Data Mining Algorithms

CS102
Winter 2019
Big Data Tools and Techniques

- **Basic Data Manipulation and Analysis**
  Performing well-defined computations or asking well-defined questions ("queries")

- **Data Mining**
  Looking for patterns in data

- **Machine Learning**
  Using data to build models and make predictions

- **Data Visualization**
  Graphical depiction of data

- **Data Collection and Preparation**
Data Mining

Looking for patterns in data

Similar to unsupervised machine learning
  • Popularity predates popularity of machine learning
  • “Data mining” often associated with specific data types and patterns

We will focus on “market-basket” data
  • Widely applicable (despite the name)

And two types of data mining patterns
  • Frequent item-sets
  • Association rules
Other Data and Patterns

Other types of data

• Networks/graphs
• Streams
• Text (“text mining”)

Other patterns

• Similar items
• Structural patterns in large graphs/networks
• Clusters, anomalies

Specific techniques for each one
(In)Famous Early Success Stories

Victoria’s Secret

Walmart

Beer & Diapers
Market-Basket Data

Originated with retail data

- Each shopper buys “market basket” of groceries
- Mine data for patterns in buying habits

General definition

- Domain of items
- Transaction - one or more items occurring together
- Dataset - set of transactions (usually large)
# Market-Basket Examples

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Data Mining

CS102
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Data Mining Algorithms

Frequent Item-Sets - sets of items that occur frequently together in transactions

- Groceries bought together
- Courses taken by same students
- Students going to parties together
- Movies watched by same people

Association Rules - When certain items occur together, another item frequently occurs with them

- Shoppers who buy phone + charger also buy case
- Students who take Databases also take Machine Learning
- Diners who order curry and rice also order bread
Frequent Item-Sets

Sets of items that occur frequently together in transactions

- How large is a “set”?
- What does “frequently” mean?
Frequent Item-Sets

Sets of items that occur frequently together in transactions

- How large is a “set”?
  Usually specify a minimum $\text{min-set-size}$
  Possibly also a maximum $\text{max-set-size}$

- What does “frequently” mean?
  Notion of support
Support for a set of items $S$ in a dataset of transactions is the fraction of the transactions containing $S$: 

\[
\frac{\text{# of transactions containing } S}{\text{total # of transactions}}
\]

Specify *support-threshold* for frequent item-sets. Only return sets where $support > support\text{-threshold}$.
Your Turn

Transactions:

T1: milk, eggs, juice
T2: milk, juice, cookies
T3: eggs, chips
T4: milk, eggs
T5: milk, juice, cookies, chips

What are the frequent item-sets if:

• \( \text{min-set-size} = 2 \) (no \( \text{max-set-size} \))
• \( \text{support-threshold} = 0.3 \)

Support: \[
\frac{\text{# of transactions containing } S}{\text{total # of transactions}}
\]
Computing Frequent Item-Sets

“Apriori” algorithm

Efficiency relies on the following property:

If $S$ is a frequent item-set satisfying support-threshold $t$, then every subset of $S$ is also a frequent item-set satisfying support-threshold $t$.

Or the inverse:

If $S$ is not a frequent item-set satisfying support-threshold $t$, then no superset of $S$ can be a frequent item-set satisfying support-threshold $t$. 
Association Rules

When a set of items $S$ occurs together, another item $i$ frequently occurs with them

$$S \rightarrow i$$

- How large is a “set”? 
- What does “occurs together” mean? 
- What does “frequently occurs with them” mean?
Association Rules

When a set of items $S$ occurs together, another item $i$ frequently occurs with them

$S \rightarrow i$

- How large is a “set”? 
  Usually specify a minimum $\text{min-set-size}$ for $S$
  Possibly also a maximum $\text{max-set-size}$ for $S$

- What does “occurs together” mean?

- What does “frequently occurs with them” mean?
Association Rules

When a set of items $S$ occurs together, another item $i$ frequently occurs with them

$S \rightarrow i$

- How large is a “set”? Usually specify a minimum \textit{min-set-size} for $S$ Possibly also a maximum \textit{max-set-size} for $S$

- What does “occurs together” mean? Notion of \textit{support}

- What does “frequently occurs with them” mean? Notion of \textit{confidence}
Support for association rule $S \rightarrow i$ in a dataset of transactions is fraction of transactions containing $S$:

\[
\frac{\text{# of transactions containing } S}{\text{total # of transactions}}
\]

Confidence for association rule $S \rightarrow i$ in a dataset of transactions is the fraction of transactions containing $S$ that also contain $i$:

\[
\frac{\text{# of transactions containing } S \text{ and } i}{\text{# of transactions containing } S}
\]
Support and Confidence

Specify \textit{support-threshold} and \textit{confidence-threshold} for association rules

Only return rules where:
\[ \text{support} > \text{support-threshold} \text{ and } \text{confidence} > \text{confidence-threshold} \]
Your Turn

Transactions:

T1: milk, eggs, juice
T2: milk, juice, cookies
T3: eggs, chips
T4: milk, eggs
T5: milk, juice, cookies, chips

What are the association rules $S \rightarrow i$ if:

- min-set-size = 1 (no max-set-size)
- support-threshold = 0.5
- confidence-threshold = 0.5

Support:

\[
\frac{\text{# of transactions containing } S}{\text{total # of transactions}}
\]

Reminder: support and confidence must be > threshold, not ≥

Confidence:

\[
\frac{\text{# of transactions containing } S \text{ and } i}{\text{# of transactions containing } S}
\]
1. Use frequent item-sets to find left-hand sides $S$ satisfying support threshold

2. Then extend to find right-hand sides $S \rightarrow i$ satisfying confidence threshold

NOT a property:

If $S \rightarrow i$ is an association rule satisfying support-threshold $t$ and confidence-threshold $c$, and $S' \subseteq S$, then $S' \rightarrow i$ is an association rule satisfying support-threshold $t$ and confidence-threshold $c$. Why Not?
Association Rules: Lift

Association rule $S \rightarrow i$ might have high confidence because item $i$ appears frequently, not because it’s associated with $S$.

Lift for association rule $S \rightarrow i$ in a dataset of transactions is the fraction of transactions containing $S$ that also contain $i$, divided by the overall frequency of $i$:

$$\frac{\text{#trans containing } S \text{ and } i}{\text{#trans containing } S} \div \frac{\text{#trans containing } i}{\text{total #trans}}$$
Transactions:

- T1: milk, eggs, juice
- T2: milk, juice, cookies
- T3: eggs, chips
- T4: milk, eggs
- T5: milk, juice, cookies, chips

**juice → cookies**  \[ \text{Lift} = \frac{2/3}{2/5} = \frac{10}{6} = 1.67 \]

**eggs → milk**  \[ \text{Lift} = \frac{2/3}{4/5} = \frac{10}{12} = 0.83 \]

Lift: \[ \frac{\#\text{trans containing } S \text{ and } i}{\#\text{trans containing } S} \div \frac{\#\text{trans containing } i}{\text{total } \#\text{trans}} \]

Lift = 1: no association
Lift > 1: association
Lift < 1: anti-association
Data Mining Algorithms

CS102

Winter 2019