



CS 412 Intro. to Data Mining

Chapter 6. Mining Frequent Patterns, Association and Correlations: Basic Concepts and Methods

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Chapter 6: Mining Frequent Patterns, Association and Correlations: Basic Concepts and Methods

Common Patterns in Data

- ☐ Basic Concepts 
- ☐ Efficient Pattern Mining Methods
- ☐ Pattern Evaluation
- ☐ Summary

Pattern Discovery: Basic Concepts

- ❑ What Is Pattern Discovery? Why Is It Important?
- ❑ Basic Concepts: Frequent Patterns and Association Rules
- ❑ Compressed Representation: Closed Patterns and Max-Patterns

What Is Pattern Discovery?

- แสดงสิ่งที่ซ่อนอยู่ใน Data
- What are patterns? การซื้อของใน market ซื้อของที่คู่กัน, ซื้อด้วยกันเสมอ
 - Patterns: A set of items, subsequences, or substructures that occur frequently together (or strongly correlated) in a data set
 - Patterns represent **intrinsic** and **important properties** of datasets
- Pattern discovery: Uncovering patterns from massive data sets
- Motivation examples:
 - What products were often purchased together? สินค้าอะไร มักจะซื้อเสมอ
 - What are the subsequent purchases after buying an iPad? ซื้อของอะไรไปแล้ว มักซื้อต่ออีก
 - What code segments likely contain **copy-and-paste bugs**? ก๊อปปี้ code มาใช้
 - What word sequences likely form phrases in this corpus? เดาคำศัพท์

Pattern Discovery: Why Is It Important?

- ❑ Finding **inherent regularities** in a data set
- ❑ **Foundation** for many essential data mining tasks
 - ❑ Association, correlation, and causality analysis
 - ❑ Mining sequential, structural (e.g., sub-graph) patterns
 - ❑ Pattern analysis in spatiotemporal, multimedia, time-series, and stream data
 - ❑ Classification: Discriminative pattern-based analysis
 - ❑ Cluster analysis: Pattern-based subspace clustering
- ❑ Broad applications
 - ❑ Market basket analysis, cross-marketing, catalog design, sale campaign analysis, Web log analysis, biological sequence analysis

Basic Concepts: k-Itemsets and Their Supports

- **Itemset**: A set of one or more items
- **k-itemset**: $X = \{x_1, \dots, x_k\}$
 - Ex. {Beer, Nuts, Diaper} is a 3-itemset
- **(absolute) support (count)** of X, $\text{sup}\{X\}$:
Frequency or the number of occurrences of an itemset X
 - Ex. $\text{sup}\{\text{Beer}\} = 3$
 - Ex. $\text{sup}\{\text{Diaper}\} = 4$
 - Ex. $\text{sup}\{\text{Beer, Diaper}\} = 3$
 - Ex. $\text{sup}\{\text{Beer, Eggs}\} = 1$

Tid	Items bought
10	Beer, Nuts, Diaper
20	Beer, Coffee, Diaper
30	Beer, Diaper, Eggs
40	Nuts, Eggs, Milk
50	Nuts, Coffee, Diaper, Eggs, Milk

- **(relative) support**, $s\{X\}$: The fraction of transactions that contains X (i.e., the probability that a transaction contains X)
 - Ex. $s\{\text{Beer}\} = 3/5 = 60\%$
 - Ex. $s\{\text{Diaper}\} = 4/5 = 80\%$
 - Ex. $s\{\text{Beer, Eggs}\} = 1/5 = 20\%$

Basic Concepts: Frequent Itemsets (Patterns)

- An itemset (or a pattern) X is *frequent* ความเกิดขึ้นบ่อย if the support of X is no less than a *minsup* threshold σ
- Let $\sigma = 50\%$ (σ : *minsup* threshold) ค่าขั้นต่ำ
For the given 5-transaction dataset ความบ่อย
 - All the frequent 1-itemsets:
 - Beer: 3/5 (60%); Nuts: 3/5 (60%)
 - Diaper: 4/5 (80%); Eggs: 3/5 (60%)
 - All the frequent 2-itemsets:
 - {Beer, Diaper}: 3/5 (60%)
 - All the frequent 3-itemsets?
 - None 2/5 (40%) → ไม่ผ่านเกณฑ์

Tid	Items bought
10	Beer, Nuts, Diaper
20	Beer, Coffee, Diaper
30	Beer, Diaper, Eggs
40	Nuts, Eggs, Milk
50	Nuts, Coffee, Diaper, Eggs, Milk

- Why do these itemsets (shown on the left) form the complete set of frequent k -itemsets (patterns) for any k ?
- **Observation:** We may need an efficient method to mine a complete set of frequent patterns

From Frequent Itemsets to Association Rules

- Comparing with itemsets, rules can be more telling

Ex. *Diaper* ^{highly} \rightarrow *Beer*

Buying diapers may likely lead to buying beers

- How strong is this rule? (support, confidence)

Measuring association rules: $X \rightarrow Y (s, c)$

Both X and Y are itemsets

Support, s : The probability that a transaction contains $X \cup Y$

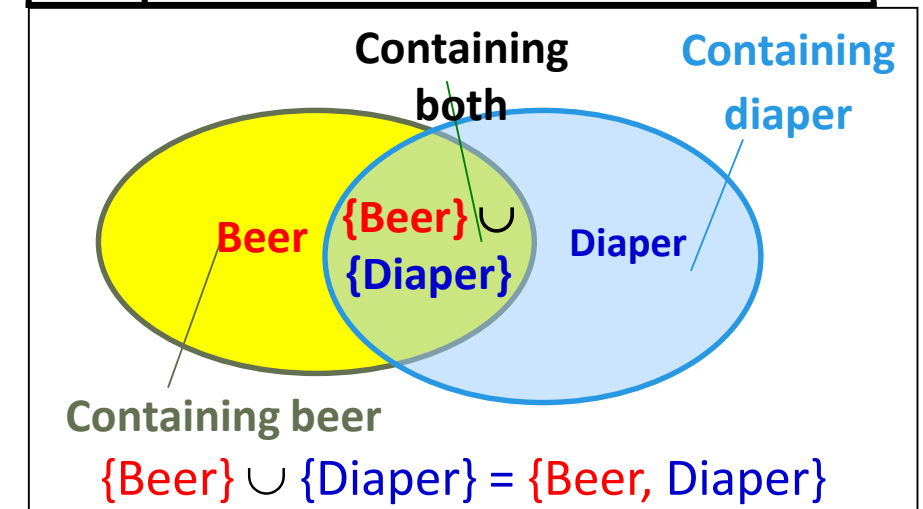
Ex. $s\{\text{Diaper, Beer}\} = 3/5 = 0.6$ (i.e., 60%)

Confidence, c : The *conditional probability* that a transaction containing X also contains Y

Calculation: $c = \text{sup}(X \cup Y) / \text{sup}(X)$

Ex. $c = \text{sup}\{\text{Diaper, Beer}\} / \text{sup}\{\text{Diaper}\} = \frac{3}{4} = 0.75$

Tid	Items bought
10	Beer, Nuts, Diaper
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Note: $X \cup Y$: the union of two itemsets
 ■ The set contains both X and Y

Mining Frequent Itemsets and Association Rules

□ Association rule mining

- Given two thresholds: $minsup$, $minconf$
- Find **all** of the rules, $X \rightarrow Y$ (s, c)
 - such that, $s \geq minsup$ and $c \geq minconf$

□ Let $minsup = 50\%$

- Freq. 1-itemsets: Beer: 3, Nuts: 3, Diaper: 4, Eggs: 3
- Freq. 2-itemsets: {Beer, Diaper}: 3

□ Let $minconf = 50\%$

- $Beer \rightarrow Diaper$ (60%, 100%)
- $Diaper \rightarrow Beer$ (60%, 75%)

(Q: Are these all rules?)

Tid	Items bought
10	Beer, Nuts, Diaper
20	Beer, Coffee, Diaper
30	Beer, Diaper, Eggs
40	Nuts, Eggs, Milk
50	Nuts, Coffee, Diaper, Eggs, Milk

□ Observations:

- Mining association rules and mining frequent patterns are very close problems
- Scalable methods are needed for mining large datasets



Challenge: There Are Too Many Frequent Patterns!

- A long pattern contains a combinatorial number of sub-patterns
- How many frequent itemsets does the following TDB₁ contain?

□ TDB₁: T₁: {a₁, ..., a₅₀}; T₂: {a₁, ..., a₁₀₀}

□ Assuming (absolute) *minsup* = 1

□ Let's have a try

1-itemsets: {a₁}: 2, {a₂}: 2, ..., {a₅₀}: 2, {a₅₁}: 1, ..., {a₁₀₀}: 1,

2-itemsets: {a₁, a₂}: 2, ..., {a₁, a₅₀}: 2, {a₁, a₅₁}: 1 ..., ..., {a₉₉, a₁₀₀}: 1,

..., ..., ..., ...

99-itemsets: {a₁, a₂, ..., a₉₉}: 1, ..., {a₂, a₃, ..., a₁₀₀}: 1

100-itemset: {a₁, a₂, ..., a₁₀₀}: 1

- The total number of frequent itemsets:

$$\binom{100}{1} + \binom{100}{2} + \binom{100}{3} + \cdots + \binom{100}{100} = 2^{100} - 1$$

A too huge set for any one to compute or store!



Expressing Patterns in Compressed Form: Closed Patterns

- ❑ How to handle such a challenge?
- ❑ Solution 1: **Closed patterns**: A pattern (itemset) X is **closed** if X is *frequent*, and there exists *no super-pattern* $Y \supset X$, with the same support as X
 - ❑ Let Transaction DB TDB_1 : $T_1: \{a_1, \dots, a_{50}\}$; $T_2: \{a_1, \dots, a_{100}\}$
 - ❑ Suppose $minsup = 1$. How many closed patterns does TDB_1 contain?
 - ❑ Two: $P_1: \{\{a_1, \dots, a_{50}\}: 2\}$; $P_2: \{\{a_1, \dots, a_{100}\}: 1\}$
- ❑ **Closed pattern** is a **lossless compression** of frequent patterns
 - ❑ Reduces the # of patterns but does not lose the support information!
 - ❑ You will still be able to say: $\{\{a_2, \dots, a_{40}\}: 2\}$, $\{\{a_5, a_{51}\}: 1\}$

Expressing Patterns in Compressed Form: Max-Patterns

- ❑ Solution 2: **Max-patterns**: A pattern X is a **max-pattern** if X is frequent and there exists no frequent super-pattern $Y \supset X$
- ❑ Difference from close-patterns?
 - ❑ Do not care the real support of the sub-patterns of a max-pattern
 - ❑ Let Transaction DB TDB_1 : $T_1: \{a_1, \dots, a_{50}\}$; $T_2: \{a_1, \dots, a_{100}\}$
 - ❑ Suppose $minsup = 1$. How many max-patterns does TDB_1 contain?
 - ❑ One: $P: \{\{a_1, \dots, a_{100}\}: 1\}$
- ❑ **Max-pattern** is a **lossy compression**!
 - ❑ We only know $\{a_1, \dots, a_{40}\}$ is frequent
 - ❑ But we do not know the real support of $\{a_1, \dots, a_{40}\}$, ..., any more!
- ❑ Thus in many applications, mining close-patterns is more desirable than mining max-patterns

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Efficient Pattern Mining Methods

- ❑ The Downward Closure Property of Frequent Patterns
- ❑ The ^{*}Apriori Algorithm
- ❑ Extensions or Improvements of Apriori
- ❑ Mining Frequent Patterns by Exploring Vertical Data Format
- ❑ FPGrowth: A Frequent Pattern-Growth Approach
- ❑ Mining Closed Patterns

The Downward Closure Property of Frequent Patterns

- Observation: From $TDB_1: T_1: \{a_1, \dots, a_{50}\}; T_2: \{a_1, \dots, a_{100}\}$
 - We get a frequent itemset: $\{a_1, \dots, a_{50}\}$
 - Also, its subsets are all frequent: $\{a_1\}, \{a_2\}, \dots, \{a_{50}\}, \{a_1, a_2\}, \dots, \{a_1, \dots, a_{49}\}, \dots$
 - There must be some hidden relationships among frequent patterns!
- The **downward closure (also called “Apriori”)** property of frequent patterns
 - If **{beer, diaper, nuts}** is frequent, so is **{beer, diaper}**
 - Every transaction containing {beer, diaper, nuts} also contains {beer, diaper}
 - Apriori: Any subset of a frequent itemset must be frequent
- Efficient mining methodology
 - If **any subset of an itemset S** is infrequent, then there is no chance for S to be frequent—why do we even have to consider S!?  A sharp knife for pruning!

Apriori Pruning and Scalable Mining Methods

- Apriori ^{ตัดออก} pruning principle: If there is any itemset which is infrequent, its superset should not even be generated! (Agrawal & Srikant @VLDB'94, Mannila, et al. @ KDD' 94)
- Scalable mining Methods: Three major approaches
 - Level-wise, join-based approach: Apriori (Agrawal & Srikant@VLDB'94)
 - Vertical data format approach: Eclat (Zaki, Parthasarathy, Ogihara, Li @KDD'97)
 - Frequent pattern projection and growth: FPgrowth (Han, Pei, Yin @SIGMOD'00)

Apriori: A Candidate Generation & Test Approach

ขั้นตอนการประมวลผล

- Outline of Apriori (level-wise, candidate generation and test)
 - Initially, scan DB once to get frequent 1-itemset
 - Repeat
 - Generate length-($k+1$) candidate itemsets from length- k frequent itemsets
 - Test the candidates against DB to find frequent ($k+1$)-itemsets
 - Set $k := k + 1$
 - Until no frequent or candidate set can be generated
 - Return all the frequent itemsets derived

The Apriori Algorithm (Pseudo-Code)

เพื่อนให้เอาไปลองได้

C_k : Candidate itemset of size k

F_k : Frequent itemset of size k

$K := 1$;

$F_k := \{\text{frequent items}\}$; // frequent 1-itemset

While ($F_k \neq \emptyset$) **do** { // when F_k is non-empty

$C_{k+1} := \text{candidates generated from } F_k$; // candidate generation

 Derive F_{k+1} by counting candidates in C_{k+1} with respect to TDB at minsup;

$k := k + 1$

}

return $\cup_k F_k$ // return F_k generated at each level

The Apriori Algorithm—An Example

Database TDB

Tid	Items
10	A, C, D
20	B, C, E
30	A, B, C, E
40	B, E

minsup = 2

C_1
1st scan

Itemset	sup
{A}	2
{B}	3
{C}	3
{D}	1
{E}	3

F_1

Itemset	sup
{A}	2
{B}	3
{C}	3
{E}	3

F_2

Itemset	sup
{A, C}	2
{B, C}	2
{B, E}	3
{C, E}	2

C_2

Itemset	sup
{A, B}	1
{A, C}	2
{A, E}	1
{B, C}	2
{B, E}	3
{C, E}	2

2nd scan

C_2

Itemset	sup
{A, B}	
{A, C}	
{A, E}	
{B, C}	
{B, E}	
{C, E}	

C_3

Itemset	sup
{B, C, E}	

3rd scan

F_3

Itemset	sup
{B, C, E}	2