

USING MARKET BASKET ANALYSIS TECHNIQUE TO FIND CONSUMER PURCHASING PATTERNS AND OPTIMIZE INVENTORY MANAGEMENT

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Abstract

Market Basket Analysis (MBA) is a data mining technique that plays a key role in finding consumer purchasing patterns to aid in optimizing inventory management and marketing strategies. It assists in the decision-making process and increases the success of the marketing strategy. A competitive market requires businesses to observe the market using data to further optimize their marketing and business strategy. Retail stores need to use all of the available resources, including data, to improve their inventory management but also their marketing strategy. Data processing is able to provide details that can be used to support marketing strategies. One of the data processing methods that is often used in marketing strategies is the use of data mining techniques. This study uses association rule mining and the Apriori algorithm to analyze transaction data from a German dataset, which included over 541,000 transactions from December 2010 to December 2011. The analysis found important product associations and customer behavior patterns using metrics such as confidence, lift, leverage, conviction, and certainty to find the strength and dependability of the discovered associations. Results showed strong associations between specific product pairs, offering insight for marketing strategy and inventory optimization.

Keywords: Market Basket Analysis, Data Mining Techniques, Inventory Management, Datasets, Apriori Algorithm

Introduction

With the advances in information technology, corporations can obtain and store transactional and demographic data on individual customers from purchases made on their stores. However, a key challenge for companies that have heavily invested in customer data collection is identifying valuable insights within their vast databases to gain an advantage.[9] Market basket analysis (MBA), also known as association rule mining, is a data mining technique employed to discover customer purchasing patterns by identifying associations or co-occurrences within transactional data. For instance, recognizing that supermarket customers frequently buy milk, bread, and cheese together.[16] The fact that bank customers commonly use specific services in combination can assist managers in optimizing store layouts, websites, product offerings, bundling strategies, and other marketing initiatives.[17] Furthermore, predictive modeling of data mining regression technique applied in a prototype presents a practical application of linear regression for predicting business profit based on product sales.[18] Using a small dataset from a one-week sales period, it demonstrates how regression coefficients are calculated and used for forecasting. It clearly can explain the methodology and offers a simple prototype with a claimed 99% confidence level in its predictions.[19] While the approach is well-suited for educational or introductory purposes, it lacks rigorous validation, scalability, and testing for model assumptions. The dataset can be too limited to generalize the results or ensure robustness. Overall, it's a useful beginner-level demonstration of regression in predictive modeling, but Market Basket Analysis helps businesses uncover hidden patterns in customer purchasing behavior, enabling smarter decision-making [9]. Inventory management is responsible for the planning and control of resources and goods that sustain manufacturing functions, maintenance activities, and customer service.[14] Due to the high level of cost that stocks can reach in an organization, the latent demand to optimize costs and customer service

has positioned inventories as a vital area for improvement in firms. This study delves into the purchasing patterns of the data from an online retail market based in Germany. By using the Apriori Algorithm, we aimed to identify popular product combinations and uncover consumer preferences.

Literature Review

[8] analyzes transaction data from "Mizan Computer Shop", a computer and accessories store, to create marketing strategies. MBA, alongside the Apriori algorithm, was used to uncover purchasing patterns that can be used for marketing strategy. They built the application using the waterfall method, with UML diagrams for design, and implemented it in PHP. The authors deduced that these patterns can help the shop create differentiation and advantageous marketing strategies. Key findings found that customers buy Laptop chargers alongside keyboards, and customers who buy Laptops also buy mice, which tracks. [6]. This research paper applied the Apriori algorithm to analyze consumer purchasing patterns in a minimarket. The objective was to generate insights for developing marketing strategies, specifically determining which items are frequently bought together. The authors used transaction data as their primary data. They processed this data by applying a minimum support value of 10% and a minimum confidence value of 65%. The method involved sorting and calculating association rules based on these thresholds. The results showed that the Apriori algorithm successfully produced combinations of consumer purchase patterns. The authors concluded that their information system can support sales decision-making by providing actionable pattern combinations derived from real transaction data. Similar patterns are applied in this paper, mostly focusing on a bigger and broader dataset. [11] provides an overview of the strategic role played by North Macedonia's FITD in fostering technological innovation. The authors trace FITD's evolution through its call cycles, mentorship programs, and partnerships with international bodies like the World Bank, UNICEF, and foreign embassies. They emphasize FITD's financial support strategy, including finance grants, innovation vouchers, and startup competitions, which have funneled millions of euros into SMEs and startups regionally. However, the MBA advantage is that it shows patterns in customer purchasing behavior, allowing companies to make data-driven decisions that boost profits. [5] This is a paper that uses data mining techniques, specifically the Apriori algorithm, to analyze consumer purchasing patterns in the "O! Fish restaurant", a restaurant in the rapidly growing food and beverage culinary industry. The authors aim to assist other restaurant owners by performing better in a competitive market by using transaction data to show consumer purchasing patterns, which can be used to improve marketing strategy. They apply data mining techniques, specifically the Apriori algorithm, to generate association rules identifying which menu items are often purchased together. These patterns are intended to be used to improve strategies and boost sales. The outcome of the study is a website-based application that analyzes consumer purchasing patterns and provides recommendations based on item associations. The authors conclude that these association rules can guide O! Fish restaurant in developing more effective and targeted promotion strategies. In paper [10], the authors examine how AI integration can enhance IoT applications in the Western Balkans, using energy optimization, smart cities, and sustainable practices. It proposes a PHP/MySQL-based web application featuring citizen profiles, region-wide fire detection, air quality monitoring, and demographic data access to support regional digital governance. However, it lacks validation of the prototype's effectiveness, scalability assessments, and user studies. Despite the limitations, the paper presents a different regional perspective on AIoT deployment and a tangible starting point for future digital transformation efforts.

Data Mining

Data mining is a technology that blends traditional data analysis methods with sophisticated algorithms for processing large volumes of data. It has also opened up exciting opportunities for exploring and analyzing new types of data and for analyzing old types of data in new ways. Data mining is the process of automatically discovering useful information in large data repositories. Data mining techniques are deployed to scour large databases in order to find novel and useful patterns that might otherwise remain unknown. They also provide capabilities to predict the outcome of a future observation, such as predicting whether a newly arrived customer will spend more than \$100 at a department store. In business data collection have allowed retailers to collect up-to-the-minute data about customer purchases at the checkout counters of their stores.[12] Retailers can utilize this information, along with other business-critical data such as Web logs from e-commerce[13]. Web sites and customer service records from call centers, to help them better understand the needs of their customers and make more informed business decisions.[14][15] Data mining techniques can be used to support a wide range of business intelligence applications such as customer profiling, targeted marketing, workflow management, store layout, and fraud detection. It can also help retailers answer important business questions such as "Who are the most profitable customers?" "What products can be cross-sold or up-sold?" and "What is the revenue outlook of the company for next year?" Some of these questions motivated the creation of association analysis, a new data analysis technique[4].

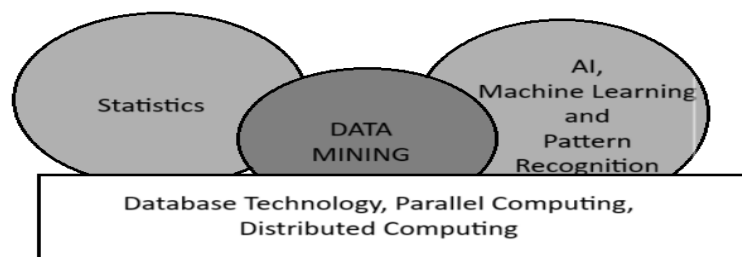


Figure 1. Core components and supporting technologies of data mining.

Data mining tasks

Data mining tasks are generally divided into a few categories: Predictive tasks - The objective of these tasks is to predict the value of a particular attribute based on the values of other attributes.[1] The attribute to be predicted is commonly known as the target or dependent variable, while the attributes used for making the prediction are known as the explanatory or independent variables. Descriptive tasks - Here, the objective is to derive patterns (correlations, trends, clusters, trajectories, and anomalies) that summarize the underlying relationships in data. Descriptive data mining tasks are often exploratory in nature and frequently require postprocessing techniques to validate and explain the results[1]. Predictive modeling – is the task of building a model for the target variable as a function of the explanatory variables. There are two types of predictive modeling tasks: classification and regression. Classification is used for discrete target variables. For example, predicting whether a Web user will make a purchase at an online bookstore is a classification task because the target variable is binary-valued. Regression is used for continuous target variables. For example, forecasting the future price of a stock is a regression task because price is a continuous-valued attribute[1]. Association Analysis – is used to discover patterns that describe strongly associated features in the data. These patterns are usually expressed as implication rules or feature subsets. Association

analysis efficiently extracts the most meaningful patterns. This technique has various applications such as recognizing frequently accessed Web pages, detecting groups of genes with similar functions, and analyzing connections between different components of Earth's climate system[1]. Example 1 (Market Basket Analysis). The transactions shown in Table 1.1 illustrate point-of-sale data collected at the checkout counters of a grocery store. Association analysis can be applied to find items that are frequently bought together by customers. For example, we may discover the rule association rules which suggests that customers who buy diapers also tend to buy milk. This type of rule can be used to identify potential cross-selling opportunities among related items. Cluster analysis seeks to find groups of closely related observations so that observations that belong to the same cluster are more similar to each other than observations that belong to other clusters. Clustering has been used to group sets of related customers, find areas of the ocean that have a significant impact on the Earth's climate, and compress data.

Table 1.1 Market basket data

Transaction ID	Items
1	{Bread, Butter, Diapers, Milk}
2	{Coffee, Sugar, Cookies, Salmon}
3	{Bread, Butter, Coffee, Diapers, Milk, Eggs}
4	{Bread, Butter, Salmon, Chicken}
5	{Egg", Bread, Butter}
6	{Salmon, Diapers, Milk}
7	{Bread, Tea, Sugar, Eggs}
8	{Coffee, Sugar, Chicken, Eggs}
9	{Bread, Diapers, Milk, Salt}
10	{Tea, Eggs, Cookies, Diapers, Milk}

Example 2 – Document Clustering: The news articles in Table 1.2 can be categorized based on their topics. Each article is represented as a set of word-frequency pairs $(t, c)(t, c)(t, c)$, where t is a word and c is its occurrence count in the article. The dataset naturally forms two clusters: the first four articles focus on economic news, while the last four pertain to healthcare. An effective clustering algorithm should be able to detect these clusters by analyzing the similarity of words appearing in the articles[1].

Table 1.2 Collection of news articles

Article	Words
1	dollar: 1, industry: 4, country: 2, loan: 3, deal: 2, government: 2
2	machinery: 2, labor: 3, market: 4, industry: 2, work: 3, country: 1
3	job: 5, inflation: 3, rise: 2, jobless: 2, market: 3, country: 2, index: 3
4	domestic: 3, forecast: 2, gain: 1, market: 2, sale: 3, price: 2
5	patient: 4, symptom: 2, drug: 3, health: 2, clinic: 2, doctor: 2
6	pharmaceutical:2, company: 3, drug: 2,vaccine:1, flu: 3
7	death: 2, cancer: 4, drug: 3, public: 4, health: 3, director: 2
8	medical: 2, cost: 3, increase: 2, patient: 2, health: 3, care: 1

Anomaly detection is the task of identifying observations whose characteristics are significantly different from the rest of the data. Such observations are known as anomalies or outliers. The goal of an anomaly detection algorithm is to discover the real anomalies and avoid falsely labeling normal objects as anomalous[1]. Example 3 – Credit Card Fraud Detection: A credit card company tracks each cardholder's transactions and stores personal details, including

credit limit, age, annual income, and address. since the number of fraudulent cases is relatively small compared to the number of legitimate transactions, anomaly detection techniques can be applied to build a profile of legitimate transactions for the users. When a new transaction occurs, it is evaluated against the user's profile. If its characteristics significantly deviate from the established profile, the transaction is flagged as potentially fraudulent[1].

Data Mining Technique

Data mining techniques and tools help enterprises to predict future trends and make more informed business decisions. There's different types of data mining techniques such as: classification, Clustering, Regression, Association Rule Mining, Anomaly Deteciton, Text Mining, Apriori Algorithm etc.

The Association Rules and the Apriori Algorithm will be the main topics of this paper and experiment.

One data mining technique for finding significant connections or patterns among several variables in a dataset is association rules. These guidelines are frequently used in market basket analysis to determine which products are frequently bought in tandem. An association rule might indicate, for example, that consumers who purchase bread and butter are also likely to buy milk.

There are two primary parts to any association rule:

- Antecedent (X): The item or items that show up in the rule's "if" section.
- Consequent (Y): The item or items mentioned in the rule's "then" section.

The rule is typically expressed as follows: Y is likely to occur if X occurs.

Key Metrics

Support measures how frequently an itemset X appears in all transactions. It calculates the probability that a transaction contains X. A higher support score means X occurs more often in the dataset.

$$Support(X \Rightarrow Y) = \frac{(Transactions\ containing\ both\ X\ and\ Y)}{(Total\ No.\ of\ transactions)}$$

Confidence measures probability that an item Y will be bought when an item X is bought, given the antecedent item, it measures the conditional probability of the succeeding item. A higher confidence score means that there is a greater chance that item Y will be bought when item X is bought.

$$confidence(X \Rightarrow Y) = \frac{Support(X \Rightarrow Y)}{Support(X)}$$

Lift evaluates the strength of the association between two items by comparing the observed probability of them being bought together to the expected probability if the items were independent. A lift value greater than 1 suggests that the items are positively correlated and are more likely to be bought together than by random chance. Lift helps identify relationships that might not be immediately obvious based on frequency alone

$$lift(X \Rightarrow Y) = confidence(X \Rightarrow Y) / support(X)$$

Leverage is a metric that helps assess how much more often X and Y appear together compared to what would be expected if the two items were independent. A positive leverage value indicates a stronger association than expected, while a negative value suggests that the items occur together less frequently than expected by chance.

$$leverage(X \Rightarrow Y) = support(X \Rightarrow Y) - support(X) \cdot support(Y)$$

Conviction measures the degree to which an association rule is reliable. It is based on how often the rule holds true compared to how often the consequent item is expected to occur in the

absence of the antecedent. A high conviction value suggests a strong, reliable rule, while a low conviction value indicates that the rule is less reliable or possibly coincidental

$$\text{Conviction}(X \Rightarrow Y) = \text{support}(Y) / \text{confidence}(X \Rightarrow Y)$$

The Apriori algorithm focuses on item combinations that exceed a predetermined support limit by assessing transactional data, such as store data records. The identification of these frequently occurring itemsets produces association rules, offering important information about the connections between the items[2].

Datasets

A dataset is a group of data used for analysis, research, and or machine learning that is usually arranged in a structured manner.[1][2]

We use transactional data in this work, which is defined as records that record the specifics of business transactions and are frequently collected by systems like banking systems, e-commerce platforms, and point-of-sale systems.

Transaction ID	Customer ID	Product	Quantity	Date	Total Amount
1	101	Milk	2	2024-12-01	5.00
1	101	Bread	1	2024-12-01	2.50
2	102	Butter	1	2024-12-01	3.00
2	102	Milk	1	2024-12-01	2.50
3	103	Eggs	12	2024-12-02	6.00
3	103	Cheese	1	2024-12-02	4.00
4	104	Milk	3	2024-12-03	7.50
5	105	Butter	1	2024-12-03	3.00
5	105	Bread	2	2024-12-03	5.00

Figure 2. An example of transactional data

The transactional dataset was originally collected by Daqing Chen from a UK-based online retailer operating without physical store locations. The dataset was sourced from the UCI Machine Learning Repository and contains all transactions recorded between 01/12/2010 and 09/12/2011 [7]. While primarily consisting of UK transactions, the dataset also includes international purchases.

Experiment

Cleaning & Preparing the data

The first step was removing all transactions marked with cancellation indicators like "C" or "A" to ensure only valid purchases remained. The dataset was then filtered to include transactions only from customers in Germany, removing all UK and other international records. The transactional data was reformatted into a binary matrix suitable for Market Basket Analysis, where each row represented an invoice, and each column indicated the presence or absence of a product. This prepared the transaction data for pattern mining using Apriori.

Execution of Algorithm

antecedents	consequents	antecedent support	consequent support	support	confidence	lift	leverage	conviction
PLASTERS IN TIN WOODLAND ANIMALS	PLASTERS IN TIN CIRCUS PARADE	0.13786	0.11597	0.06783	0.49206	4.24289	0.05185	1.74043
PLASTERS IN TIN CIRCUS PARADE	PLASTERS IN TIN WOODLAND ANIMALS	0.11597	0.13786	0.06783	0.58491	4.24289	0.05185	2.07698
ROUND SNACK BOXES SET OF 4 FRUITS	PLASTERS IN TIN CIRCUS PARADE	0.15755	0.11597	0.05033	0.31944	2.75445	0.03206	1.29898
PLASTERS IN TIN CIRCUS PARADE	ROUND SNACK BOXES SET OF 4 FRUITS	0.11597	0.15755	0.05033	0.43396	2.75445	0.03206	1.48833
ROUND SNACK BOXES SET OF 4 WOODLAND	PLASTERS IN TIN CIRCUS PARADE	0.24508	0.11597	0.05689	0.23214	2.00168	0.02847	1.15129
PLASTERS IN TIN CIRCUS PARADE	ROUND SNACK BOXES SET OF 4 WOODLAND	0.11597	0.24508	0.05689	0.49057	2.00168	0.02847	1.48189
PLASTERS IN TIN WOODLAND ANIMALS	PLASTERS IN TIN SPACEBOY	0.13786	0.10722	0.06127	0.44444	4.14512	0.04649	1.60700
PLASTERS IN TIN SPACEBOY	PLASTERS IN TIN WOODLAND ANIMALS	0.10722	0.13786	0.06127	0.57143	4.14512	0.04649	2.01167
PLASTERS IN TIN WOODLAND ANIMALS	ROUND SNACK BOXES SET OF 4 WOODLAND	0.13786	0.24508	0.07440	0.53968	2.20210	0.04061	1.64001
ROUND SNACK BOXES SET OF 4 WOODLAND	PLASTERS IN TIN WOODLAND ANIMALS	0.24508	0.13786	0.07440	0.30357	2.20210	0.04061	1.23795
WOODLAND CHARLOTTE BAG	RED RETROSPOT CHARLOTTE BAG	0.12691	0.07002	0.05908	0.46552	6.64817	0.05019	1.73996
RED RETROSPOT CHARLOTTE BAG	WOODLAND CHARLOTTE BAG	0.07002	0.12691	0.05908	0.84375	6.64817	0.05019	5.58775
ROUND SNACK BOXES SET OF 4 FRUITS	ROUND SNACK BOXES SET OF 4 WOODLAND	0.15755	0.24508	0.13129	0.83333	3.40030	0.09268	4.52954
ROUND SNACK BOXES SET OF 4 WOODLAND	ROUND SNACK BOXES SET OF 4 FRUITS	0.24508	0.15755	0.13129	0.53571	3.40030	0.09268	1.81451
ROUND SNACK BOXES SET OF 4 WOODLAND	SPACEBOY LUNCH BOX	0.24508	0.10284	0.07002	0.28571	2.77812	0.04482	1.25602
SPACEBOY LUNCH BOX	ROUND SNACK BOXES SET OF 4 WOODLAND	0.10284	0.24508	0.07002	0.68085	2.77812	0.04482	2.36543
WOODLAND CHARLOTTE BAG	ROUND SNACK BOXES SET OF 4 WOODLAND	0.12691	0.24508	0.06346	0.50000	2.04018	0.03235	1.50985
ROUND SNACK BOXES SET OF 4 WOODLAND	WOODLAND CHARLOTTE BAG	0.24508	0.12691	0.06346	0.25893	2.04018	0.03235	1.17814

Figure 3. Results of algorithm execution

In Figure 3, we can see the raw results of the algorithm. Strong associations can be observed between themed items such as “PLASTERS IN TIN WOODLAND ANIMALS,” “PLASTERS IN TIN CIRCUS PARADE,” and “ROUND SNACK BOXES SET OF 4 WOODLAND.” The high confidence and lift suggest to us that people who purchase one of these products are significantly more likely to purchase the related product as well.

This means that customers are influenced by the product themes, collections or complementary designs while deciding on a purchase. The results may be useful for product placement management, bundle offer creation and inventory management.

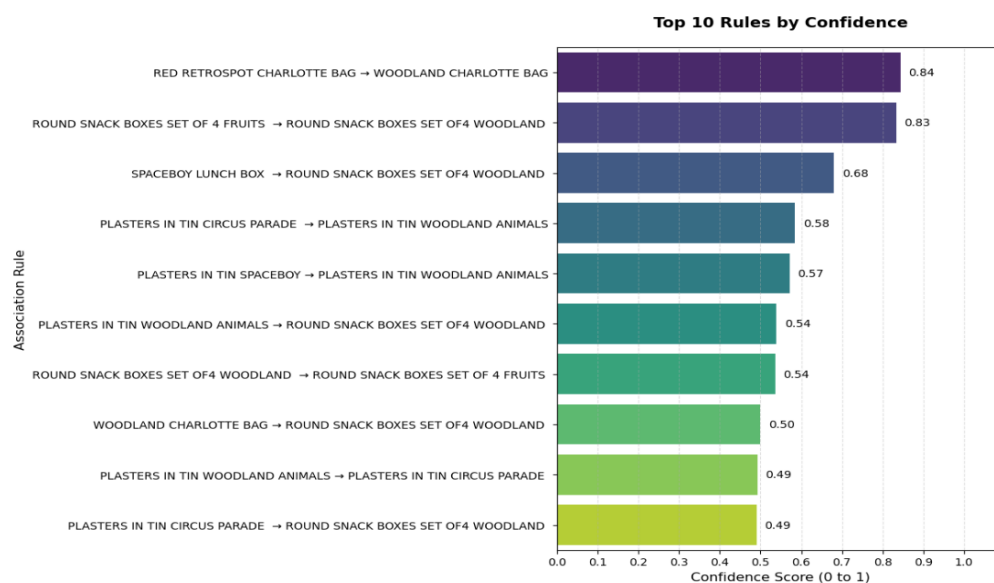


Figure 4. Results by arranged by confidence

Figure 4 shows us the results generated by the algorithm, based on confidence scores. They show a few strong product associations, mostly within matching product categories. The “Red Retrosport” and “Woodland Charlotte bags” have the strongest association, which means that these products are often bought together. It can be seen that customers who buy the “Round Snack Boxes Set of 4 Fruits” are also likely to buy the Woodland version, meaning a trend to buy multiple versions of similar products. The plaster tins explain thematic purchasing patterns, with the space-themed products showing association with other products in the space theme, while the woodland items form their own distinct grouping. When comparing different product pairs, the confidence values reveal that certain combinations such as the Charlotte bags, exhibit stronger associations than others like the snack box and plaster tin combinations. These patterns suggest that customers tend to purchase complementary items that share either functional relationships or thematic consistency.

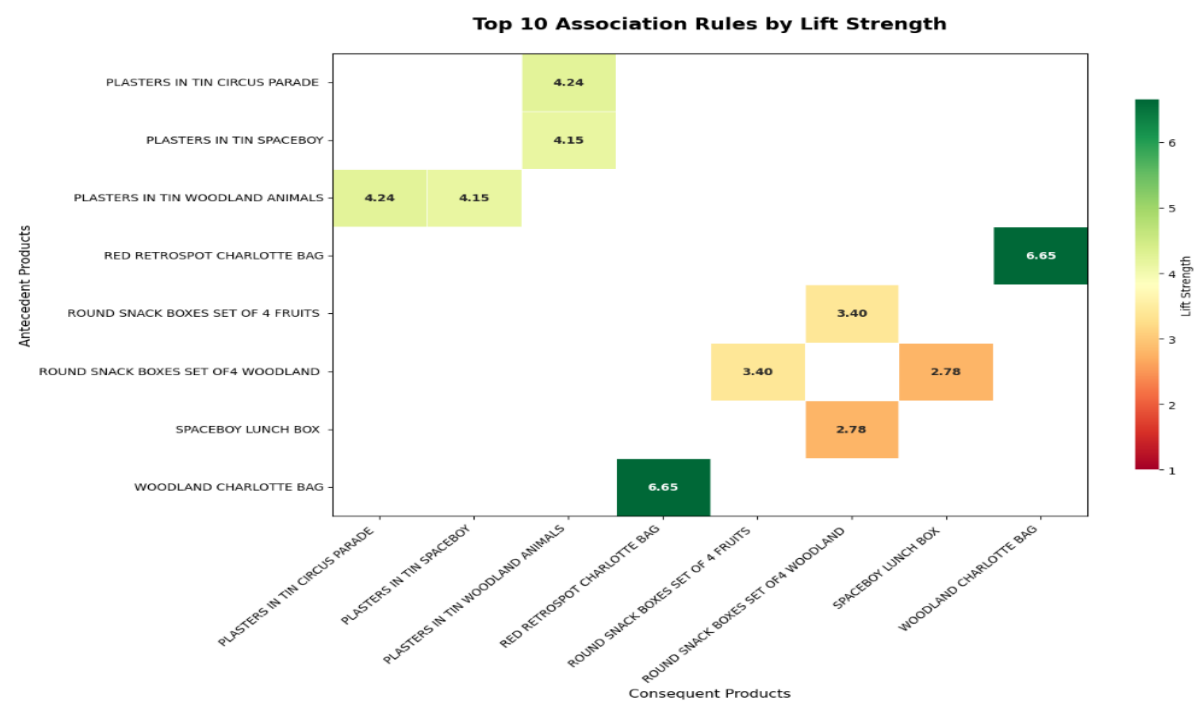


Figure 5. Results arranged by lift strength

Figure 5 shows us the top association rules ranked by lift, showing the most noteworthy product relationships. The results show particularly strong associations between specific itemsets with the highest lift showing especially notable patterns. A few product pairs demonstrate lift values above the threshold of 1 suggesting these combinations occur together more frequently than would be expected by random chance. The "Plasters In Tin" products show multiple strong associations with each other, while the "Charlotte Bags" exhibit the most apparent relationship. "Snack Box" also shows us meaningful associations, particularly between different variants. Space-themed items form their own distinct cluster of associations. These results indicate that customer purchasing behavior follows consistent patterns, with clear preferences for combining certain complementary products

Inventory Management

Due to the complexity and importance of inventory control in the age of globalization, new innovations have been proposed to enhance the computerized procedures for establishing, maintaining, or updating inventory records[3]. For example, an inventory management system

can automatically determine which items in the inventory may need replenishment most likely. Another computer system uses a linear programming engine to choose the priority of customer orders and arrange limited inventory accordingly.

Using the data from Figures 3, 4, and 5, we can come to the conclusion that placing frequently bought-together items near each other can encourage additional purchases. Whether it be space-themed boxes or boxes of different materials. With the usage of MBA, businesses can optimize inventory placement and promotions to increase sales and efficiency

Conclusion and future work

The purpose of this study was to analyze customer purchasing patterns by analyzing transaction data to identify significant associations between frequently bought items. The analysis showed several interesting correlations, highlighting strong and medium relationships between products. From the results, we can conclude that the Apriori algorithm is still used to an effective extent with useful data for marketing strategy and inventory management, but compared to other techniques, such as the FPGrowth Algorithm, it isn't as effective at tackling larger datasets[16]. While the dataset used with the Apriori algorithm provided valuable insights into customer behavior, it is important to acknowledge potential limitations.

This analysis was based on a dataset that was collected over 13 months., from December 2010 to December 2011, which includes 541,911 rows and 8 columns. While the data provides useful insights, the limited timeframe and sample size may influence the reliability of the results. With the dataset also being older than 10 years, an efficient and reliable marketing strategy based on it wouldn't be effective. A broader dataset covering a longer period could offer more accurate and comprehensive findings, leading to more precise predictions and associations. Future research could improve by incorporating larger, more diverse datasets to refine the analysis and enhance decision-making for inventory management and marketing strategies.

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