Compact Representation of Association Rule

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COMPACT REPRESENTATION OF ASSOCIATION RULE

A Thesis

Presented to

The Faculty of the Department of Computer Science

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Mien K. Siao

December 2006
Bitmap is an extremely efficient way of representing data, but the drawback is that the order of data is fixed in a bitmap. Granular computing is a new theory that frees the bitmap method from fixed order of data in the same manner as linear algebra frees the matrix theory from a fixed basis. To obtain meaningful information using data mining techniques has been a central idea in recent database applications [2]. One of the core techniques in data mining is to find associations (undirected association rules) between attribute values [4]. The complexity of finding associations is often very high.

In this work, a data warehouse is constructed utilizing bitmap fundamentals. Classic method of obtaining association rules is implemented along with the granular computing method of obtaining association rules. The performances from classic method and granular computing method is carefully analyzed and compared.
ACKNOWLEDGEMENTS

This work would not have been possible without Dr. T. Y. Lin’s guidance. Committee members, Dr. John Avila and Eric Louise’s support was essential to give this work an identity.


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CHAPTER 1
INTRODUCTION

1.1 Background

Data exists in various forms. Banks have data for each client to maintain bank accounts. Schools have data for its student’s academic records. Data has an ever growing presence in this world. Obtaining meaningful information from data that show trends and patterns is the science of data mining. A data warehouse provides important organization and storage of data before data mining is performed. Data in a raw form is meaningless.

To facilitate better understanding, data can be analyzed through the use of “item sets.” Item sets that occur frequently or show patterns lay the foundation of data mining and take the form of association rules. Large scale stores such as Safeway spreading across different locations possess humongous amounts of data due to their transaction volume. Prime reasons for chain stores to find association rules are: to adjust prices strategically, to promote new products effectively, and have the best decision support for better business.

A classical example suggests an association rule of the relationship between buying trends of diaper and beers. The item set formed in this example would be \{diaper, beer\}. Association rule “diaper => beer (60%)” means that three out of five customers buying diapers also bought beer. Suppose that the buying trend is observed over transactional data ‘D’. So diaper => beer will have confidence ‘c’ and support ‘s’ in D. In transactional data D, the number of transactions having diaper and beer together will
show support $s$ in $D$. Confidence $c$ in $D$ will be indicated by transactions having either diaper or beer.

1.2 Related Work

The most profound impact in the realm of data mining world by any single algorithm has been achieved by the Apriori algorithm (proposed by Rakesh et al). Apriori algorithm approaches the problem of determining all association rules in transactional data $D$ by sub-dividing the problem into two tasks. In the first task, all the frequent item sets are found. And in the second task, rules based on the frequent item sets that are found in the first task are generated. Apriori algorithm results in having multiple scans of the whole data set to find relationships between attribute values. This endeavor requires a lot of computational power.

In granular computing method, attribute values of a data set are represented by 1’s and 0’s in a bit map. Presence of a certain value is represented by 1 while the absence of that value is represented by 0. On parallel thoughts, 1 and 0 can be viewed as True and False. Computational power can be greatly reduced when using bit maps. In this way, using bit maps that need higher computational complexity, results are achieved with lesser computational power. From our earlier example of transactional data from a store such as Safeway, it will be a daunting task to find association rules using Apriori algorithm. Hypothetically, a set of transactional data having 100,000 attribute values and 1,000,000 rows of data will require $2^{100,000}$ scans to find all possible combinations resulting in frequent item sets.
CHAPTER 2

REQUIREMENTS

2.1 Project Scope

Exploring the fundamental idea of having more efficient data mining techniques influenced by granular method entails two phases. First phase provides an avenue for storing data utilizing bit properties and requires a data warehouse that is built from ground up based on bit maps. Second phase encompasses the use of bit properties to find meaningful information in a faster manner.

This project covers the first phase by presenting a model for a bit map based data warehouse. The architecture and properties of a bit map based data warehouse are studied. A data mining centric data warehouse is constructed as part of the first phase in this project to facilitate the testing of bit association rules.

The second phase of exploring the fundamental idea of having a highly efficient data mining approach is implemented. Support for this implementation is demonstrated by providing the results from the bit association rules. Performance of the general method of obtaining association rules is compared with the bit algorithm for finding the same association rules.
CHAPTER 3
DESIGN

3.1 Architecture

3.1.1 Upload Initial Data

Data used in this project is initially present in a raw format as a text file (datasort.txt). Prior to uploading this data, a table INITIAL_DATA_TABLE (refer to Create Table SQL in Appendices) and a corresponding sequence are created in Oracle (refer to Create Sequence SQL in Appendices).

The data set used in this work has 136 attributes with 150,418 rows.

<table>
<thead>
<tr>
<th>V0</th>
<th>V1</th>
<th>V2</th>
<th>.</th>
<th>.</th>
<th>V133</th>
<th>V136</th>
<th>V137</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.</td>
<td>.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>21</td>
<td>.</td>
<td>.</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>35</td>
<td>0</td>
<td>.</td>
<td>.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>999</td>
<td>.</td>
<td>.</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Fig. 1: INITIAL_DATA_TABLE**

There are 137 columns representing 136 attributes in INITIAL_DATA_TABLE plus a column ‘ROWNO’ for keeping track of the rows. INITIAL_DATA_TABLE has 150,418 rows with each row having varying values. Each of the attribute column in INITIAL_DATA_TABLE has different number of distinct values.
3.1.2 Bit Map Table Creation

For the purposes of this project, the columns in INITIAL_DATA_TABLE are filtered based on 32 distinct values in a particular column. Any column having more than 32 distinct values is left out during the data conversion into bitmaps. The data set from the INITIAL_DATA_TABLE are converted into 5 bitmaps for using granular computing approach. The need to create 5 separate bit map tables arises from the fact that Oracle 10g has a limitation of 1000 columns. One can easily see that the 1000 columns limitation could be exceeded if only 40 columns were to have 30 distinct values in INITIAL_DATA_TABLE.

The new bit map table has 1000 columns. The first column is the ‘NAME_VALUE’, where NAME is the column name and VALUE is the distinct value in that column. The subsequent 998 columns are ‘SET0’ through ‘SET997’. The last column is ‘ROWNO’. Each SET has the 32 values corresponding to 32 rows in a column. SET0 will have the first 32 rows while SET1 will have the next 32 rows. 998 SETs will cover 31936 (998*32) rows from INITIAL_DATA_TABLE.

Each bit map table follows the scheme depicted in Fig. 2. NAME_VALUE has the format of column followed by the distinct value of that column. ‘K’ in Fig. 2 represents the column while ‘i’ through ‘j’ represents the distinct values found in column K.
The first 32 values (rows) in column V0 are taken and put in SET0. The next 32 values are put in SET1. Values in a SET are represented using 1s’ and 0s’.

To help understand this architecture, let’s take column V0 through the bit map conversion process. In the data set, column V0 has 10 distinct values. Therefore, column V0 is retained since it fits the criteria of having less than 32 distinct values. The distinct values for column V0 are: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Following the NAME_VALUE scheme (NAME => Column Name and VALUE => distinct value in the column) gives: v0_0, v0_1, v0_2, v0_3, v0_4, v0_5, v0_6, v0_7, v0_8, and v0_9. From an earlier description of the bit map table, the presence of that value in that particular position is translated to 1 (True). In the first constructed bit map table, v0_0 has 111111111111111111111111111111100. Looking at this bit representation, the first thirty 1 (True) bits denotes the occurrence of value ‘0’ in column V0 and the 0 (False) 31st/32nd bits means that the value ‘0’ is not present. In other words, column V0 in INITIAL_DATA_TABLE has the value ‘0’ in its first 30 rows and some value other than ‘0’ in rows 31 and 32. Fig. 3 shows the actual values in INITIAL_DATA_TABLE.
An interesting observation in this process is that if any of the distinct values hold true for a particular position (row), values for the remaining distinct values would be false automatically. Column V0 in INITIAL_DATA_TABLE has 10 distinct values (0 – 9). This means that any row from INITIAL_DATA_TABLE for column V0 will only have values from within 0 through 9.

Visualizing this information in a tabular format where the NAME_VALUE pair is mapped horizontally would be more helpful to further understand this concept. In the table below, the NAME_VALUE pair is represented in the first row by v0_0, v0_1, v0_2, v0_3, v0_4, v0_5, v0_6, v0_7, v0_8, and v0_9. Subsequent rows in the table below indicate the status of the rows in INITIAL_DATA_TABLE. First row in INITIAL_DATA_TABLE has the value of 0 in column V0. This row is represented in the table below by putting a 1 (True) under v0_0, and the remaining distinct values as 0 (False). The technique of bitwise logical operation (AND) is utilized in this project to enable efficient association rule mining.
<table>
<thead>
<tr>
<th>$v_{0.0}$</th>
<th>$v_{0.1}$</th>
<th>$v_{0.2}$</th>
<th>$v_{0.3}$</th>
<th>$v_{0.4}$</th>
<th>$v_{0.5}$</th>
<th>$v_{0.6}$</th>
<th>$v_{0.7}$</th>
<th>$v_{0.8}$</th>
<th>$v_{0.9}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Fig. 4: Property obtained from Distinct Values*
CHAPTER 4
IMPLEMENTATION

4.1 Implementation issues

Challenges faced in the implementation of this endeavor can be broadly classified into two categories: issues encountered during the construction of the data warehouse and issues encountered during the implementation of algorithms for finding association rules.

4.1.1 Data warehouse construction issues

The primary implementation issue under this category was the absorption of the bit map concept and determining a way to implement this idea.

A major hurdle that influenced the implementation architecture of the data warehouse was Oracle 10g’s thousand columns limitation. Existing values in a regular table are taken and represented in terms of bits for the granular approach. This results in more bit map tables depending on the number of distinct values in each column and the number of rows (representing transactional data) in a given table. In this project, a general bit map table consisting of 1000 columns (maximizing Oracle 10g’s in-built feature) can represent 31936 rows from a table.

4.1.2 Association rule algorithm implementation issues

When implementing the computation of 1-itemset support, “Out of memory on Java Heap” errors were encountered. The ‘BitmapRow’ object that contains information related to a row in the bitmap table was causing the memory error. This object has a String array that is responsible for storing the counts of all values before converting to
binary format. The size of this String array object is larger than 150,000 as each row has over 150,000 values. Running the data file of size ‘n’ columns by ‘m’ distinct values results in n*m BitmapRow objects. With each BitmapRow object containing such a large-sized String array, space on the Java runtime heap is quickly exhausted with few iterations, causing out of memory errors.

This issue was handled by approaching the storage of the original value string from the bitmap into one single String value instead. The revised strategy uses getOrgString() method to break up into each individual value only prior to performing a bitwise ‘AND’ operation. The original count obtained from the BitmapRow objects are stored using String and each individual value is only processed when necessary. This methodology relieves excessive heap space utilization tremendously as each individual count is computed in a temporary String array instead of being stored with each row object.

4.2 Algorithms

Algorithms to generate association rules in the form of frequent item sets are implemented in two approaches for studies in this project. The two types of algorithms employed during the scope of this work are: classic algorithm to generate the association rules and algorithm utilizing bit map properties.

No major implementation issues were encountered with the classic algorithm for generating association rules. The classic algorithm was implemented using SQL in conjunction with JAVA.
4.2.1 Generating frequent 1-itemset(s) using the classic algorithm

The distinct values in a column are obtained using the SQL statement:

```
“SELECT COUNT (DISTINCT v"f") FROM initial_data_table”
```

where ‘f’ is the column number ranging from 0 to 137. For this project, if a column has more than 32 distinct values, that column is not considered in the frequent itemset generation.

Support for each of the distinct values in each of the columns in the table is calculated by the SQL statement:

```
SELECT COUNT (*) FROM initial_data_table WHERE v"f"="count"
```

where ‘count’ is the distinct value in the table. Support for each distinct value in a ‘valid’ (meeting the criteria of having at most 32 distinct values) column is calculated by implementing the support formula for a single item set:

\[
support = \frac{\text{total distinct values}}{\text{number of transactions}}
\]

A sample table is given below as an example:

<table>
<thead>
<tr>
<th>V0</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

*Fig. 5: Sample Table*
Column V0 through V6 from Fig. 5 are queried to determine the number of distinct values in that particular column. In this sample, columns V2 and V6 are not considered during frequent itemset generation because they exceed the threshold of 32 distinct values.

<table>
<thead>
<tr>
<th>Column</th>
<th>V0</th>
<th>V1</th>
<th>V2</th>
<th>V3</th>
<th>V4</th>
<th>V5</th>
<th>V6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distinct Values</td>
<td>10</td>
<td>8</td>
<td>142</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>61</td>
</tr>
</tbody>
</table>

*Fig. 6: Distinct values for columns from sample table*

Considering only the first 4 rows from the sample table in Fig. 5, the following support values are obtained for frequent 1-itemset:

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>v0_1</th>
<th>v0_2</th>
<th>v0_7</th>
<th>V0_9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

*Fig. 7: Support for column V0’s distinct values*

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>v1_1</th>
<th>v1_2</th>
<th>v1_3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support %</td>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

*Fig. 8: Support for column V1’s distinct values*

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>v3_1</th>
<th>v3_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support %</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

*Fig. 9: Support for column V3’s distinct values*

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>v4_1</th>
<th>v4_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support %</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

*Fig. 10: Support for column V4’s distinct values*

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>v5_4</th>
<th>v5_5</th>
<th>v5_7</th>
<th>v5_9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

*Fig. 11: Support for column V5’s distinct values*
4.2.2 Generating frequent 2-itemset(s) using the classic algorithm

For generating frequent 2-itemsets, the algorithm checks the distinct values for column V0. If the column has less than 33 distinct values, it becomes the first entity against which other subsequent distinct values of other columns are compared. The first column V0 has 10 distinct values, and column V1 has 8 distinct values. Both columns pass the threshold validity check and the support level is computed between these two columns. In the next column set comparison, V0 and V2, since V2 has 142 distinct values, therefore this column would not be considered in any future calculations. The algorithm continues to consider the next column as the second entity with V0 until it reached the last column in the table. The next set of iteration is performed against the next column number or V1 as the first entity. Proceeding in this fashion, this approach computes the support level for all distinct value pairs for all qualifying columns.

The common occurrences of distinct values in two columns are obtained by using the following SQL statement:

```
SELECT COUNT (*) FROM initial_data_table
WHERE V"first column"=distinct value AND V"second column"= distinct value
```

The detailed algorithm to generate all frequent 2-itemset can be abstracted in terms of two loops where the frequent 2-itemset will consists of a first entity and a second entity with the pair under consideration:
Outer loop

- Increments the column number of first entity till the last column is reached in the table

Inner loop

- Starts with initial iteration where column number of second entity equals to column number of first entity plus one
- Increments the column number of second entity after each iteration
- Generates support for each distinct value in first entity and second entity

Using the same sample table from frequent 1-itemset, all frequent 2-itemset obtained are:

<table>
<thead>
<tr>
<th>Column/Distinct</th>
<th>Support %</th>
</tr>
</thead>
<tbody>
<tr>
<td>v0 1, v1 1</td>
<td>25</td>
</tr>
<tr>
<td>v0 1, v3 1</td>
<td>25</td>
</tr>
<tr>
<td>v0 1, v4 1</td>
<td>25</td>
</tr>
<tr>
<td>v0 2, v1 2</td>
<td>25</td>
</tr>
<tr>
<td>v0 2, v3 2</td>
<td>25</td>
</tr>
<tr>
<td>v0 2, v4 2</td>
<td>25</td>
</tr>
<tr>
<td>v0 7, v5 7</td>
<td>25</td>
</tr>
<tr>
<td>v0 9, v5 9</td>
<td>25</td>
</tr>
<tr>
<td>v1 1, v3 1</td>
<td>25</td>
</tr>
<tr>
<td>v1 1, v4 1</td>
<td>50</td>
</tr>
<tr>
<td>v1 2, v3 2</td>
<td>25</td>
</tr>
<tr>
<td>v1 2, v4 2</td>
<td>25</td>
</tr>
<tr>
<td>v3 1, v4 1</td>
<td>25</td>
</tr>
<tr>
<td>v3 2, v4 2</td>
<td>25</td>
</tr>
</tbody>
</table>

Fig. 12: Support for all frequent 2-itemset
4.2.3 Generating frequent 1-itemset(s) using the bit algorithm

Bit algorithm uses the file ‘disk.txt’ for generating the frequent itemsets. This flat file is obtained by concatenating the 5 bit map tables previously constructed as described in section 3.1.2 (Bit Map Table Creation).

Consider the first line from disk.txt as a sample structure:

16777216 4294967292 0 0 0 . . .

These decimal representations are converted to binary for obtaining the column and distinct value information. Converting the header value ‘16777216’ to binary gives ‘1000000000000000000000000’.

This binary representation is interpreted as –

0000000000000000 – the lowest sixteen bits represent the distinct value
00000000 – the next eight bits represent the column number
1 – the highest bit represents the disk number.

Thus, the value ‘16777216’ or ‘1000000000000000000000000’ in binary, translates to V0_0 (column V0, distinct value 0).

The next value after ‘16777216’ is ‘4294967292’, which represents the presence or absence of distinct value ‘0’ at that particular position (first 32 rows in initial_data_table). Converting ‘4294967292’ to binary gives ‘111111111111111111111111100’. This indicates that in the first 30 rows of the original table (INITIAL_DATA_TABLE), ‘0’ is present followed by some other value on the thirty-first and thirty-second rows.
For generating frequent 1-itemsets, all the non-zero values are processed to get the total (presence or true) bit count. To calculate the associated support level, the following formula is used:

\[
\text{support} = \frac{\text{total bit count}}{\text{number of transactions}}
\]

4.2.4 Generating frequent 2-itemset(s) using the bit algorithm

In generating frequent 2-itemsets, the Apriori algorithm is utilized in the implementation. This approach reduces the total time taken to produce the output by 60% compared to the original implementation. Instead of simply computing for each possible combination of itemsets, validation of support requirement is performed prior to computation.

Suppose itemsets are calculated for support level of 30. The first entity in the comparison is checked against the specified support level. If the first entity does not meet the support level, subsequent computation of any possible permutations with the first entity is skipped. In the case that the first entity is at least the specified support level, the second entity is validated to ensure that it also fulfills the support level before the computation of common bits takes place.

Let’s demonstrate this strategy with an example:

Recall the sample data from Fig. 5. In finding 2-itemsets that have at least 30% support level, the algorithm first considers the entity v0_1. Since v0_1 has a support of 25%, it fails the check against the desired support level and the remaining computations (v0_1, v1_1), (v0_1, v2_1), \ldots, (v0_1\ldots v137_1) are skipped. It then considers the next entity
v1_1 and checks against the support level. It validates that v1_1 with support of 50% meets the minimum support and the support of the second entity is checked. It finds that the support for v2_1 does in fact fulfill the specified support of 30% so the algorithm would process the itemset (v1_1, v2_1). The original bitmap strings stored in the v1_1 and v2_1 objects are broken up into String arrays, converted back to binary and performed bitwise AND operation to compute the count of common occurrences of bits in both columns. The total count is finally used to return the support level of this itemset. The algorithm continues in the same manner in computing for (v1_1, v3_1), …, (v1_1, v137_1) until all possible 2-itemset combinations have been considered.

The bit algorithms for generating frequent itemsets were implemented to give the same results as the classic algorithm.
CHAPTER 5
DEPLOYMENT

5.1 Performance Analysis

Computer utilized in this work had the following configurations:

- 2.16Mhz Intel Dual Core CPU
- 2GB PC2-5300 DDR2 SDRAM
- Windows XP Professional SP2

The original data that was uploaded in Oracle resulted in 150,418 rows and 136 attribute values. This data formed the base from which algorithms in this project obtain frequent itemsets.

<table>
<thead>
<tr>
<th>Data</th>
<th>Rows</th>
<th>Attribute Values (Columns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>datasort</td>
<td>150,418</td>
<td>136</td>
</tr>
</tbody>
</table>

*Fig. 13: Data tested*

Association rules using the classic method and the granular computing method were used to generate frequent itemsets from the same data. Time was accounted for both the results.

<table>
<thead>
<tr>
<th></th>
<th>Frequent 1-itemset</th>
<th>Frequent 2-itemset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic algorithm</td>
<td>81 seconds</td>
<td>5331 seconds</td>
</tr>
<tr>
<td>Bit based algorithm</td>
<td>2 seconds</td>
<td>193 seconds</td>
</tr>
</tbody>
</table>

*Fig. 14: Time comparison between algorithms*

The classic method used SQL for getting the relevant information during its computation of frequent itemsets. An approach of having the data values from the
INITIAL_DATA_TABLE exported to a flat file and then using the classical method to obtain frequent itemsets was also examined. Time taken to obtain frequent itemsets from the flat file are not mentioned in this report as it was significantly higher than the classic algorithm using SQL and would not be meaningful to compare against the granular method.

## 5.2 Performance Data

Part of the data obtained from generating frequent itemsets is included in this section.

### 5.2.1 Data from frequent 1-itemset generation

<table>
<thead>
<tr>
<th>Frequent 1-itemset using classic method:</th>
<th>Frequent 1-itemset using granular method:</th>
</tr>
</thead>
<tbody>
<tr>
<td>v0_0</td>
<td>(V0_0) Support: 0</td>
</tr>
<tr>
<td>v0_1 [<strong>Support:</strong> 27]</td>
<td>(V0_1) [<strong>Support:</strong> 27]</td>
</tr>
<tr>
<td>v0_2</td>
<td>(V0_2) Support: 3</td>
</tr>
<tr>
<td>v0_3</td>
<td>(V0_3) Support: 4</td>
</tr>
<tr>
<td>v0_4</td>
<td>(V0_4) Support: 3</td>
</tr>
<tr>
<td>v0_5</td>
<td>(V0_5) Support: 8</td>
</tr>
<tr>
<td>v0_6</td>
<td>(V0_6) Support: 3</td>
</tr>
<tr>
<td>v0_7</td>
<td>(V0_7) Support: 38</td>
</tr>
<tr>
<td>v0_8</td>
<td>(V0_8) Support: 9</td>
</tr>
<tr>
<td>v0_9</td>
<td>(V0_9) Support: 5</td>
</tr>
<tr>
<td>v1_0</td>
<td>(V1_0) Support: 0</td>
</tr>
<tr>
<td>v1_1 [<strong>Support:</strong> 68]</td>
<td>(V1_1) [<strong>Support:</strong> 68]</td>
</tr>
<tr>
<td>v1_2 [<strong>Support:</strong> 32]</td>
<td>(V1_2) [<strong>Support:</strong> 32]</td>
</tr>
<tr>
<td>v1_3</td>
<td>(V1_3) Support: 0</td>
</tr>
<tr>
<td>v1_4</td>
<td>(V1_4) Support: 0</td>
</tr>
<tr>
<td>v1_5</td>
<td>(V1_5) Support: 0</td>
</tr>
<tr>
<td>v1_6</td>
<td>(V1_6) Support: 0</td>
</tr>
<tr>
<td>v1_9</td>
<td>(V1_9) Support: 1</td>
</tr>
</tbody>
</table>

**Time elapsed: 81 seconds**

**Time elapsed: 2 seconds**

****Time elapsed: 81 seconds****

****Time elapsed: 2 seconds****
5.2.2 Data from frequent 2-itemset generation

Note the ordering scheme of the following output varies for the two approaches although the two computed values are the same.

Frequent 2-itemset using classic method:

- \((v0_0, v1_0)\) Support: 0
- \((v0_1, v1_1)\) **Support: 18**
- \((v0_2, v1_2)\) Support: 1
- \((v0_3, v1_3)\) Support: 0
- \((v0_4, v1_4)\) Support: 0
- \((v0_5, v1_5)\) Support: 0
- \((v0_6, v1_6)\) Support: 0
- \((v0_7, v1_7)\) Support: 0
- \((v0_8, v1_8)\) Support: 0
- \((v0_9, v1_9)\) Support: 0
- \((v0_0, v3_0)\) Support: 0
- \((v0_1, v3_1)\) Support: 6
- \((v0_2, v3_2)\) Support: 0
- \((v0_3, v3_3)\) Support: 0
- \((v0_4, v3_4)\) Support: 0
- \((v0_5, v3_5)\) Support: 0
- \((v0_6, v3_6)\) Support: 0
- \((v0_7, v3_7)\) Support: 0
- \((v0_8, v3_8)\) Support: 0
- \((v0_9, v3_9)\) Support: 1
- \((v70_2, v111_2)\) **Support: 91**
- \((v70_3, v111_3)\) Support: 1
- \((v70_2, v116_2)\) **Support: 88**
- \((v70_3, v116_3)\) Support: 0

***Time elapsed: 5331 seconds

Frequent 2-itemset using granular method:

- \((v0_0, v1_0)\) Support: 0
- \((v0_1, v1_1)\) **Support: 18**
- \((v0_2, v1_2)\) Support: 1
- \((v0_3, v1_3)\) Support: 0
- \((v0_4, v1_4)\) Support: 0
- \((v0_5, v1_5)\) Support: 0
- \((v0_6, v1_6)\) Support: 0
- \((v0_7, v1_7)\) Support: 0
- \((v0_8, v1_8)\) Support: 0
- \((v0_9, v1_9)\) Support: 0
- \((v0_0, v3_0)\) Support: 0
- \((v0_1, v3_1)\) Support: 6
- \((v0_2, v3_2)\) Support: 0
- \((v0_3, v3_3)\) Support: 0
- \((v0_4, v3_4)\) Support: 0
- \((v0_5, v3_5)\) Support: 0
- \((v0_6, v3_6)\) Support: 0
- \((v0_7, v3_7)\) Support: 0
- \((v0_8, v3_8)\) Support: 0
- \((v0_9, v3_9)\) Support: 1
- \((v70_2, v111_2)\) **Support: 91**
- \((v70_3, v111_3)\) Support: 1
- \((v70_2, v116_2)\) **Support: 88**
- \((v70_3, v116_3)\) Support: 0
- \((v70_2, v112_2)\) Support: 95
- \((v70_2, v113_2)\) Support: 94
- \((v70_2, v114_2)\) Support: 96
- \((v70_2, v115_2)\) Support: 96
- \((v70_2, v116_2)\) **Support: 88**
- \((v70_2, v117_2)\) Support: 0

***Time elapsed: 193 seconds
CHAPTER 6
CONCLUSION

6.1 Project Achievements

None of the current compact methods of association mining utilize bitmaps in their implementation. Significant achievement of this project was to implement current compact methods of association mining by application of granular computing to reduce the complexity of dealing with a high number of associations.

A bit map based data warehouse was constructed to lay the basic foundation for application of granular computing methods and obtaining association rules based on these methods. The performances between the classic method of obtaining association rules was compared with the bit based method of obtaining association rules. One of the primary purposes of this work was served by demonstrating time efficiency of granular computing methods.

6.2 Future work

Future work in this subject area can be directed towards two aspects: size of the data that needs to be analyzed and algorithms that are more efficient than the classical Apriori algorithm.

Data size is an important factor of data mining that should not be overlooked. The data used in this project consisted of approximately 150,000 rows with 137 attribute values. Time taken to obtain association rules using bit based algorithm was considerably less than the time taken to obtain the same set of association rules using the classic algorithm.
Suppose if a data of 5 attribute values and 5 rows was taken, would there be a significant time difference in the performance of granular method and classic method? No. On the contrary, as the data size increases, the need for efficient methods to find association rules efficiently becomes evident. Future direction can test these algorithms on larger data sets so that comparisons can be made effectively at that level as well.

Compact representations of association rules are one of the major efforts in reducing complexity of finding associations. Various methods have been reported, such as disjunction-free generators [7], constraints based mining [12], and mining closed itemsets (CLOSET, Charm) [13, 14]. Future work can test other algorithms and provide comparative data on those algorithms.
BIBLIOGRAPHY


**APPENDIX A**

**JAVADOC APPENDIX**

Package dw

<table>
<thead>
<tr>
<th>Class Summary</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BitmapDM</td>
<td>BitmapDM class containing data mining operations for handling bitmap data</td>
</tr>
<tr>
<td>ColumnDM</td>
<td>ColumnDM class containing data mining operations for handling raw data</td>
</tr>
<tr>
<td>DataMining</td>
<td>DataMining class containing data mining operations for generating frequent 1-itemset using classical algorithm</td>
</tr>
<tr>
<td>DataMining2</td>
<td>DataMining2 Class containing data mining operations for generating frequent 2-itemset using classical algorithm</td>
</tr>
<tr>
<td>DB2File</td>
<td>DB2File class writes data retrieved from database onto a file</td>
</tr>
<tr>
<td>Item</td>
<td>Item class containing information of database item</td>
</tr>
<tr>
<td>ItemComparator</td>
<td>ItemComparator class which contains logic to compare Items</td>
</tr>
<tr>
<td>ItemSet</td>
<td>ItemSet class storing row items for support</td>
</tr>
<tr>
<td>ItemSetComparator</td>
<td>ItemSetComparator class which contains logic to compare ItemSet objects</td>
</tr>
<tr>
<td>Row</td>
<td>Row class to store information of a row in the bitmap.</td>
</tr>
<tr>
<td>RowComparator</td>
<td>RowComparator class which contains logic to compare Row object</td>
</tr>
<tr>
<td>RowTotal</td>
<td>RowTotal class that stores the total for a column</td>
</tr>
<tr>
<td>Utility</td>
<td>Utility class that contains common utility functions</td>
</tr>
</tbody>
</table>

---

dw
Class BitmapDM
java.lang.Object
   - dw.BitmapDM

public class BitmapDM
extends java.lang.Object
BitmapDM class containing data mining operations for handling bitmap data
### Field Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private ArrayList</td>
<td><strong>bmRowList</strong> List of Row objects for each Vi_n, Vj_n...</td>
</tr>
<tr>
<td>RowComparator</td>
<td><strong>comp</strong> RowComparator for sorting rows</td>
</tr>
<tr>
<td>java.util.Date</td>
<td><strong>endTime</strong> Timer stopper for each operation</td>
</tr>
<tr>
<td>ArrayList</td>
<td><strong>itemSet2List</strong> List of 2-itemSets under consideration</td>
</tr>
<tr>
<td>ArrayList</td>
<td><strong>itemSetList</strong> List of 1-itemSets under consideration</td>
</tr>
<tr>
<td>int</td>
<td><strong>NUM_OF_ROWS</strong> Number of rows in bitmap</td>
</tr>
<tr>
<td>ArrayList</td>
<td><strong>rowTotalList</strong> List of RowTotal objects for Total count of each Vi_n</td>
</tr>
<tr>
<td>ItemSetComparator</td>
<td><strong>setComp</strong> ItemSetComparator for sorting item sets</td>
</tr>
<tr>
<td>java.util.Date</td>
<td><strong>startTime</strong> Timer starter for each operation</td>
</tr>
</tbody>
</table>

### Constructor Summary

<table>
<thead>
<tr>
<th>Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BitmapDM()</strong></td>
<td>Constructor that initializes all member variables</td>
</tr>
</tbody>
</table>

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private void addRow(Row row)</td>
<td>Helper method to add Row to the ArrayList of Rows using binary search</td>
</tr>
<tr>
<td>private String decodeHeader(long lcode)</td>
<td>Helper method that decode the header value of the row Note: bit [0] corresponds to disk number bit [1-9] corresponds to binary value of column number bit [9-25] corresponds to binary value of distinct value</td>
</tr>
<tr>
<td>void generate1_itemset(String filename)</td>
<td>Generates all 1-itemsets from the input bitmap file</td>
</tr>
<tr>
<td>void generate2_itemset(int minSup)</td>
<td>Generates 2-itemsets that meets the minimum support level Operation is based on 1-itemset previously computed</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><code>java.util.ArrayList</code> getItemSet1List()</td>
<td>Returns ArrayList of 1-itemsets</td>
</tr>
<tr>
<td><code>java.util.ArrayList</code> getItemSet2List()</td>
<td>Returns ArrayList of 2-itemsets</td>
</tr>
<tr>
<td><code>int getSupport(Row row)</code></td>
<td>Getting support level for the single row</td>
</tr>
<tr>
<td><code>private int getTotalCount(int col)</code></td>
<td>Tracking total count of a given column</td>
</tr>
<tr>
<td><code>private boolean isMinSupport(Row row, int min)</code></td>
<td>Helper method to check if row meets minimum support</td>
</tr>
<tr>
<td><code>void printItemSetList(java.lang.String file, java.util.ArrayList itemSetList)</code></td>
<td>Prints list of n-itemsets to a file</td>
</tr>
<tr>
<td><code>void printRowList(java.lang.String file)</code></td>
<td>Prints row list to a file</td>
</tr>
<tr>
<td><code>private java.util.ArrayList setPrevSupport(java.util.ArrayList itemsets, int rowTotal, int start, int end)</code></td>
<td>Helper method for generate1_itemset() Sets support for previous rows in the list</td>
</tr>
</tbody>
</table>

### Methods inherited from class java.lang.Object

- clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait

### Field Detail

- `bmRowList` private java.util.ArrayList: List of Row objects for each $V_i_n, V_j_n$
- `itemSetList` private java.util.ArrayList: List of 1-itemSets under consideration
- `itemSet2List` private java.util.ArrayList: List of 2-itemSets under consideration
- `rowTotalList` private java.util.ArrayList: List of RowTotal objects for Total count of each $V_i_n`
comp
private RowComparator comp
RowComparator for sorting rows

setComp
private ItemSetComparator setComp
ItemSetComparator for sorting item sets

startTime
private java.util.Date startTime
Timer starter for each operation

endTime
private java.util.Date endTime
Timer stopper for each operation

NUM_OF_ROWS
private final int NUM_OF_ROWS
Number of rows in bitmap
See Also:
Constant Field Values

Constructor Detail

BitmapDM
public BitmapDM()
Constructor that initializes all member variables

Method Detail

generate1_itemset
public void generate1_itemset(java.lang.String filename)
Generates all 1-itemsets from the input bitmap file
Parameters:
filename - the name of bitmap file to be processed

setPrevSupport
private java.util.ArrayList setPrevSupport(java.util.ArrayList itemsets,
int rowTotal,
int start,
int end)
Helper method for generate1_itemset() Sets support for previous rows in the list
Parameters:
itemsets - ArrayList of itemsets
rowTotal - total number of rows
start - start index
end - end index
generate2_itemset
public void generate2_itemset(int minSup)
Generates 2-itemsets that meets the minimum support level Operation is based on 1-itemset previously computed

Parameters:
minSup - minimum support level to consider

isMinSupport
private boolean isMinSupport(Row row, int min)
Helper method to check if row meets minimum support

Parameters:
row - Row object to consider
min - int that sets the minimum support

Returns:
true if row is at least the minimum support false otherwise

addRow
private void addRow(Row row)
Helper method to add Row to the ArrayList of Rows using binary search

Parameters:
row - Row object to be added

decodeHeader
private java.lang.String decodeHeader(java.lang.Long lcode)
Helper method that decode the header value of the row Note: bit [0] corresponds to disk number bit [1-9] corresponds to binary value of column number bit [9-25] corresponds to binary value of distinct value

Parameters:
lcode - the Long value to be decoded

Returns:
String representing the header of the row

getSupport
public int getSupport(Row row)
Getting support level for the single row

Parameters:
row - Row to calculate support for

Returns:
integer of support percentage * 100

getTotalCount
private int getTotalCount(int col)
Tracking total count of a given column

Parameters:
col - int of the column number to consider
**Returns:**
integer of total count

---

printRowList
public void **printRowList**(java.lang.String file)
Prin ts row list to a file

**Parameters:**
file - String of file name to print rows to

---

printItemSetList
public void **printItemSetList**(java.lang.String file,
java.util.ArrayList itemSetList)
Prints list of n-itemsets to a file

**Parameters:**
file - String of file name to print rows to
itemSetList - ArrayList of item-sets to be printed

---

getItemSet1List
public java.util.ArrayList **getItemSet1List()**
Returns ArrayList of 1-itemsets

**Returns:**
ArrayList of 1-itemsets

---

getItemSet2List
public java.util.ArrayList **getItemSet2List()**
Returns ArrayList of 2-itemsets

**Returns:**
ArrayList of 2-itemsets

---

dw
Class ColumnDM
java.lang.Object
dw.ColumnDM

public class **ColumnDM**
extends java.lang.Object
ColumnDM class containing data mining operations for handling raw data
### Field Summary

<table>
<thead>
<tr>
<th>Field Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private java.util.ArrayList</td>
<td>colSet</td>
<td>List of items for column</td>
</tr>
<tr>
<td>private ItemComparator</td>
<td>comp</td>
<td>ItemComparator that carries logic to perform Item comparison in insertion</td>
</tr>
<tr>
<td>private java.io.PrintWriter</td>
<td>out</td>
<td>PrintWriter to print result to</td>
</tr>
</tbody>
</table>

### Constructor Summary

<table>
<thead>
<tr>
<th>Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColumnDM()</td>
<td>Constructor that initializes all member variables</td>
</tr>
</tbody>
</table>

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private void addItem(Item item)</td>
<td>Adds an Item to the list of column items</td>
</tr>
<tr>
<td>void calcColData(int col)</td>
<td>Calculates column data</td>
</tr>
<tr>
<td>void clearSet()</td>
<td>Clear the list of column set</td>
</tr>
<tr>
<td>void closePrint()</td>
<td>Closes the opened printwriter</td>
</tr>
<tr>
<td>void extractColumn(int col)</td>
<td>Extracts column from initial_data_table, processes each value and creates an Item</td>
</tr>
<tr>
<td>int getSupport(Item item)</td>
<td>Returns the support level</td>
</tr>
<tr>
<td>int getTotalCount()</td>
<td>Returns the total count for the column set</td>
</tr>
<tr>
<td>private boolean isQualifiedColumn(int col)</td>
<td>Determines if a column is qualified to be considered</td>
</tr>
<tr>
<td>void printItemSet(int min)</td>
<td>Prints the set of items in the column that meets the given minimum support level</td>
</tr>
<tr>
<td>void printSet(int col)</td>
<td>Prints the set of column items for the given column number</td>
</tr>
</tbody>
</table>
Methods inherited from class java.lang.Object
clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

Field Detail
colSet
private java.util.ArrayList colSet
List of items for column

out
private java.io.PrintWriter out
PrintWriter to print result to

comp
private ItemComparator comp
ItemComparator that carries logic to perform Item comparison in insertion

Constructor Detail
ColumnDM
public ColumnDM()
Constructor that initializes all member variables

Method Detail
extractColumn
public void extractColumn(int col)
Extracts column from initial_data_table, processes each value and creates an Item
Parameters:
col - column number to be extracted

isQualifiedColumn
private boolean isQualifiedColumn(int col)
Determines if a column is qualified to be considered
Parameters:
col - column number to be checked
Returns:
true if at most 32 distinct values found in given column false otherwise

addItem
private void addItem(Item item)
Adds an Item to the list of column items
Parameters:
item - Item to be added to the list

getSupport
public int getSupport(Item item)
Returns the support level
Parameters:
item - Item to get support level for

Returns:
int of support percentage * 100

---

getTotalCount
public int getTotalCount()
Returns the total count for the column set

Returns:
int of total count

---

printSet
public void printSet(int col)
throws java.io.IOException
Prints the set of column items for the given column number

Parameters:
col - int of column number

Throws:
java.io.IOException

---

closePrint
public void closePrint()
Closes the opened printwriter

---

clearSet
public void clearSet()
Clear the list of column set

---

calcColData
public void calcColData(int col)
throws java.io.IOException
Calculates column data

Parameters:
col - int of column number

Throws:
java.io.IOException

---

printItemSet
public void printItemSet(int min)
Prints the set of items in the column that meets the given minimum support level

Parameters:
min - minimum support level
public class **DataMining**
extends java.lang.Object
DataMining class containing data mining operations for generating frequent 1-itemset using classical algorithm

### Field Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td><strong>minSupport</strong></td>
<td>Support level</td>
</tr>
</tbody>
</table>

### Constructor Summary

**DataMining()**

### Method Summary

```java
void **support**()
Calculates the support for 1-itemset that meets the minimum support level
```

### Methods inherited from class java.lang.Object

clon, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

### Field Detail

minSupport
private int **minSupport**
Support level

### Constructor Detail

DataMining
public **DataMining()**

### Method Detail

support
public void **support**()
Calculates the support for 1-itemset that meets the minimum support level
public class DataMining2
extends java.lang.Object
DataMining2 Class containing data mining operations for generating frequent 2-itemset using classical algorithm

### Field Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private</td>
<td>int</td>
<td>columnD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distinct values for the first attribute</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>constantColumn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>First attribute in the 2-itemset</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>constantDistinct</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distinct value of the first attribute in the 2-itemset</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>dv</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distinct values for the second attribute</td>
</tr>
<tr>
<td>private</td>
<td>java.util.Date</td>
<td>endTime</td>
</tr>
<tr>
<td></td>
<td></td>
<td>End timer for operation</td>
</tr>
<tr>
<td>private</td>
<td>java.io.PrintWriter</td>
<td>out</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PrintWriter for output</td>
</tr>
<tr>
<td>private</td>
<td>java.util.Date</td>
<td>startTime</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Start timer for operation</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>totalRows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total rows</td>
</tr>
</tbody>
</table>

### Constructor Summary

**DataMining2()**
Constructor to initialize member variables

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int calcDistinct(int f)</td>
<td>Helper method to count distinct values</td>
</tr>
<tr>
<td>private numRows()</td>
<td></td>
</tr>
</tbody>
</table>
### Helper method for getting the total number of values in a column

<table>
<thead>
<tr>
<th>int</th>
<th>Helper method for getting the total number of values in a column</th>
</tr>
</thead>
</table>

### void **support2()**
Calculates the support for 2-itemsets

### Methods inherited from class java.lang.Object
clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

### Field Detail

- **totalRows**
  - private int **totalRows**
  - Total rows

- **constantColumn**
  - private int **constantColumn**
  - First attribute in the 2-itemset

- **constantDistinct**
  - private int **constantDistinct**
  - Distinct value of the first attribute in the 2-itemset

- **columnD**
  - private int **columnD**
  - Distinct values for the first attribute

- **dv**
  - private int **dv**
  - Distinct values for the second attribute

- **out**
  - private java.io.PrintWriter **out**
  - PrintWriter for output

- **startTime**
  - private java.util.Date **startTime**
  - Start timer for operation

- **endTime**
  - private java.util.Date **endTime**
  - End timer for operation

### Constructor Detail

- **DataMining2**
  - public **DataMining2()**
  - Constructor to initialize member variables
### Method Detail

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>support2</td>
<td>Calculates the support for 2-itemsets</td>
</tr>
<tr>
<td>numRows</td>
<td>Helper method for getting the total number of values in a column</td>
</tr>
<tr>
<td>calcDistinct</td>
<td>Helper method to count distinct values</td>
</tr>
</tbody>
</table>

#### numRows

private int **numRows()**

Helper method for getting the total number of values in a column

**Returns:**

int number of values in a column

#### calcDistinct

public int **calcDistinct(int f)**

Helper method to count distinct values

**Parameters:**

f - int column number

**Returns:**

int of total number of distinct values

---

### dw

Class **DB2File**

dw.DB2File

java.lang.Object

public class **DB2File**

extends java.lang.Object

DB2File class writes data retrieved from database onto a file

---

### Constructor Summary

**DB2File()**

---

### Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>void <strong>read2File()</strong></td>
<td>Reads data from tables and writes</td>
</tr>
</tbody>
</table>

### Methods inherited from class java.lang.Object

clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait
### Constructor Detail

**DB2File**

**public** *DB2File()*

### Method Detail

**read2File**

**public void read2File()**

Reads data from tables and writes

---

**dw**

Class Item

java.lang.Object

└— dw.Item

**public class Item**

extends java.lang.Object

Item class containing information of database item

### Field Summary

<table>
<thead>
<tr>
<th>Field Type</th>
<th>Field Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private int</td>
<td>count</td>
<td>Count of the item</td>
</tr>
<tr>
<td>private int</td>
<td>value</td>
<td>Value of the item</td>
</tr>
</tbody>
</table>

### Constructor Summary

**Item()**

Default constructor that initializes an empty item

**Item(int val)**

Constructor that initializes all member variables

### Method Summary

<table>
<thead>
<tr>
<th>Return Type</th>
<th>Method Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>getCount()</td>
<td>Getter of count</td>
</tr>
<tr>
<td>int</td>
<td>getValue()</td>
<td>Getter of support</td>
</tr>
<tr>
<td>void</td>
<td>incCount()</td>
<td>Increments count by 1</td>
</tr>
<tr>
<td>void</td>
<td>setValue(int i)</td>
<td>Setter of value</td>
</tr>
<tr>
<td>------</td>
<td>------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>java.lang.String</td>
<td>toString()</td>
<td>Returns the String representation of the ItemSet</td>
</tr>
</tbody>
</table>

**Methods inherited from class java.lang.Object**
clone, equals, finalize, getClass, hashCode, notify, notifyAll, wait, wait, wait

**Field Detail**
value
private int value
Value of the item

count
private int count
Count of the item

**Constructor Detail**
Item
public Item()
Default constructor that initializes an empty item

Item
public Item(int val)
Constructor that initializes all member variables
**Parameters:**
val - int of value to set

**Method Detail**
setValue
public void setValue(int i)
Setter of value
**Parameters:**
i - value of item

getValue
public int getValue()
Getter of support
**Returns:**
int value of item

incCount
public void incCount()
Increments count by 1
getCount
public int getCount()
Getter of count
**Returns:**
int count of item

toString
public java.lang.String toString()
Returns the String representation of the ItemSet
**Overrides:**
toString in class java.lang.Object
**Returns:**
String representation of the ItemSet object

---

dw
Class ItemComparator
java.lang.Object
  └-- dw.ItemComparator
**All Implemented Interfaces:**
java.util.Comparator

public class ItemComparator
extends java.lang.Object
implements java.util.Comparator
ItemComparator class which contains logic to compare Items

---

**Constructor Summary**

<table>
<thead>
<tr>
<th>ItemComparator()</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default constructor</td>
</tr>
</tbody>
</table>

**Method Summary**

<table>
<thead>
<tr>
<th>int compare(java.lang.Object o1, java.lang.Object o2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compares 2 items and returns the lexicographical order</td>
</tr>
</tbody>
</table>

**Methods inherited from class java.lang.Object**

clon, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

**Methods inherited from interface java.util.Comparator**
equals
**Constructor Detail**

ItemComparator
public ItemComparator()
Default constructor

**Method Detail**

compare
public int compare(java.lang.Object o1,
       java.lang.Object o2)
Compares 2 items and returns the lexicographical order

**Specified by:**
compare in interface java.util.Comparator

**Parameters:**
o1 - Item object1
o2 - Item object2

**Returns:**
int value of the comparison result -1 if o1 comes before o2 0 if order of o1 and o2 are equal 1 if o1 comes after o2

---

dw
Class ItemSet
java.lang.Object
   ↓ dw.ItemSet

public class ItemSet
extends java.lang.Object
ItemSet class storing row items for support

---

**Field Summary**

<table>
<thead>
<tr>
<th>private</th>
<th>int</th>
<th>commonCount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Common occurrence of the itemset</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>NUM_OF_ROWS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total number of rows in bitmap</td>
</tr>
<tr>
<td>private</td>
<td>java.util.ArrayList</td>
<td>rows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ArrayList of Row objects</td>
</tr>
<tr>
<td>private</td>
<td>int</td>
<td>support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Support level</td>
</tr>
</tbody>
</table>

**Constructor Summary**

ItemSet()
Constructor that initializes all member variables
## Method Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
</table>
| void   | **addtoItemSet(Row r)**  
         | Adds a row to the itemset |
| void   | **calcCommon2ItemSet()**  
         | Getter of support level |
| void   | **calcSupport()**  
         | Computation of support level of the itemset and sets the support value |
| int    | **getCommonCount()**  
         | Getter of common count |
| java.util.ArrayList | **getItems()**  
         | Getter of the list of rows in ItemSet |
| int    | **getSupport()**  
         | Getter of support level |
| void   | **setCommonCount(int i)**  
         | Setter of common count |
| void   | **setSupport(int i)**  
         | Setter of support |
| java.lang.String | **toString()**  
         | Returns the String representation of the ItemSet |

**Methods inherited from class java.lang.Object**
clone, equals, finalize, getClass, hashCode, notify, notifyAll, wait, wait

## Field Detail

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
</table>
| rows  | private java.util.ArrayList **rows**  
         | ArrayList of Row objects |
| commonCount | private int **commonCount**  
         | Common occurrence of the itemset |
| support | private int **support**  
         | Support level |
| NUM_OF_ROWS | private final int **NUM_OF_ROWS** |  
         | |
Total number of rows in bitmap

**See Also:**

[Constant Field Values](#)

### Constructor Detail

**ItemSet**

public **ItemSet()**

Constructor that initializes all member variables

### Method Detail

**addtoItemSet**

public void **addtoItemSet(Row r)**

Adds a row to the itemset

**Parameters:**

r - Row to be added

**getItems**

public java.util.ArrayList **getItems()**

Getter of the list of rows in ItemSet

**Returns:**

ArrayList of Rows in ItemSet

**setCommonCount**

public void **setCommonCount(int i)**

Setter of common count

**Parameters:**

i - number of common occurrences of the value

**setSupport**

public void **setSupport(int i)**

Setter of support

**Parameters:**

i - support level of the itemset

**calcSupport**

public void **calcSupport()**

Computation of support level of the itemset and sets the support value

**getCommonCount**

public int **getCommonCount()**

Getter of common count

**Returns:**

int of common count

**getSupport**

public int **getSupport()**

Getter of support level
**Returns:**
int of support level

calcCommon2ItemSet
public void **calcCommon2ItemSet**()
Getter of support level

toString
public java.lang.String **toString**()
Returns the String representation of the ItemSet
**Overrides:**
toString in class java.lang.Object
**Returns:**
String representation of the ItemSet object

dw
Class ItemSetComparator
java.lang.Object
    ↓ dw.ItemSetComparator
**All Implemented Interfaces:**
java.util.Comparator

public class **ItemSetComparator**
extends java.lang.Object
implements java.util.Comparator
ItemSetComparator class which contains logic to compare ItemSet objects

**Constructor Summary**

| **ItemSetComparator**() |

**Method Summary**

| int **compare**(java.lang.Object o1, java.lang.Object o2) |
|↓ Compresses 2 ItemSet objects and returns the lexicographical order. |

**Methods inherited from class java.lang.Object**

clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

**Methods inherited from interface java.util.Comparator**

equals
Constructor Detail

ItemSetComparator
public ItemSetComparator()

Method Detail

compare
public int compare(java.lang.Object o1,
        java.lang.Object o2)

Compares 2 ItemSet objects and returns the lexicographical order. Comparison is performed on the Row items within each ItemSet

Specified by:
compare in interface java.util.Comparator

Parameters:
o1 - Item object1
o2 - Item object2

Returns:
int value of the comparison result -1 if o1 comes before o2 0 if order of o1 and o2 are equal 1 if o1 comes after o2

dw
Class Row
java.lang.Object
   └ dw.Row

public class Row
extends java.lang.Object
Row class to store information of a row in the bitmap. This is the bitmap conversion of a column of the original table

Field Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>private int</td>
<td>column</td>
<td>Column number of bitmap row</td>
</tr>
<tr>
<td>private int</td>
<td>count</td>
<td>Number of occurrence for the value in the column</td>
</tr>
<tr>
<td>private java.lang.String</td>
<td>header</td>
<td>String of the decoded header value</td>
</tr>
<tr>
<td>private java.lang.String</td>
<td>orgString</td>
<td>String containing original row of the bitmap file</td>
</tr>
<tr>
<td>private int</td>
<td>value</td>
<td>Distinct value of bitmap row</td>
</tr>
</tbody>
</table>
### Constructor Summary

**Row()**

Constructor that initializes all member variables

### Method Summary

<table>
<thead>
<tr>
<th>Type</th>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>int</td>
<td>getColumn()</td>
<td>Getter for the column number</td>
</tr>
<tr>
<td>int</td>
<td>getCount()</td>
<td>Getter for the count</td>
</tr>
<tr>
<td>java.lang.String</td>
<td>getHeader()</td>
<td>Getter for the header string</td>
</tr>
<tr>
<td>java.lang.String</td>
<td>getString()</td>
<td>Getter for the original string of the row</td>
</tr>
<tr>
<td>java.lang.String[]</td>
<td>getStringArr()</td>
<td>Returns the original bitmap row value without the header as a String array</td>
</tr>
<tr>
<td>int</td>
<td>getValue()</td>
<td>Getter for the distinct value</td>
</tr>
<tr>
<td>void</td>
<td>setColumn(int i)</td>
<td>Setter for the column number</td>
</tr>
<tr>
<td>void</td>
<td>setCount(int i)</td>
<td>Setter for the count</td>
</tr>
<tr>
<td>void</td>
<td>setHeader(java.lang.Long lcode)</td>
<td>Setter for the header string of the bitmap row</td>
</tr>
<tr>
<td>void</td>
<td>setString(java.lang.String s)</td>
<td>Setter for the original string of the bitmap row</td>
</tr>
<tr>
<td>void</td>
<td>setValue(int i)</td>
<td>Setter for the distinct value</td>
</tr>
<tr>
<td>java.lang.String</td>
<td>toString()</td>
<td>Returns the String representation of the Row</td>
</tr>
</tbody>
</table>

### Methods inherited from class java.lang.Object

clone, equals, finalize, getClass, hashCode, notify, notifyAll, wait, wait, wait

### Field Detail

- **column**
  - private int column
  - Column number of bitmap row
value
private int **value**
Distinct value of bitmap row

count
private int **count**
Number of occurrence for the value in the column

header
private java.lang.String **header**
String of the decoded header value

**orgString**
private java.lang.String **orgString**
String containing original row of the bitmap file

### Constructor Detail

**Row**
public **Row**()
Constructor that initializes all member variables

### Method Detail

**setColumn**
public void **setColumn**(int **i**)
Setter for the column number
**Parameters:**
i - the column number of the row

**setValue**
public void **setValue**(int **i**)
Setter for the distinct value
**Parameters:**
i - the distinct value of the row

**setCount**
public void **setCount**(int **i**)
Setter for the count
**Parameters:**
i - the number of times this distinct value appeared in the column

**setString**
public void **setString**(java.lang.String **s**)
Setter for the original string of the bitmap row
**Parameters:**
s - original String of the bitmap row
setHeader
public void setHeader(java.lang.Long lcode)
Setter for the header string of the bitmap row

Parameters:
lcode - Long value to be converted into header

getColumn
public int getColumn()
Getter for the column number

Returns:
int column number

getValue
public int getValue()
Getter for the distinct value

Returns:
int distinct value

getCount
public int getCount()
Getter for the count

Returns:
int number of times this distinct value appeared in the row

getHeader
public java.lang.String getHeader()
Getter for the header string

Returns:
String of the decoded header of the bitmap row

getString
public java.lang.String getString()
Getter for the original string of the row

Returns:
String of the original text of the bitmap row

getStringArr
public java.lang.String[] getStringArr()
Returns the original bitmap row value without the header as a String array

Returns:
String[] containing each broken-down value of the original string

toString
public java.lang.String toString()
Returns the String representation of the Row

Overrides:
toString in class java.lang.Object

**Returns:**
String representation of the Row object

---

dw
Class RowComparator
java.lang.Object
  └ dw.RowComparator

**All Implemented Interfaces:**
java.util.Comparator

public class RowComparator
extends java.lang.Object
implements java.util.Comparator

RowComparator class which contains logic to compare Row object

---

**Constructor Summary**

<table>
<thead>
<tr>
<th>Constructor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RowComparator()</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

**Method Summary**

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>int compare(java.lang.Object o1, java.lang.Object o2)</strong></td>
<td></td>
</tr>
<tr>
<td>Compares 2 Row objects and returns the lexicographical order</td>
<td></td>
</tr>
</tbody>
</table>

---

**Methods inherited from class java.lang.Object**

clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

---

**Methods inherited from interface java.util.Comparator**
equals

---

**Constructor Detail**

RowComparator
public **RowComparator()**

---

**Method Detail**

compare
public int **compare(java.lang.Object o1, java.lang.Object o2)**

Compares 2 Row objects and returns the lexicographical order
Specified by:
compare in interface java.util.Comparator

Parameters:
o1 - Item object1
o2 - Item object2

Returns:
int value of the comparison result -1 if o1 comes before o2 0 if order of o1 and o2 are
equal 1 if o1 comes after o2

dw
Class RowTotal
java.lang.Object
   ↓ dw.RowTotal

public class RowTotal
extends java.lang.Object
RowTotal class that stores the total for a column

Field Summary

| private int[] | column | Int array that stores the column numbers |
| private int   | total  | Total for the column                   |

Constructor Summary

RowTotal()
Constructor that initializes all member variables

Method Summary

| int[] | getColumn() | Getter of column numbers in itemset |
| int   | getTotal()  | Getter of total row count            |
| void  | setColumn(int i) | Setter of column for 1-itemset |
| void  | setColumn(int i, int j) | Setter of column for 2-itemset |
### Method Detail

#### Field Detail

<table>
<thead>
<tr>
<th>Field</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>column</td>
<td>int[]</td>
<td>Int array that stores the column numbers</td>
</tr>
<tr>
<td>total</td>
<td>int</td>
<td>Total for the column</td>
</tr>
</tbody>
</table>

#### Constructor Detail

```java
public RowTotal()
```
Constructor that initializes all member variables

#### Method Detail

<table>
<thead>
<tr>
<th>Method</th>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>setColumn</code></td>
<td>int i</td>
<td>Setter of column for 1-itemset</td>
</tr>
<tr>
<td><code>setColumn</code></td>
<td>int i, int j</td>
<td>Setter of column for 2-itemset</td>
</tr>
<tr>
<td><code>setColumn</code></td>
<td>int i, int j, int k</td>
<td>Setter of column for 3-itemset</td>
</tr>
</tbody>
</table>
k - third column number in the 3-item

```java
public void setTotal(int i)
  Setter of row Total
  Parameters:
  i - total of the row count
```

```java
public int[] getColumn()
  Getter of column numbers in itemset
  Returns:
  array of column numbers of items
```

```java
public int getTotal()
  Getter of total row count
  Returns:
  int of total row count
```

```java
public class Utility
  extends java.lang.Object
```

public class Utility
  extends java.lang.Object
Utility class that contains common utility functions

<table>
<thead>
<tr>
<th>Constructor Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility()</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>static int binary2int(java.lang.String binary)</td>
</tr>
<tr>
<td>Static method that convert from based-2 value String into binary value</td>
</tr>
<tr>
<td>static int countBits(java.lang.String str)</td>
</tr>
<tr>
<td>Helper methods that count the numbers of bits after converting based-2 number into binary</td>
</tr>
</tbody>
</table>

Methods inherited from class java.lang.Object
clone, equals, finalize, getClass, hashCode, notify, notifyAll, toString, wait, wait, wait

**Constructor Detail**

Utility
public Utility()

**Method Detail**

binary2int
public static int binary2int(java.lang.String binary)
Static method that convert from based-2 value String into binary value
**Parameters:**
binary - the String that holds binary value
**Returns:**
int of equivalent value in based-2

countBits
public static int countBits(java.lang.String str)
Helper methods that count the numbers of bits after converting based-2 number into binary
**Parameters:**
str - the String that holds the based-2 value
**Returns:**
number of 1 bits in the binary representation of the input string
APPENDIX B

UML DIAGRAMS APPENDIX

UML Class Diagrams

1. Original Data Management

ColumnDM contains methods that reads the original data from the INITIAL_DATA_TABLE and keeps a list of Items of data retrieved. ItemComparator provides the rules of sorting the Item list. ColumnDM uses DB2File class to produce a flat file of the original data.

![UML Class Diagram for the Original Data Management Scheme](image)

Fig. B 1: UML Class Diagram for the Original Data Management Scheme

2. Classic Algorithm

This diagram below describes the classes involved in performing datamining operations using the classic algorithm. DataMining class provides operations to compute the support level for 1-itemset, while DataMining2 conducts computation for 2-itemsets.

![UML Class Diagram for the Itemsets Generation using Classic Algorithm](image)

Fig. B 2: UML Class Diagram for the Itemsets Generation using Classic Algorithm
3. Bitmap Datamining

BitmapDM class contains a list of Rows, RowTotals, ItemSets for datamining operations using the bitmaps approach. The list of Row objects maintains the information of each row of the bitmap, sorted by the rules defined within the RowComparator class. N ItemSet lists are kept to track the N-itemsets that meets the specified support level. Each of the itemset list is in the lexicographical order noted in the ItemSetComparator class to ensure the speediness of insertion/retrieval of items within the list. The list of RowTotal objects are used to find the support level for 1-itemsets. The Utility class contains common methods that aids in the operations for BitmapDM and Row processing.

Fig. B 3: UML Class Diagram for the Itemsets Generation using Bitmap Approach
package dw;
import java.io.*;
import java.sql.*;
import java.util.*;

/**
 * BitmapDM class containing data mining operations for handling bitmap data
 * @author Mien Siao
 */
public class BitmapDM {

    /**
     * List of Row objects for each Vi_n, Vj_n...
     */
    private ArrayList bmRowList;

    /**
     * List of 1-itemSets under consideration
     */
    private ArrayList itemSetList;

    /**
     * List of 2-itemSets under consideration
     */
    private ArrayList itemSet2List;

    /**
     * List of RowTotal objects for Total count of each Vi_n
     */
    private ArrayList rowTotalList;

    /**
     * RowComparator for sorting rows
     */
    private RowComparator comp;
private ItemSetComparator setComp;

/**
 * Timer starter for each operation
 */
private java.util.Date startTime;

/**
 * Timer stopper for each operation
 */
private java.util.Date endTime;

/**
 * Number of rows in bitmap
 */
private final int NUM_OF_ROWS = 137;

/**
 * Constructor that initializes all member variables
 */
public BitmapDM()
{
    bmRowList = new ArrayList();
    itemSetList = new ArrayList();
    itemSet2List = new ArrayList();
    rowTotalList = new ArrayList();
    comp = new RowComparator();
    setComp = new ItemSetComparator();
}

/**
 * Generates all 1-itemsets from the input bitmap file
 * @param filename the name of bitmap file to be processed
 */
public void generate1_itemset(String filename)
{
    // Start timer
    startTime = new java.util.Date();

    BufferedReader reader = null;
    try
    {
        reader = new BufferedReader(new FileReader(filename));

        // Read and process the file
        //...
    }
    catch (IOException e)
    {
        // handle exception
    }
    finally
    {
        // Close the reader
        try
        {
            reader.close();
        }
        catch (IOException e)
        {
            // handle exception
        }
    }
}
StringBuffer safeBuffer = new StringBuffer();
String line;
int totalBits = 0;
int rowTotCount = 0;
int col1 = 0;
int col2 = 0;
int start = 0;
int end = 0;
int i = 0;

// Process each line of the bitmap file
while( ( line = reader.readLine() ) != null )
{
    Row row = new Row();
    ItemSet set = new ItemSet();
    row.setString(line);
    totalBits = 0;  // reset total count

    StringTokenizer st = new StringTokenizer(line);
    // Store the first token of each line as header
    if (st.hasMoreTokens())
    {
        String s = st.nextToken();
        row.setHeader(new Long(s));
    }
    while (st.hasMoreTokens())
    {
        totalBits += Utility.countBits(st.nextToken().toString());
    }
    row.setCount(totalBits);
    addRow(row);    // adding row to member list
    set.addtoItemSet(row);
    set.setCommonCount(totalBits);
    itemSetList.add(set);

    // Reached next column, store last column count and restart
    if (row.getColumn() != col1)
    {
        RowTotal rowTot = new RowTotal();
        rowTot.setColumn(col1);
        rowTot.setTotal(rowTotCount);
        rowTotalList.add(rowTot);
        itemSetList = setPrevSupport(itemSetList, rowTotCount, start, end);
        rowTotCount = 0;
        col1 = row.getColumn();
    }
}
start = end;
}
end++;
rowTotCount += totalBits;
}
reader.close();
Collections.sort(itemSetList, setComp);
}
catch (IOException ex)
{
    ex.printStackTrace();
}
endTime = new java.util.Date(); // stop timer
}

/**
 * Helper method for generate1_itemset()
 * Sets support for previous rows in the list
 * @param itemsets     ArrayList of itemsets
 * @param rowTotal     total number of rows
 * @param start        start index
 * @param end          end index
 */
private ArrayList setPrevSupport(ArrayList itemsets, int rowTotal, int start, int end)
{
    ArrayList list = itemsets;
    ItemSet set = new ItemSet();
    for (int i = start; i < end; i++)
    {
        set = (ItemSet)list.get(i);
        int sup = Math.round(((float)set.getCommonCount())/((float)rowTotal) * 100);
        set.setSupport(sup);
        list.set(i, set);
    }
    return list;
}

/**
 * Generates 2-itemsets that meets the minimum support level
 * Operation is based on 1-itemset previously computed
 * @param minSup minimum support level to consider
 */
public void generate2_itemset(int minSup)
{
    startTime = new java.util.Date();       // start timer
    ItemSet set = new ItemSet();
Row temp1, temp2;

// Looping through each Value: Va_i ... Va_n
for (int i=0; i < NUM_OF_ROWS; i++)
{
    // Looping through each column: Vj_n ... Vm_n
    for (int j = 0; j < NUM_OF_ROWS; j++)
    {
        temp1 = new Row();
        temp1.setColumn(j);
        temp1.setValue(i);
        int rowIndex1 = Collections.binarySearch(bmRowList, temp1, comp);
        if(rowIndex1 > -1)
        {
            temp1 = (Row)bmRowList.get(rowIndex1);
            // Looping for the 2nd row; process only if support of first row >= requested
            if (isMinSupport(temp1, minSup))
            {
                for (int k = j+1; k < NUM_OF_ROWS; k++)
                {
                    temp2 = new Row();
                    temp2.setColumn(k);
                    temp2.setValue(i);
                    int rowIndex2 = Collections.binarySearch(bmRowList, temp2, comp);
                    if(rowIndex2 > -1)
                    {
                        temp2 = (Row)bmRowList.get(rowIndex2);
                        // process only if support of second row >= requested
                        if (isMinSupport(temp2, minSup))
                        {
                            set = new ItemSet();
                            set.addItemSet(temp1);
                            set.addItemSet(temp2);
                            set.calcCommon2ItemSet();
                            set.calcSupport();

                            // Add to 2-itemset list only if it meet minimum support
                            if (set.getSupport() >= minSup)
                                itemSet2List.add(set);
                        }
                    }
                }
            }
        }
    }
}
endTime = new java.util.Date(); // stop timer

/**
 * Helper method to check if row meets minimum support
 * @param row Row object to consider
 * @param min int that sets the minimum support
 * @return true if row is at least the minimum support
 *         false otherwise
 */
private boolean isMinSupport(Row row, int min)
{
    ItemSet s = new ItemSet();
    s.addtoItemSet(row);
    int index = Collections.binarySearch(itemSetList, s, setComp);
    int sup = 0;
    if(index > -1)
    {
        ItemSet temp = (ItemSet)itemSetList.get(index);
        sup = temp.getSupport();
    }
    return (sup >= min);
}

/**
 * Helper method to add Row to the ArrayList of Rows using binary search
 * @param row Row object to be added
 */
private void addRow(Row row)
{
    int rowIndex = Collections.binarySearch(bmRowList, row, comp);
    if(rowIndex < 0)
    {
        bmRowList.add(row);
        Collections.sort(bmRowList, comp);
    }
}

/**
 * Helper method that decode the header value of the row
 * Note: bit [0] corresponds to disk number
 *       bit [1-9] corresponds to binary value of column number
 *       bit [9-25] corresponds to binary value of distinct value
 * @param lcode the Long value to be decoded
 * @return String representing the header of the row
private String decodeHeader(Long lcode) {
    String headerStr = Long.toBinaryString(lcode.longValue());
    StringBuffer sb = new StringBuffer("V");
    int iTemp = Utility.binary2int(headerStr.substring(1,9));
    sb.append(iTemp + ".");
    iTemp = Utility.binary2int(headerStr.substring(9,25));
    sb.append(iTemp);
    return sb.toString();
}

/**
 * Getting support level for the single row
 * @param row Row to calculate support for
 * @return integer of support percentage * 100
 */
public int getSupport(Row row) {
    int rowTotal = getTotalCount(row.getColumn());
    return Math.round(((float)row.getCount())/((float)rowTotal) * 100);
}

/**
 * Tracking total count of a given column
 * @param col int of the column number to consider
 * @return integer of total count
 */
private int getTotalCount(int col) {
    RowTotal tot = null;
    for(int i = 0; i < rowTotalList.size(); i++) {
        tot = (RowTotal) rowTotalList.get(i);
        int temp[] = tot.getColumn();
        if(temp[0] == col) {
            return tot.getTotal(); // return total count when column number matched
        }
    }
    return 0;
}

/**
 * Prints row list to a file
 * @param file String of file name to print rows to
public void printRowList(String file) {
    PrintWriter writer = null;
    try {
        writer = new PrintWriter(new FileWriter(file));
    } catch (IOException ex) {
        ex.printStackTrace();
    }
    Row row;
    for(int i = 0; i<bmRowList.size(); i++) {
        row = (Row)bmRowList.get(i);
        writer.print(row.toString());
        writer.print("\t  Support: "+getSupport(row));
        writer.println();
    }
    writer.close();
}

/**
 *  Prints list of n-itemsets to a file
 *  @param file         String of file name to print rows to
 *  @param itemSetList  ArrayList of item-sets to be printed
 */
public void printItemSetList(String file, ArrayList itemSetList) {
    PrintWriter writer = null;
    try {
        writer = new PrintWriter(new FileWriter(file));
    } catch (IOException ex) {
        ex.printStackTrace();
    }
    ItemSet set;
    for(int i = 0; i<itemSetList.size(); i++) {
        set = (ItemSet)itemSetList.get(i);
        writer.print(set.toString());
        writer.println();
    }
}
long sec = (endTime.getTime() - startTime.getTime());
writer.println("****Time elapsed: " + (sec/1000) + " seconds");
writer.close();
}

/**
 * Returns ArrayList of 1-itemsets
 * @return ArrayList of 1-itemsets
 */
public ArrayList getItemSet1List()
{
    return itemSetList;
}

/**
 * Returns ArrayList of 2-itemsets
 * @return ArrayList of 2-itemsets
 */
public ArrayList getItemSet2List()
{
    return itemSet2List;
}
/**
 * ColumnDM.java
 */
package dw;

import java.io.*;
import java.sql.*;
import java.util.*;

/**
 * ColumnDM class containing data mining operations for handling raw data
 * @author Mien Siao
 */
public class ColumnDM
{
    /**
     * List of items for column
     */
    private ArrayList colSet;

    /**
     * PrintWriter to print result to
     */
    private PrintWriter out;

    /**
     * ItemComparator that carries logic to perform Item comparison in insertion
     */
    private ItemComparator comp;

    /**
     * Constructor that initializes all member variables
     */
    public ColumnDM()
    {
        colSet = new ArrayList();
        comp = new ItemComparator();
        try
        {
            out = new PrintWriter(new FileWriter("outColn.txt"));
        }
        catch (IOException ex)
        {
            ex.printStackTrace();
        }
    }
}
/**
 * Extracts column from initial_data_table, processes each value and creates an Item
 * @param col  column number to be extracted
 */
public void extractColumn(int col)
{
    try
    {
        Class.forName("oracle.jdbc.driver.OracleDriver");

        Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@bodog:1521:orcl","system","ronnielt");

        Statement stmt = conn.createStatement();
        String sqlStr = "select V" + col + " from initial_data_table where ROWNO <= 451315";
        ResultSet rs = stmt.executeQuery(sqlStr);

        Item item;
        while (rs.next())
        {
            item = new Item(rs.getInt(1));
            System.out.println(item.toString());
            addItem(item);
        }

        stmt.close();
        rs.close();
        conn.close();

        System.out.println("!!Number of items in colset: " + colSet.size());
    }
    catch(Exception e)
    {
        System.out.println(e);
    }
}

/**
 * Determines if a column is qualified to be considered
 * @param col  column number to be checked
 * @return true if at most 32 distinct values found in given column
 *         false otherwise
 */
private boolean isQualifiedColumn(int col)
int distinctVal = 0;
try {
    Class.forName("oracle.jdbc.driver.OracleDriver");
    Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@bodog:1521:orcl" , "system","ronnielt");
    Statement stmt = conn.createStatement();
    String sqlStr = "select count (distinct(V + col + ")) from initial_data_table where
    ROWNO <= 451315";
    ResultSet rs = stmt.executeQuery(sqlStr);
    rs.next();
    distinctVal = rs.getInt(1);
    stmt.close();
    rs.close();
    conn.close();
} catch(Exception e) {
    System.out.println(e);
}
return distinctVal <= 32;

/**
 * Adds an Item to the list of column items
 * @param item Item to be added to the list
 */
private void addItem(Item item) {
    int itemIndex = Collections.binarySearch(colSet, item, comp);
    if(itemIndex < 0) {
        System.out.println("New Item added!");
        colSet.add(item);
        Collections.sort(colSet, comp);
    } else {
        System.out.println("Dup found!");
        Item foundItem = (Item)colSet.get(itemIndex);
        foundItem.incCount();
    }
}
/**
 * Returns the support level
 * @param item  Item to get support level for
 * @return      int of support percentage * 100
 */
public int getSupport(Item item)
{
    return Math.round(((float)item.getCount()) / ((float)getTotalCount()) * 100);
}

/**
 * Returns the total count for the column set
 * @return      int of total count
 */
public int getTotalCount()
{
    int total = 0;
    for (Iterator it = colSet.iterator(); it.hasNext(); )
        total += ((Item)it.next()).getCount();
    return total;
}

/**
 * Prints the set of column items for the given column number
 * @param col   int of column number
 */
public void printSet(int col) throws IOException
{
    if (col >= 0)
    {
        out.println("\n\n< 1-ITEMSET FOR COLUMN V" + col + " >");
        for(int i = 0; i<colSet.size(); i++)
            { Item item = (Item)colSet.get(i);
                out.print(item.toString());
                out.print("  Support: "+getSupport(item));
                out.println();
            }
    }
    else
        out.println("\nSKIPPING COLUMN!!");
/**
 * Closes the opened printwriter
 */
public void closePrint()
{
    out.close();
}

/**
 * Clear the list of column set
 */
public void clearSet()
{
    colSet = new ArrayList();
}

/**
 * Calculates column data
 * @param col   int of column number
 */
public void calcColData(int col) throws IOException
{
    clearSet();
    extractColumn(col);
}

/**
 * Prints the set of items in the column that meets the given minimum support level
 * @param min   minimum support level
 */
public void printItemSet(int min)
{
    Item item;
    for(int i = 0; i<colSet.size(); i++)
    {
        item = (Item)colSet.get(i);
        if(getSupport(item) >= min)
        {
            out.print(item.toString());
            out.print("  Support: "+getSupport(item));
            out.println();
        }
    }
}
package dw;

import java.sql.*;
import java.io.*;
import java.lang.*;
import java.util.*;

/**
 * DataMining class containing data mining operations for generating frequent 1-itemset
 * using classical algorithm
 * @author Mien Siao
 */

public class DataMining
{

    /**
     * Support level
     */
    private int minSupport;

    public DataMining()
    {
        minSupport = 0;
    }

    /**
     * Calculates the support for 1-itemset that meets the minimum support level
     */
    public void support()
    {
        int totalDistinctValues = 0;  // Distinct values in a column
        int dv = 0;                   // distinct value
        float percentageValue = 0;    // Calculated the support percentage
        int countDV = 0;               // Count of distinct values
        int totalRows = 0;             // Total rows
        PrintWriter out = null;       // PrintWriter for outputting result
        java.util.Date startTime = new java.util.Date();

        try
        {
            out = new PrintWriter(new FileWriter("outDataMining.txt"));
        }
        catch (IOException ex)
try {
  // Setting connections for Oracle
  Class.forName("oracle.jdbc.driver.OracleDriver");
  Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@IBM-2A24156C376:1521:orcl","system","cs257");

  Statement stmt = conn.createStatement();
  Statement numRows = conn.createStatement();
  Statement createTableStmt = conn.createStatement();

  // Getting the total number of rows in Initial_Data_Table
  ResultSet tempRows = numRows.executeQuery("SELECT COUNT(*) FROM initial_data_table");
  tempRows.next();
  String rows = tempRows.getString(1);

  // Converting to integer value
  totalRows = java.lang.Math.round(Integer.parseInt(rows));

  out.print("Total # of values in column is "+totalRows);
  out.print("n");

  for(Integer f=0; f<=137; f++)
  {
    // For the case when 134th row is reached, skip over the 2 empty rows
    if(f==134)
      f = 136;

    // Getting the total number of distinct values in column V??? in initial_Data_Table
    ResultSet temp = numRows.executeQuery("SELECT COUNT (DISTINCT v" + f.toString() + ") FROM initial_data_table");
    temp.next();

    String distinctValues = temp.getString(1);

    // Converting to integer value
    totalDistinctValues = Integer.parseInt(distinctValues);

    out.println("Total distinct values in v" + f.toString() + ": "+
totalDistinctValues);
// Process only if column qualifies the 32 maximum distinct value criteria
if(totalDistinctValues <= 32)
{

    ResultSet rs = stmt.executeQuery("SELECT DISTINCT(v" + f.toString() + ") FROM initial_data_table ORDER BY v" + f.toString() + "");

    while(rs.next())
    {

        String distinctV = rs.getString(1);

        //converting to integer value
        dv = Integer.parseInt(distinctV);

        ResultSet tem = numRows.executeQuery("SELECT COUNT (*) FROM initial_data_table WHERE v" + f.toString() + "+ dv +"");
        tem.next();

        String temCount = tem.getString(1);
        countDV = java.lang.Math.round(Integer.parseInt(temCount));
        percentageValue = java.lang.Math.round(((float)countDV/(float)totalRows)*100.0));

        //Checking if a distinct value in a column is greater than the support threshold
        if (percentageValue >= minSupport)
        {
            out.println("v" + f + ""+ dv +");
            out.println("support is " + (int)percentageValue);
        }
    }
}
conn.close();

} catch(Exception e)
{
    out.println(e);
}
java.util.Date endTime = new java.util.Date();

long sec = (endTime.getTime() - startTime.getTime());
out.print("****Time elapsed: " + sec/1000 + " seconds");
out.close();
}
}
/* 
* DataMining2.java 
*/

package dw;

import java.sql.*;
import java.io.*;
import java.lang.*;
import java.util.*;

/**<*
* DataMining2 Class containing data mining operations for generating frequent 2-itemset
* using classical algorithm
* @author Mien Siao
*/

public class DataMining2 {

/**
* Total rows
*/
private int totalRows;

/**
* First attribute in the 2-itemset
*/
private int constantColumn;

/**
* Distinct value of the first attribute in the 2-itemset
*/
private int constantDistinct;

/**
* Distinct values for the first attribute
*/
private int columnD;

/**
* Distinct values for the second attribute
*/
private int dv;

/**
* PrintWriter for output
*/
private PrintWriter out;

/**
 * Start timer for operation
 */
private java.util.Date startTime;

/**
 * End timer for operation
 */
private java.util.Date endTime;

/**
 * Constructor to initialize member variables
 */
public DataMining2()
{
    totalRows = 0;
    constantColumn = 0;
    constantDistinct = 0;
    columnD = 0;
    dv = 0;

    try {
        out = new PrintWriter(new FileWriter("outDataMining2.txt"));
    } catch (IOException ex) {
        ex.printStackTrace();
    }
}

/**
 * Calculates the support for 2-itemsets
 */
public void support2()
{
    startTime = new java.util.Date();

    // Getting total rows
    totalRows = numRows();

    // Outer loop for moving through the columns and keeping the current column as the
    first attribute value
    for (Integer i=0; i<=136; i++) {
        if(i==134) {
            i = 136;
            constantColumn = i;
        }
    }
}
try{
    Class.forName("oracle.jdbc.driver.OracleDriver");
    Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@IBM-2A24156C376:1521:orcl","system","cs257");
    Statement numRows = conn.createStatement();
    ResultSet temp2 = numRows.executeQuery("SELECT COUNT (DISTINCT v" + constantColumn + ") FROM initial_data_table");
    temp2.next();
    String distinctCValues = temp2.getString(1);
    columnD = Integer.parseInt(distinctCValues);
    out.print("\n");
    out.print("Total distinct values in v " + constantColumn + " : " + columnD);
    // Inner loop to move throught the columns and keep the current column as the second attribute value
    if(columnD <= 32){
        for(int f=(constantColumn+1); f<=137; f++) {
            if(f==134)      // to skip over 134th and 135th rows which are empty
                f = 136;
            calcDistinct(f);
        }
    }
    conn.close();
} catch(Exception e) {
    out.println(e);
}
endTime = new java.util.Date();
long sec = (endTime.getTime() - startTime.getTime());
out.print("\n****Time elapsed: " + sec/1000 + " seconds\n");
out.close();
}

/**
 * Helper method for getting the total number of values in a column
* @return int number of values in a column
* /
private int numRows() {
    try{
        //Setting connections for Oracle
        Class.forName("oracle.jdbc.driver.OracleDriver");
        Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@IBM-2A24156C376:1521:orcl","system","cs257");

        Statement stmt = conn.createStatement();
        Statement numRows = conn.createStatement();
        Statement createTableStmt = conn.createStatement();

        //Getting the total number of rows in Initial_Data_Table
        ResultSet tempRows = numRows.executeQuery("SELECT COUNT(*) FROM initial_data_table");
        tempRows.next();

        String rows = tempRows.getString(1);

        //Converting to integer value
        totalRows = Integer.parseInt(rows);

        out.println("Total # of values in column is " + totalRows);
        conn.close();
    }catch(Exception e) {
        out.println(e);
    }
    return totalRows;
}

/**
 * Helper method to count distinct values
 * @param f int column number
 * @return int of total number of distinct values
 */
public int calcDistinct(int f) {
    int totalDistinctValues = 0;  // Total distinct values in a column
    int countDV = 0;             // Count of distinct values
    float percentageValue = 0;  // Percentage of support level
try{
    // Setting connection for Oracle
    Class.forName("oracle.jdbc.driver.OracleDriver");
    Connection conn = DriverManager.getConnection("jdbc:oracle:thin:@IBM-2A24156C376:1521:orcl","system","cs257");

    Statement numRows = conn.createStatement(); // Getting number of rows
    ResultSet temp = numRows.executeQuery("SELECT COUNT (DISTINCT v" + f + ") FROM initial_data_table");
    temp.next(); // Getting number of distinct values in the column
    String distinctValues = temp.getString(1);

    // Converting to integer value
    totalDistinctValues = Integer.parseInt(distinctValues);
    out.print("\n");
    out.print("Total distinct values in v" + f + ": " + totalDistinctValues);
    out.print("\n");
    out.print("\n");

    // Check the number of distinct values in current column
    if(totalDistinctValues <=32) {
        Statement stmt = conn.createStatement();
        ResultSet rs = stmt.executeQuery("SELECT DISTINCT(v" + f + ") FROM initial_data_table ORDER BY v" + f + ");

        // loop through the distinct values
        while(rs.next()) {
            String distinctV = rs.getString(1);
            // converting to integer value
            dv = Integer.parseInt(distinctV);
            Statement stmtC = conn.createStatement();
            ResultSet rsC = stmt.executeQuery("SELECT DISTINCT(v" + constantColumn + ") FROM initial_data_table ORDER BY v" + constantColumn + ");

            while(rsC.next())
            {
                String distinctC = rsC.getString(1);
            }
        }
    }
}
constantDistinct = Integer.parseInt(distinctC);

ResultSet tem = numRows.executeQuery("SELECT COUNT (*) FROM initial_data_table " +
                         "WHERE v" + constantColumn + "=" + constantDistinct + " AND v" + f + "=" + constantDistinct + "");

    tem.next();
    String temCount = tem.getString(1);
    countDV = java.lang.Math.round(Integer.parseInt(temCount));

    out.println("v" + constantColumn + "=" + constantDistinct + " = v" + f + "=" + constantDistinct + "");

    percentageValue = java.lang.Math.round(((countDV/totalRows)*100));

    out.println("support is " + (int)percentageValue);
    
    conn.close();
} catch(Exception e) {
    out.println(e);
}
return totalDistinctValues;
/*
 * DB2File.java
 */

text/oracle.jdbc.driver.OracleDriver"
Connection conn = DriverManager.getConnection(
   "jdbc:oracle:thin:@bodog:1521:orcl","system","ronnielt");
Statement stmt = conn.createStatement();
Statement numRows = conn.createStatement();

//ResultSet rs1 = stmt.executeQuery("select * from initial_data_table where rowno <= 451315");
ResultSet rs1 = stmt.executeQuery("select * from initial_data_table where rowno <= 100000");

PrintWriter out = new PrintWriter(new FileWriter("out1.txt");

while (rs1.next())
{
    for(int i=1; i<137; i++)
        out.print(rs1.getString(i) + " ");
    out.println();
}
out.close();
conn.close();

} catch(Exception e) {
    System.out.println(e);
}
package dw;

import java.util.ArrayList;

public class Item {

    private int value;
    private int count;

    public Item() {
        count = 0;
    }

    public Item(int val) {
        value = val;
        count = 1;
    }
}
public void setValue(int i)
{
    value = i;
}

public int getValue()
{
    return value;
}

public void incCount()
{
    count++;
}

public int getCount()
{
    return count;
}

public String toString()
{
    return "Value: " + value + "	 Count: " + count;
}
package dw;

import java.util.Comparator;

public class ItemComparator implements Comparator {

    public ItemComparator() {
    }

    public int compare(Object o1, Object o2) {
        Item i1 = (Item)o1;
        Item i2 = (Item)o2;

        if(i1.getValue() < i2.getValue())
            return -1;
        else if (i1.getValue() == i2.getValue())
            return 0;
        else
            return 1;
    }
}
package dw;

import java.util.*;

public class ItemSet {

    private ArrayList rows;

    private int commonCount;

    private int support;

    private final int NUM_OF_ROWS = 150400;

    public ItemSet() {
        rows = new ArrayList();
        commonCount = 0;
        support = 0;
    }

    /**
     * ArrayList of Row objects
     */
    private ArrayList rows;

    /**
     * Common occurrence of the itemset
     */
    private int commonCount;

    /**
     * Support level
     */
    private int support;

    /**
     * Total number of rows in bitmap
     */
    private final int NUM_OF_ROWS = 150400;

    /**
     * Constructor that initializes all member variables
     */
    public ItemSet() {
        rows = new ArrayList();
        commonCount = 0;
        support = 0;
    }

    /**
     */
* Adds a row to the itemset
  * @param r Row to be added
*/
public void addtoItemSet(Row r)
{
    rows.add(r);
}

/**
 * Getter of the list of rows in ItemSet
 * @return ArrayList of Rows in ItemSet
 */
public ArrayList getItems()
{
    return rows;
}

/**
 * Setter of common count
 * @param i number of common occurrences of the value
 */
public void setCommonCount(int i)
{
    commonCount = i;
}

/**
 * Setter of support
 * @param i support level of the itemset
 */
public void setSupport(int i)
{
    support = i;
}

/**
 * Computation of support level of the itemset and sets the support value
 */
public void calcSupport()
{
    long sup = Math.round( (float)commonCount/(float)NUM_OF_ROWS * 100.0);
    setSupport( (int)sup);
}

/**
 * Getter of common count
* @return int of common count
*/
public int getCommonCount()
{
    return commonCount;
}

/**
* Getter of support level
* @return int of support level
*/
public int getSupport()
{
    return support;
}

/**
* Getter of support level
*/
public void calcCommon2ItemSet()
{
    Row r1 = (Row)rows.get(0);
    Row r2 = (Row)rows.get(1);
    String[] rString1 = r1.getStringArr();
    String[] rString2 = r2.getStringArr();
    Long int1;
    Long int2;
    int i;
    long n1, n2, res;

    // Compute using the r1 as reference if it has the least non-zero values
    if(r1.getCount() < r2.getCount())
    {
        for(int b = 0; b < rString1.length; b++)
        {
            int1 = new Long(rString1[b]);
            n1 = int1.longValue();
            if(n1 > 0)
            {
                int2 = new Long(rString2[b]);
                n2 = int2.longValue();
                res = n1 & n2;
                commonCount += Long.bitCount((long)res); // convert res to binary and add
                bitcount to count.
            }
        }
    }
else    // Compute using the r2 as reference if it has the least non-zero values
{
    for(int b = 0; b < rString2.length; b++)
    {
        int2 = new Long(rString2[b]);
        n2 = int2.longValue();
        if(n2 > 0)
        {
            int1 = new Long(rString1[b]);
            n1 = int1.longValue();
            res = n1 & n2;
            commonCount += Long.bitCount((long)res); // convert res to binary and add bitcount to count.
        }
    }
}

/**
 * Returns the String representation of the ItemSet
 * @return     String representation of the ItemSet object
 */
public String toString()
{
    StringBuffer sb = new StringBuffer("(");
    int num = rows.size();
    for (int i = 0; i < num; i++)
    {
        sb.append(((Row)rows.get(i)).getHeader());
        if(i != num-1)
            sb.append(", ");
    }
    sb.append(")");
    sb.append("\t  Common count: " + commonCount);
    sb.append("\t  Support: " + support);
    return sb.toString();
}
/**
 * ItemSetComparator.java
 */

to

class ItemSetComparator implements Comparator
{
 public ItemSetComparator()
 {
  
 }

 /**
 * Compares 2 ItemSet objects and returns the lexicographical order.
 * Comparison is performed on the Row items within each ItemSet
 * @param o1 Item object1
 * @param o2 Item object2
 * @return int value of the comparison result
 *  -1 if o1 comes before o2
 *  0 if order of o1 and o2 are equal
 *  1 if o1 comes after o2
 */
 public int compare(Object o1, Object o2)
 {
  ItemSet b1 = (ItemSet)o1;
  ItemSet b2 = (ItemSet)o2;

  ArrayList list1 = (b1.getItems());
  ArrayList list2 = (b2.getItems());

  int result = 0;
  RowComparator comp = new RowComparator();
  for (int i = 0; i < list1.size(); i++)
  {
   result = comp.compare((Row)list1.get(i), (Row)list2.get(i));
   if (result != 0)
    return result;
  }
  return result;}}
package dw;

import java.util.*;

public class Row {
    /**
     * Column number of bitmap row
     */
    private int column;

    /**
     * Distinct value of bitmap row
     */
    private int value;

    /**
     * Number of occurrence for the value in the column
     */
    private int count;

    /**
     * String of the decoded header value
     */
    private String header;

    /**
     * String containing original row of the bitmap file
     */
    private String orgString;

    /**
     * Constructor that initializes all member variables
     */
    public Row() {
    }
column = 0;
value = 0;
count = 0;
header = new String();
orgString = new String();
}

/**
 * Setter for the column number
 * @param i    the column number of the row
 */
public void setColumn(int i)
{
    column = i;
}

/**
 * Setter for the distinct value
 * @param i    the distinct value of the row
 */
public void setValue(int i)
{
    value = i;
}

/**
 * Setter for the count
 * @param i    the number of times this distinct value appeared in the column
 */
public void setCount(int i)
{
    count = i;
}

/**
 * Setter for the original string of the bitmap row
 * @param s    original String of the bitmap row
 */
public void setString(String s)
{
    orgString = s;
}

/**
 * Setter for the header string of the bitmap row
 * @param lcode    Long value to be converted into header

public void setHeader(Long lcode)
{
    // bits 1-8-16 represents disk-column-distinctValue
    String headerStr = Long.toBinaryString(lcode.longValue());

    StringBuffer sb = new StringBuffer("V");
    int iTemp = Utility.binary2int(headerStr.substring(1,9));
    setColumn(iTemp);
    sb.append(iTemp + "_");
    iTemp = Utility.binary2int(headerStr.substring(9,25));
    setValue(iTemp);
    sb.append(iTemp);
    header = sb.toString();
}

/**
 * Getter for the column number
 * @return int column number
 */
public int getColumn()
{
    return column;
}

/**
 * Getter for the distinct value
 * @return int distinct value
 */
public int getValue()
{
    return value;
}

/**
 * Getter for the count
 * @return int number of times this distinct value appeared in the row
 */
public int getCount()
{
    return count;
}

/**
 * Getter for the header string
 * @return String of the decoded header of the bitmap row
 */
public String getHeader()
{
    return "V"+column+"_"+value;
}

/**
 * Getter for the original string of the row
 * @return String of the original text of the bitmap row
 */
public String getString()
{
    return orgString;
}

/**
 * Returns the original bitmap row value without the header as a String array
 * @return String[] containing each broken-down value of the original string
 */
public String[] getStringArr()
{
    String s = orgString.substring(9);
    return s.split("\s");
}

/**
 * Returns the String representation of the Row
 * @return String representation of the Row object
 */
public String toString()
{
    return "Header: " + header + "  Count: " + count;
}
package dw;

import java.util.Comparator;

public class RowComparator implements Comparator {

    public RowComparator() {
    }

    public int compare(Object o1, Object o2) {
        Row b1 = (Row)o1;
        Row b2 = (Row)o2;

        if(b1.getValue() < b2.getValue())
            return -1;
        else if (b1.getValue() == b2.getValue()){
            if(b1.getColumn() < b2.getColumn())
                return -1;
            else if(b1.getColumn() > b2.getColumn())
                return 1;
            else
                return 0;
        }
    }
}

else
    return 1;
}
}
package dw;

public class RowTotal {

    private int[] column;
    private int total;

    public RowTotal() {
        column = null;
        total = 0;
    }

    public void setColumn(int i) {
        column = new int[] {i};
    }

    public void setColumn(int i, int j) {
    }

}
```java
{
    column = new int[] {i, j};
}

/**
 * Setter of column for 3-itemset
 * @param i   first column number in the 2-item
 * @param j   second column number in the 2-item
 * @param k   third column number in the 3-item
 */
public void setColumn(int i, int j, int k)
{
    column = new int[] {i, j, k};
}

/**
 * Setter of row Total
 * @param i   total of the row count
 */
public void setTotal(int i)
{
    total = i;
}

/**
 * Getter of column numbers in itemset
 * @return     array of column numbers of items
 */
public int[] getColumn()
{
    return column;
}

/**
 * Getter of total row count
 * @return     int of total row count
 */
public int getTotal()
{
    return total;
}
}
/**
 * Utility.java
 */

package dw;

/**
 * Utility class that contains common utility functions
 * @author Mien Siao
 */

public class Utility {

    public Utility() {
    }

    /**
     * Static method that converts a base-2 value String into binary value
     * @param binary the String that holds binary value
     * @return int of equivalent value in base-2
     */
    public static int binary2int(String binary) {
        int ans = 0;
        for (int i = 0; i < binary.length(); i++) {
            char c = binary.charAt(i);
            if (c == '0')
                ans = 2 * ans;
            else if (c == '1')
                ans = 2 * ans + 1;
        }
        return ans;
    }

    /**
     * Helper method that counts the number of bits after converting a base-2 number into binary
     * @param str the String that holds the base-2 value
     * @return number of 1 bits in the binary representation of the input string
     */
    public static int countBits(String str) {
        Long ll = new Long(str);
        long l = ll.longValue();
        return ll.longValue();
    }
}
return Long.bitCount(l);