

# APCOMP 297r Capstone Project



# Spotify®

## Final Presentation

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# Spotify® Music in perspective

Spotify's key mission is to help people find the right music every moment, for every mood.



Music streaming services:  
\$47.5 billion dollar industry worldwide



Spotify has more than 200 petabytes of data, for context Netflix's has ~60 petabytes.

Personalization and automatization is key to growth.



# Spotify® State of the art for playlists



“The truffle pig”: Spotify’s tool to help editorial staff build playlists

“curates mood and occasion specific playlists...searches for songs based on **adjectives** or **feelings**...created in part by algorithms and music experts”

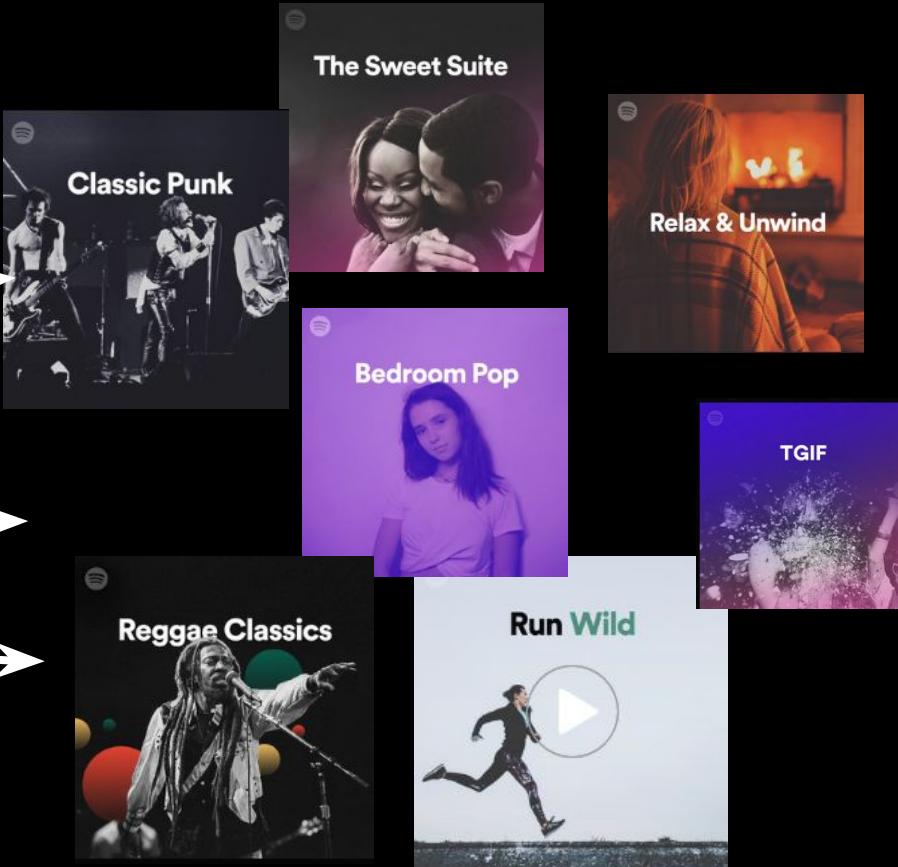
”

# Challenge: Choosing the “right” playlist is context dependant



Mood  
Activity  
Artists  
Popularity  
Order

?



**Random  
User**

# Our goal: “Smart” Continuation of Playlists

PLAYLIST  
Industrial

Created by: Bernard Gingras • 28 songs, 2 hr 12 min

| TRACK                            | ARTIST          | TIME | ALBUM               |
|----------------------------------|-----------------|------|---------------------|
| + Closer                         | Nine Inch Nails | 6:13 | The Downward Spiral |
| + The Hand That Feeds            | Nine Inch Nails | 3:32 | With Teeth          |
| + Copy of a                      | Nine Inch Nails | 5:23 | Hesitation Marks    |
| + Wish                           | Nine Inch Nails | 3:47 | Broken              |
| + Megalomaniac (Single Mix Edit) | KMFDM           | 3:10 | Greatest Shit       |
| + Juke-Joint Jezebel             | KMFDM           | 5:40 | Nihil               |
| + Light                          | KMFDM           | 6:12 | Angst               |

?

|                         |                |      |                          |
|-------------------------|----------------|------|--------------------------|
| + My Monkey             | Marilyn Manson | 4:31 | Portrait Of An Americ... |
| + Jesus Built My Hotrod | Ministry       | 4:53 | KE*A*H** (Psalm 69)      |
| + Just One Fix          | Ministry       | 5:10 | KE*A*H** (Psalm 69)      |
| + N.W.O.                | Ministry       | 5:30 | KE*A*H** (Psalm 69)      |
| + More Human Than Human | White Zombie   | 4:28 | Best Of/20th Century     |
| + Thunder Kiss '65      | White Zombie   | 3:55 | Best Of/20th Century     |

|                  |                       |      |                         |
|------------------|-----------------------|------|-------------------------|
| + Black Sunshine | White Zombie, Iggy... | 4:49 | La Sexorcisto: Devil... |
| + Assimilate     | Skinny Puppy          | 6:57 | Bites                   |
| + Furios         | Armageddon Dildos     | 6:19 | Untergrund              |
| + Evil Speaks    | Leæther Strip         | 3:52 | Satanic Reasons - Th... |
| + Motorskill     | 16 Volt               | 5:13 | The Best Of Sixteen...  |

|               |                   |      |                         |
|---------------|-------------------|------|-------------------------|
| + Assimilate  | Skinny Puppy      | 6:57 | Bites                   |
| + Furios      | Armageddon Dildos | 6:19 | Untergrund              |
| + Evil Speaks | Leæther Strip     | 3:52 | Satanic Reasons - Th... |
| + Motorskill  | 16 Volt           | 5:13 | The Best Of Sixteen...  |
| + Uplift      | 16 Volt           | 3:51 | The Best Of Sixteen...  |

# Our data: the million playlist dataset



Most comprehensive generally available playlist dataset available and first of its kind.



- 50 to 250 tracks,
- 66 on average per playlist
- 2.2 million unique tracks
- 300k unique artists.
- Most playlist come from US
- Young demographic



- We augment with additional data
- Lyric, Genre, Audio Feature, Genius and User Survey

# Our approach: Pooling and ranking

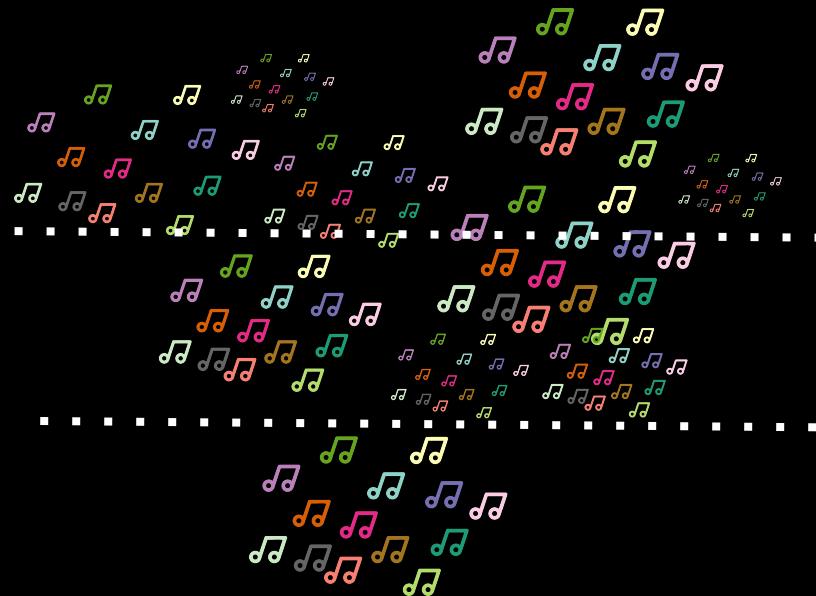
Making our problem more manageable

Initial set of songs



2.2 m songs

Pooling



10k songs



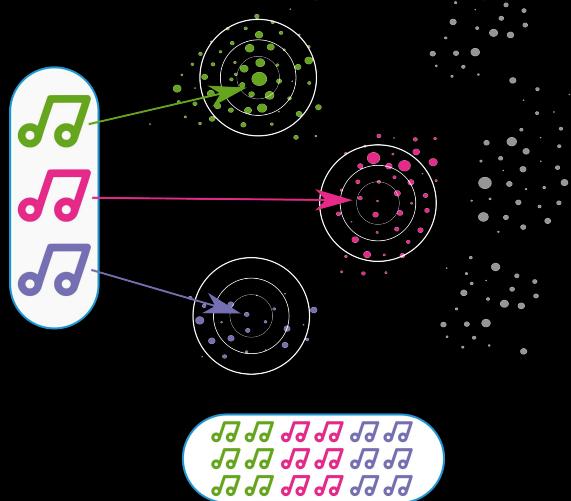
Ranking

500 songs

# Our model: Pooling (Track2Vec)

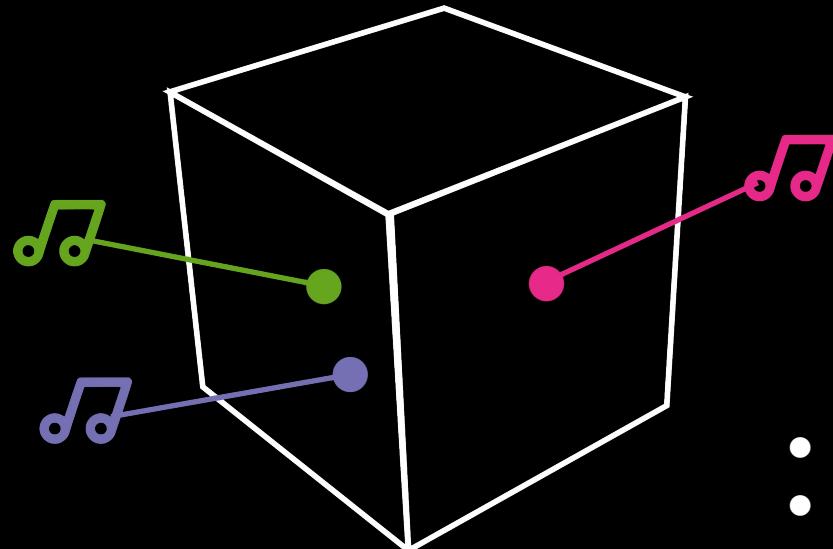
We treat each **song** as a “**word**” in a **playlist** (“**sentence**”).

Picking “good” centroids/medoids from our vector space



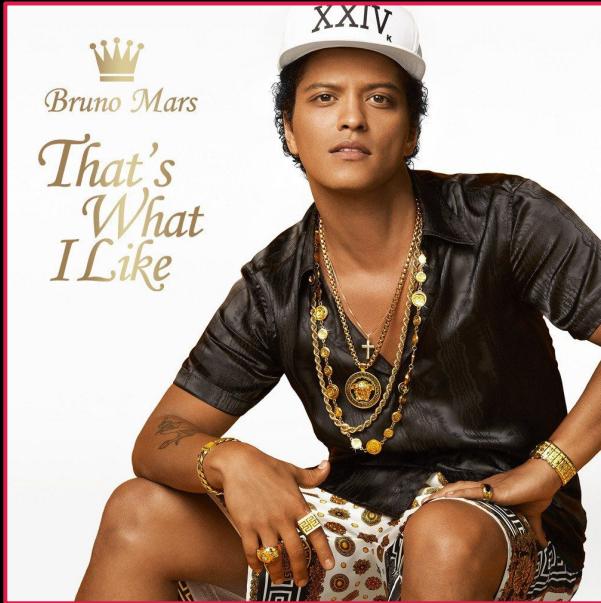
# Ranking tools: Embeddings of data

Learning how to fit different data sources into a vector space



- **Track2Vec**
- **word2vec**
- **sense2vec**
- **LSTM embeddings**

# Our Focus: Incorporating different types of information



**Artist:** Bruno Mars



**Album:** 24K Magic



**Genres:** Contemporary R&B, New jack swing, Hip hop soul



**Lyrics:** "...Strawberry champagne on ice.."



**Popularity:** 100



**Audio Features:** Danceability, Energy, Speechiness, Tempo , etc.



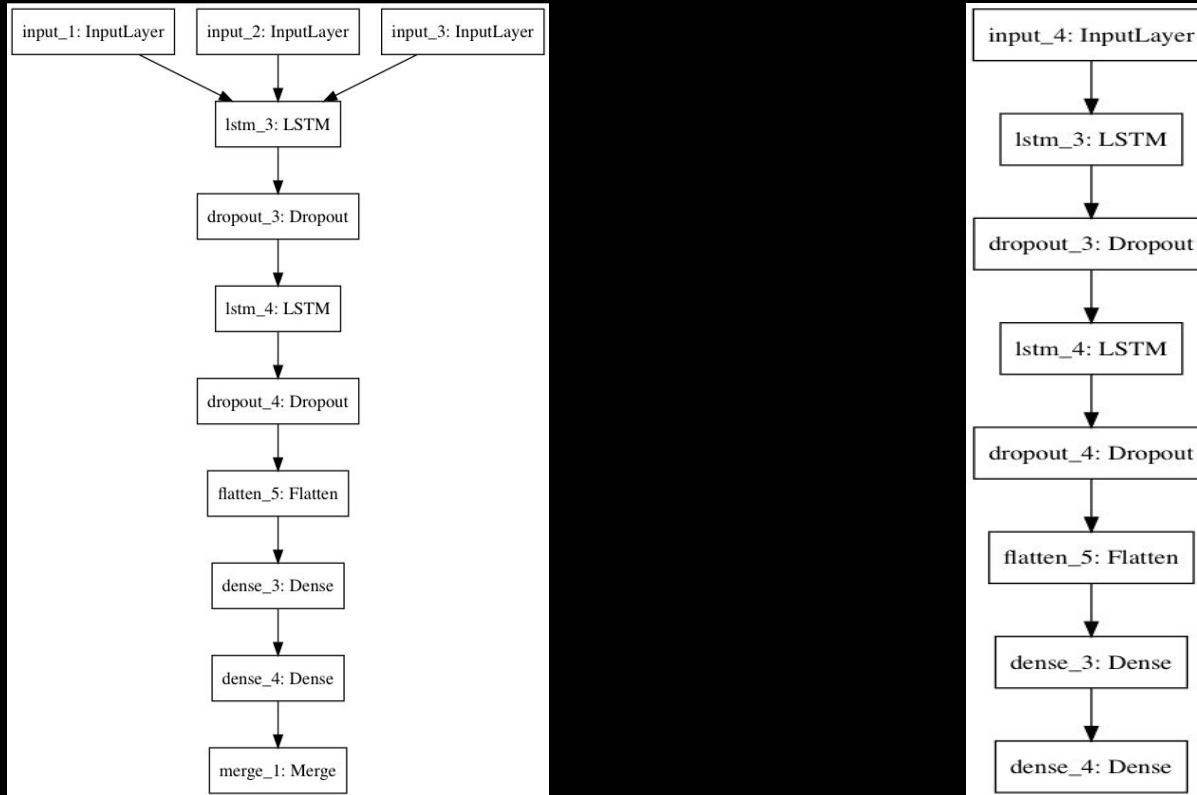
**Genius Annotations:**

"In doing so, he implies that the girl can have it all with him"



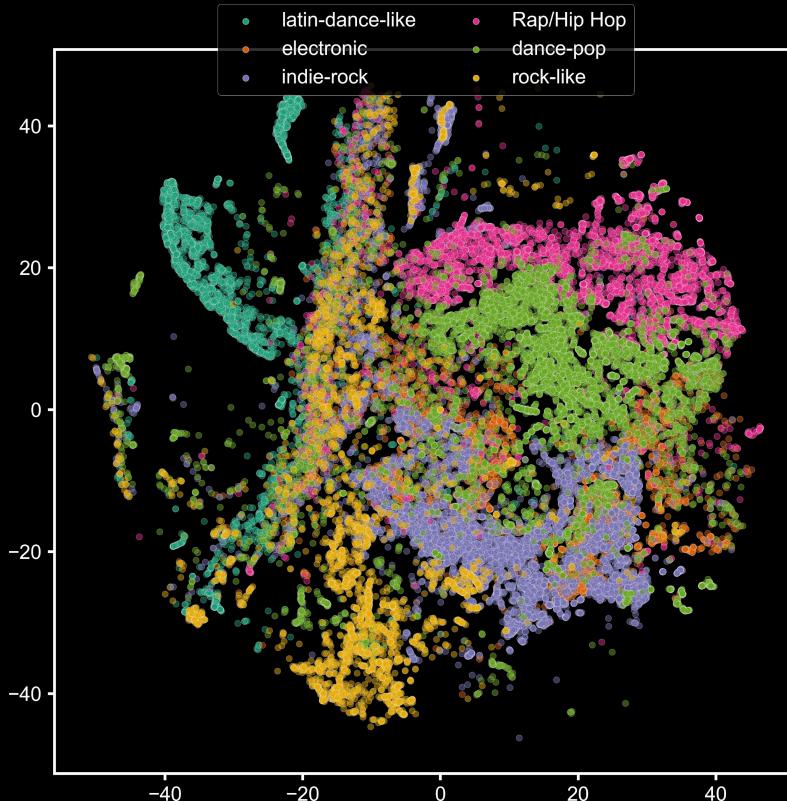
**Youtube Comments:** "Lol sugar daddy anthem. Haha"

# Explaining Embeddings: LSTMs



# Does it make sense?: Embedding of data

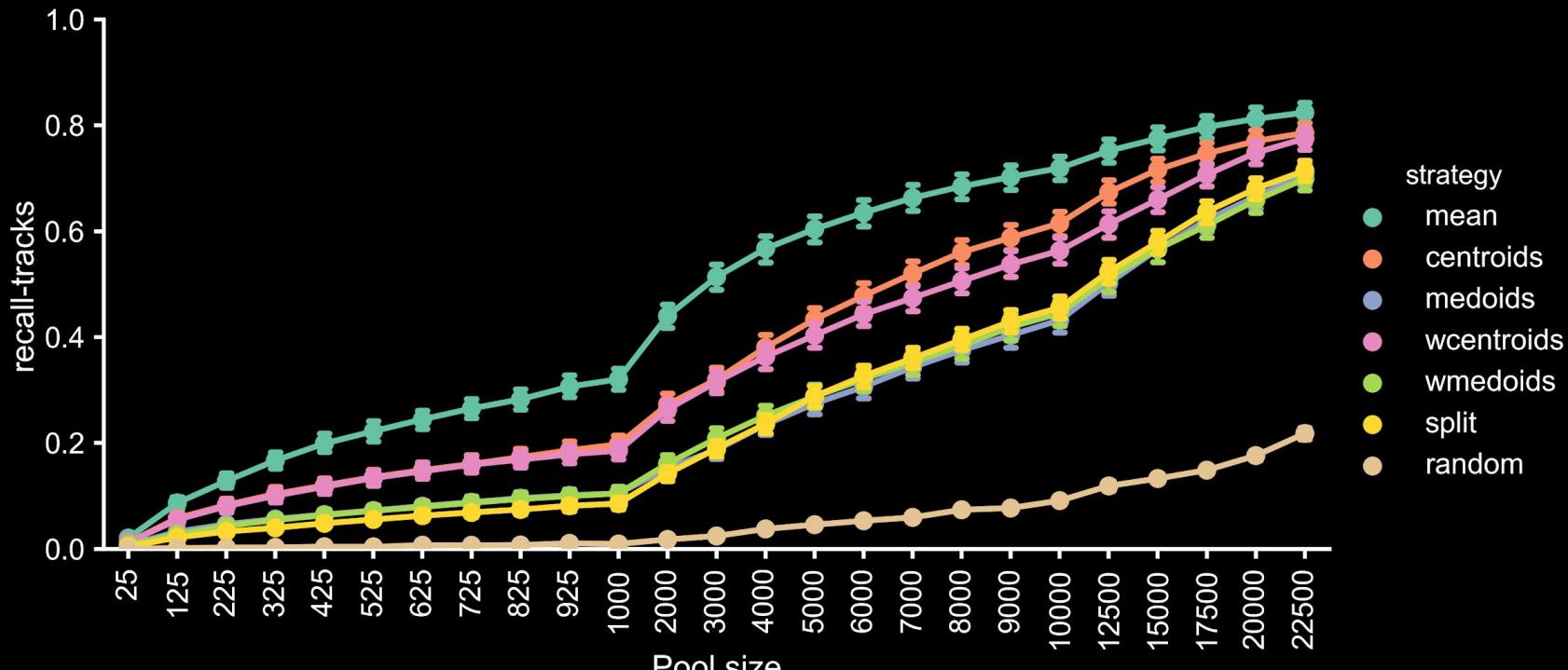
Visualizing the track embedding space with t-SNE, coloring genre topics



- Genres has been clustered with LDA
- Takes into account playlist co-occurrences.
- Works like collaborative filtering.

# Our model: Pooling

Picking “good” centroids/medoids from our vector space



# Our model: Pooling

Picking “good” centroids/medoids from our vector space

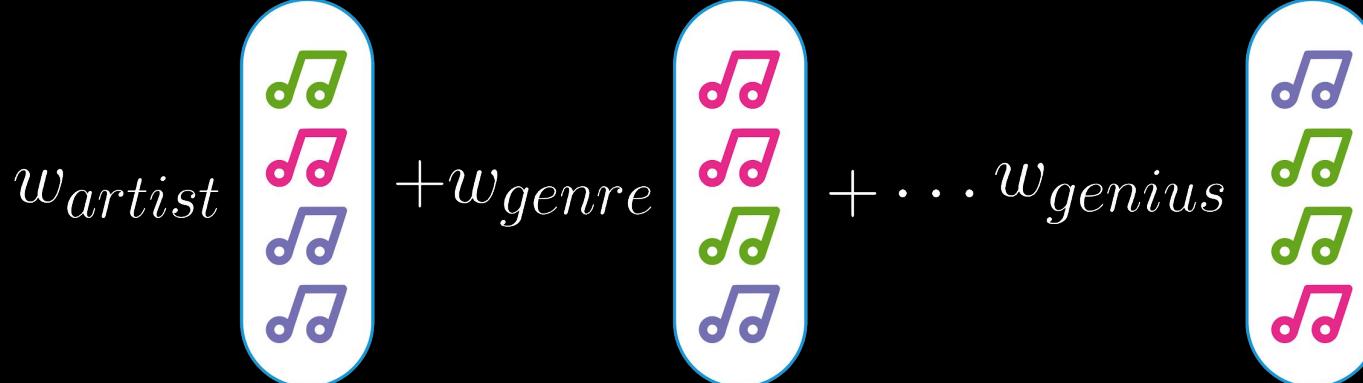
| k   | recall-tracks<br>mean (std) | recall-artist<br>mean (std) |
|-----|-----------------------------|-----------------------------|
| 5   | 0.703 (0.256)               | 0.869 (0.162)               |
| 10  | 0.726 (0.248)               | 0.877 (0.163)               |
| 25  | 0.740 (0.243)               | 0.889 (0.147)               |
| 100 | 0.722 (0.243)               | 0.894 (0.163)               |

# Our model: Ranking

Learning the optimal mix of all types of information

Bayesian black box optimization of **weights** and  
**distance measures** for each type of feature

$$D_{rank} = \sum_{f \in features} w_f D_f(pool) =$$





# Our model: Ranking

Results on ranking

<https://recsys-challenge.spotify.com/leaderboard>

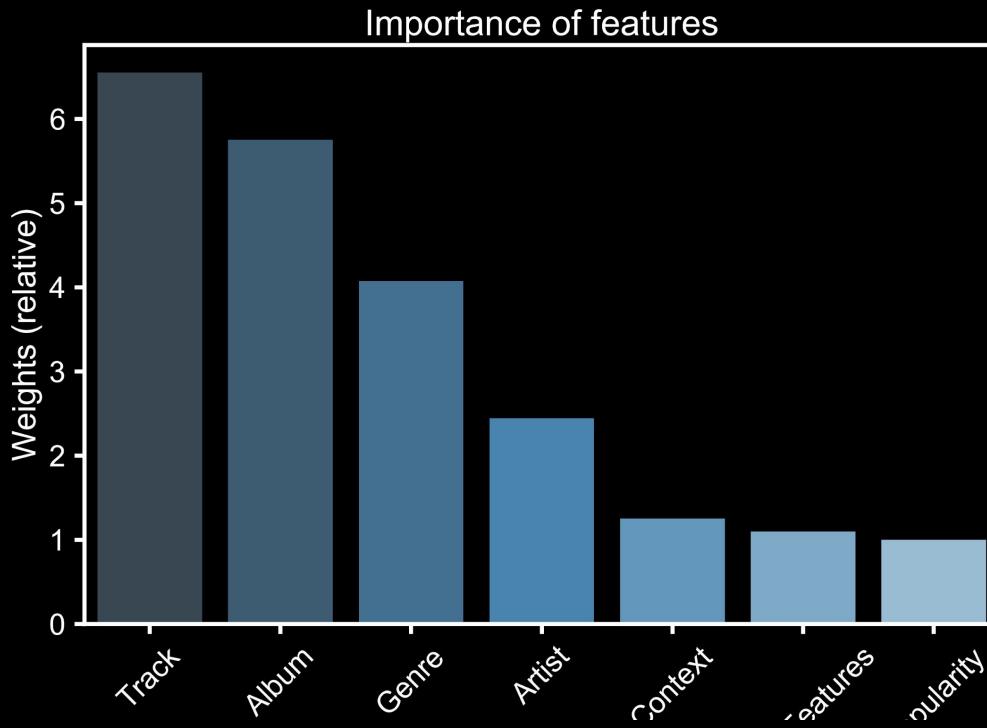
\*Not a fair comparison

| k   | r-precision tracks | r-precision artist | NDCG tracks | NDCG artist |
|-----|--------------------|--------------------|-------------|-------------|
| 5   | 0.31               | 0.40               | 0.19        | 0.56        |
| 10  | 0.30               | 0.42               | 0.17        | 0.51        |
| 25  | 0.32               | 0.40               | 0.19        | 0.53        |
| 50  | 0.25               | 0.39               | 0.17        | 0.49        |
| 100 | 0.20               | 0.36               | 0.18        | 0.54        |

## Current ranking for the main track

| # | TEAM           | RPREC    | RPREC RANK | NDCG     | NDCG RANK | CLICKS | CLICKS RANK | BORDA | DATE                |
|---|----------------|----------|------------|----------|-----------|--------|-------------|-------|---------------------|
| 1 | MIPT_MSU       | 0.175683 | 1          | 0.360266 | 1         | 2.2278 | 2           | 107   | 2018-05-07 16:46:00 |
| 2 | vl6            | 0.174441 | 2          | 0.351682 | 3         | 2.6404 | 4           | 102   | 2018-05-08 14:05:21 |
| 3 | Freshwater Sea | 0.167571 | 6          | 0.351859 | 2         | 2.1334 | 1           | 102   | 2018-05-06 08:15:04 |
| 4 | Elysium        | 0.171978 | 4          | 0.349802 | 4         | 2.579  | 3           | 100   | 2018-05-05 14:49:12 |

# What did we learn?





# Example playlists

The screenshot shows a mobile application interface for a playlist. At the top, there's a header section with a play button icon, the title "Perfect", the artist "Ed Sheeran", and a small circular icon with two dots. Below this is a Spotify logo. The main area displays a list of five songs:

| Rank | Song Title       | Artist        | Duration |
|------|------------------|---------------|----------|
| 1    | Perfect          | Ed Sheeran    | 4:23     |
| 2    | All of Me        | John Legend   | 4:29     |
| 3    | Counting Stars   | OneRepublic   | 4:17     |
| 4    | Sorry            | Justin Bieber | 3:20     |
| 5    | Hey, Soul Sister | Train         | 3:36     |

The screenshot shows a mobile application interface for a "AutoGen2" playlist. At the top, there's a back arrow, the title "AutoGen2", a three-dot menu, and a "SHUFFLE PLAY" button with a green gradient background. Below this is a "Download" toggle switch. The main area lists several songs:

- Wish You Were Here (Pink Floyd • Wish You Were Here)
- Stairway To Heaven (Led Zeppelin • Led Zeppelin IV (Deluxe Edition))
- All Along the Watchtower (Jimi Hendrix • Electric Ladyland)
- Riders On The Storm (The Doors • L.A. Woman)
- Come As You Are (Nirvana • Nevermind (Remastered))

At the bottom, there's a navigation bar with icons for Home, Browse, Search, Radio, and Your Library, along with standard Android navigation buttons.

# UX Experiment

## Team Spotify: Survey

Survey to understand music and playlist choices of music enthusiasts

\* Required

### How are you feeling right now? \*

|            | Not At All            | A Little              | Moderately            | Quite A Lot           | Extremely             |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Happy      | <input type="radio"/> |
| Tired      | <input type="radio"/> |
| Dark       | <input type="radio"/> |
| Active     | <input type="radio"/> |
| Chill      | <input type="radio"/> |
| Lively     | <input type="radio"/> |
| Determined | <input type="radio"/> |
| Angry      | <input type="radio"/> |
| Neutral    | <input type="radio"/> |
| Annoyed    | <input type="radio"/> |
| Stressed   | <input type="radio"/> |
| Sad        | <input type="radio"/> |

NEXT

Playlist 10

Description (optional)

Livin' On The Edge - Aerosmith



Roses - The Chainsmokers



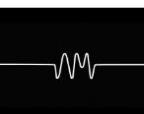
Cocaine - Eric Clapton



You Shook Me All Night Long - AC/DC



Do I Wanna Know? - Arctic Monkeys



When would you use the above playlist? \*

- Date Night
- Party
- Travel
- Workout/Running
- Breakup
- General

What mood do you associate with the above playlist? \*

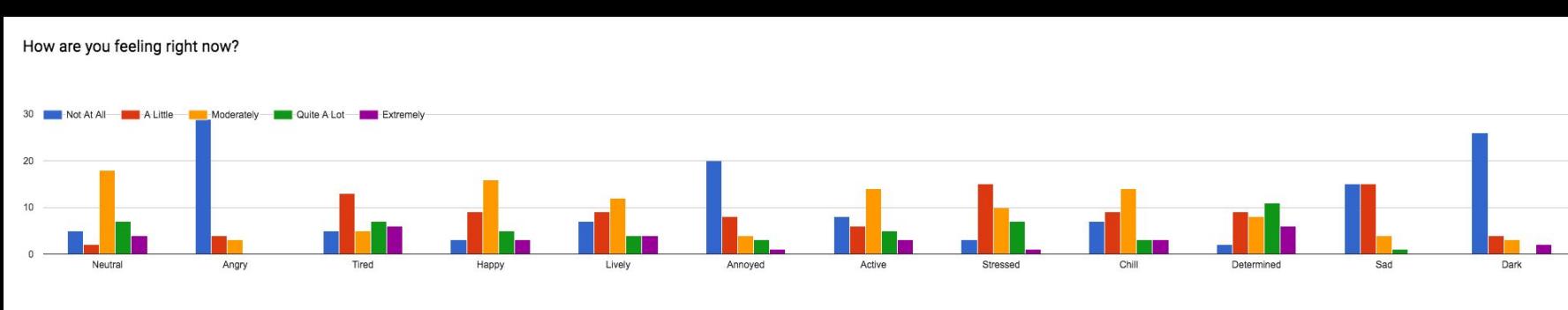
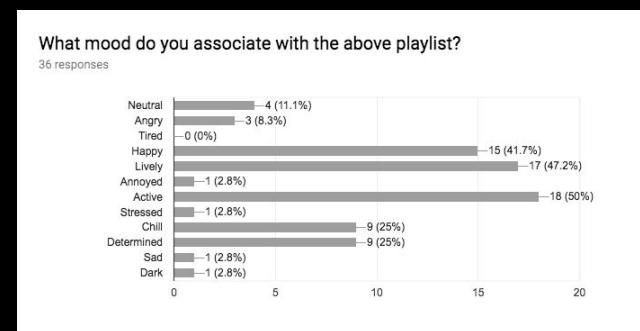
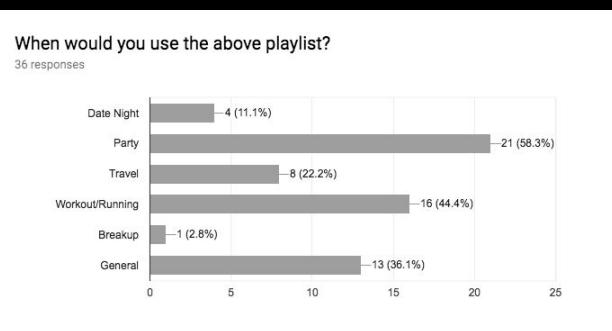
- Neutral
- Angry
- Tired
- Happy
- Lively
- Annoyed
- Active
- Stressed
- Chill
- Determined
- Sad
- Dark

# UX Experiment

Songs:

1. Livin' On The Edge - Aerosmith
2. Roses - The Chainsmokers
3. Cocaine - Eric Clapton
4. You Shook Me All Night Long - AC/DC
5. Do I Wanna Know? - Arctic Monkeys

From playlist called 'WorkoutJams'



# Next Steps

- Generate results for the million playlists.
- Harness user studies for utility conditioned playlists. (For ex: Dating vs Workout).
- Adding conditioning based on user mood at the time of creating playlist.
- Improving LSTM embeddings to prevent mode collapse.
- Improving contextual embedding (we tried sense2vec)
- Explore Bayesian methods for pooling

# Summary

- Playlist continuation
- Too many songs (200 petabytes): Hierarchical suggestion model
- Collaborative filtering like Pooling
- Ranking Goal: Harnessing multiple sources of data including context.
- Interpretable bayesian ranking.
- Bayesian: can be conditioned by utility.
- User studies to understand class conditioning.

Any questions?