15-826: Multimedia Databases and Data Mining

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

- Han + Kamber, chapter 6.1-4 (1st Edition); or Chapter 5.1-4 (2nd Edition)

Must-read Material

- Rakesh Agrawal, Tomasz Imieliński 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

Data Mining - Detailed outline
- data warehouses; data cubes; OLAP
- classifiers
  - association rules

Classifiers - outline
- Case study: ‘Interval Classifier’ (‘IC’)
  - recent developments and variations

NOT in Final Exam
Tree Classifiers

Database issues: how about huge (training) datasets?

Case study: Interval Classifier [Agrawal+92]
Goal: build a classifier (eg., for target mailing)

Differences from AI/ML:
• retrieval efficiency (could use DBMS indices!)
• generation efficiency (large training dataset)

Tree Classifiers - ‘IC’

Proposed method: use classification tree, but
• split a range (= num. attribute) into \( k \) sub-ranges, as opposed to just 2
• do ‘dynamic pruning’ (ie., don’t expand a node that is fairly homogeneous)

Decision trees

• Pictorially, we have

\[
\begin{array}{c}
\text{num. attr#1 (eg., ‘age’)} \\
\text{num. attr#2 (eg., chol-level)} \\
\end{array}
\]

\[
\begin{array}{ccc}
+ & + & - \\
+ & + & - \\
+ & + & - \\
+ & - & - \\
\end{array}
\]
Decision trees

• and we want to label ‘?’

\[
\begin{array}{c|ccc}
\text{num. attr#2} & + & + & - \\
\text{num. attr#1 (eg., ‘age’)} & + & - & - \\
\end{array}
\]

so we build a decision tree:

\[
\begin{array}{c|ccc}
\text{num. attr#2} & + & + & - \\
\text{num. attr#1 (eg., ‘age’) 40} & + & - & - \\
\text{50} & + & + & - \\
\end{array}
\]

Tree Classifiers - ‘IC’

Sketch of algorithm

make-tree():
  partition set in groups by label
  obtain histograms for each group and each attribute
  Apply goodness function to pick winning attribute \( A' \)
  Partition the domain of \( A' \) into “strong” and “weak” intervals
  For each “strong” interval: assign it to majority label
  For each “weak” interval: make-tree()
Tree Classifiers - ‘IC’

- “strong” interval: = homogeneous (or close enough)
- \( k \): depends on # of distinct values
- ‘interval’ = ‘range’ for a continuous attribute;
- ‘interval’ = ‘value’ for a categorical one
- histograms: equi-width

Classification accuracy: comparable to standard algorithms (ID3, C4)

Tree Classifiers - ‘IC’

Conclusions: compared to standard algorithms (ID3, C4):
- Faster, because of
  - \( k \)-way splitting and
  - dynamic pruning
- comparable classification accuracy

Classifiers - outline

- Case study: ‘Interval Classifier’ (‘IC’)
- variations
Classifiers - newer methods

- SLIQ [Mehta+96]
- SPRINT [Shafer+, vldb96]
- PUBLIC [Rastogi+Shim, vldb98]
- RainForest [Gehrke+, 2000]

Goal: how to make build decision trees, when the training set does not fit in memory

Classifiers - newer methods

SLIQ: use vertical partitioning (att-value, record-id) for each attribute; keep the (label, record-id) list in main memory

SPRINT: like SLIQ, but attach 'label' on each attribute list: (attr-value, label, record-id)

Classifiers - conclusions

Variations: try to improve scalability/speed with
- 'dynamic' pruning
- elaborate file structures / data placement
- parallelism
Data Mining - Detailed outline

- data warehouses; data cubes; OLAP
- classifiers
- 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
\[ I_j, I_k, \ldots, I_m \rightarrow I_x \mid c \]
‘c’ = ‘confidence’ (how often people by Ix, given that they have bought Ij, \ldots, Im
‘s’ = support: how often people buy Ij, \ldots, Im, Ix

Association rules - idea

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

Association rules - idea

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’
Association rules - idea

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

Association rules - idea

Naive solution: scan database once; keep $2^{|I|}$ counters
Drawback? $2^{1000}$ 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

Association rules - idea

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>first pass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>200</td>
<td>2</td>
<td>min-sup:10</td>
</tr>
</tbody>
</table>
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 \( i \))

Compute \( L(1) \), by scanning the database.
repeat, for \( i=2,3,... \),
   'join' \( L(i-1) \) with itself, to generate \( C(i) \)
   two itemsets 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
  - Specifically:
    - First pass, to find counts of each item - sort items in decreasing count order
    - Second pass: build the TRIE, and update its counts

  (e.g., 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:

{A} 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
• Variations / Applications
• 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?

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

Association rules - outline

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

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