15-826: Multimedia Databases and Data Mining

Lecture #28: Data Mining - trees + assoc. rules

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Reading Material

• Han + Kamber, chapter 6 (1st Edition); or Chapter 5 (2nd Edition)

Outline

Goal: ‘Find similar / interesting things’
• Intro to DB
• Indexing - similarity search
• Data Mining
Data Mining - Detailed outline

- Statistics
- AI - decision trees
- DB
  - (data warehouses; data cubes; OLAP)
  - classifiers
  - association rules

Classifiers - outline

- Case study: 'Interval Classifier' ('IC')
  - recent developments and variations

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

```
num. attr#1 (eg., ‘age’)
```

```
num. attr#2 (eg., chol-level)
```

- + - -
- + - -
+ - - -
+ - - -
+ - - -

```
num. attr#1 (eg., ‘age’)
```

- + - -
- + - -
+ - - -
+ - - -
+ - - -
+ - - -

- and we want to label ‘?’

```
num. attr#2 (eg., chol-level)
```

```
num. attr#1 (eg., ‘age’)
```
Decision trees

- so we build a decision tree:

<table>
<thead>
<tr>
<th>num. attr#1 (eg., ‘age’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>num. attr#2 (eg., chol-level)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
</tr>
</tbody>
</table>

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’)
- newer developments and 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

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

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

Recent methods: try to improve scalability/speed with
• ‘dynamic’ pruning
• elaborate file structures / data placement
• parallelism

Data Mining - Detailed outline

• Statistics
• AI - decision trees
• DB
  – (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’, e.g., rules of the form:
  - milk, bread -> chocolate | 90%

Association rules - idea

In general, for a given rule
  - I_j, I_k, ... I_m \rightarrow I_x | c
  - ‘c’ = ‘confidence’ (how often people buy I_x, given that they have bought I_j, ... I_m)
  - ‘s’ = support: how often people buy I_j, ... I_m, I_x
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”
Ij, Ik, ... Im, Ix
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? $2^{1000}$ 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

```
A  100
B  200
C   2
```
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 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 (eg., for parallelism): find ‘local large itemsets’, and merge.
- Sampling
- Report only ‘maximal large itemsets’ (dfn?)
- FP-tree (seems to be the fastest)

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**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

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

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**Association rules - improvements**

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

```
   A  B  C
   32 10  2
   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’
2) Sequential patterns:
   ‘car’, ‘now’ -> ‘tires’, ‘2 months later’
   Also: given a stream of (time-stamped) events:
   \[ A \ A \ B \ A \ C \ A \ B \ A \ C \ldots \]
   find rules like
   \[ B, A \rightarrow C \]
   [Manilla+KDD97]

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

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:

<table>
<thead>
<tr>
<th>salary</th>
<th>age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 means that there is a positive correlation between ‘milk’ and ‘bread’ sales?
Association rules - follow-up concepts

What to do, then?

A: report only pairs of items that are indeed correlated - i.e., 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