15-826: Multimedia Databases and Data Mining

Lecture #29: Data Mining - assoc. rules
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Must-read Material

- Rakesh Agrawal, Tomasz Imielinski and Arun Swami Mining Association Rules Between Sets of Items in Large Databases Proc. ACM SIGMOD, Washington, DC, May 1993, pp. 207-216

Outline

Goal: 'Find similar / interesting things'
• Intro to DB
• Indexing - similarity search
• Data Mining
   – Association Rules
Association rules - outline

- Main idea [Agrawal+SIGMOD93]
- performance improvements
- Variations / Applications
- Follow-up concepts

Association rules - idea

[Agrawal+SIGMOD93]
- Consider ‘market basket’ case:
  (milk, bread)
  (milk)
  (milk, chocolate)
  (milk, bread)
- Find ‘interesting things’, eg., rules of the form:
  milk, bread -> chocolate | 90%

Association rules - idea

In general, for a given rule
Ij, Ik, ... Im -> Ix | c
- ‘c’ = ‘confidence’ (how often people buy Ix, given that they have bought Ij, ... Im)
- ‘s’ = support: how often people buy Ij, ... Im, Ix
Association rules - idea

Problem definition:
• given
  – a set of ‘market baskets’ (=binary matrix, of N rows/baskets and M columns/products)
  – min-support ‘s’ and
  – min-confidence ‘c’
• find
  – all the rules with higher support and confidence

Closely related concept: “large itemset”

\[ I_j, I_k, \ldots, I_m, I_x \]

is a ‘large itemset’, if it appears more than ‘min-support’ times

Observation: once we have a ‘large itemset’, we can find out the qualifying rules easily (how?)
Thus, let’s focus on how to find ‘large itemsets’

Naive solution: scan database once; keep \(2^{*|I|}\) counters

Drawback?
Improvement?
Association rules - idea

Naive solution: scan database once; keep $2^{\|I\|}$ counters

Drawback? $2^{\|I\|} = 2^{1000}$ is prohibitive...

Improvement? scan the db $\|I\|$ times, looking for 1-, 2-, etc itemsets

Eg., for $\|I\| = 3$ items only (A, B, C), we have

- first pass
- min-sup: 10

A 100
B 200
C 2

AB
AC
BC

A
B
C

100
200
2

min-sup: 10
Association rules - idea

Anti-monotonicity property:
if an itemset fails to be 'large', so will every superset
of it (hence all supersets can be pruned)

Sketch of the (famous!) 'a-priori' algorithm
Let \( L(i-1) \) be the set of large itemsets with \( i-1 \)
elements
Let \( C(i) \) be the set of candidate itemsets (of size \( i \))

Association rules - idea

Compute \( L(1) \), by scanning the database.
repeat, for \( i=2,3,... \),
  'join' \( L(i-1) \) with itself, to generate \( C(i) \)
  two itemset can be joined, if they agree on their first \( i-2 \) elements
prune the itemsets of \( C(i) \) (how?)
  scan the db, finding the counts of the \( C(i) \) itemsets - set
  this to be \( L(i) \)
  unless \( L(i) \) is empty, repeat the loop
(see example 6.1 in [Han+Kamber])

Association rules - outline

• Main idea [Agrawal+SIGMOD93]
• performance improvements
• Variations / Applications
• Follow-up concepts
Association rules - improvements

- Use the independence assumption, to second-guess large itemsets a few steps ahead
- Eliminate ‘market baskets’, that don’t contain any more large itemsets
- Partitioning (e.g., for parallelism): find ‘local large itemsets’, and merge.
- Sampling
- Report only ‘maximal large itemsets’ (dfn?)
- FP-tree (seems to be the fastest)

Association rules - improvements

- FP-tree: no candidate itemset generation - only two passes over dataset
- Main idea: build a TRIE in main memory
  - First pass, to find counts of each item - sort items in decreasing count order
  - Second pass: build the TRIE, and update its counts

(eg., let A,B, C, D be the items in frequency order:)

Association rules - improvements

- Eg., let A,B, C, D be the items in frequency order:

```
\[
\begin{array}{c}
A & 32 \\
B & 10 \\
C & 1 \\
\{\} & 32 \\
\end{array}
\]
```

32 records
10 of them have A
4 have AB
2 have AC
1 has C

32 records
10 of them have A
4 have AB
2 have AC
1 has C
Association rules - improvements

- Traversing the TRIE, we can find the large itemsets (details: in [Han+Kamber, §6.2.4])
- Result: much faster than ‘a-priori’ (order of magnitude)

Association rules - outline

- Main idea [Agrawal+SIGMOD93]
- Performance improvements
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- Follow-up concepts

Association rules - variations

1) Multi-level rules: given concept hierarchy
   - ‘bread’, ‘milk’, ‘butter’ -> foods;
   - ‘aspirin’, ‘tylenol’ -> pharmacy
   - look for rules across any level of the hierarchy, eg ‘aspirin’ -> foods
   - (similarly, rules across dimensions, like ‘product’, ‘time’, ‘branch’):
     - ‘bread’, ‘12noon’, ‘PGH-branch’ -> ‘milk’
Association rules - variations

2) Sequential patterns:
   ‘car’, ‘now’ -> ‘tires’, ‘2 months later’
   Also: given a stream of (time-stamped) events:
   A   A   B   A   C   A   B   A   C .....  
   find rules like  
   B, A -> C  
   [Manilla+KDD97]

Association rules - variations

3) Spatial rules, eg:
   ‘house close to lake’ -> ‘expensive’

Association rules - variations

4) Quantitative rules, eg:
   ‘age between 20 and 30’, ‘chol. level <150’ ->
   ‘weight > 150lb’
   I.e., given numerical attributes, how to find rules?
**Association rules - variations**

4) Quantitative rules

Solution:
- bucketize the (numerical) attributes
- find (binary) rules
- stitch appropriate buckets together:

- salary
- age

**Association rules - outline**

- Main idea [Agrawal+SIGMOD93]
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**Association rules - follow-up concepts**

Associations rules vs. correlation.

Motivation: if

```
milk, bread
```

is a 'large itemset', does this mean that there is a positive correlation between 'milk' and 'bread' sales?
Association rules - follow-up concepts
Associations rules vs. correlation.
Motivation: if milk, bread is a 'large itemset', does this mean that there is a positive correlation between 'milk' and 'bread' sales?
NO!! 'milk' and 'bread' ANTI-correlated, yet milk+bread: frequent

Association rules - follow-up concepts
What to do, then?
A: report only pairs of items that are indeed correlated - ie, they pass the Chi-square test
The idea can be extended to 3-, 4- etc itemsets (but becomes more expensive to check)
See [Han+Kamber, §6.5], or [Brin+,SIGMOD97]
Association rules - Conclusions

Association rules: a new tool to find patterns

• easy to understand its output
• fine-tuned algorithms exist