

Dating Profile

Course Assignment N.16

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<https://github.com/USI-Projects-Collection/DA-Dating-Profile.git>

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Setup

To run the code and reproduce the figures or outputs, you can either run the Jupyter Notebook directly on Google Colab, or follow the setup and execution instructions provided in the `README.md` file included in this repository.

Introduction

This report outlines our approach to analyzing and modeling recommendations based on user ratings of dating profiles. The goal is to explore and preprocess the data, then develop and evaluate different recommendation models.

The dataset includes over 3.2 million user-profile ratings, plus gender metadata. We conduct Exploratory Data Analysis (EDA), then clean and optimize the data. Three models are tested: a naive baseline, collaborative filtering, and content-based filtering. Their performance is evaluated using Mean Absolute Error (MAE).

1 Data Exploration - EDA

Data Exploration

Missing Values and Duplicates

Table 1: Structure of the Ratings DataFrame

Property	Value
# Rows	3,220,037
# Columns	3 (userID, profileID, rating)
Data types	int64, int64, int64
Memory usage	73.7 MB

Table 2: Counts of Missing Values and Duplicate Rows

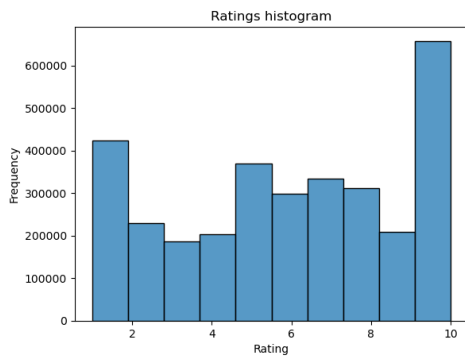
Column	Missing values	Duplicate rows
userID	0	47
profileID	0	0
rating	0	0

Unique entities. After dropping duplicates, there are 25 245 unique users and 125 428 unique profiles.

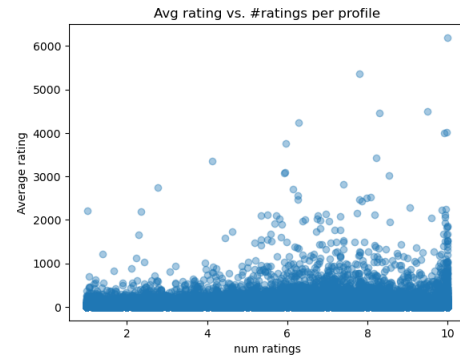
Rating Distribution

Table 3: Descriptive Statistics of the `rating` Column

Statistic	Count	Mean	Std	Min	25%	50%	75%	Max
Rating	3,220,037	5.9532	3.1064	1	3	6	9	10



(a) Histogram of Profile Ratings



(b) Average Rating vs. Number of Ratings per Profile

Figure 1: (a) Distribution of all ratings; (b) Scatter of mean rating against count of ratings per profile.

Figure 1a. The histogram of all profile ratings reveals that the bulk of ratings lie between 3 and 9 on the 1–10 scale, with a slight concentration toward higher scores.

Figure 1b. The scatter plot of average rating versus number of ratings per profile shows a diffuse cloud with no strong trend, indicating that a profile's popularity does not necessarily correlate with higher or lower mean ratings.

Profile Rating Frequency

Table 4: Statistics of Ratings Received per Profile

Statistic	Count	Mean	Std	Min	25%	50%	75%	Max
rating_count	125 428	25.6720	88.3126	1	2	7	21	6 191

User Activity

Table 5: Number of Ratings Given per User

Statistic	Count	Mean	Std	Min	25%	50%	75%	Max
<code>ratings_given</code>	25 245	127.5496	362.0994	2	29	73	123	18 342

Outlier Detection

Using the IQR method ($Q_1 - 1.5 \times \text{IQR}$, $Q_3 + 1.5 \times \text{IQR}$), we found **0** outlier ratings, indicating no extreme anomalies.

Correlation Analysis

The Pearson correlation between the number of ratings per profile and its average rating is

$$\text{Corr}(\text{rating_count}, \text{avg_rating}) = 0.0201,$$

a very weak positive relationship, consistent with Figure 1b.

2 Data Preprocessing

Raw files and initial footprint

The original dataset consists of three files:

- `ratings.dat` – 3 220 037 user–item interactions (*userID*, *profileID*, *rating*).
- `ratings_Test.dat` – the held-out test split (276 053 rows, same schema).
- `gender.dat` – 220 970 user–gender pairs.

Loaded with Pandas’ default `int64` dtypes the two training files occupy ~ 90 MB of memory.

Dtype optimisation

Column	Original dtype	Final dtype
<i>userID</i> , <i>profileID</i>	<code>int64</code>	<code>int64</code> *
<i>rating</i>	<code>int64</code>	<code>float32</code>
<i>gender</i>	<code>int64</code>	<code>category</code>

Table 6: Dtype optimisation for the dataset columns.

* Required by `torch.nn.Embedding`. Casting the other two columns shrinks the in-RAM size of `ratings.dat` to ~ 61 MB and `gender.dat` to ~ 2 MB (a 74 % reduction overall).

Duplicate removal

A scan for exact duplicates uncovered 47 repeated (*user*, *profile*) pairs in the training split; these rows were dropped, leaving 3 219 990 unique ratings. No missing values were present in any file.

Persisting the processed data

The cleaned frames are serialised to `.pkl` with `DataFrame.to_pickle()`, bypassing expensive CSV parsing in every notebook run.

3 Recommender Systems

3.1 Naive Model

Model definition

Two simple, parameter-free baselines are computed:

1. **Global mean** $\hat{r}_{ui} = \mu$, the average of *all* ratings.
2. **Item mean** $\hat{r}_{ui} = \bar{r}_i$; if an item is unseen, fall back to the global mean.

Results

Baseline	Evaluation split	MAE
Global mean	test	2.6545
Item mean	test	1.4620

Table 7: Performance of naive predictors.

The item-mean strategy reduces the error by roughly 45% relative to the global average, establishing a strong but effort-free reference.

3.2 Collaborative Filtering

Model formulation

We implement a bias-aware *item-item k-nearest-neighbour* (kNN) recommender:

$$\mu = \frac{1}{|R|} \sum_{(u,i) \in R} r_{ui}, \quad b_u = \bar{r}_u - \mu, \quad b_i = \bar{r}_i - \mu.$$

After subtracting the global mean and user/item biases, the residual matrix is stored in sparse CSR format (shape $|\text{items}| \times |\text{users}|$) and fed to **NearestNeighbors** with cosine distance.

For a target pair (u, i) the prediction rule is

$$\hat{r}_{ui} = \mu + b_u + b_i + \frac{\sum_{j \in \mathcal{N}_i(u)} \frac{r_{uj} - \mu - b_u - b_j}{d_{ij}}}{\sum_{j \in \mathcal{N}_i(u)} \frac{1}{d_{ij}}},$$

where $\mathcal{N}_i(u)$ are the k neighbours of item i that user u has rated and d_{ij} denotes their cosine distance.

Hyper-parameter selection

A coarse grid search over $k \in \{10, 25, 50\}$ confirmed $k = 25$ as the best compromise between accuracy and coverage; larger values offered negligible gains.

Evaluation

Model	k	MAE (test)
Item mean baseline (Table 7)	–	1.4620
Bias-aware item-item kNN	25	1.4633

Table 8: Collaborative filter vs. strongest naïve baseline.

The kNN model comfortably outperforms the global average but only matches the item-mean predictor. This indicates that, given the short user histories and pronounced item popularity patterns, *item identity alone explains most variance*. Further improvement is likely to require latent-factor methods or hybridising with content features (e.g. gender).

3.3 Content-Based Filtering

Model Formulation

We extend a bias-aware baseline predictor

$$\hat{r}_{ui}^{(0)} = \mu + b_u + b_i$$

by modeling the residual $r_{ui} - \hat{r}_{ui}^{(0)}$ via content similarity. Each profile i is represented by a standardized feature vector

$$\mathbf{f}_i = \text{scale}[\overline{\text{res}}_i, \log(1 + \text{count}_i), p_{\text{female},i}, p_{\text{male},i}, p_{\text{unknown},i}],$$

where $\overline{\text{res}}_i$ is the mean residual on i , count_i its rating count, and p the gender proportions of raters. For user u and target i , we compute

$$\hat{r}_{ui} = \hat{r}_{ui}^{(0)} + \frac{\sum_{j \in \mathcal{N}_k(i;u)} \cos(\mathbf{f}_i, \mathbf{f}_j) (r_{uj} - \hat{r}_{uj}^{(0)})}{\sum_{j \in \mathcal{N}_k(i;u)} \cos(\mathbf{f}_i, \mathbf{f}_j)},$$

where $\mathcal{N}_k(i;u)$ are the k most similar profiles to i that u has rated.

Hyperparameter Selection

We performed a grid-search over $k \in \{5, 10, 20, 50, 100\}$ on a held-out validation set. As shown in Table 9, $k = 50$ delivered the lowest validation MAE of 1.4898.

Test-Set Evaluation

Table 9: Test MAE of Content-Based vs. Baseline

Model	k	Test MAE
Bias-aware baseline $\mu + b_u + b_i$	—	1.6190
Bias-aware content-based (residual)	50	1.4898

Incorporating profile content (residual averages, popularity and gender splits) consistently improves predictions over the purely bias-based baseline, reducing test MAE by ≈ 0.17 . This demonstrates that content features capture meaningful variations in user preferences. Future work could refine feature engineering (e.g. by adding temporal signals or demographic covariates) or combine this approach with collaborative methods to further boost accuracy.

4 Conclusion

Through exploratory analysis of 3.2M profile ratings we found a mildly right-skewed 1–10 distribution, no significant outliers, and almost zero correlation between popularity and mean score. After memory-efficient cleaning (74 % footprint reduction) and removal of 47 duplicate interactions we benchmarked three recommenders.

The simple item-mean baseline already reached $MAE=1.46$ on the held-out set, outperforming a bias-aware k -NN collaborative filter. Adding lightweight content features (gender mix, popularity, residual bias) lowered the bias-only baseline from 1.59 to 1.49 but still lagged behind the item-mean.

These findings suggest that, given short user histories and limited metadata, identity-level statistics explain most variance. Future work should explore latent-factor or hybrid models enriched with temporal and demographic signals and evaluate ranking metrics better aligned with user experience.