Rare Pattern Mining

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# Introduction

Data mining is defined as the non-trivial extraction of implicit, previously unknown, and potentially useful information from data . Rare Pattern mining is the extraction of patterns that occur very infrequently within a database. Currently, much of the research available on data mining focuses on frequent pattern mining; however, rare pattern mining is an exceedingly interesting, growing field within computer science . My research will demonstrate that a frequent pattern mining algorithm, the Frequent Pattern Growth algorithm, can be modified to retrieve interesting rare itemsets that can then be studied. We hope to also show that our Rare Pattern Growth algorithm can do this efficiently.

There are quite a few different applications for rare pattern mining. For example, rare pattern mining can be employed for fraud detection. In a database of credit card transactions, the rare patterns could turn out to be fraudulent, and the credit card company could use a rare pattern mining algorithm to detect and prevent these transactions from harming their customers. A company that does this might be able to attract more customers by promising them protection.

There are two important ways to determine whether or not a pattern can be considered rare: its support, and its confidence level. Support represents the number of time the items that make up the set occur together in the database . Confidence represents a proportional value that shows how frequently one part of the itemset occurs with the other(s) . Because an itemset with very little support is likely, if not guaranteed to have a low confidence measure, it is only necessary to consider the support value of the itemset to determine whether or not it is rare.

The Frequent Pattern Growth algorithm uses a divide-and-conquer approach toward mining frequent patterns. The frequent single items of each transaction are added one at a time into a tree data structure, and then each frequent itemset is mined from the tree using a recursive function. My Rare Pattern Growth will operate in much the same way. The more frequent rare items will be added into the tree first, and mined from it last.

The organization of this report is as follows: first I will examine existing literature in data mining that focuses on rare itemset mining, as well as Frequent Pattern Growth. Second, I will describe my algorithm to mine rare itemset using diagrams and pseudo-code. I will also be examining the efficiency of using VIPER. Third, I will analyze the results of my algorithm. And finally I will conclude with an examination of what I learned from running the algorithm, and how it could be applied to the data mining field as a whole.

# Literature Review

Aggrawal and Han wrote one an excellent, comprehensive book about the study of frequent pattern mining. This resource has proved invaluable in examining Frequent Pattern Growth for this project, and other areas of data mining, as it successfully provides an overview of the different frequent pattern mining methods .

Weng proposed an Apriori-based mining approach called Fuzzy Apriori Rare Itemset Mining [FARIM], for mining “specific rare itemsets consisting of quantitative data” .[[1]](#footnote-1) Weng proposed using FARIM for low test or quiz scores in a school setting; if there was a student, or a group of students struggling with class content, then determining exactly what it is they are struggling with would go a long way in finding a solution [5]. Weng believed that his approach would be more successful if it included clustering and classification methods, and if the support parameter was inferred from the data.

Hemalatha, Vaidehi, and Lakshmi wrote about finding rare itemsets in data streams, as opposed to static datasets . To that end, they proposed an algorithm for finding Minimal Infrequent Patterns from Data Streams, defined three measures for outlier detection, and created a Minimal Infrequent Pattern based Outlier Detection algorithm. They found, among other things, that their methods were well suited for extracting useful data from sensor data streams and identifying meaningful outliers from those streams.

Wu, Chen, and Chang wrote about Attribute-Oriented Induction (AOI), and proposed using AOI to mine negative generalized knowledge from datasets . Their reasoning has to do with medical data; for example, if only a few Taiwanese people were infected with the H1N1 flu virus the number of people that are Taiwanese and have contracted H1N1 will be very small, and not considered a frequent itemset. However, if few Taiwanese contracted H1N1, then that might indicate that the Taiwanese were somehow resistant to the disease.

Agrawal and Agrawal presented an overview of how data mining techniques could be used to detect anomalies in datasets . Their Classification approach was to build a model based on the normal behavior of the system, and then feed testing data into that model in order to determine which datasets were anomalous . They tried various different Clustering approaches including k-Means, k-Medoids, and other approaches. They found that hybrid approaches, which combine Clustering and Classification based anomaly detection systems, had the best chance at finding anomalous behaviors in Intrusion Detection Systems.

Lin, Liao, and Chen actually wrote about using the Frequent Pattern Growth algorithm to find frequent itemsets, and in particular to reduce the number of candidate itemsets examined by the algorithm, and reducing the number of times it is necessary to scan the entire database . This is because the Apriori algorithm requires scanning the database repeatedly, and Dynamic Hashing and Pruning algorithm improves the performance of Apriori and lowers the cost of database scanning. But FP-Growth goes even further to improve the performance of Frequent Pattern Mining.

Lin, Lao, and Chen then propose using an Improved FP-Growth algorithm to improve the performance of FP-growth . They do this in part by using an address-table structure to lower the complexity of mapping frequent 1-itemsets in an FP-tree, and by using a hybrid FP-tree mining method that reduced the need to rebuild conditional FP-trees. Their simulation shows that their algorithm improved the performance of FP-growth by an order of magnitude in terms of execution time.

Cagliero and Garza actually use FP-Growth in a similar to fashion to what I am using it for, rare pattern mining .

Bhattacharyys, Jha, Tharakunnel, and Westland wrote about how data mining could be utilitzed to detect or prevent credit card fraud . According to them $4 billion was lost in 2008. They went on to identify two different approaches for detecting fraud: supervised and unsupervised. Supervised fraud detection methods detect fraudulent transactions by estimating based on samples of both fraudulent and legitimate transactions in order to classify new transactions as one or the other . In unsupervised fraud detection models outliers are identified as potential cases of fraud and sought out.

Bhattacharyya et al then went on to examine two different mining techniques for finding fraudulent transactions: random forests and support vector machines, together with logical regression . They concluded that the random forests demonstrated better performance and greater efficiency compared to support vector machines . They suggested that future study should focus on the different varieties of fraudulent behavior, for example the difference between stolen and counterfeit credit cards.

Yu, Sheikholeslami, and Zhang wrote about finding outliers in very large datasets . This is because, as they put it, “Modern companies are awash in data on customers, clients, suppliers, and industry trends” . Their contribution, called FindOut, was intended to detect outliers in complicated data patterns of various densities. It did so using signal-processing techniques and a novel deviation outlier detection approach. It was also successful in indentifying various percentages of outliers in large datasets .

Adda, Wu, White, and Feng wrote about finding rare patterns . They modeled their approach on the Apriori algorithm, and used it to detect abnormal usage in web applications. They found that their approach was flexible and able to detect suspicious behaviors not seen before .

# Description

The software prototype operates in a number of steps. First, it reads in the transaction database, then it creates an array of Transaction objects, then it removes the non-rare items from those transactions, then it adds those transactions one-at-a-time to a tree structure, then it analyzes that tree structure to find all the rare patterns in the database. All of these steps are completed for each transaction database that the software uses, and all the objects that are created are deleted before it can move on to the next database.

## Transaction Stage

The transaction stage is fairly simple to understand. The software reads in the transaction database. The database is stored in the form of a simple text file with each line indicating a transaction, and the first l-line indicating the number of transactions in the file. Each one of these lines is used to initialize a Transaction object, and each transaction contains one or more items. These items may or may not be rare in the database at this point.

The transaction database used by this software is also quite simple. It is a text file where the first line indicates the total number of transactions. Each line after that first one represents a transaction, where the first number is the transaction’s unique identifier, a natural number starting with one. After that, on the same line, is the number of items in the transaction. Lastly are the items themselves, also indicated by natural numbers. The simplest transaction database the software uses, called PreciseDB.txt, is shown below.

4

1 3 1 3 4

2 3 2 3 5

3 4 1 2 3 5

4 2 2 5

This transaction database contains four transactions, which have IDs of one through four. The largest transaction has four items (1, 2, 3, and 5), and the smallest only has two (2 and 5). The transaction stage will return a TransactionList containing four transactions. Some basic pseudo-code for this stage follows.

get\_transactions(contents, transactions, transaction\_list)

{

istringstream f(contents)

line = ""

getline(stream, line)

int i = 0

while (getline(stream, line) && i < transactions)

{

Transaction \*t = new Transaction(line)

transaction ->add\_transaction(t)

i++

}

}

This function takes the contents of the database, the number of transactions, and the initial transaction list as parameters. Each line is used to create a transaction, and then that transaction is added to the list. The transaction list is updated in place, so there is no need to return it. The transaction itself is comprised of the ID, number of items, and the items themselves. All of these are integers.

## Pruning Stage

The Pruning Stage is where the non-rare items are removed from all the transactions in the database. The database itself is not altered, but any number of Transaction objects that the software uses could be. This stage is completed in several steps. First, every item in the database is added to a Set object, along with its support.

get\_itemset()

{

total = 0

for (i = 0; i < present; i++)

{

// total represents the largest possible number of items in the database

total+=list[i]->get\_length()

}

set = new Set(total)

if (set != NULL)

{

// first get the support of all items in the transaction database

for (i = 0; i < present; i++)

{

items = list[i]->get\_items()

length = list[i]->get\_length()

for (j = 0; j < length; j++)

{

curr = items[j]

item = new Item(curr)

// add\_item automatically increments support if the item is already present in the database

set->add\_item(item)

}

}

set->resize(set->get\_present())

}

return set

}

The code above creates a new set to be used for the header table for the tree. Each item in the database is added to that set, which automatically increments the support of an item if it is added more than once, rather than storing that item multiple times. After this the non-rare items are removed from the set and from the list of transactions.

Next, the actual pruning begins .The software removes each item that has too much support in the database from the Itemlist. Once again, this is a multi-step process. First, the non-rare items must be removed from the header table stored as a set, then those non-rare items have to be removed from the transactions themselves. Any transaction that contains nothing but non-rare items is removed from the list.

Set::remove\_non\_rare\_items(max\_support)

{

non-rares = 0

for (i = 0; i < present; i++)

if (set[i]->get\_support() > max\_support)

non-rares++

int new\_size = size - non-rares

// create replacement set of ListItems

new\_set = new ListItem \*[new\_size]

next = 0

for (i = 0; i < present; i++)

{

if (set[i]->get\_support() <= max\_support)

{

n = new Item(curr->get\_name(), set[i]->get\_support())

new\_set[next] = n

next++

}

}

this->present = next

this->size = new\_size

this->set = new\_set

}

TransactionList::remove\_non\_rare\_items(set)

{

revised = 0

for (i = 0; i < present; i++)

{

temp = list[i]->remove\_non\_rare\_items(set)

if (temp != NULL)

{

revised++

}

list[i] = temp

}

replacement = new Transaction\*[revised]

index = 0

for (i = 0; i < present; i++)

{

if (list[i] != NULL)

{

replacement[index] = new Transaction(list[i])

index++

}

}

list = replacement

present = revised

size = revised

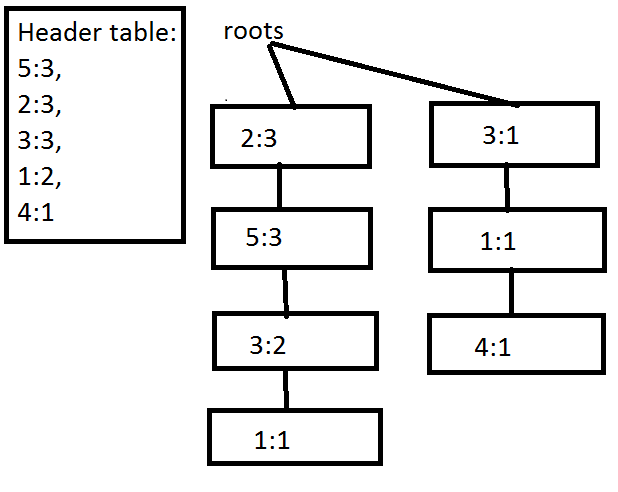
}

The first function, which is part of the Set class, is responsible for removing non-rare items from the header table. It first creates a new set large enough for all the rare items. Then it creates copies of all the rare items and adds them to the new set. The second function takes this header table and applies it to the list of transactions. It determines the number of transactions that will still have items. If a transaction contains only non-rare items it is not added to the new list.

Both the list of transactions and the header table are sorted using a modified quick sort algorithm in this stage as well. The items with the most support are placed at the front of both. This optimizes the tree, making it more likely to be a balanced, and therefore more efficient, tree structure. The last step of this stage is to print out the revised transaction list and the revised header table to the console.

## Construction Stage

In this stage, the transactions are used to construct a Rare Pattern tree. This tree has an array of roots rather than a single one. For the input file PreciseDB.txt, which was shown above, the final RPTree, along with the header table, looks like this:



The reason it looks the way it does has to do with the way the transactions are added to the tree. The items with the most support are the ones that are likely to have the most children. The tree that resulted from the software in this instance was perhaps not the most efficient shape it could have been, since it is two smaller trees where no node has more than one child. However, this database is simple enough to get away with this, and it is likely that the trees constructed for larger databases will be more efficient. If they are not, then that says something about the data which will be addressed later.

RPTree::add\_transaction(transaction)

{

items = transaction->get\_items()

size = transaction->get\_length()

added = false

if (present > 0)

{

for (i = 0; i < present && !added; i++)

{

item = roots[i]->get\_item();

name = item->get\_name();

for (j = 0; j < size && !added; j++)

{

if (name == items[j])

{

temp->increment\_support();

// remove items[j] from items array

int rep[size-1];

int q;

for (q = 1; q < size; q++)

{

rep[q-1] = items[q];

}

size--;

roots[i]->add\_transaction(rep, size);

added = true;

}

}

}

// added is false if the transaction has nothing in common with any of the roots

if (!added)

{

// none of the items in the transaction correspond to a branch, need a new root

q = new Item(items[0])

add = new TreeNode(q)

replacement[size-1]

for (i = 1; i < size; i++)

replacement[i-1] = items[i]

size--

items = replacement

add->add\_transaction(replacement, size)

add\_root(add)

}

}

else

{

// first root case

q = new Item(items[0])

add = new TreeNode(q)

replacement[size-1]

for (i = 1; i < size; i++)

replacement[i-1] = items[i]

size--

add->add\_transaction(replacement, size)

add\_root(add)

}

}

This function shows how each transaction is added to the RPTree data structure. First, the roots are examined to see if the transaction can be added to any of the sub-trees. If so, then the support value of the root is incremented and the transaction is recursively added to that root’s children. Otherwise it is necessary to create a new root for the tree. The rest of the transaction is then added recursively to that new root. The third case accommodates adding the very first transaction to the tree, which is done in much the same way.

void TreeNode::add\_transaction(array, size)

{

if (size > 0)

{

// first case: this node has no children

if (children\_number == 0)

{

i = new Item(array[0])

child = new TreeNode(i)

add\_child(child)

new\_array = revise\_array(array, size)

child->add\_transaction(new\_array, size-1)

}

else

{

// Second, try to add the transaction to one of the children

curr = NULL;

stop = false;

for (i = 0; i < children\_number && !stop; i++)

{

curr = children[i];

name = q->get\_name();

for (j = 0; j < size && !stop; j++)

{

if (name == array[j])

{

stop = true

curr->increment\_quantity()

swap(0, j, array)

int \*new\_array = revise\_array(array, size)

curr->add\_transaction(new\_array, size-1)

}

}

}

// Third, create a new group of children for this node

if (!stop)

{

i = new Item(array[0])

i->set\_support(1)

child = new TreeNode(i)

add\_child(child)

new\_array = revise\_array(array, size)

child->add\_transaction(new\_array, size-1)

}

}

}

}

## Mining Stage

The final stage of the software is to recursively mine the RPTree to get a list of rare patterns that are present in the tree. Since the only items that are present in the tree at all are themselves rare, there’s no need to ensure that the sets returned are rare. However, it is interesting to note the closed itemsets.

The examine method for the RPTree class is quite straight forward. It calls each root’s examine method and then combines the rare patterns found by that method with those of all the other roots. The Node’s examine method is more complex, and it was also the source of a number of memory leaks that needed plugging while writing the software.

TreeNode::examine()

{

set = new Set()

singleton = new Set(this->item)

set->add\_item(singleton)

if (children\_number > 0)

{

for (i = 0; i < children\_number; i++)

{

// examine each child node

Set \*child\_set = children[i]->examine()

// merge only adds the contents of the new set to set right now

set->add\_sets(child\_set)

child\_set->add\_item\_to\_sets(q);

set->add\_sets(child\_set);

}

}

return set;

}

This function creates and combines several very similar sets. First, it creates a set for the item stored by the current node, and adds it to the set that will be returned. This is possible because Sets contain a number of ListItems, of which Sets are a subclass. Anyway, it calls examine recursively for each child node, and then combines the resulting set with the one it will be returning, and also adds the node’s item to each of the sets returned by the child’s examine method.

Both of the Set methods that are called in TreeNode::examine are very simple. The add\_sets method simply adds the sets returned by the child’s examine method to the set used to call the method. The add\_item\_to\_sets method adds the supplied item to each subset stored within a set. The rare patterns are then printed to the console, and then added to the output file corresponding to the trial number.

# Analysis

I was able to use the software prototype to find and determine the support values for a number of different rare itemsets. In this section I will examine the results of the experiments, and press the significance of being able to find the rare itemsets in a transactional database using a Rare Pattern Growth algorithm over some of the other possibly approaches, namely the Apriori-based approach. Lastly, I will compare the results of the algorithm to the results of other documented experiments.

## Results

I was successful in finding quite a few different rare itemsets in the transaction databases used by the software. For example, when running the software using the simplest transaction database, the previously mentioned PreciseDB.txt with a maximum support value of three, it returns twenty different rare itemsets. These itemsets are shown in the table below, along with their support values.

|  |  |  |
| --- | --- | --- |
| Itemset | Support |  |
| {2} | 3 | 0.75 |
| {3} | 3 | 0.75 |
| {5} | 3 | 0.75 |
| {1} | 2 | 0.5 |
| {1,5} | 1 | 0.25 |
| {5,3} | 2 | 0.5 |
| {1,3} | 1 | 0.25 |
| {1,5,3} | 1 | 0.25 |
| {3,2} | 2 | 0.5 |
| {5,2} | 3 | 0.75 |
| {1,2} | 1 | 0.25 |
| {1,5,2} | 1 | 0.25 |
| {5,3,2} | 2 | 0.5 |
| {1,3,2} | 1 | 0.25 |
| {1,5,3,2} | 1 | 0.25 |
| {4} | 1 | 0.25 |
| {4,3} | 1 | 0.25 |
| {3,1} | 1 | 0.25 |
| {4,1} | 1 | 0.25 |
| {4,3,1} | 1 | 0.25 |

## Comparisons to Literature

# Conclusion

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|  |  |
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1. The Apriori algorithm is a frequent pattern mining algorithm where frequent single-item-sets are combined to create larger frequent itemsets, and then the database is scanned to determine the support of the new itemsets. This process continues until there are no more itemsets that can be combined [10] [↑](#footnote-ref-1)