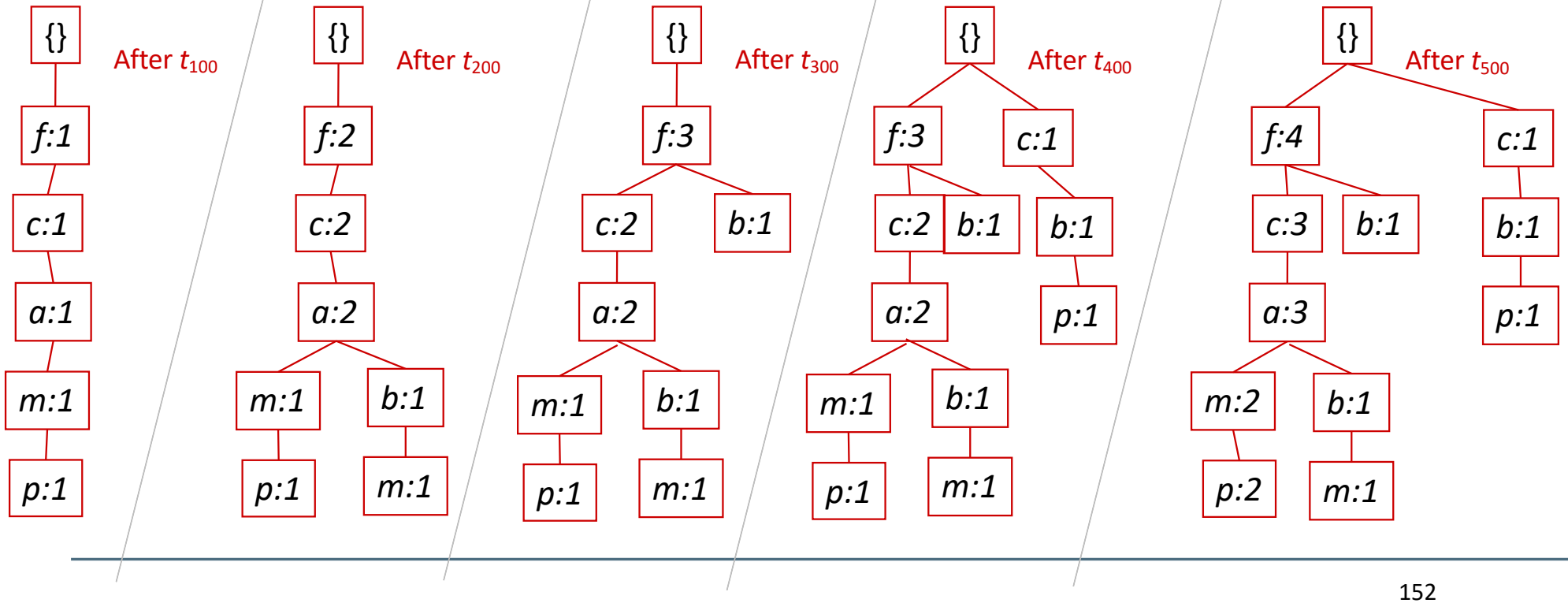
| TID | (ordered) frequent items |
|---|---|
| 100 | {f, c, a, m, p} |
| 200 | {f, c, a, b, m} |
| 300 | {f, b} |
| 400 | {c, b, p} |
| 500 | {f, c, a, m, p} |





# FP-tree construction step by step

| 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} |



# The complete FP-tree

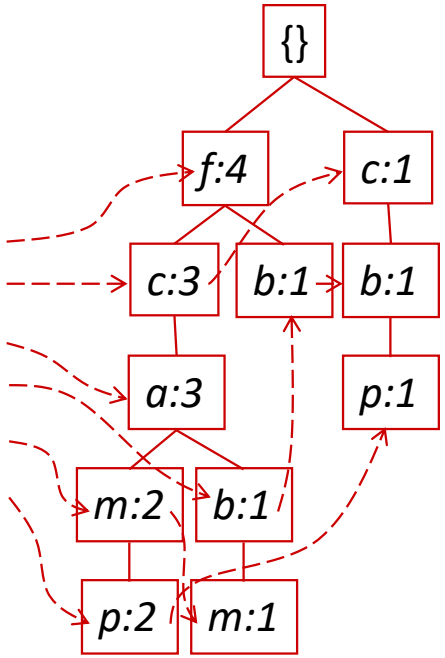
| TID | Items bought | (ordered) frequent items |
|---|---|---|
| 100 | {f, a, c, d, g, i, m, p} | {f, c, a, m, p} |
| 200 | {a, b, c, f, l, m, o} | {f, c, a, b, m} |
| 300 | {b, f, h, j, o, w} | {f, b} |
| 400 | {b, c, k, s, p} | {c, b, p} |
| 500 | {a, f, c, e, l, p, m, n} | {f, c, a, m, p} |

*minSupport* = 3

*f*-list = f-c-a-b-m-p

**Header Table**

| *Item* | *frequency* | *head* |
|---|---|---|
| *f* | 4 | |
| *c* | 4 | |
| *a* | 3 | |
| *b* | 3 | |
| *m* | 3 | |
| *p* | 3 | |




- Each transaction is mapped into a path in the FP-tree
- To facilitate tree traversal, each item in the header table points to its occurrences in the tree via a chain of node-links
- most common items appear close to the root

# Advantages of the FP-tree structure

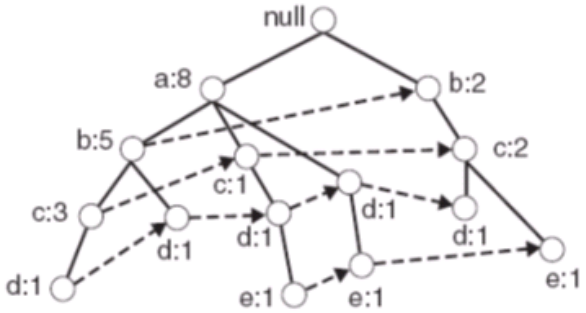
- Completeness
  - Preserves complete information for frequent pattern mining
  - Never breaks a long pattern of any transaction
- Compactness
  - Reduces irrelevant info—infrequent items are gone
  - Items in frequency descending order (*f*-list): the more frequently occurring, the more likely to be shared
  - Never is larger than the original database (not counting *node-links* and the *node-counts* fields)
  - Achieves high compression ratio


What is the best-case compression scenario for an FP-tree?


What is the worse-case compression scenario for an FP-tree?

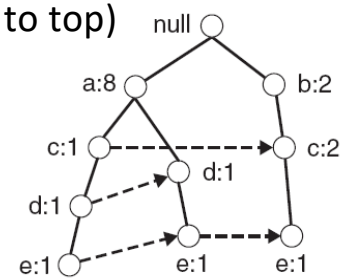
# Frequent itemsets generation from FP-tree

- Explore the tree in a bottom-up fashion, finding all frequent itemsets ending with a particular suffix
  - Rationale: all the patterns containing frequent items that a node $a_i$ participates can be collected by starting at $a_i$'s node-link head and following its node-links.
  - Start with the frequent item header table (bottom to top) in the FP-tree: first look for e, d, c, b, a
  - Traverse the FP-tree by following the link of each frequent item *e* → prefix paths ending in *e*

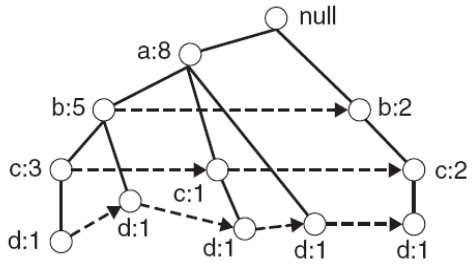



(iv) After reading TID=10

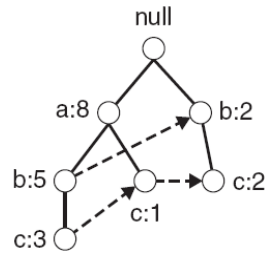
**Figure 6.24.** Construction of an FP-tree.



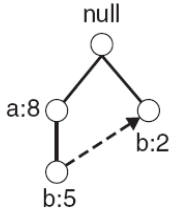

(a) Paths containing node e




(b) Paths containing node d




(c) Paths containing node c




(d) Paths containing node b


(e) Paths containing node a

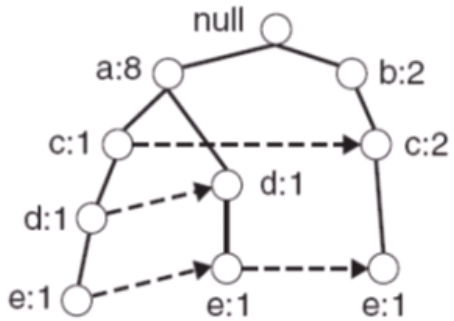
**Figure 6.26.** Decomposing the frequent itemset generation problem into multiple subproblems, where each subproblem involves finding frequent itemsets ending in $e$, $d$, $c$, $b$, and $a$.

# From prefix paths ending in *e* to conditional FP-tree for *e*

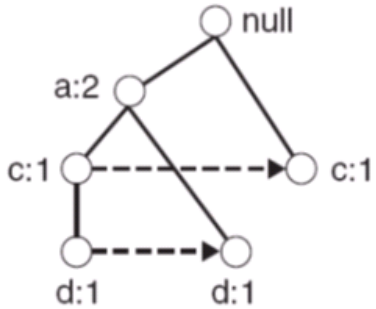
- Start with prefix paths ending in *e*
  - Update the support counts because some contain transactions without e.
    - E.g., {null-b:2-c:2-e:1} includes a transaction bc that does not contain e
  - Truncate the prefix paths by removing nodes for e
  - Remove non-frequent nodes (due to support update)
    - E.g., b:1 is not frequent anymore
- The result is *e*' conditional pattern base
- Conditional FP-tree
  - similar to FP-tree but encodes

items ending with a specific suffix,

*e* in our case



(a) Prefix paths ending in e



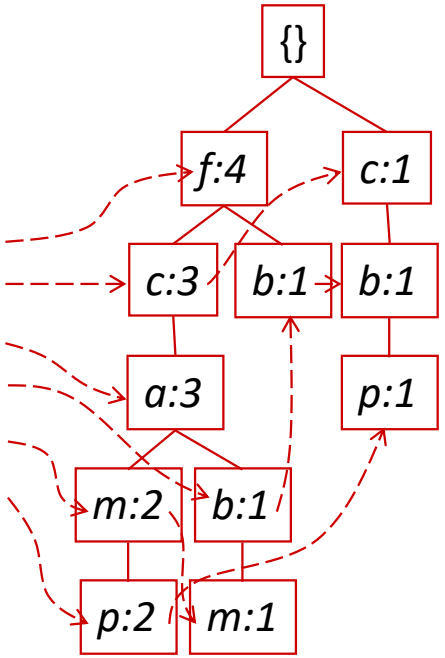
(b) Conditional FP-tree for e

# Conditional pattern bases

| TID | (ordered) frequent items |
|---|---|
| 100 | {f, c, a, m, p} |
| 200 | {f, c, a, b, m} |
| 300 | {f, b} |
| 400 | {c, b, p} |
| 500 | {f, c, a, m, p} |

**Header Table**

| *Item* | *frequency* | *head* |
|---|---|---|
| *f* | *4* | |
| *c* | *4* | |
| *a* | *3* | |
| *b* | *3* | |
| *m* | *3* | |
| *p* | *3* | |

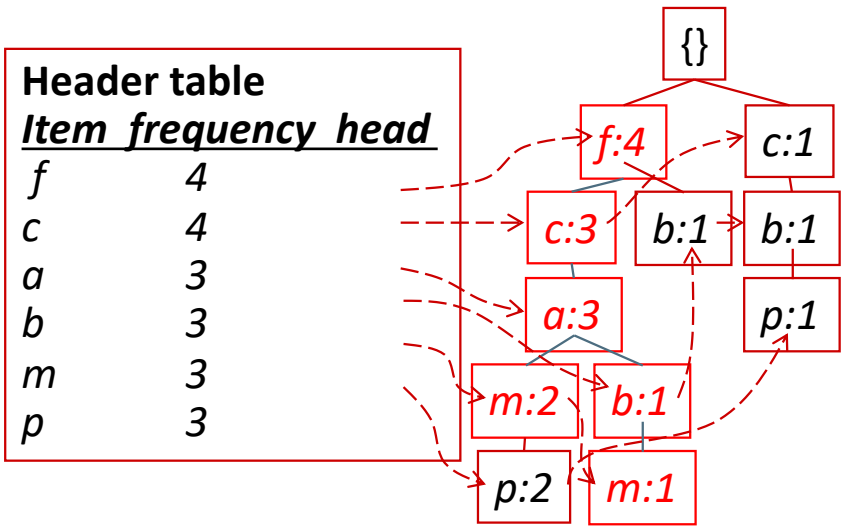



**Conditional pattern bases**

| *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* |

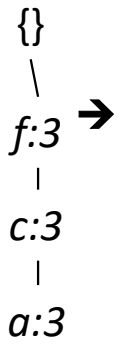
# Conditional FP-trees

- For each conditional 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***




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

**All frequent patterns relate to *m***

***m,***

***fm, cm, am,***

***fcm, fam, cam,***

***fcam***

# FP-Growth: Frequent itemsets generation from FP-tree

**FP-Growth procedure**

- Starting with the least frequent item, construct its conditional pattern-base, and then its conditional FP-tree
- After removing the infrequent items from the conditional FP-tree, retrieve all the frequent itemsets that involves item x.
- Repeat the above process for each frequent item in the order of increasing frequency (i.e. accessing the items of the Header table bottom up).