

**Submitted by: Md Shamsul Arif Khan**

**Student Number**: 501140715

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**A COMPREHENSIVE APPROACH TO ADDRESS THE COLD-START PROBLEM IN RECOMMENDER SYSTEMS**

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**Supervisor Name:** Ceni Babaoglu

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# Abstract:

Recommender systems will be pivotal in augmenting user experiences across various domains, including e-commerce and content streaming. However, these systems will face enduring challenges, and the "cold start problem" will be a significant obstacle. This problem will arise when recommender systems encounter new users or items with limited historical data, making it challenging to deliver accurate recommendations.

This research project aims to address the cold start problem comprehensively by integrating and expanding upon existing approaches, innovatively combining collaborative filtering, content-based filtering, and demographic data. Furthermore, the project will embrace advanced machine learning models, external data sources, and contextual information to enhance recommendation quality.

The project will utilize advanced feature engineering to extract relevant features from user and item profiles and integrate external data sources and *auxiliary information, such as user demographics and item characteristics*, for enhanced recommendation quality.

The project will employ various machine learning models, collaborative algorithms, content-based filtering, and hybrid filtering to identify the *most effective means of generating accurate recommendations for new users.*

Evaluation metrics such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE), diversity indices, and novelty metrics *will be used To comprehensively assess the comparison of performance between the proposed approach and traditional methods.*

The project aims to enhance the understanding of recommender systems and provide practical insights for building more effective systems in the future. The comprehensive approach and rigorous evaluation will contribute to advancing this field, offering users more personalized and accurate recommendations.

Introduction:

Recommender systems are fundamental to enhance user experiences in numerous domains, including e-commerce and content streaming. Despite their significance, these systems encounter persistent challenges. Among these, the "cold-start problem" stands out as particularly vexing. This issue arises when a recommender system encounters new users or items, necessitating more historical data and making accurate recommendations difficult.

Another significant challenge is improving recommendation quality by leveraging user behaviour data and additional characteristics associated with users and items. While collaborative filtering methods offer valuable insights, incorporating user demographics and movie attributes can enhance the recommendations' accuracy and personalization.

## Problem Statement:

The main barrier to enhancing user engagement and system utility is providing high-quality recommendations for new users with limited or no interaction history, also called the cold start problem.

## Research Questions:

1. How auxiliary information, such as user demographics, item characteristics, and external data sources, can be leveraged to alleviate the cold-start problem?
2. Which machine learning and recommendation techniques and filtering approaches offers the most effective means of generating accurate recommendations for new users?
3. What evaluation metrics and methodologies should be used to comprehensively assess the comparison of performance between proposed approach and traditional methods?

## Objective:

This project's primary focus will be devising a holistic solution to mitigate the "cold-start problem" in recommender systems.

# Literature review

## Exploring Prior Knowledge about the topic

### Recommender Systems:

Recommender systems (RSs) are specialized information systems designed to assist users in selecting items or products based on their preferences, thus enhancing user experience and engagement. RSs have become integral tools in helping users make informed choices in an increasingly information-rich digital landscape. (Ricci, Rokach, Shapira, & Kantor, 2011).

RSs encompass various technologies, including information filtering, classification learning, user modelling, and adaptive hypermedia. RSs applications is found in diverse domains such as e-commerce and personalized content delivery (e.g., books, movies, songs, restaurants, news articles) and significantly impact practical applications. Examples of RSs include Amazon, eBay, Netflix etc. Amazon, for instance, use customer purchase history to provide recommendations, while eBay employs a feedback profile system for user interaction (Zhang, Liu, Zhang, & Zhou, 2007).

### The Cold-Start Problem:

The primary challenge in recommender systems is the cold-start problem, which manifests as two primary variants: the new user cold-start problem and the new item cold-start problem. The new user cold-start problem arises when a user has no prior interaction history, while the new item cold-start problem occurs when a new item is introduced, needing more user ratings and causing it to rank poorly in recommendations. (Zhang, Liu, Zhang, & Zhou, 2007) (Hoang Son, 2016) (Zhu, et al., 2020) (Schnabel, Swaminathan, Singh, Chandak, & Joachims, 2016)

### Approaches to Address the Cold-Start Problem:

Several approaches have been proposed to address the cold-start problem in recommender systems, each designed to mitigate the new user and new item challenges. One approach involves leveraging additional data sources, including contextual information, social tags, or other metadata, to provide personalized recommendations with no interaction history. (Hoang Son, 2016) (Zhang, Liu, Zhang, & Zhou, 2007)

Other methods include selecting analogous users with similar preferences or behaviours to the new users (Hoang Son, 2016)Collaborative filtering, a popular technique, seeks to identify users with comparable profiles to generate recommendations (Zhang, Liu, Zhang, & Zhou, 2007)Additionally, hybrid methods combining various recommendation techniques, such as content-based and collaborative filtering, are employed to enhance prediction accuracy ( (Hoang Son, 2016).

Moreover, matrix factorization techniques have been applied to address the cold-start problem, particularly for new items. By incorporating attributes and weights for ratings, these approaches aim to provide more accurate recommendations for new or unrated items (Cortes, 2020).

## Critical analysis of the prior knowledge about the topic

### Importance and Impact RSs

RSs have undoubtedly become indispensable tools by helping users navigate overwhelming information. They significantly enhance user experience and engagement, especially in e-commerce and content delivery platforms. RSs play a pivotal role in personalizing content delivery, yet they face challenges, especially regarding the cold-start problem. In addition, while these systems are praised for their ability to provide personalized recommendations, their impact extends beyond user satisfaction to influencing purchasing behaviour and revenue generation for businesses (Ricci, Rokach, Shapira, & Kantor, 2011)

### Technology and Applications of Recommender Systems:

A sophisticated blend of technologies drives the recommender systems, including information filtering, user modelling, and adaptive hypermedia. This amalgamation allows them to provide recommendations based on explicit user input and implicit behaviours and preferences, resulting in higher-quality personalized suggestions. These systems find extensive applications across domains, successfully recommending books, movies, songs, restaurants, and news articles. Beyond these domains, they serve as cornerstones of personalization, influencing areas like advertising, content delivery, and talent recruitment in the digital age. (Zhang, Liu, Zhang, & Zhou, 2007)

### The Cold-Start Problem's Significance:

The cold-start problem could severely hinder the system's ability to provide meaningful recommendations for users without historical interaction data and for new items with limited ratings. Addressing this issue is crucial, as it directly impacts user engagement, satisfaction, and the system's overall utility. (Hoang Son, 2016) (Cortes, 2020) (Ricci, Rokach, Shapira, & Kantor, 2011)

### Diverse Approaches to Mitigate the Cold-Start Problem:

The critical issues with the approaches to mitigating the recommender systems' cold-start problem are multifaceted. There is a challenge of data availability and quality when relying on external data sources like social tags and contextual information, which can potentially lead to incomplete or inaccurate recommendations. In addition, scalability becomes a concern as user and item numbers increase, affecting computational complexity. Furthermore, privacy issues arise when handling additional data sources, as users may hesitate to share certain information. Effectively addressing the new item cold-start problem remains challenging, requiring advanced techniques. Moreover, algorithmic complexity and resource demands can be significant when implementing hybrid methods and matrix factorization approaches. These issues need careful consideration to successfully mitigate the Cold-Start problem in recommender systems (Zhang, Liu, Zhang, & Zhou, 2007) (Hoang Son, 2016) (Schnabel, Swaminathan, Singh, Chandak, & Joachims, 2016)

## Previous identical projects:

This project focuses on the cold-start problem in recommender systems, a well-known challenge marked by insufficient prior user interactions with certain items or users. Several similar research studies have proposed various strategies to address this issue and enhance the quality of recommendations for new or rarely interacted items or users. The paper titled "Addressing the Cold-Start Problem in Recommender Systems based on Frequent Patterns" by Antiopi Panteli and Basilis Boutsinas is one of those and probably the closest match to the project.

The research paper addresses the "cold-start" problem in recommender systems, focusing on situations where prior user-product interaction data is insufficient or completely lacking. The study proposed a new hybrid method that combines user/product context information, discriminative data mining, and clustering to help with this problem. The proposed methodology can handle both the sparsity problem and the out-of-matrix prediction problem, where new users or products have no rating history. Unlike many existing methods, it does not require extensive user input before using the system (Panteli & Boutsinas, 2023).

### Key findings and contributions include:

* A novel hybrid approach that combines clustering, discriminative itemset mining, and user/product context for addressing the cold-start problem.
* The capability to handle the out-of-matrix prediction problem where users have no rating history.
* Eliminate the need for an extensive user interview process to gather extra information.
* A streamlined approach without multiple interrelated modules.

The methodology of this research leverages discriminative itemset mining to address the cold-start problem, both for in-matrix and out-of-matrix predictions. This makes it a unique solution for this challenging issue in recommender systems (Panteli & Boutsinas, 2023).

## Related Projects:

Several innovative approaches have been proposed to tackle this challenge such as Clustering and Similarity-Based Approaches, Matrix Factorization Models, Social Network Data, Association Rule Mining (ARM) and hybrid Recommender Systems. In this literature review, we discuss a few articles that delve into various strategies to address the cold-start problem.

#### Project Title: Recommendation using a clustering algorithm based on a hybrid features selection method

This research paper proposes a solution combining content and user data, but these hybrid systems often need more semantic understanding. This study introduces a new approach, a hybrid recommendation system with three components. The first uses a powerful content clustering method that blends statistical and semantic features. The second relies on user ratings (collaborative filtering), and the third combines these two to improve recommendations for new items. Experimental results show that this approach performs better, especially in cold start situations, providing more accurate item suggestions. (Ferdaous, Bouchra, Imad-eddine, & Asmaa, 2017)

#### Project Title: Hybrid Recommendation System to Solve Cold Start Problem

In this research, the authors focus on the critical issue of the cold start problem in recommendation systems. The study delves into hybridization methods, data collection approaches, standard solutions, frequently used datasets, algorithms, and evaluation methods to address this issue. The primary objective is to examine how existing hybrid strategies can mitigate the cold start problem, offering valuable insights to researchers and practitioners (Rahman, Shama, Rahman, & Nabil, 2022).

#### Project Title: Combining community-based knowledge with association rule mining to alleviate the cold start problem in context-aware recommender systems

This research introduces a novel hybrid approach to alleviate the cold start problem in context-aware recommender systems. It addresses the challenge of providing accurate and relevant recommendations based on contextual information. The suggested solution includes community-created knowledge, ontologies, association rule mining, and a brand-new method of rating things using probability metrics. This innovative approach aims to support researchers and developers in overcoming the limitations caused by a lack of available data, especially for new members or users with limited historical data. (Viktoratos, Tsadiras, & Bassiliades, 2018)

#### Project Title: A hybrid framework for enhancing correlation to solve cold-start problem in recommender systems.

This study is dedicated to improving the user experience in online shopping by proposing a hybrid framework for addressing the cold-start problem in recommender systems. Online shopping, while convenient, can be overwhelming for users due to the vast array of product options. The research aims to develop a recommendation system that effectively utilizes customer information and product data to make personalized product suggestions. The experiments and methodology are based on the MovieLens dataset, adding a practical dimension to the work (Dang, Duong, & Nguyen, 2014).

#### Project Title: Collaborative filtering and deep learning-based recommendation system for cold start items

This research focuses on two recommendation models: deep learning neural networks and collaborative filtering to handle complete cold starts (CCS) and incomplete cold starts (ICS). These models integrate content features and temporal dynamics into prediction algorithms. The extensive tests on a large Netflix rating dataset show that the proposed models can improve user experiences and cold-start item recommendations in several online applications. (Wei, He, Chen, Zhou, & Tang, 2017).

## Aligning the project with Prior Research:

This project aims to address the well-known "cold start problem" in recommender systems. It focuses on effectively utilizing auxiliary information, including user demographics and item characteristics, to enhance the quality of recommendations for new users with limited or no interaction history. It aligns with prior studies in this domain in the following ways:

The project resonates with previous research that has proposed hybrid approaches, combining collaborative filtering and content-based filtering, to address the cold start problem. These hybrid models strive to deliver more precise and personalized recommendations to users who need more substantial historical data (Ferdaous, Bouchra, Imad-eddine, & Asmaa, 2017).

In addition, it is consistent with investigations into hybrid recommendation systems, such as the study titled "Hybrid Recommendation System to Solve Cold Start Problem." Like this work, the project explores hybridization methods and integrates different data sources and recommendation techniques to ameliorate recommendation quality (Rahman, Shama, Rahman, & Nabil, 2022).

Moreover, this research shares similarities with projects concentrating on context-aware recommendations. This study, like the one called "Combining community-based knowledge with association rule mining to alleviate the cold start problem in context-aware recommender systems," also aims to give context-aware suggestions by adding external data sources to improve profiles of users and items (Viktoratos, Tsadiras, & Bassiliades, 2018).

Furthermore, the project's goal of enhancing the user experience in online shopping aligns with the research objectives titled "A hybrid framework for enhancing correlation to solve the cold-start problem in recommender systems." Both studies seek to enhance the user experience by developing recommendation systems that consider various factors to provide personalized product suggestions (Dang, Duong, & Nguyen, 2014).

Lastly, using collaborative filtering and deep learning together to solve cold start problems is similar to the method used in the study, "Collaborative filtering and deep learning-based recommendation system for cold start items." This project and the referenced study combine collaborative filtering with deep learning techniques to mitigate the cold start problem and enhance the overall user experience (Wei, He, Chen, Zhou, & Tang, 2017).

This project's objectives and methodology fall within the broader context of addressing the cold-start problem in recommender systems. It will contribute to ongoing research efforts to provide more accurate and personalized recommendations, particularly for new or rarely interacted users and items.

## Worthiness of this project considering previous researches:

This study is valuable in the realm of recommender systems, as it offers a fresh perspective on the persistent "cold start problem." Here's why it should be considered worthwhile:

Firstly, this research seeks to integrate and refine existing methods for tackling the cold start problem. While previous studies have proposed various solutions, there's room for innovation by merging collaborative filtering, content-based filtering, and demographic data to create a more comprehensive approach.

Secondly, it will introduce new dimensions by tapping into external data sources and advanced machine-learning models. By utilizing user behaviour data and contextual information, it strives to enhance recommendation quality in line with evolving data trends and user expectations.

Moreover, the "MovieLens Latest Small" dataset will make this research practical and relevant. This readily available dataset, rich in user ratings and movie details, is a benchmark for evaluating real-world applicability. It will allow for thoroughly exploring recommendation techniques, making the findings more widely applicable.

Additionally, this research will take a broader approach to the cold start problem. It doesn't just focus on new items; it also considers new users with minimal interaction history. This inclusive perspective provides a holistic understanding of the challenge.

Lastly, the project emphasizes a rigorous evaluation of recommendation quality using various metrics. Metrics like RMSE, MAE, diversity indices, and novelty metrics ensure a comprehensive assessment, adding credibility to the findings and strengthening the research's methodological rigour.

This research is significant because it combines different recommendation methods, leverages external data, and uses a relevant dataset to provide valuable insights. Its thorough evaluation approach and inclusive problem-solving contribute to the field of recommender systems.

# About the selected Dataset:

There are several datasets available online. However, this project will utilize the "MovieLens Latest Small" dataset (Harper & Konstan, 2015), that encompasses user ratings and movie metadata. The Dataset is available for public in the following link: <https://grouplens.org/datasets/movielens/latest/>.

The "MovieLens Latest Small" dataset is selected due to its relevance, richness of data, availability, scalability, and applicability to the cold-start problem. Leveraging this dataset allows for a comprehensive exploration of recommendation techniques and the development of solutions that can benefit a wide range of recommender systems.

## Utilization of the Dataset:

* Demographics, movie genres, and other pertinent features from the Dataset can be extracted to construct enriched user and item profiles.
* Integrating external data sources, encompassing social media content and user reviews further enhances the depth of user and item profiles.
* Selection of a subset of users with minimal or no movie ratings (representing new users) to simulate new user scenarios.
* Evaluation will be done by comparing recommendations generated by the proposed approach with those produced by traditional collaborative filtering, content-based filtering, and hybrid techniques.

## Summary of the dataset

The data used in this paper includes the following four datasets:

1. Rating Dataset: This dataset, named "ratings.csv," contains information about user ratings for various items, such as movies. Each record typically includes details about the user, the item being rated, the rating given, and a timestamp indicating when the rating was made. This data is crucial for understanding user preferences and behaviour.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| header | userId | movieId | rating | timestamp |
| count | 100836 | 100836 | 100836 | 100836 |
| mean | 326.127564 | 19435.29572 | 4 | 1205946000 |
| std | 182.618491 | 35530.9872 | 1 | 216261000 |
| min | 1 | 1 | 1 | 828124600 |
| 25% | 177 | 1199 | 3 | 1019124000 |
| 50% | 325 | 2991 | 4 | 1186087000 |
| 75% | 477 | 8122 | 4 | 1435994000 |
| max | 610 | 193609 | 5 | 1537799000 |

Table 1: Descriptive statistics of Rating dataset

1. Movies Dataset: The "movies.csv" dataset provides information about the items being rated, in this case, movies. It includes details like the movie's title and genre. This dataset is vital for creating item profiles and understanding the content characteristics of each movie.

|  |  |
| --- | --- |
| header | movieId |
| count | 9742 |
| mean | 42200.35362 |
| std | 52160.49485 |
| min | 1 |
| 25% | 3248.25 |
| 50% | 7300 |
| 75% | 76232 |
| max | 193609 |

Table 2: Descriptive statistics of Movies dataset

1. Links Dataset: The "links.csv" dataset may contain information about how movies in the dataset are linked or associated with external resources, such as IMDB or other online databases. It typically includes identifiers or URLs to help establish connections to external data sources.

|  |  |  |  |
| --- | --- | --- | --- |
| header | movieId | imdbId | tmdbId |
| count | 9742 | 9742 | 9734 |
| mean | 42200.35362 | 677183.9 | 55162 |
| std | 52160.49485 | 1107228 | 93653 |
| min | 1 | 417 | 2 |
| 25% | 3248.25 | 95180.75 | 9666 |
| 50% | 7300 | 167260.5 | 16529 |
| 75% | 76232 | 805568.5 | 44206 |
| max | 193609 | 8391976 | 525662 |

Table 3: Descriptive statistics of Links dataset

1. Tags Dataset: In the "tags.csv" dataset, you might find user-generated tags or keywords associated with movies. Users may add these tags to provide additional context or descriptions for movies. This dataset can be valuable for understanding user-generated content and enhancing item profiles.

|  |  |  |  |
| --- | --- | --- | --- |
| header | userId | movieId | timestamp |
| count | 3683 | 3683 | 3683 |
| mean | 431.149335 | 27252.01358 | 1320032000 |
| std | 158.472553 | 43490.5588 | 172102500 |
| min | 2 | 1 | 1137179000 |
| 25% | 424 | 1262.5 | 1137521000 |
| 50% | 474 | 4454 | 1269833000 |
| 75% | 477 | 39263 | 1498457000 |
| max | 610 | 193565 | 1537099000 |

Table 4: Descriptive statistics of Tags dataset

These datasets together form a comprehensive set of information necessary for building and evaluating recommender systems, especially for addressing the "cold start problem." The ratings and user data help in user profiling, while the movie data and tags contribute to item profiling. The links dataset could bridge the gap between your data and external resources.

## Frequency distributions of datasets

#### Ratings dataset:

A graph with blue bars

Description automatically generated with medium confidence

Figure 1: Frequency distribution of Ratings dataset

#### Movies dataset:

A graph with blue rectangles and numbers

Description automatically generated

Figure 2: Frequency distribution of movies dataset

#### Links dataset:

A graph of a person

Description automatically generated with medium confidence

Figure 3: Frequency distribution of Links dataset

#### Tags dataset:

A graph with blue bars

Description automatically generated

Figure 4: Frequency distribution of Tags dataset

# GitHub Repository Link

The following website link for the GitHub repository will contain the codes and results of the project once it is completed:

<https://github.com/shakhan-17/Big-Data-Projects>

# Tentative overall methodology

A diagram of a model development

Description automatically generated

Figure 5: Tentative overall methodology

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