Final Project: Anime Recommendation System Report

DSCI 641 – Recommendations Systems – Winter 2025

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1. Problem Statement

Domain:
This project focuses on *anime recommendations*, helping users discover new shows based on their preferences.

Intended Users:
The recommender system is designed for *anime enthusiasts* who want to:

- Discover new anime based on their watching history.
- Get personalized recommendations tailored to their tastes.
- Explore top-rated and trending anime in various genres.

User Interaction:
Users interact with the system by:

- Rating anime they have watched.
- Receiving personalized recommendations based on their preferences.
- Browsing popular anime by genre or overall rating.

Characteristics of a Good Recommendation:
A useful recommendation should:

- Match the user's past preferences.
- Balance *accuracy, diversity, and novelty.*
- Introduce new but relevant anime.

User Story:
Alice is a college student who enjoys watching anime. She has rated several shows on the platform, including action-packed series like *Attack on Titan* and fantasy adventures like *Sword Art Online*. She wants to find new anime that match her tastes. The system analyzes her preferences and recommends top-rated shows in similar genres, while also suggesting lesser-known gems she might enjoy.

2. Data Description

Ideal Data:

- User interactions: Watch history, time spent, explicit feedback.
- Community trends: Trending anime, social media discussions.
- Contextual data: Mood-based or time-based recommendations.
- Metadata: Tags, keywords, and themes extracted via NLP.

Experimental Data Used:

- **Anime Dataset:** Contains metadata about anime, including genres, types, and popularity.
- **User Ratings Dataset:** Contains user-generated ratings for different anime.
- **Merged Dataset:** Combined both datasets to build a recommendation engine.

Data Preprocessing:

- Handled missing values by filling in genres and averaging missing ratings.
- Merged datasets using the `anime_id` key.
- Created a cleaned dataset `merged_cleaned_anime_ratings.parquet` for modeling.

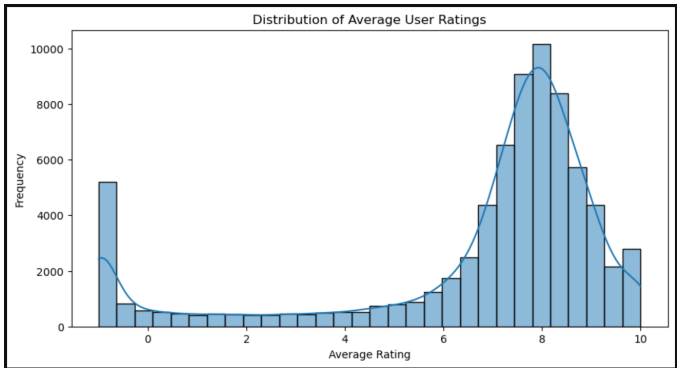

Figure 1: Distribution of Average User Ratings

3. Algorithms Implemented

1. Popularity-Based Model (Baseline):

- Ranks anime based on average rating and number of members.
- Simple but does not provide personalization.

Top 10 Popular Anime for Genre: Comedy

	anime_id	avg_rating	member_count	genre	name
0	28977	9.25	114262	Action, Comedy, Historical, Parody, Samurai, S...	Gintama°
1	9969	9.16	151266	Action, Comedy, Historical, Parody, Samurai, S...	Gintama'
2	32935	9.15	93351	Comedy, Drama, School, Shounen, Sports	Haikyuu!!: Karasuno Koukou VS Shiratorizawa Ga...
3	15417	9.11	81109	Action, Comedy, Historical, Parody, Samurai, S...	Gintama': Enchousen
4	15335	9.10	72534	Action, Comedy, Historical, Parody, Samurai, S...	Gintama Movie: Kanketsu-hen - Yorozuya yo Eien...
5	918	9.04	336376	Action, Comedy, Historical, Parody, Samurai, S...	Gintama
6	28891	8.93	179342	Comedy, Drama, School, Shounen, Sports	Haikyuu!! Second Season
7	263	8.83	157670	Comedy, Drama, Shounen, Sports	Hajime no Ippo
8	30276	8.82	552458	Action, Comedy, Parody, Sci-Fi, Seinen, Super ...	One Punch Man
9	1	8.82	486824	Action, Adventure, Comedy, Drama, Sci-Fi, Space	Cowboy Bebop

Figure 2: Top 10 Popular Anime for Genre: Comedy

Top 10 Popular Anime for Genre: Sci-Fi

	anime_id	avg_rating	member_count	genre	name
0	28977	9.25	114262	Action, Comedy, Historical, Parody, Samurai, S...	Gintama°
1	9253	9.17	673572	Sci-Fi, Thriller	Steins;Gate
2	9969	9.16	151266	Action, Comedy, Historical, Parody, Samurai, S...	Gintama'
3	15417	9.11	81109	Action, Comedy, Historical, Parody, Samurai, S...	Gintama': Enchousen
4	820	9.11	80679	Drama, Military, Sci-Fi, Space	Ginga Eiyuu Densetsu
5	15335	9.10	72534	Action, Comedy, Historical, Parody, Samurai, S...	Gintama Movie: Kanketsu-hen - Yorozuya yo Eien...
6	918	9.04	336376	Action, Comedy, Historical, Parody, Samurai, S...	Gintama
7	2904	8.98	572888	Action, Drama, Mecha, Military, Sci-Fi, Super ...	Code Geass: Hangyaku no Lelouch R2
8	1575	8.83	715151	Action, Mecha, Military, School, Sci-Fi, Super...	Code Geass: Hangyaku no Lelouch
9	30276	8.82	552458	Action, Comedy, Parody, Sci-Fi, Seinen, Super ...	One Punch Man

Figure 3: Top 10 Popular Anime for Genre: Sci-Fi

2. Collaborative Filtering (SVD):

- Uses Singular Value Decomposition (SVD) to model user preferences.
- Trained on user-anime ratings to predict unseen ratings.
- **Strength:** Personalized recommendations.
- **Weakness:** Cold-start problem (requires user data).

Top 10 Recommended Anime for User 64514:

	anime_id	predicted_rating	name	members	actual_rating
0	8841	10.0	Kore wa Zombie Desu ka?	295782	7.67
1	19163	10.0	Date A Live II	186187	7.50
2	22199	10.0	Akame ga Kill!	492133	7.84
3	430	10.0	Fullmetal Alchemist: The Conqueror of Shamballa	186465	7.74
4	14513	10.0	Magi: The Labyrinth of Magic	317513	8.24
5	18115	10.0	Magi: The Kingdom of Magic	245026	8.50
6	72	10.0	Full Metal Panic? Fumoffu	171086	8.21
7	6347	10.0	Baka to Test to Shoukanjuu	301282	7.83
8	10620	10.0	Mirai Nikki (TV)	657190	8.07
9	20689	10.0	Hamatora The Animation	133571	7.41

Figure 4: Top 10 Recommended Anime for User 64514

3. **Content-Based Filtering (PCA + Nearest Neighbors):**

- Uses Truncated SVD to reduce dimensionality of genre features.
- Applies Nearest Neighbors to find anime similar to a user's highly-rated shows.
- **Strength:** Works even for new users.
- **Weakness:** Limited diversity in recommendations.

Top 10 Content-Based Recommended Anime for User ID 45916:

	anime_id	name	genre	members	rating_y
1086553	986	Dragon Ball Z Special 1: Tatta Hitori no Saish...	Adventure, Comedy, Fantasy, Sci-Fi, Shounen	46276	7.75
4679594	1008	Ranma ½ Specials	Comedy, Drama, Romance, Shounen	11084	7.78
4107437	7333	Koisuru Tenshi Angelique: Kagayaki no Ashita S...	Fantasy, Romance	1315	6.94

Figure 5: Top 10 Content- Based Recommendation Anime for User ID 45916

4. **Hybrid Model (SVD + Content-Based):**

- Combines SVD predictions with content-based scores.
- Weighted scoring method (60% collaborative, 40% content-based).
- **Strength:** Balances personalization and diversity.

Top 10 Hybrid Recommended Anime for User ID 7880:

	anime_id	svd_predicted_rating	content_score	hybrid_score	name	genre	members	rating_y
39	59	7.4087	10.0	8.44522	Chobits	Comedy, Drama, Ecchi, Romance, Sci-Fi, Seinen	266846	7.57
1776	1974	10.0000	5.0	8.00000	Glass no Kamen (2005)	Drama, Shoujo	17038	8.23
1995	2214	10.0000	5.0	8.00000	Black Jack 21	Action, Drama	6063	7.77
4009	5784	10.0000	5.0	8.00000	Ai no Kusabi (2012)	Drama, Romance, Sci-Fi, Yaoi	17943	6.97
7352	24701	10.0000	5.0	8.00000	Mushishi Zoku Shou 2nd Season	Adventure, Fantasy, Historical, Mystery, Seine...	75894	8.88
5057	9332	10.0000	5.0	8.00000	.hack//Quantum	Action, Adventure, Fantasy, Game, Sci-Fi	26163	7.36
8176	32182	10.0000	5.0	8.00000	Mob Psycho 100	Action, Comedy, Slice of Life, Supernatural	193716	8.55
7029	21939	10.0000	5.0	8.00000	Mushishi Zoku Shou	Adventure, Fantasy, Historical, Mystery, Seine...	101351	8.80
3868	5420	10.0000	5.0	8.00000	Kemono no Souja Erin	Drama, Fantasy	36751	8.45
7014	21843	10.0000	5.0	8.00000	Shingeki no Bahamut: Genesis	Action, Adventure, Demons, Fantasy, Magic, Sup...	143701	7.77

Figure 6: Top 10 Hybrid Recommended Anime for User ID 28970

Top 10 Hybrid Recommended Anime for User ID 28970:

	anime_id	svd_predicted_rating	content_score	hybrid_score	name	genre	members	rating_y
7192	23317	7.542744	10.0	8.525647	Kuroshitsuji: Book of Murder	Comedy, Demons, Fantasy, Historical, Mystery, ...	67261	8.41
7951	31043	10.000000	5.0	8.000000	Boku dake ga Inai Machi	Mystery, Psychological, Seinen, Supernatural	402381	8.65
3818	5300	10.000000	5.0	8.000000	Zoku Natsume Yuujinchou	Drama, Fantasy, Shoujo, Slice of Life, Superna...	114173	8.64
7681	28977	10.000000	5.0	8.000000	Gintama°	Action, Comedy, Historical, Parody, Samurai, S...	114262	9.25
5689	11665	10.000000	5.0	8.000000	Natsume Yuujinchou Shi	Drama, Fantasy, Shoujo, Slice of Life, Superna...	98431	8.75
5456	10582	10.000000	5.0	8.000000	Astarotte no Omocha! EX	Comedy, Demons, Ecchi, Fantasy, Romance, Seinen	20824	6.83
1033	1142	10.000000	5.0	8.000000	Hachimitsu to Clover II	Drama, Josei, Romance	61493	8.37
7652	28725	10.000000	5.0	8.000000	Kokoro ga Sakebitagatterunda.	Drama, Romance, School	59652	8.32
5261	9989	10.000000	5.0	8.000000	Ano Hi Mita Hana no Namae wo Bokutachi wa Mada...	Drama, Slice of Life, Supernatural	463835	8.62
5981	13335	10.000000	5.0	8.000000	Fuse: Teppou Musume no Torimonochou	Action, Drama, Historical, Supernatural	13412	7.52

Figure 7: Top 10 Hybrid Recommended Anime for User ID 7880

4. Experimental Design

Data Preparation & Splitting:

- Train-Test Split: 70% training, 30% testing.
- Feature Engineering: Encoded genres into a sparse matrix.
- Model Training:
  - **SVD Model:** Trained using Surprise Library.
  - **Content-Based Model:** Applied PCA and Nearest Neighbors.
  - **Hybrid Model:** Combined both approaches with weighted scores.

Evaluation Metrics:

- **RMSE (Root Mean Squared Error):** Measures rating prediction accuracy.
- **MAE (Mean Absolute Error):** Measures average prediction deviation.
- **Precision@10:** Measures the proportion of relevant recommendations.
- **Diversity:** Measures uniqueness of recommended items.
- **Novelty:** Ranks recommendations by popularity (lower rank = more novel).

Hyperparameter Tuning:

- **SVD Parameters:** Optimized `n_factors`, `n_epochs`, `lr_all`, `reg_all`.
- **Content-Based:** Optimized number of nearest neighbors.
- **Hybrid Model:** Tuned weight ratio between content-based and SVD models.

5. Results & Key Findings

Performance Comparison:

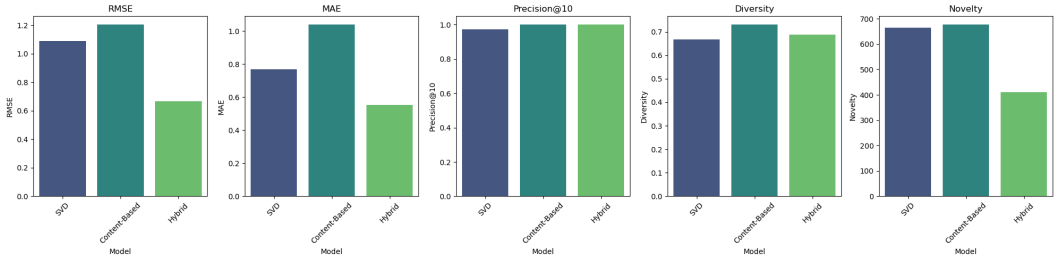

Figure 8: Evalution Metrics

Observations:

- SVD provides high accuracy but has a cold-start issue.
- Content-based filtering improves novelty but lacks personalization.
- Hybrid model balances accuracy, diversity, and novelty, making it the best approach overall.
- Diversity score is highest in the Hybrid Model, suggesting a broader range of recommendations.

6. Reflection

RMSE (Root Mean Squared Error):

- Hybrid (0.668): Has the lowest RMSE, which indicates that its predicted ratings are closest to the actual ratings. In other words, it is the most accurate in terms of error magnitude.
- SVD (1.0878): Performs moderately; its error is higher than Hybrid but lower than Content-Based.
- Content-Based (1.2024): Has the highest RMSE, meaning it's less accurate in predicting ratings compared to the other two models.

MAE (Mean Absolute Error):

- Hybrid (0.5512): Again, the lowest MAE suggests that on average, the absolute prediction error is the smallest, reinforcing its strong performance.
- SVD (0.7694): Moderate performance in terms of absolute error.
- Content-Based (1.0378): The highest MAE indicates larger average deviations from the true ratings.

Precision@10:

- Content-Based (1.0) & Hybrid (1.0): Both achieve perfect precision@10, meaning that the top 10 recommendations they provide are all relevant (assuming your relevance threshold).
- SVD (0.9735): Very high precision, nearly perfect, but slightly below the other two models.

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- Content-Based (1.2024): Has the highest RMSE, meaning it's less accurate in predicting ratings compared to the other two models.

Diversity:

- Content-Based (0.73): Offers the highest diversity. This means its recommendations cover a broader range of items (possibly in terms of genres, styles, or topics), which can be beneficial for users looking for varied content.
- Hybrid (0.6887): Slightly less diverse than the Content-Based approach.
- SVD (0.6681): Has the lowest diversity among the three, indicating that its recommendations might be more similar to each other.

Novelty:

- Content Based (676.5) & SVD (664.3): These models provide recommendations that are relatively more novel (assuming a higher novelty value indicates items that are less popular or more unique).
- Hybrid (411.2): Exhibits the lowest novelty value, suggesting that its recommendations are more mainstream or popular. This could be a trade-off for its higher prediction accuracy.

Overall Summary:

- The Hybrid model stands out for its high accuracy (lowest RMSE and MAE) and perfect precision, but it tends to recommend less diverse and more popular items.
- The Content-Based model provides the most varied (diverse) recommendations and also scores a perfect precision@10, though it has slightly higher error metrics.
- The SVD model is very competitive in precision and prediction error, though it lags slightly behind in diversity compared to the Content-Based model.

This analysis can help guide decisions on which model to use depending on whether you prioritize accuracy, diversity, or novelty in your recommendation system.

7. Future Work

- Incorporate implicit feedback (e.g., watch history, browsing patterns).
- Improve cold-start handling using clustering or deep learning.
- Test real-world user engagement metrics beyond rating accuracy.
- Enhance interpretability with Explainable AI (XAI).

By refining these areas, the Anime Recommendation System can be more effective in guiding users to their next favorite anime!