**VIETNAM GENERAL CONFEDERATION OF LABOR**

**TON DUC THANG UNIVERSITY**

**FACULTY OF INFORMATION TECHNOLOGY**



**REPORT**

**DESIGN AND ANALYSIS OF ALGORITHMS**

*Instructor*: **NGUYEN CHI THIEN**

*Student*: **BUI ANH PHU - 521H0508**

**BUI HAI DUONG - 521H0220**

**NGUYEN HOANG PHUC - 521H0511**

*Class*: **21H50302**

**HO CHI MINH CITY, 2023**

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**COMPLETION OF THESIS**

**AT TON DUC THANG UNIVERSITY**

We here by certify that this thesis is my/our own work and was conducted under the guidance of Nguyen Chi Thien. The research and results presented in this thesis are truthful and have not been published previously in any form. The data presented in tables and figures used for analysis, comments, and evaluations were collected by the author from various sources and are clearly cited in the reference section.

Moreover, this thesis includes some comments, evaluations, and data from other authors and organizations, which are properly cited and referenced.

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*Ho Chi Minh City, October 22, 2023*

*Author*

*(signature and full name)*

ACKNOWLEDGEMENT AND EVALUATION SECTION BY INSTRUCTOR

**Instructor's Acknowledgement Section**

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Ho Chi Minh City, 2023

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**Instructor's Evaluation Section**

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Ho Chi Minh City, 2023

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SUMMARY

This document showing the theory based on the research document of Efficient weighted probabilistic frequent itemset mining in uncertain databases, explain the java code following the research then represent the result benchmark.

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**LIST OF SYMBOLS AND ABBREVIATIONS**

**Symbols**

Uncertain dataset of size n

A set of transaction identifiers

An itemset of size m

An existential probability for item appearing in the transaction

A weight table for the itemset I. Each item has a real-valued weight

An integer between (0, n], the minimum support for expected support- based FI mining

**msup** An integer between (0, n], the minimum support for probabilistic FI mining

A real value between (0, 1], the probabilistic frequent threshold for probabilistic FI mining

A real value between [0, 1], the scale factor

**Abbreviations**

**PFI** probability frequent itemset

**w-PFI** weighted probability frequent itemset

CHAPTER 1 – EFFICIENT WEIGHTED PROBABILISTIC FREQUENT ITEMSET MINING IN UNCERTAIN DATABASES THEORY BASED ON THE STUDY DOCUMENT

* 1. Problem definitions

Uncertain data mining has attracted so much interest in many emerging applications over the past decade. Several probability models are presented to measure the frequency of an itemset in the dataset, and it is noted that the frequency itself cannot identify useful or meaningful patterns in some scenarios. Therefore, weighted (importance) frequent itemset mining in uncertain databases has been done in some studies but the result is still inefficient. To overcome this issue, we introduce the new algorithms and some pruning methods for narrowing space and improve the candidate generation for the result.

* 1. Definitions

In this section, there are all the fundamental definitions mentioned in the study document, which are needed before dealing with the problem of finding efficient weighted probabilistic frequent itemset mining in uncertain databases.

* + 1. Definition 1 (Uncertain dataset):

An uncertain dataset DB consists of a set of transactions DB = , Each transaction contains a subset of an itemset I = {}. There is an existential probability for each item in the transaction of DB.

For example:

DB = {}

= {(Milk, 0.4), (Fruit, 0.9), (Video, 0.6)}

= {(Milk, 0.3), (Fruit, 0.7)}

With:

DB is the uncertain database.

is the transaction identifier of DB.

In Itemset contains items Milk, Fruit, Video with the corresponding probability 0.4, 0.9, 0.6.

* + 1. Definition 2 (Possible world):

A possible world is the subset of domain . With the existential probability can be calculated by the formular:

.

For example:

We have DB = {}

|  |  |  |
| --- | --- | --- |
| W | Tuples in W | Probability |
| 1 |  | 0.35 |
| 2 |  | 0.15 |
| 3 |  | 0.35 |
| 4 |  | 0.15 |

Apply the algorithm for calculating the probability:

* + 1. Definition 3 (Expected support-based frequent itemset):

An itemset is an expected support-based frequent itemset if and only if:

With:

) is the support (occurrence) of the itemset in the possible world ..

is the minimum expected support.

For example:

|  |  |  |
| --- | --- | --- |
| W | Tuples in W | Probability |
| 1 |  | 0.35 |
| 2 |  | 0.15 |
| 3 |  | 0.35 |
| 4 |  | 0.15 |

We set:

Based on the table above:

Since , then is the Expected support-based frequent itemset.

* + 1. Definition 4 (Probabilistic frequent itemset):

An itemset is a probabilistic frequent itemset if and only if:

The probability can be calculated by:

With:

is the probabilistic frequent threshold.

is the minimum support.

is the support (occurrence) of the itemset

is the possible world.

For example:

|  |  |  |
| --- | --- | --- |
| W | Tuples in W | Probability |
| 1 |  | 0.35 |
| 2 |  | 0.15 |
| 3 |  | 0.35 |
| 4 |  | 0.15 |

We set:

Therefore is the Probabilistic frequent itemset ()

* + 1. Definition 5 (Weighted probabilistic frequent itemset):

Weighted probabilistic frequent itemset is the probabilistic frequent itemset product with the weight of the itemset :

With:

is the weight of the itemset

is the minimum support.

is the support (occurrence) of the itemset

For example:

Weight table

|  |  |
| --- | --- |
| Item | Weight |
|  |  |
|  |  |

Possible world:

|  |  |  |
| --- | --- | --- |
| W | Tuples in W | Probability |
| 1 |  | 0.35 |
| 2 |  | 0.15 |
| 3 |  | 0.35 |
| 4 |  | 0.15 |

The itemset weight will be mentioned in definition 6 below.

Since 0.39 > , then is the Weighted probabilistic frequent itemset ()

* + 1. Definition 6 (Itemset weight):

The weight of X is the average weight of the items in the itemset X:

Itemset weight calculated by the formula:

For example:

Weight table

|  |  |
| --- | --- |
| Item | Weight |
|  |  |
|  |  |
|  |  |

We have the itemset = {Milk, Fruit, Video}

The weight of X:

* 1. Theory

In this section, here are the theorems mentioned in the document which have been used in the research. Some of these theorems are mainly used for the candidate generating and pruning algorithm, which will be present below soon.

* + 1. Theorem 1 (Equivalence between PFI and w-PFI):

Given a probabilistic frequent threshold t, a under if and only if under .

The theorem 1 represent the connection between the and the based on the weight.

* + 1. Theorem 2 (Anti-monotonicity property for PFI):

If an itemset is a , then any itemset is also a .

This is the pruning method for the PFI for pruning the search space by eliminating any candidate itemset that contain a non-PFI subset. By using this method, it can help to decrease items added to the itemset.

* + 1. Theorem 3 (Anti-monotonicity property for weighted PFI):

If an itemset is a , with the length of the set is k, there is at least one itemset with the length of the set is is a .

From which has been said in the paper, the anti-monotonicity property for the weighted PFI is different from the PFI. Therefore, they decided to design the new novel candidate generation items in the set without having the combination of the duplicated items.

Corollary 1:

The Corollary 1 based on the theorem 3:

We have the and where is the set of the wPFI with the size , is the item have the smallest weight in the itemset .

With , is not a if and ,

where and consist of all size 1 item of .

* + 1. Theorem 4:

We have is the random variable, following the Poisson Binomial Distribution.

With:

is the probability of the itemset , where is the subset of transaction

is the mean in the Poisson Binomial Distribution.

is the variance in the Poisson Binomial Distribution.

Frequentness probability of an itemset X calculated by this formular:

With:

F(.) is the cumulative distribution function of Poisson distribution.

* + 1. Theorem 5:

The frequentness probability increases monotonically with

Following the paper (Wang et al., 2010), an itemset X is more likely to be PFI if it has higher .

* + 1. Theorem 6:

We have two itemset and .

~PBD (), where the mean and variance

~PBD (), where the mean and variance

, where the mean and the variance

Based on the theorem:

Corollary 2:

The Corollary 2 based on the Theorem 6:

We have the itemset is not a if by applying from the Theorem 6

With:

The

Corollary 3:

We also have the Corollary 3

We have the itemset is not a if

With:

The .

is the number of transactions.

* 1. Algorithm
     1. Algorithm 1

Pseudocode given by the paper:

The algorithm 1 is implemented by applying the corollary 1.

A computer screen shot of a computer code

Description automatically generated

Understanding the algorithm:

The algorithm starts by finding all candidates. This is done by simply scanning the database and keeping the items that have a support of at least the minimum support threshold.

Once the set of candidates has been found, the algorithm proceeds to generate all possible candidates by joining the size-k candidates with each other. The algorithm then prunes the candidate set by removing any candidates that are not downwardly closed. A candidate is downwardly closed if it contains all its subsets.

The remaining candidates are then scanned in the database to count their support. Any candidates with a support of at least the minimum support threshold are added to the set of . The algorithm then repeats until no more WPFI candidates can be generated.

* + 1. Algorithm 2

Pseudocode given by the paper:

The algorithm 2 is implemented by applying the corollary 2.

A screenshot of a computer program

Description automatically generated

Understanding the algorithm:

Using the iteration to take each itemset obtained by the , then combine these itemset with each item which is not contained by the itemset . If the weight of the combination reaches the condition that is smaller or equal to the threshold t, then that combination would be added into a set of the result.

In the iteration, continuing take each item in the list contains the itemset except the itemset of the combination mentioned above. Then combine that item with the itemset . If the new combination reaches the condition that is smaller or equal to threshold t and the weight of combined item greater than the item has the minimum the weight of the itemset then adding the combination to the list.

The algorithm then repeats until no more itemset remaining.

* + 1. Algorithm 3

Pseudocode:

The algorithm 3 is based on the corollary 3.

A screenshot of a computer program

Description automatically generated

Understanding the algorithm:

Using the iteration to take each itemset obtained by the , then combine these itemset with each item which is not contained by the itemset . If the weight of the combination reaches the condition that is smaller or equal to the threshold t, then it go to the next condition. If the min between the mu of itemset with the greater than or equal to the and the product of mu and is greater than or equal to the product of scale factor, number of transaction and then that combination would be added into a set of the result.

In the iteration, continuing take each item in the list contains the itemset except the itemset of the combination mentioned above. Then combine that item with the itemset . If the new combination reaches the condition that is smaller or equal to threshold t and the weight of combined item greater than the item has the minimum the weight of the itemset , then we go to the next condition. If the min between the mu of itemset with the greater than or equal to the and the product of mu and is greater than or equal to the product of scale factor, number of transaction and then adding the combination to the list.

The algorithm then repeats until no more itemset remaining.

**CHAPTER 2 – JAVA CODE IMPLIMENTATION FOR EFFICIENT WEIGHTED PROBABILISTIC FREQUENT ITEMSET MINING IN UNCERTAIN DATABASES**

* 1. **Java classes** 
     1. **UncertainDatabase class**

**Introduction:** The UncertainDatabase class represent for the uncertain database with existential probabilities. This class is implemented based on the definition 1.

**Detail:**

Attribute:

private final HashSet<wPFIItem> allItems = new HashSet<wPFIItem>();

private final ArrayList<HashSet<wPFIItem>> transactions = new ArrayList<>();

Method:

public int size()

**Parameter:** None

**Output:** the integer value is the size of the database.

* Get the database size.

public ArrayList<HashSet<wPFIItem>> getTransactions()

**Parameter:** None

**Output:** the list of Transactions.

* Get the list of transactions.

public HashSet<wPFIItem> getAllItems()

**Parameter:** None

**Output:** a Set of Items

* Get the set of items in this database.

private void processTransactions(String itemsString[])

**Parameter:** None

**Output:** itemsString the list of items

* Process a transaction from a list of items, then add it to the transaction list.

private void processTransactionsWithProbability(String itemsString[])

**Parameter:** None

**Output:**

public void printDatabase(boolean hasProbability)

**Parameter:** None

**Output:** None

* Printing out the database.

public void printDatabaseProperties(String path)

**Parameter:** None

**Output:** None

* Printing out database properties.

private static double gaussianDistribution()

**Parameter:** None

**Output:**

* + 1. **wPFIItem class**

**Introduction:** The wPFIItem class is implement for the representation of the item in the uncertain database. The class is created based on the definition 1 of the definition mentioned in the chapter 1.

**Detail:**

Attribute:

protected UncertainDatabase db;

protected HashSet<wPFIItem> allItems;

protected HashMap<Integer, Double> weightTable;

protected int k;

protected int minsup;

protected int databaseSize;

protected float t;

Method:

public void runAlgorithm(float msup\_ratio, float threshold, float scale\_factor)

**Parameter:**

msup\_ratio: a float representing the minimum support ratio.

Threshold: a float representing the minimum confidence threshold.

scale\_factor: a float representing the scaling factor for the probability model.

**Output:** None

* The implementation of Algorithm 1 from the research paper

protected HashMap<Integer, Double> generateWeightTable()

**Parameter:** None

**Output:** a HashMap of integer keys and double values representing the weight of each item.

* Generate a weight table that assigns a random weight between 0 and 1 to each item

protected double itemsetWeight(HashSet<wPFIItem> itemset)

**Parameter:**

Itemset: a HashSet of wPFIItem objects representing an itemset.

**Output:** a double value representing the average weight of the items in the itemset.

* Calculate the average weight of items within a given itemset.

protected ArrayList<HashSet<wPFIItem>> scanFindSize1()

**Parameter:** None

**Output:** a HashSet of HashSet of wPFIItem objects representing FPIs of size 1.

* Finds wPFIs of size 1

protected ArrayList<HashSet<wPFIItem>> scanFindSizeK(ArrayList<HashSet<wPFIItem>> wPFI\_k)

**Parameter:**

wPFI\_k: a HashSet of HashSet of wPFIItem objects representing candidate PFIs of size k.

**Output:** a HashSet of HashSet of wPFIItem objects representing FPIs of size k.

* Identify PFIs of size k from a set of candidates wPFI.

protected double itemsetSupportInTransaction(int j, HashSet<wPFIItem> itemset)

**Parameter:**

j: an integer value representing the index of the transaction to be analyzed.

Itemset: a HashSet of wPFIItem objects representing the itemset for which support is calculated.

**Output:** a double value representing the probability of the given itemset occurring in the specified transaction.

* Calculate the support of a given itemset within a specific transaction.

protected double Pr(HashSet<wPFIItem> itemset)

**Parameter:**

Itemset: a HashSet of wPFIItem objects representing an itemset.

**Output:** a double value representing the probability of the given itemset occurring in a transaction.

* Calculate the probability of a given itemset occurring in a transaction.

protected double minWeightItemset(HashSet<wPFIItem> itemset)

**Parameter:**

Itemset: a HashSet of wPFIItem objects representing an itemset.

**Output:** a double value representing the minimum weight of any item in the given itemset.

* Find the minimum weight of the items within the given itemset.

protected ArrayList<HashSet<wPFIItem>> wPFIAprioriGenerate(ArrayList<HashSet<wPFIItem>> wPFI\_K\_1)

**Parameter:**

wPFI\_k: a HashSet of HashSet of wPFIItem objects representing candidate PFIs of size k.

**Output:** a HashSet of HashSet of wPFIItem objects representing FPIs of size k.

* The implementation of Algorithm 2 in the research paper for generating candidates wPFI of size k from wPFI of size k-1

protected double factorial(int n)

**Parameter:**

n: an integer representing the non-negative number for which the factorial is to be calculated.

**Output:** a double value representing the factorial of n.

* Calculate the factorial of a given non-negative integer n.

protected double CDF(int k, double lambda)

**Parameter:**

k: an integer representing the number of occurences.

Lambda: a double value representing the average rate of occurences.

**Output:** a double value representing the CDF at step k.

* Calculate the CDF of Poisson Distribution at a given k value.

protected double calculateMu\_(double maxWeight, int lower, int upper)

**Parameter:**

maxWeight: a double value representing the maximum weight in the weight table.

Lower: an integer representing the lower bound for the binary search.

Upper: an integer representing the upper bound for the binary search.

**Output:** a double value representing the mu\_ threshold.

* This method approximates the mu\_ threshold using a binary search algorithm.

protected boolean conditionAlgorithm3(HashSet<wPFIItem> itemset, wPFIItem item, double mu\_)

**Parameter:**

Itemset: a HashSet of wPFIItem objects.

Item: a wPFIItem object.

mu\_: a double value representing the minimum support threshold.

**Output:** a boolean flag indicating whether the given itemset and item satisfy the conditions of the algorithm.

* The implementation of additional conditions from Algorithm 3 in the research paper. These condition will be added in the algorithm 2 to early prune the candidates.
  + 1. **wPFIApriori class**

**Introduction:** The wPFIApriori class is implemented for the representation of 3 algorithms mentioned in the theory in chapter 1. This also call 2 java classes definition above in the chapter 2 for the use of the algorithm function.

**Detail:**

Attribute:

private final int id;

private final double probability;

Method:

public int getId()

**Parameter:** None

**Output:** an integer number represent for item

* Get the item id.

public double getProbability()

**Parameter:** None

**Output:** a double number represent for probability of item

* Get the existential probability of the item.

public boolean equals(Object object)

**Parameter:** object another item

**Output:** true if equal, otherwise false.

* Check if this item is equal to another.

public int hashCode()

**Parameter:** None

**Output:** a hash code as a int.

* Generate a hash code for the item.

public String toString()

**Parameter:** None

**Output:** a string

* Get a string representation of this item.

public String toStringWithProbability()

**Parameter:** None

**Output:** a string

* Get a sting representation of this item and its probability.
  1. **Asymptotic Complexity Analysis**

**Overall Complexity:**

The overall time complexity of the wPFIApriori algorithm is dominated by the candidate generation step (wPFIAprioriGenerate). This step involves iterating over all PFIs of size k-1 and generating candidate PFIs of size k. For each candidate, several checks are performed, including weight checks and probability calculations.

Therefore, the overall time complexity is

With:

is the iteration number (size of PFIs being generated)

is the number of PFIs of size

| is the total number of items

**Individual Function:**

scanFindSize1: This step iterates over all items and calculates their weight and confidence. The time complexity is

scanFindSizeK: This step iterates over all candidate PFIs of size k and calculates their weight and confidence. The time complexity is

itemsetSupportInTransaction: This step iterates over the items in a transaction and checks if they are present in a given PFI. The time complexity is , where is the size of the transaction.

Pr: This step calculates the probability of a PFI occurring in a transaction. It involves several nested loops and calculations. The time complexity is

minWeightItemset: This step iterates over the items in a PFI and finds the minimum weight. The time complexity is

wPFIAprioriGenerate: This step iterates over all PFIs of size k-1 and generates candidate PFIs of size k. Several checks are performed for each candidate, including:

Weight check:

Probability check with conditionAlgorithm3:

Generation of new candidates: **𝑂(|| ∗ |𝐼|)**

Mu\_ calculation: **𝑂(𝑙𝑜𝑔(𝑑𝑎𝑡𝑎𝑏𝑎𝑠𝑒𝑆𝑖𝑧𝑒))**

* 1. **Benchmark**
     1. **Runtime based on msup changing**

**Dataset:** accidents.dat

**Setting:**

**A graph with a line and a line

Description automatically generated**

**Dataset:** accidents.dat

**Setting:**

**A graph with blue and orange lines

Description automatically generated**

**Dataset:** T40I10D100K.dat

**Setting:**

**A graph with a line and a blue line

Description automatically generated**

* + 1. **Runtime based on threshold t changing**

**Dataset:** connect.dat

**Setting:**

**A graph with blue and orange lines

Description automatically generated**

**Dataset:** accidents.dat

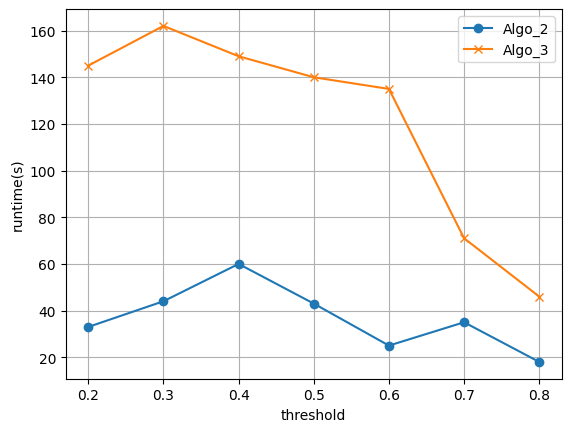
**Setting:**

**A graph with a line and a line

Description automatically generated**

**Dataset:** T40I10D100K.dat

**Setting:**



**REFERENCES**

1. Zhiyang Li | Fengjuan Chen | Junfeng Wu | Zhaobin Liu | Weijiang Liu (2020), Efficient weighted probabilistic frequent itemset mining in uncertain databases.