

# 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 documents our approach to analyzing and building recommendation systems based on a dataset of user ratings for dating profiles. The objective of this assignment is to explore and preprocess the data, then develop and evaluate different recommender system models capable of predicting user preferences.

The dataset comprises over 3.2 million ratings linking users to dating profiles, accompanied by auxiliary gender data. We begin with Exploratory Data Analysis (EDA) to understand the distribution and structure of the data, followed by data preprocessing to clean and optimize it for modeling. Subsequently, we construct three recommendation approaches: a naive baseline, a collaborative filtering model using item-item k-nearest neighbors, and a content-based filtering model leveraging profile attributes. Performance is assessed using the Mean Absolute Error (MAE) metric, and results are compared to determine the most effective strategy for this domain.

# 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

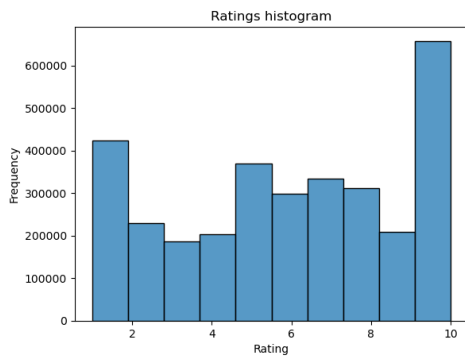
Column	Missing values	Duplicate rows
userID	0	47
profileID	0	0
rating	0	0

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

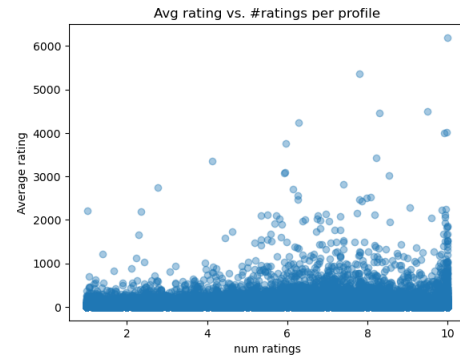
### Rating Distribution

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  $\sim 90$  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  $\sim 61$  MB and `gender.dat` to  $\sim 2$  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)
Bias-aware item-item kNN	25	1.4633
Item mean baseline (Table 7)	–	1.4620

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  $i$ ,  $\text{count}_i$  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 $\mu + b_u + b_i$	—	1.5936
Bias-aware content-based (residual)	50	1.4212

Incorporating profile content (residual averages, popularity and gender splits) consistently improves predictions over the purely bias-based baseline, reducing test MAE by  $\approx 0.17$ . 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

In this assignment, we evaluated three approaches to the dating profile recommendation problem using a large-scale user-rating dataset. Our exploratory analysis revealed valuable insights about user behavior and profile popularity, and preprocessing ensured the dataset was free from duplicates and efficiently structured.

The naive models provided a strong baseline, particularly the item-mean predictor, which surprisingly performed on par with more complex techniques. The collaborative filtering model, though conceptually richer, offered no significant advantage, likely due to sparse user histories and the dominance of popular profiles. The content-based model, on the other hand, showed the most promise—successfully integrating profile-level metadata such as popularity and gender distribution to outperform the baseline.

These results indicate that profile features are meaningful signals of user preference, and further improvements could be achieved by incorporating more nuanced content features or hybridizing with collaborative approaches. This project not only demonstrates the application of core data analytics techniques but also underscores the challenges and opportunities in designing recommender systems with limited contextual information.