

# Music Recommendation at Spotify

HOW SPOTIFY RECOMMENDS MUSIC

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xx.xx.2016

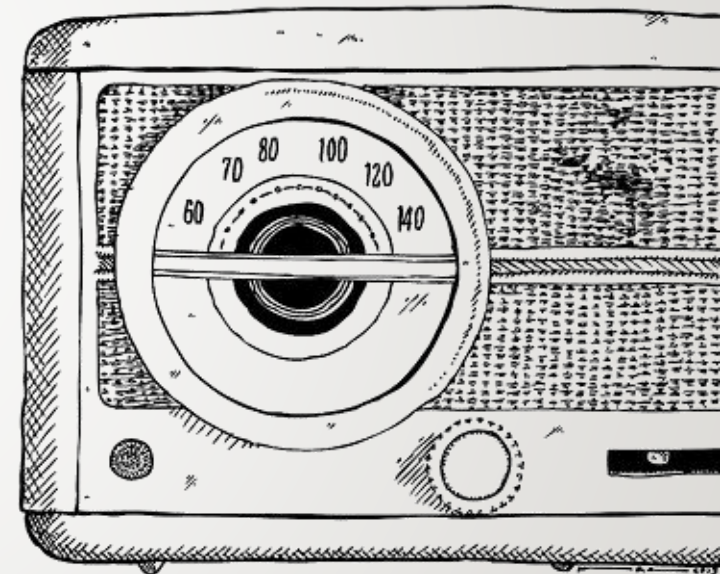


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Formerly



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Nowadays

rdio™

 Rhapsody™

You Tube



 MUSIC



# Spotify

- [illegible]

# Spotify

„ We now have more technology than ever before to ensure that if you’re [...] doing something that only 20 people in the world will dig, we can now find those 20 people and connect the dots between the artist and listeners “ - Matthew Ogle

## Explicit Feedback

## Implicit Feedback

- Introduction
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## Explicit Feedback

- relies on the explicit input by users

→ Actual Rating

## Implicit Feedback



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## Explicit Feedback

- relies on the explicit input by users

→ Actual Rating

## Implicit Feedback

- extracted out of the users behavior

→ Predicted Rating

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## Content-Based Filtering



Track: May 16

Artist: Lagawagon

Album: Let's Talk About Feelings

Release: 1998

## 3. Content-Based Filtering

### Basic Idea:

Compare sets of features which represent the items in a meaningful way

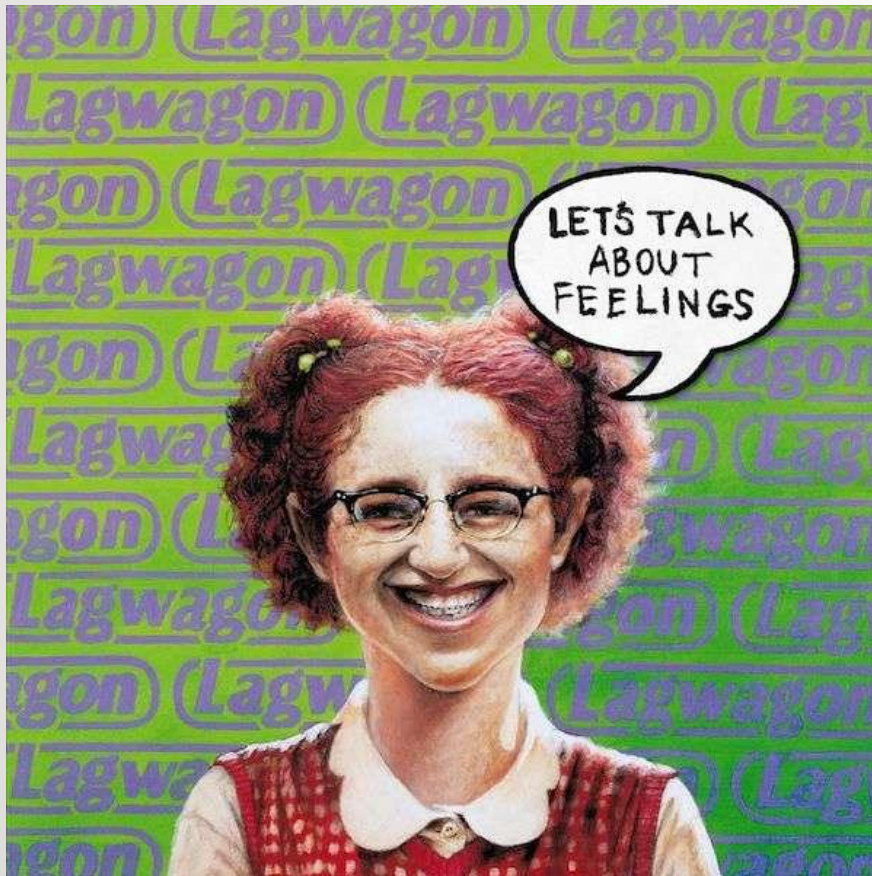
### Usage:

Spotify Radio

- Introduction
- Explicit/Implicit Feedback
- **Content-Based Filtering**
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But which features to compare?



- Artist
- Album Cover
- Lyrical Meaning
- Audio Signals
- ...



```
{
  "danceability" : 0.560,
  "energy" : 0.527,
  "key" : 2,
  "loudness" : -9.783,
  "mode" : 1,
  "speechiness" : 0.0374,
  "acousticness" : 0.516,
  "instrumentalness" : 0.0000240,
  "liveness" : 0.156,
  "valence" : 0.336,
  "tempo" : 93.441,
  "type" : "audio_features",
  "id" : "2z7D7kbpRcTvEdT71tdiNQ",
  "uri" : "spotify:track:2z7D7kbpRcTvEdT71tdiNQ",
  "track_href" : "https://api.spotify.com/v1/tracks/2z7D7kbpRcTvEdT71tdiNQ",
  "analysis_url" : "http://echonest-analysis.s3.amazonaws.com/TR/-ENytQjtFbuV9XJtXVpEI2tp9PXqI7k",
  "duration_ms" : 168720,
  "time_signature" : 4
}
```

Figure 1. Audio Features for a Spotify-Track

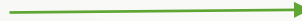
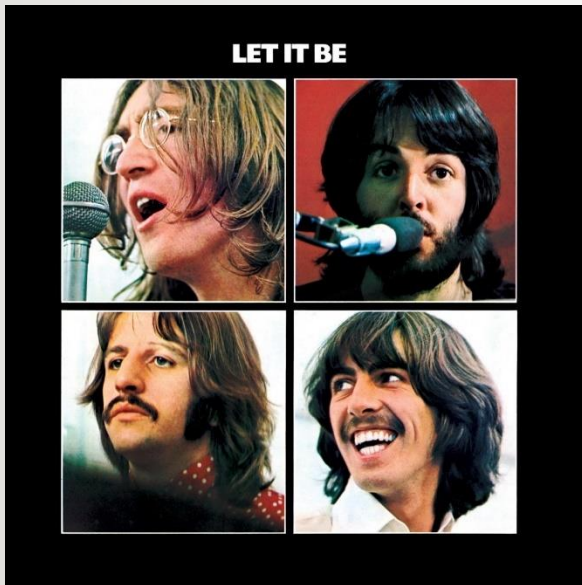


## The semantic gap in music

- the characteristics that affect user preference aren't equal to the corresponding audio signal.
- some properties are impossible to obtain from audio signals

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## Predictable Recommendations



## Spotify Radio

Create a Radio Channel based on:

- Song
- Album
- Artist
- Playlist

HAUPTMENÜ

Browse

Aktivitäten

Radio

DEINE MUSIK

Songs

Alben

Künstler

+ Neue Playlist



Because Of You  
Unwritten Law



May 16 - Acoustic von Lagwagon

TITEL-RADIO

NEUER SENDER



Because Of You

Unwritten Law



Finde heraus, was  
Deine Freunde  
hören.

FINDE FREUNDE



Julia Eger

Heartbeats – José Gonzá.

The Indie Mix



Ben Khan

Night Changes – One DirectL

Gully Pleasures



Sean Aquilina

Fleashing Lights – Kanye West

Graduation



Maddie Stocker

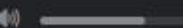
12m



0:58

3:03

SONGTEXTE



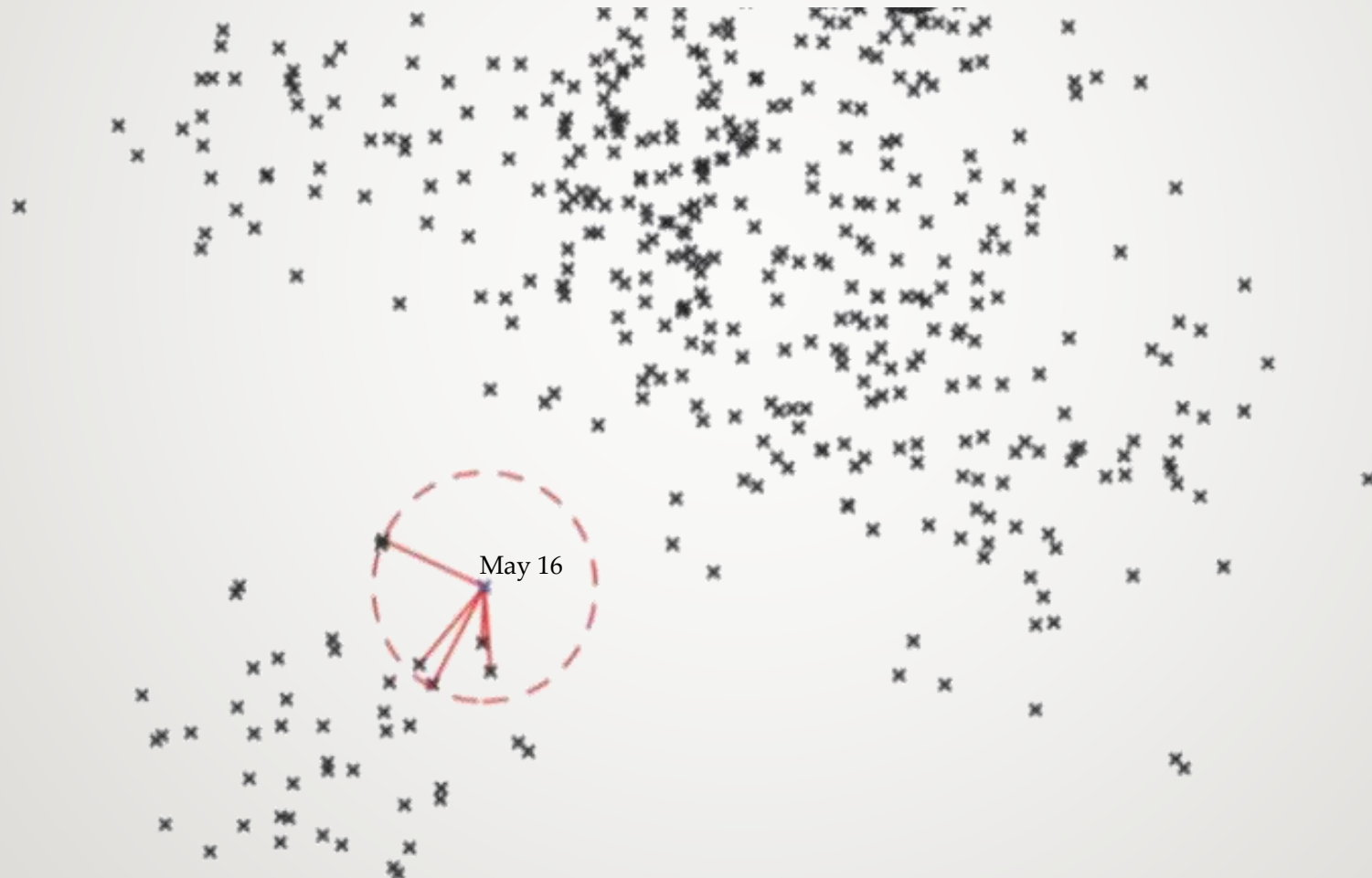
## Spotify Radio

- User plays radio -> load 250 nearest neighbors and shuffle
- Thumbs up -> Load more tracks from the thumbed-up song
- Thumbs down -> remove that song / re-weight tracks



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## Nearest Neighbors



## Spotify Radio

- User plays radio -> load 250 nearest neighbors and shuffle
- Thumbs up -> Load more tracks from the thumbed-up song
- Thumbs down -> remove that song / re-weight tracks

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## Collaborative Filtering

### Basic Idea:

What do other people (with a similar music taste) listen to?

### Usage:

Discovery Weekly Playlist

- Introduction
- Explicit/Implicit Feedback
- Content-Based Filtering
- **Collaborative Filtering**
- Conclusion

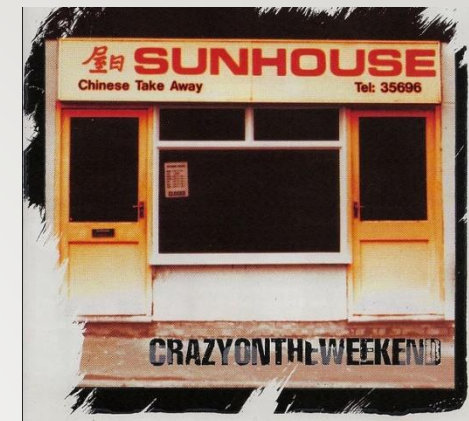
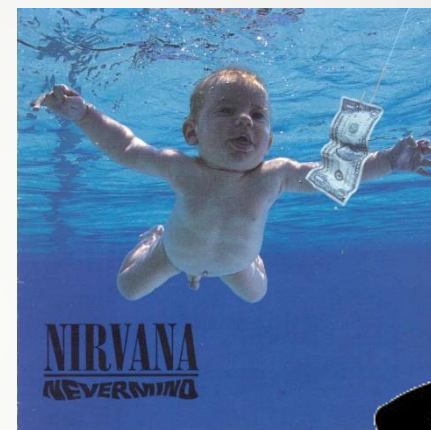
20



A:



B:



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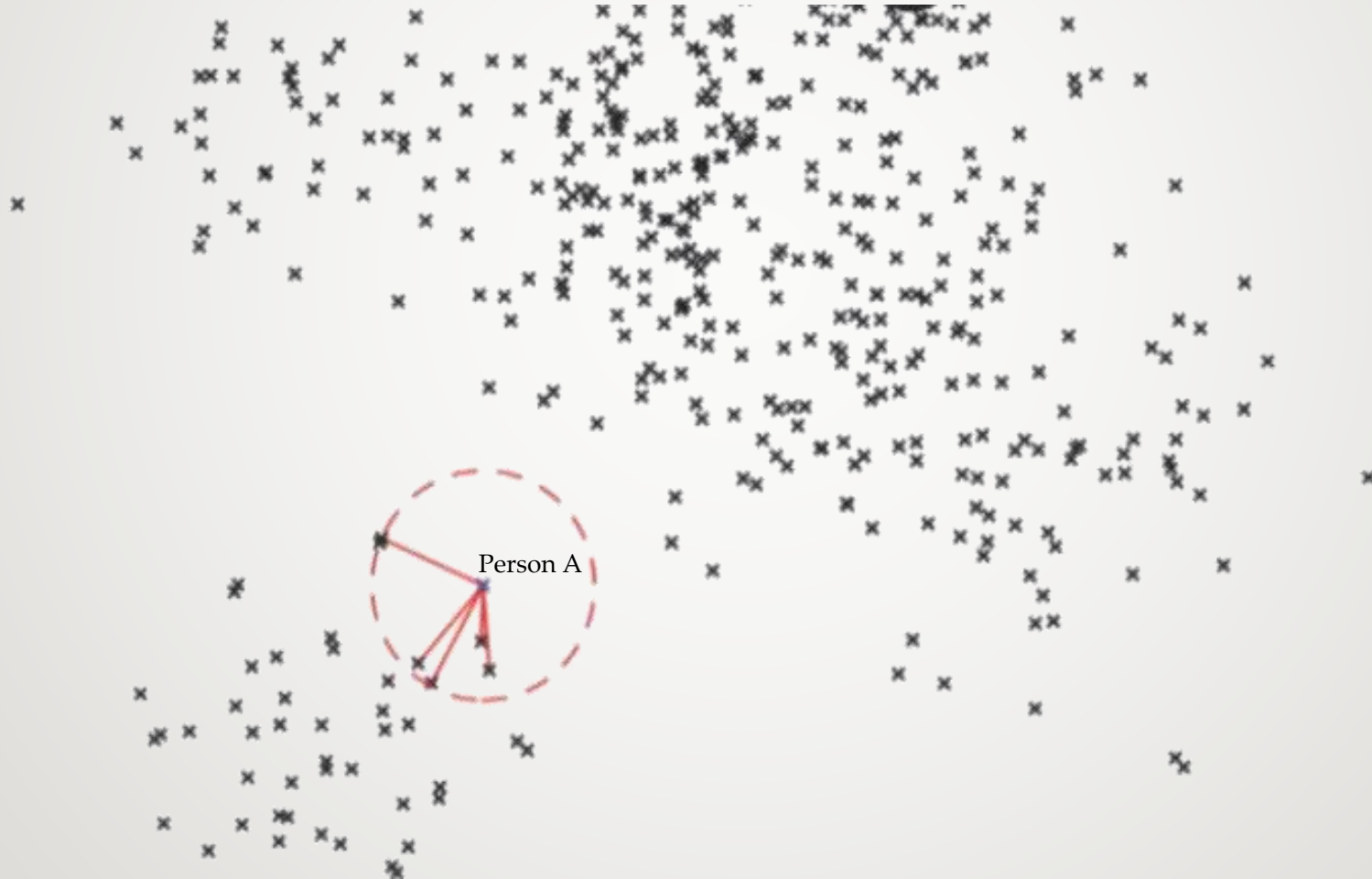
A very big matrix...

$$M = \underbrace{\begin{pmatrix} c_{11} & c_{12} & \dots & c_{1n} \\ c_{21} & c_{22} & \dots & c_{2n} \\ \vdots & & & \vdots \\ c_{m1} & c_{m2} & \dots & c_{mn} \end{pmatrix}}_{30\text{mio items}} \left. \vphantom{\begin{pmatrix} c_{11} & c_{12} & \dots & c_{1n} \\ c_{21} & c_{22} & \dots & c_{2n} \\ \vdots & & & \vdots \\ c_{m1} & c_{m2} & \dots & c_{mn} \end{pmatrix}} \right\} 100\text{mio users}$$



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## Nearest Neighbors



# Implicit Matrix Factorization

$$\begin{array}{c} \text{Users} \end{array} \begin{pmatrix} 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{pmatrix} \approx \underbrace{\begin{pmatrix} X \end{pmatrix}}_f \left( \begin{array}{c} Y \end{array} \right) \Bigg\}^e$$

Songs

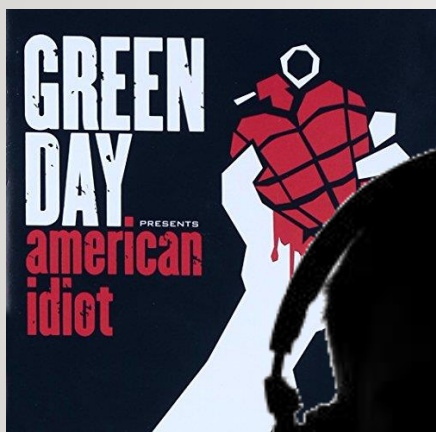
- $p_{ui} = \begin{cases} 1, & \text{user } u \text{ has listened to song } i \\ 0, & \text{user } u \text{ hasn't listened to song } i \end{cases}$
- Goal :  $x_u^* y_i = p_{ui}$
- $c_{ui}$  : describes the confidence, that user  $u$  likes song  $i$
- $\lambda$  : regularization penalty to avoid overfitting

$$\min_{x,y} \sum_{u,i} c_{ui} (p_{ui} - x_u^T * y_i)^2 + \lambda \left( \sum_u \|x_u\|^2 + \sum_i \|y_i\|^2 \right)$$

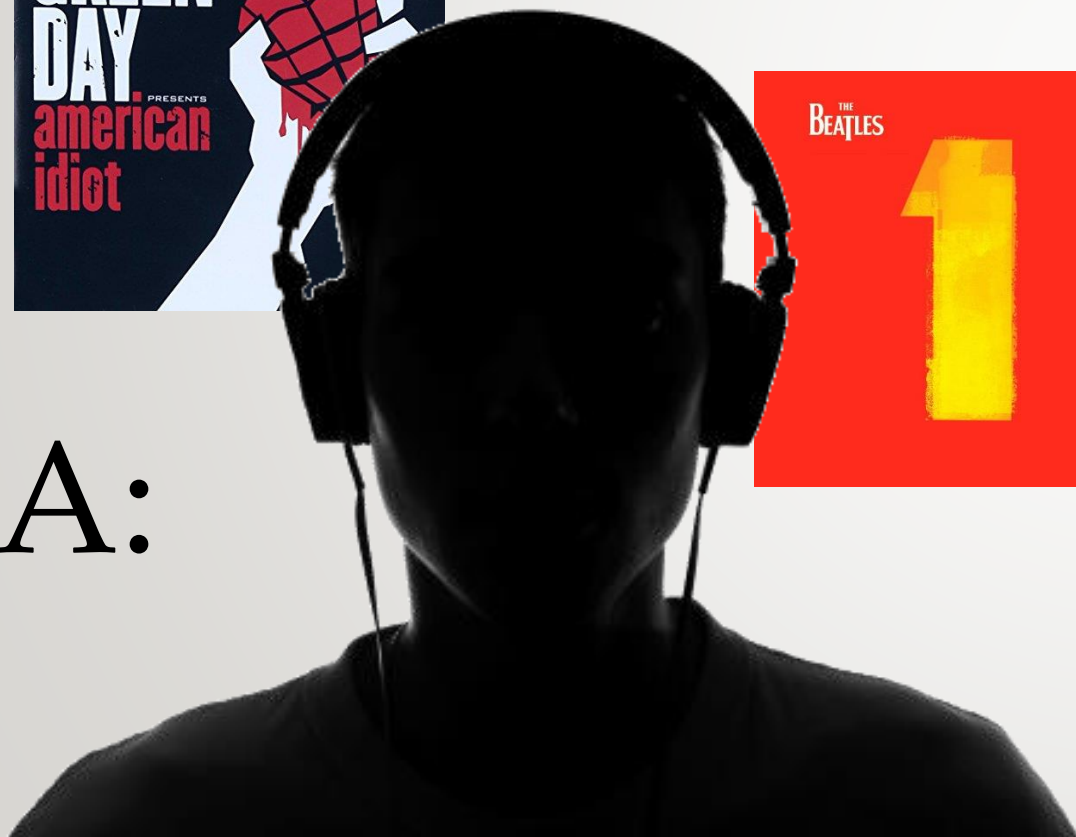
## Alternating Least Squares

1. Initialize user & item vectors
2. Fix item vectors and solve for optimal user vectors  $x_u = (Y^T C^u Y + \lambda I)^{-1} Y^T C^u p(u)$ 
  - Take the derivative of loss function with respect to user's vector, set equal to 0 and solve
3. Fix user vectors and solve for optimal item vectors  $y_i = (X^T C^i X + \lambda I)^{-1} X^T C^i p(i)$
4. Repeat until convergence

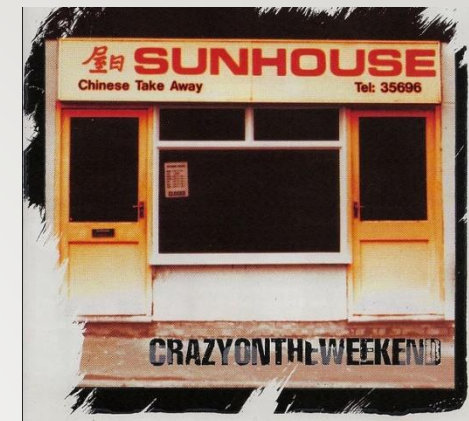
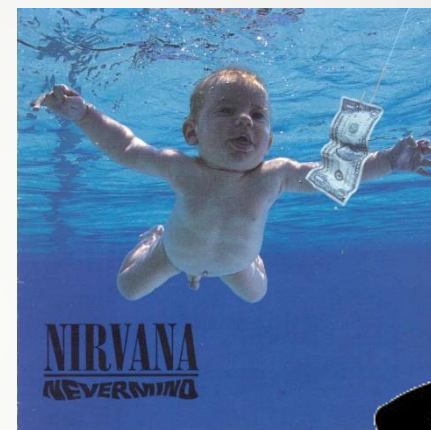
25



A:



B:



## The Harry-Potter Effect:

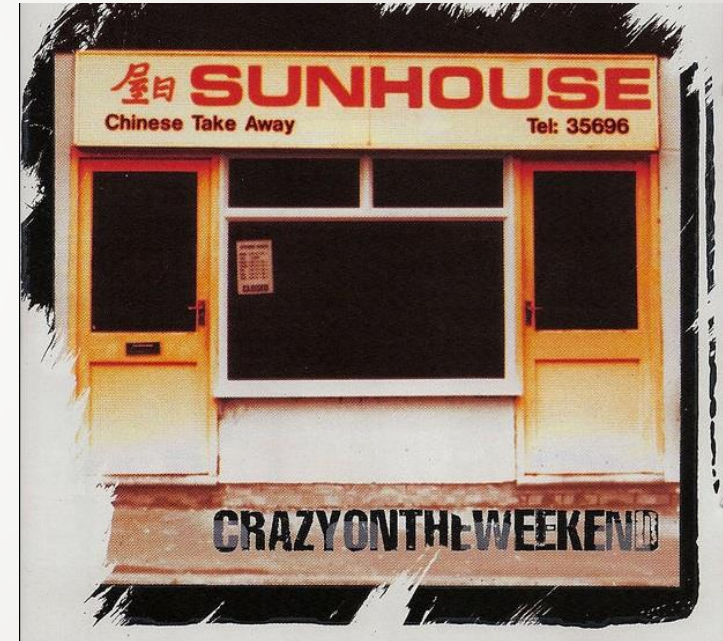


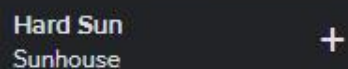


The Harry-Potter Effect:



The Cold-Start Problem:






FOLLOWER 711

ÄHNLICHE KÜNSTLER

BELIEBT

ÄHNLICHE KÜNSTLER


  **Hard Sun**



30.957

Ed Harcourt

# Discover Weekly Playlist



PLAYLIST

## Dein Mix der Woche

Dein wöchentlicher Musikmix. Speichere Deine Lieblingssongs in der Bibliothek. Jeden Montag gibt es eine neue Auswahl speziell für Dich!

Dein Mix der Woche

PLAY FOLGE ICH

FOLLOWER 1

Erstellt von: Spotify • 30 Songs, 2 Std. Offline verfügbar

	SONG	KÜNSTLER	ALBUM		
+	Ein Herz kann man nicht reparieren (feat. Ing...	Udo Lindenberg, Inga Humpe	MTV Unplugged - Live aus dem H...	vor 4 Tagen	4:43
+	4th Of July	Amy Macdonald	Life In A Beautiful Light (Deluxe V...	vor 4 Tagen	3:48
+	Down Down Down	Itchy Poopzki	Lights out London	vor 4 Tagen	3:30
+	Too Many Friends	Placebo	Loud Like Love	vor 4 Tagen	3:35
+	Ich sang die ganze Zeit von dir	Tomte	Buchstaben über der Stadt	vor 4 Tagen	4:23

# Discover Weekly Playlist

Other users create  
billions of Playlists

Spotify  
identifies  
similar  
songs

You listen to  
and save songs

Develops  
„Taste  
Profile“

Spotify  
finds songs  
that fit  
your  
profile

Discover  
Weekly Playlist

- ....  
- ....  
- ....  
- ....  
- ....  
- ....  
- ....



## The Spotify blob that represents my musical tastes

Core taste preferences →

White line = Discover Weekly songs

### Funk/soul

- > The Jackson 5
- > James Brown
- > Allen Toussaint

### Indie folk/rock

- > Passion Pit
- > The Arcs
- > José González

Kids' songs  
(for my daughter)  
> Susie Tallman

### Folk, Singer-songwriter

- > Joni Mitchell
- > Brenton Wood
- > The Beach Boys



# Conclusion

## Content-Based Filtering



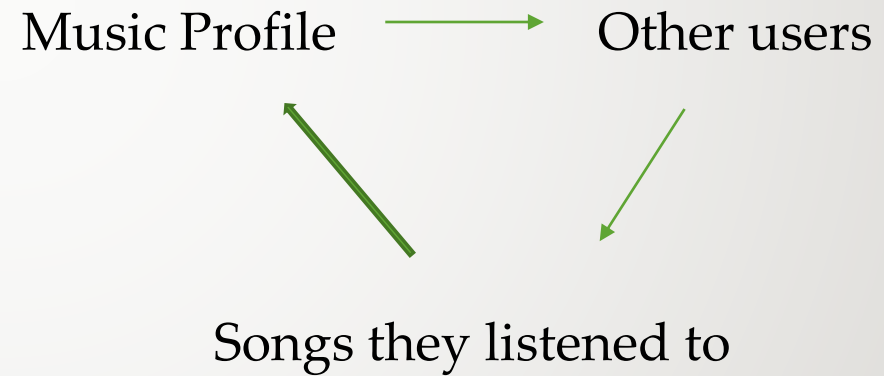
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- **Conclusion**

## Conclusion

### Content-Based Filtering



### Collaborative Filtering



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## Conclusion



## References

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