Exploiting Music Play Sequence for Music Recommendation

CSE/ECE471 | SPRING 2019

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Base Paper

This project is an implementation of the following base paper:

- **Title:** Exploiting Music Play Sequence for Music Recommendation
- **Author:** Zhiyong Cheng and Jialie Shen, Lei Zhu, Mohan Kankanhalli, Liqiang Nie
- **Publication:** Proceedings of the Twenty-Sixth International Joint Conference on Artificial Intelligence (IJCAI-17)

Flow of presentation

Intro
- Motivation
- Problem Statement
- Proposed Solution

Module
- Data Preprocessing
- MF and BMF
- Song2Vec

Project
- Experimental Setup
- Results
- Future Directions

Misc.
- References
- Contributions

Introduction

- Users leave digital footprints when interacting with various music streaming services.
- Music play sequence (MPS), contains rich information about personal music preference and song similarity.
- MPS has been largely ignored in previously developed music recommender systems.

Picture Credit: https://i.pinimg.com/736x/cf/e9/e9/cfe9e94b429a75d57ab1b4e6b7edaab7.jpg

Motivation

- Include the much neglected Music Play Sequence (MPS) to make the song recommendation more relevant

Picture Credit: https://memegenerator.net/instance/54611478/dwight-meme-all-you-need-is-motivation-false-you-need-fear-and-an-approaching-deadline

Problem Statement:

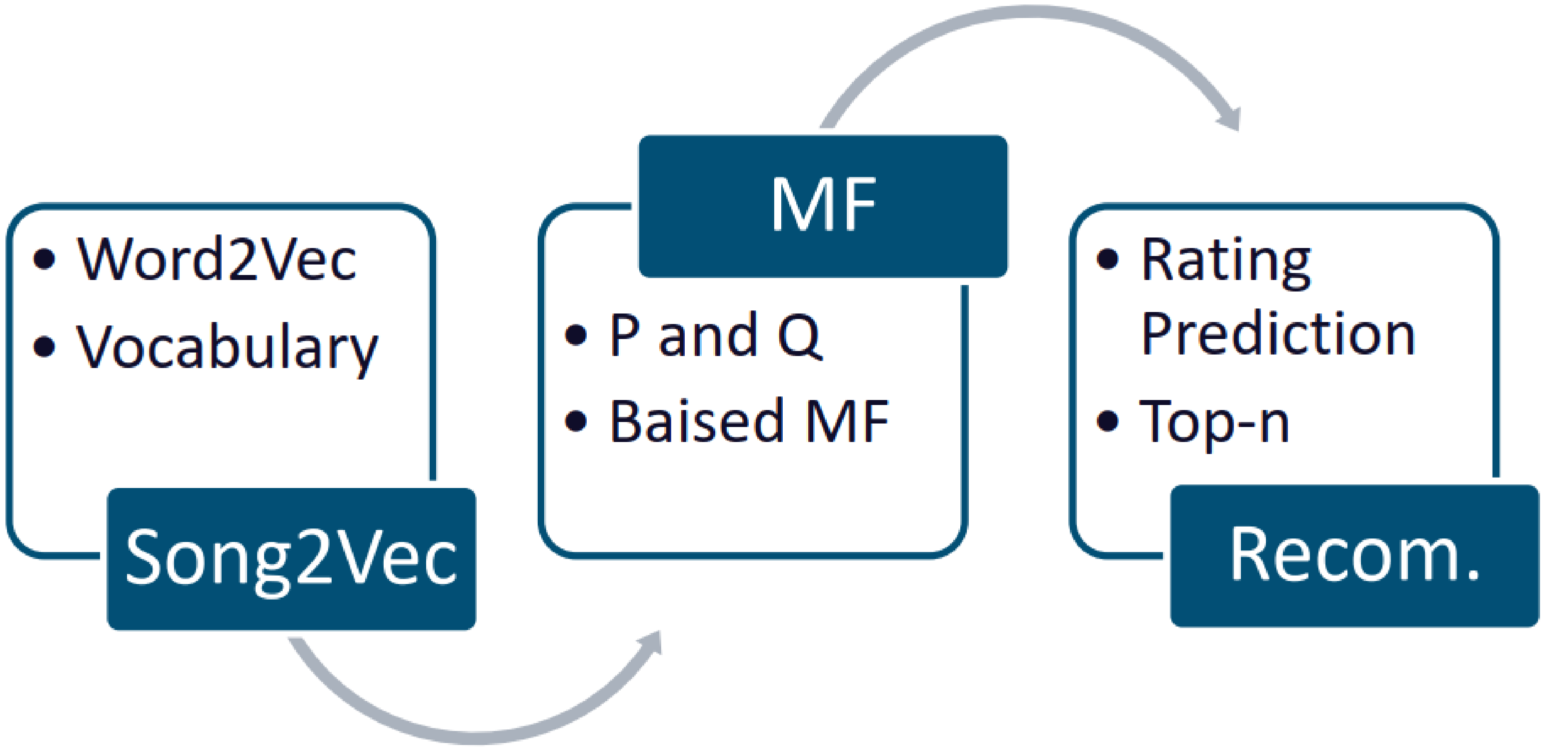
- Incorporate the effect of Music Play Sequence (MPS) along with Matrix Factorization (MF) methods to generate more relevant music recommendations.

Proposed Solution:

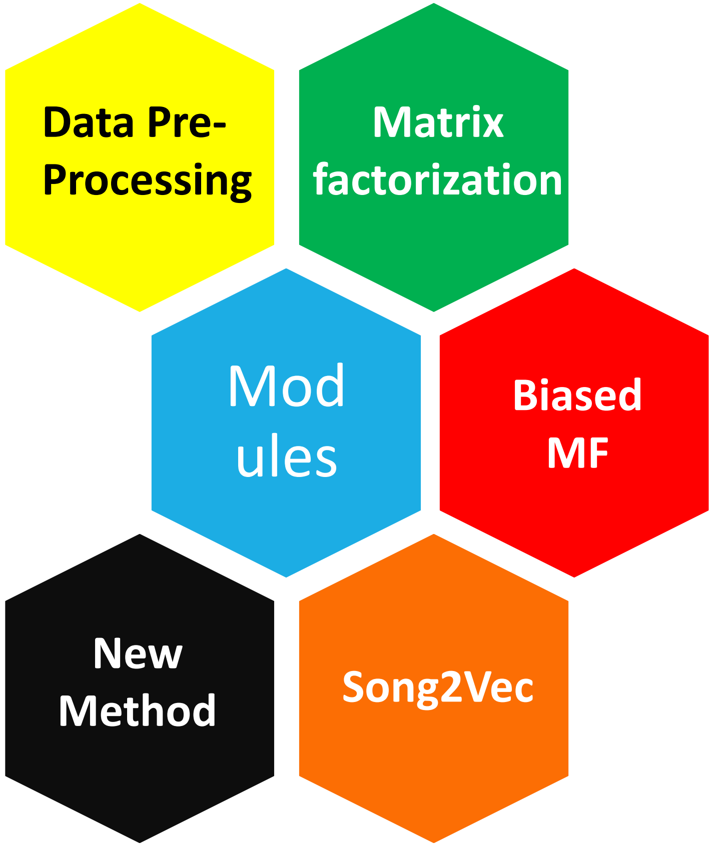
- Use word embedding techniques in MPS to estimate the similarity between songs.
- Embed learned similarity into matrix factorization
- k-nearest songs in the learning process to avoid the increase in time complexity

Picture Credit: https://clipartstation.com/wp-content/uploads/2018/10/have-clipart-6.jpg

Overview:


Word2Vec
Vocabulary
Song2Vec
MF
P and Q
Baised MF
Rating Prediction
Top-n
Recom.

Modules


Data Pre-Processing
Matrix factorization
Mod ules
Biased MF
New Method
Song2Vec

Data Processing

We are using Last.fm dataset, which has the following characteristics:

- No. of data points : 4752899
- No. of unique songs : 72678
- No. of unique users : 249

Snapshot of Raw Data

```
user_000001	2009-05-03T15:10:18Z	463a94f1-2713-40b1-9c88-dcc9c0170cae	Minus 8 4e78efc4-e545-47af-9617-05ff816
d86e2	Elysian Fields

user_000001	2009-05-03T15:04:31Z	ad0811ea-e213-451d-b22f-fa1a7f9e0226	Beanfield	fb51d2c4-cc69-4128-92f5
-77ec38d66859	Planetary Deadlock

user_000001	2009-05-03T14:56:25Z	309e2dfc-678e-4d09-a7a4-8eab9525b669	Dj Linus	4277434f-e3c2-41ae-9ce3
-23fd157f9347	Good Morning Love Coffee Is Ready

user_000001	2009-05-03T14:50:51Z	6f3d4a7b-45b2-4c08-9306-8d271e92cb4f	Alif Tree	1151b040-8022-4965-96d2
-8a4605ce456c	Deadly Species

user_000001	2009-05-03T14:46:29Z	463a94f1-2713-40b1-9c88-dcc9c0170cae	Minus 8 f78c95a8-9256-4757-9a9f-213df5c
6854e	Cold Fusion

user_000001	2009-05-03T14:39:20Z	45bdb5be-ec03-484f-b58d-d22afc944b24	Wei-Chi c4fc8802-d186-4c4d-85cd-d5d063b
935c2	Clouds
```

Data Processing

The following are the preprocessing steps used before using the data to train the model.

1. Exclude the users only listened to less than 10 songs
2. Exclude the songs which have been played by less than 10 users.
3. Exclude the irrelevant data columns i.e. song id, artist id, artist name

	UserID	TimeStamp	Song
0	1	2009-05-04T23:08:57Z	Fuck Me Im Famous (Pacha Ibiza)-09-28-2007
1	1	2009-05-04T13:54:10Z	Composition 0919 (Live_2009_4_15)
2	1	2009-05-04T13:52:04Z	Mc2 (Live_2009_4_15)
3	1	2009-05-04T13:42:52Z	Hibari (Live_2009_4_15)
4	1	2009-05-04T13:42:11Z	Mc1 (Live_2009_4_15)

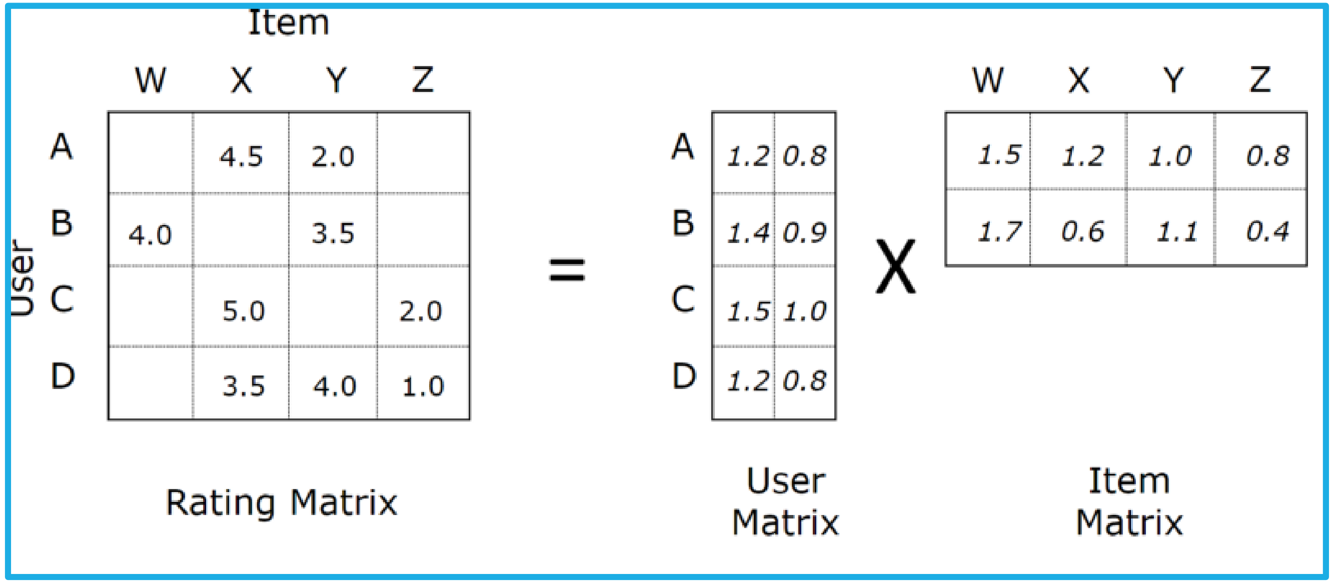
Music Play Sequence (MPS)

- Play event to be part of a session if it occurs no later than 800 seconds
- We only keep the listening sessions with no less than 10 songs.
- Number of sessions 125181 (with each session having 10 or more songs)


```
{1: [['Lust', 'The Essence', 'Idioteque', 'Change Of Seasons',
idal Reprise', 'Landing', 'Detchibe', 'Watching Windows', 'Rid
less', 'Id', 'Zazen Bo', 'What You Gonna Do?', 'Rusty Gears Lo
'], ['Ozma', 'Hint Oyaji', 'Cow', 'Cow', 'Extra Ignored', 'Hib
n The Forest (Interlude Mix)', 'Waltz For Jason (Full Nine Yar
', 'Gum', 'Clap & Whistle & Walking', 'The Star Spangle-Gayo']
Tune', 'More Than Ever People', 'Appreciation (Radio Mix)', 'P
re Is The Line', 'Vökuró', 'Öll Birtan', 'Who Is It', 'Submari
ss', 'Where Is The Line', 'Vökuró', 'Öll Birtan', 'Who Is It',
e Down', 'Surrender', 'Misunderstanding', '花狂い', 'Element Wa
de Mix)', 'Waltz For Jason (Full Nine Yards Re-Edit) (2 Banks
gle-Gayo', 'Music', 'Gum', 'Clap & Whistle & Walking', 'The St
```

Matrix Factorization

- Collection of feedback can be represented in a form of a matrix.
- **Row** represents users
- **Column** represents different songs.
- Sparse Matrix
- It can incorporate implicit feedback (derived by analyzing user behavior.)



Matrix Factorization

- Predicted user Rating : $\hat{r}_{ui} = \boldsymbol{q_i^T} \, \boldsymbol{p_u}$
- Optimization Objective : $\min\limits_{q^*, p^*} \sum_{(u,i)\in K} \left(r_{ui} - q_i^T p_u\right)^2 + \lambda\left(\|q_i\|^2 + \|p_u\|^2\right)$

Item

User	W	X	Y	Z
A		4.5	2.0	
B	4.0		3.5	
C		5.0		2.0
D		3.5	4.0	1.0

Rating Matrix

=

A	1.2	0.8
B	1.4	0.9
C	1.5	1.0
D	1.2	0.8

User Matrix

X

W	X	Y	Z
1.5	1.2	1.0	0.8
1.7	0.6	1.1	0.4

Item Matrix

Matrix Factorization

- Regularization term:

$$\boldsymbol{\lambda}(\|\boldsymbol{q_i}\|^{\mathbf{2}} + \|\boldsymbol{p_u}\|^{\mathbf{2}})$$

- Avoid decomposed matrix *q* and *p* to over-fit to the original matrix.
- Goal is to generalize the previous ratings in a way that predicts future-unknown ratings.

MF Learning Method

- Stochastic gradient descent
- Squared error loss function :

$$\boldsymbol{e_{ui} \triangleq r_{ui} - q_i^T p_u}$$

- Update rule :

$$\boldsymbol{q_i \leftarrow q_i + \gamma.(e_{ui}.p_u + \lambda.q_i)}$$
$$\boldsymbol{p_u \leftarrow p_u + \gamma.(e_{ui}.q_i + \lambda.p_u)}$$

Biased Matrix Factorization

- Some songs are biased in that it is widely perceived better (or worse) than other song.
- Some users may be biased too.
- Include the bias terms into our original equation.

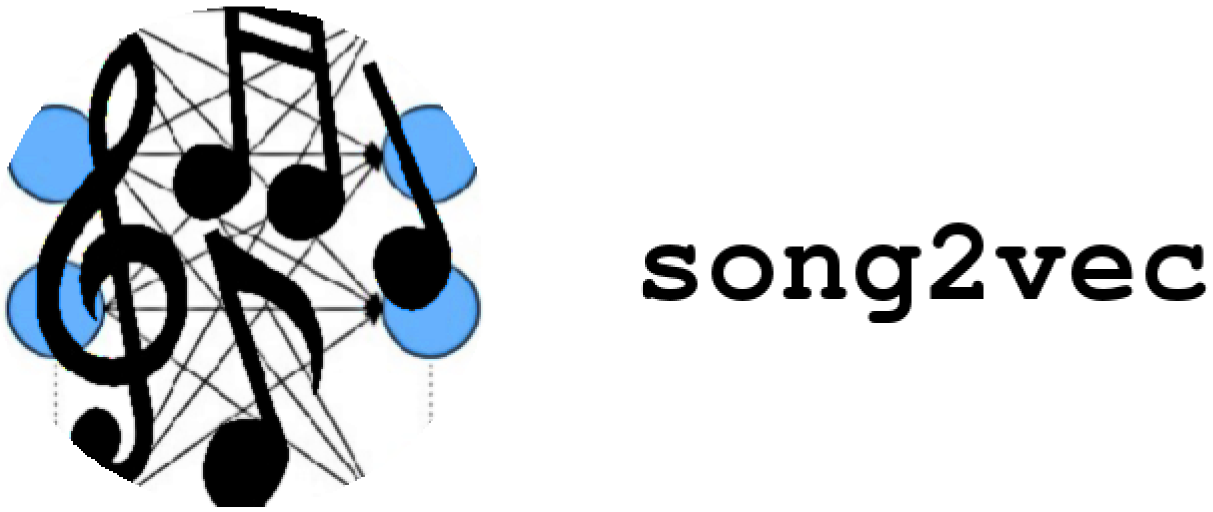
$$\hat{r}_{ui} = \boldsymbol{\mu} + \boldsymbol{b_i} + \boldsymbol{b_u} + \boldsymbol{q_i^T p_u}$$

- The new objective function would look something like below

$$\min_{q^*,p^*,b^*} \sum_{(u,i)\in K} \left(\boldsymbol{r_{ui}} - \boldsymbol{\mu} - \boldsymbol{b_u} - \boldsymbol{b_i} - \boldsymbol{p_u^T q_i}\right)^2 + \boldsymbol{\lambda}\left(||\boldsymbol{p_u}||^2 + ||\boldsymbol{q_i}||^2 + \boldsymbol{b_u^2} + \boldsymbol{b_i^2}\right)$$

Song2Vec

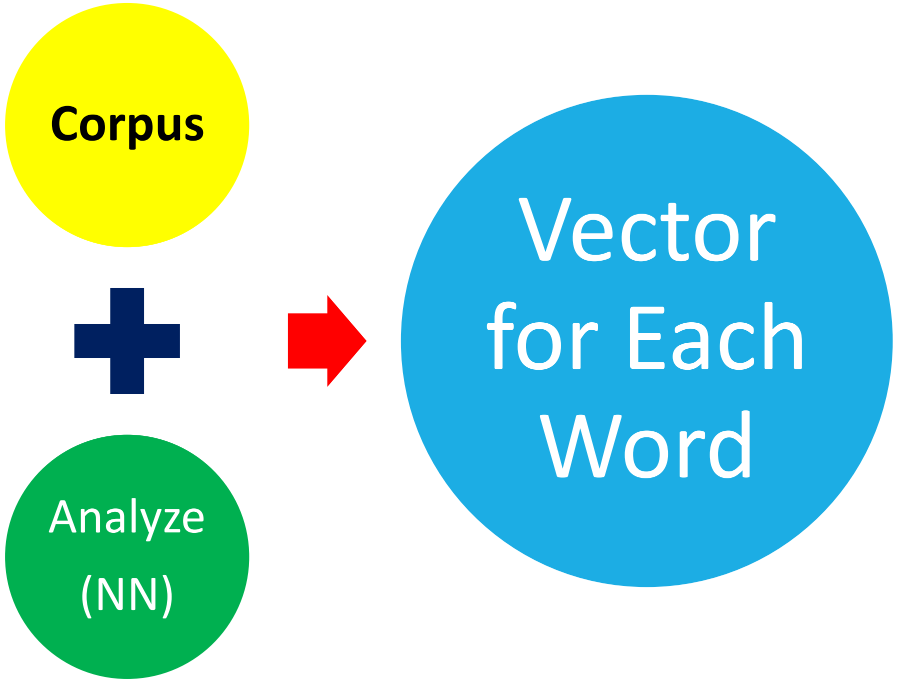
- Capture what songs are listened to frequently together in very similar contexts.
- This is where Word2Vec comes in.



Picture Credit: https://github.com/ruanchaves/song2vec

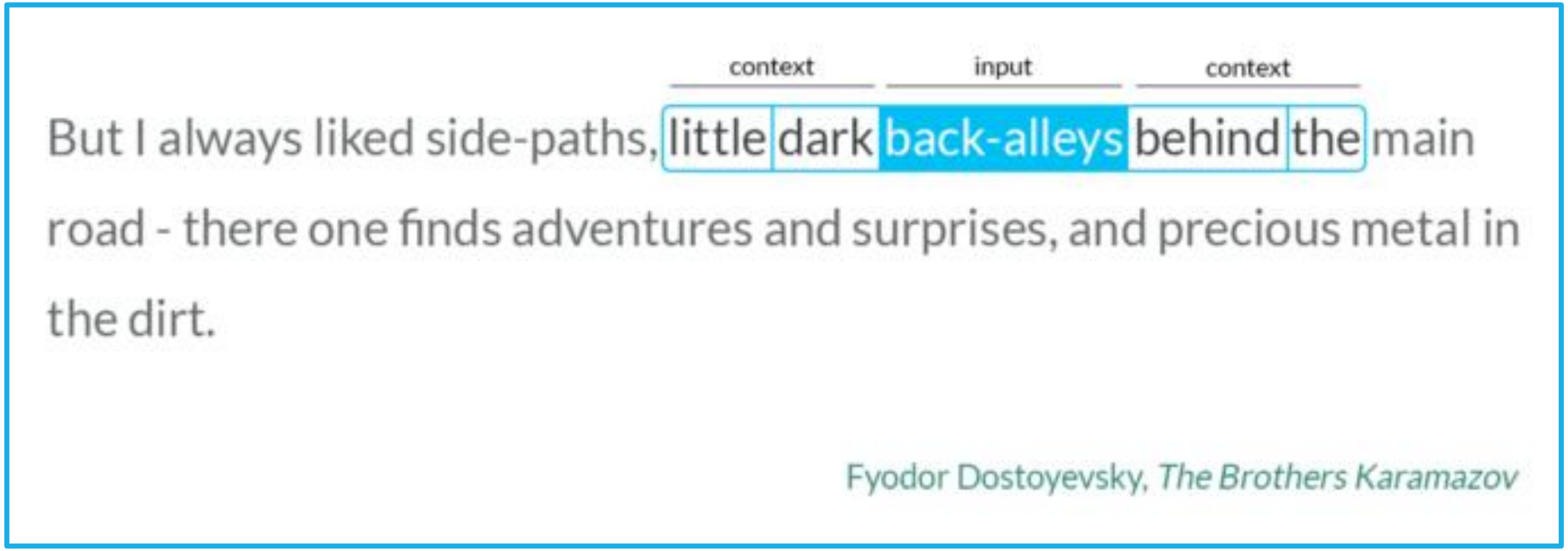
Word2Vec

- Word2vec is a class of neural network models.
- Introduced for learning word embedding’s that are highly useful for NLP.



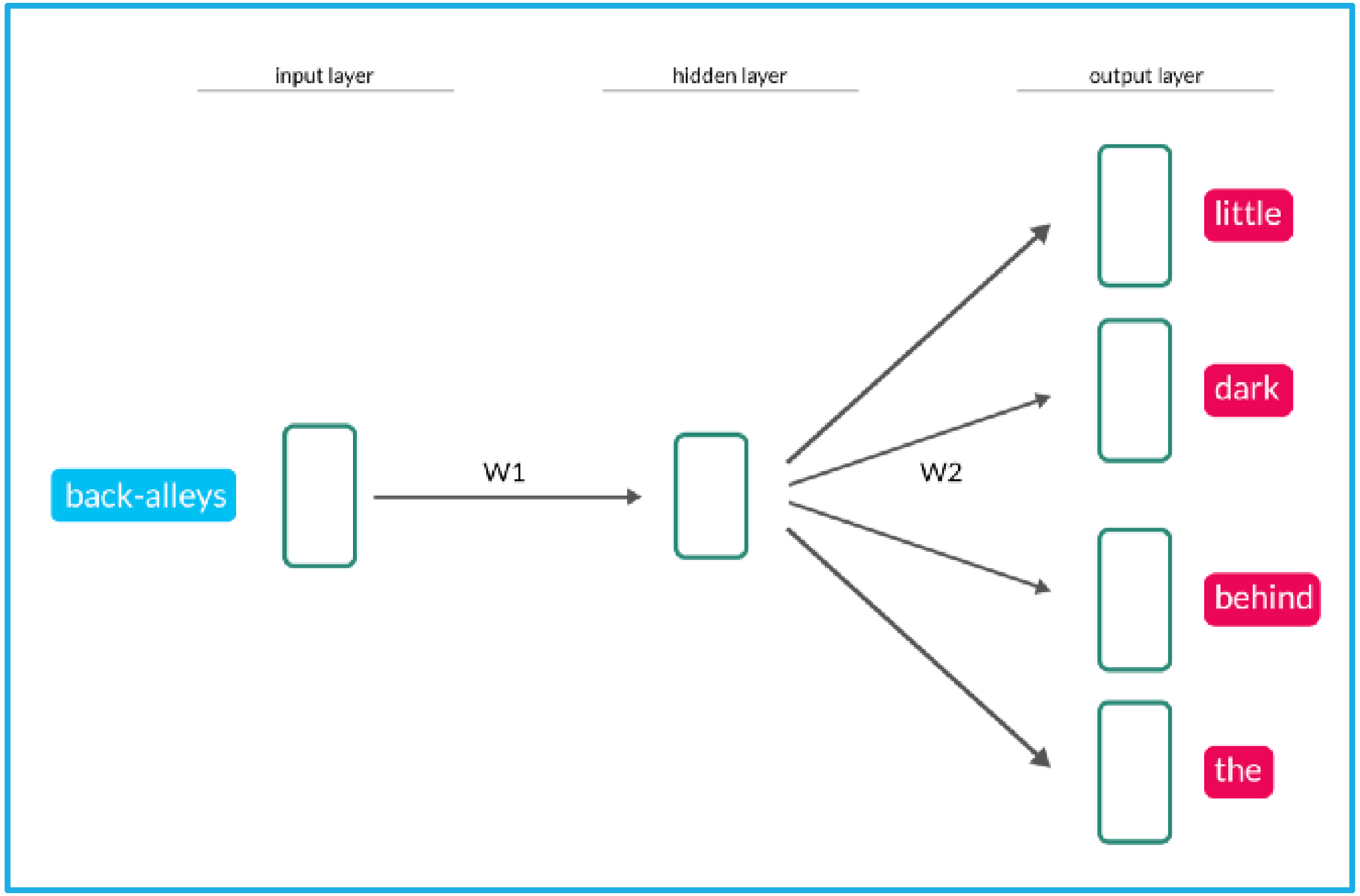
Word2Vec : Skip Gram Model

- Shallow neural network with a single hidden layer.
- Word as input and tries to predict the context



Picture Credit: https://towardsdatascience.com/using-word2vec-for-music recommendations-bb9649ac2484

Word2Vec : Skip Gram Model



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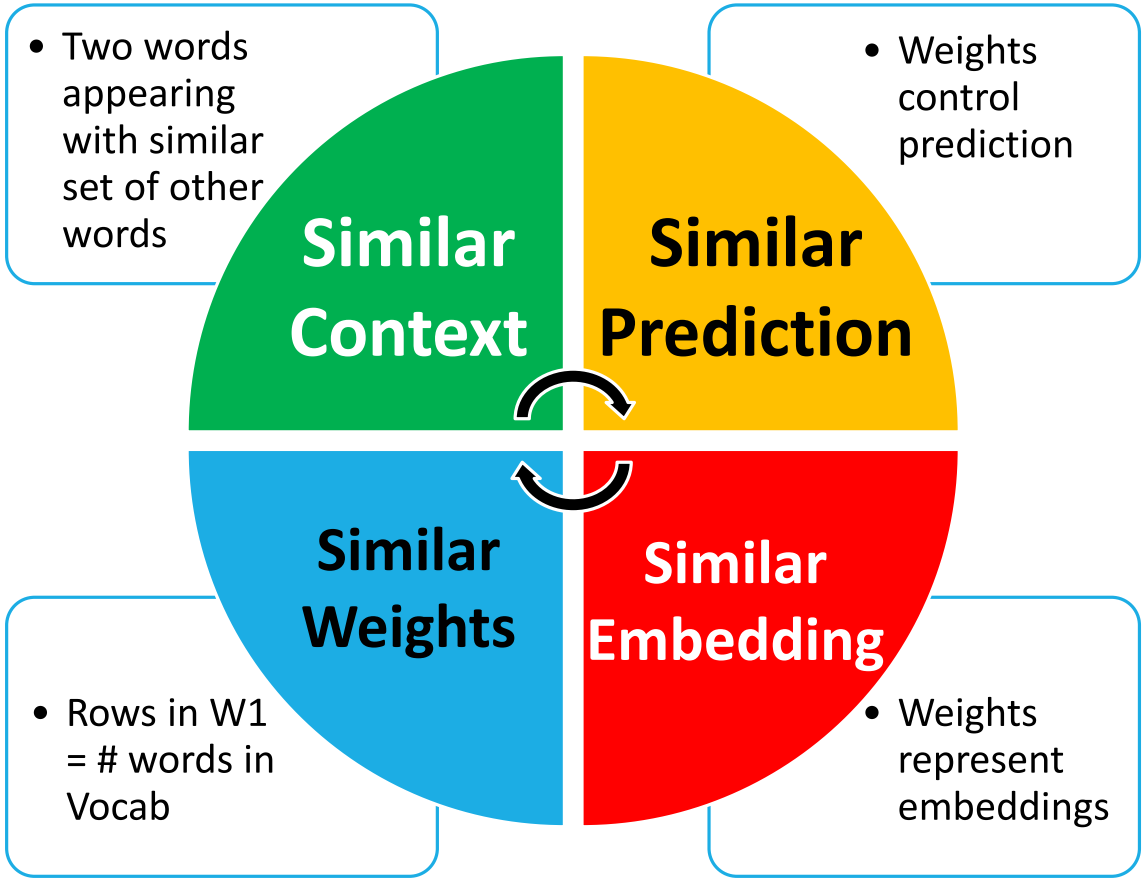
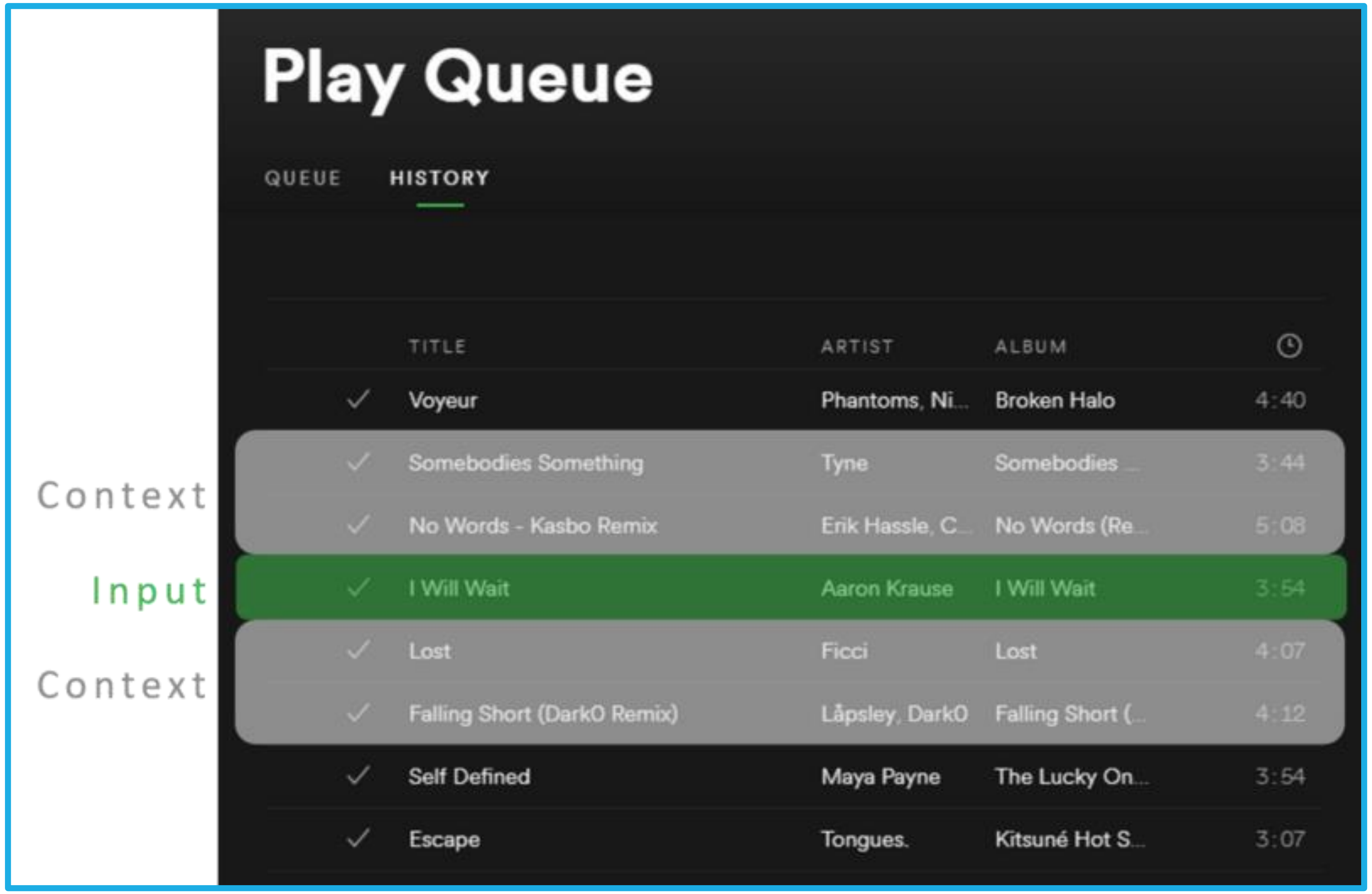
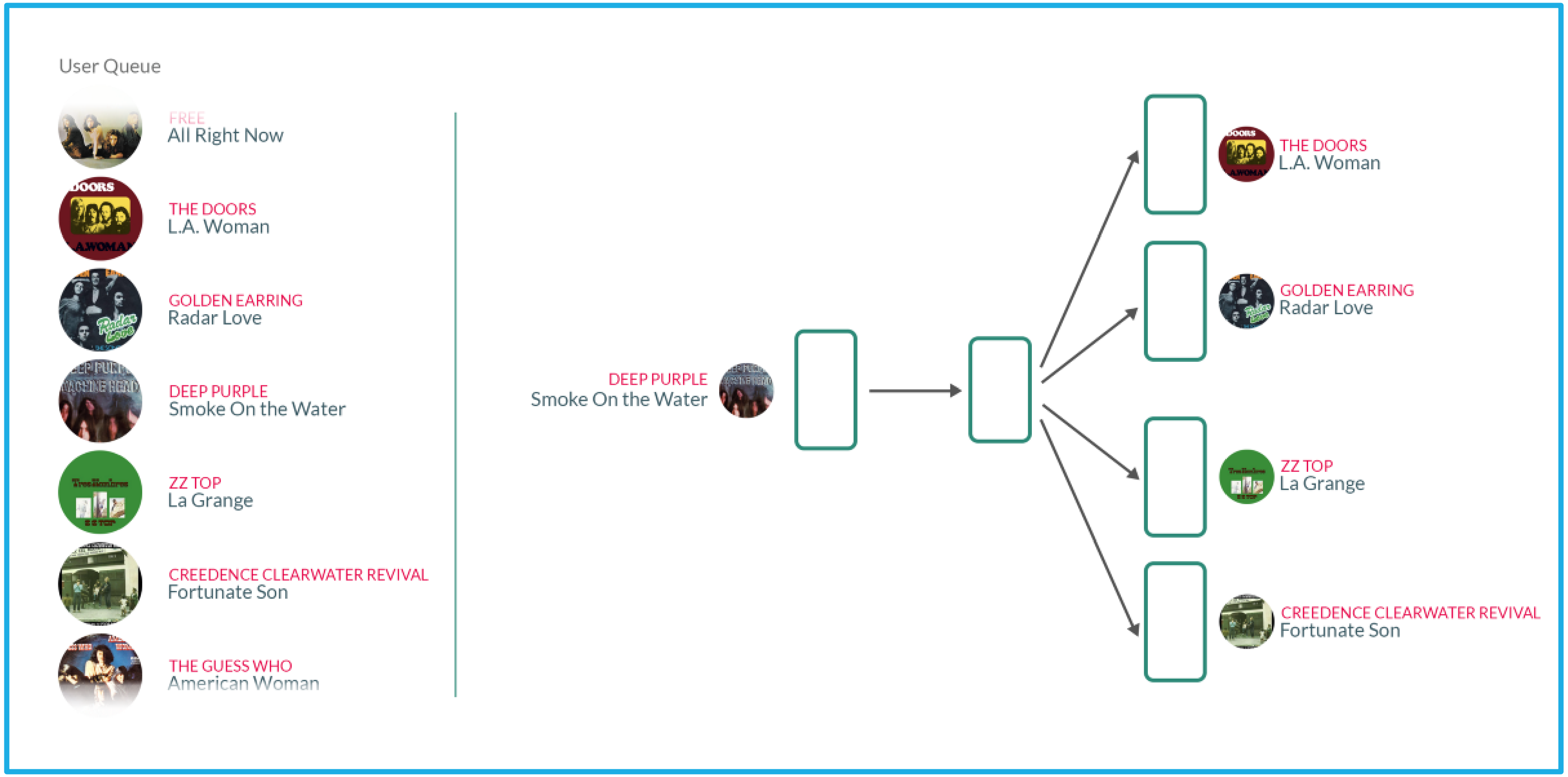
Word2Vec : Skip Gram Model



Song2Vec


Play Queue
QUEUE
HISTORY
TITLE
ARTIST
ALBUM
Voyeur
Phantoms, Ni...
Broken Halo
4:40
Context
Somebodies Something
Tyne
Somebodies ...
3:44
No Words - Kasbo Remix
Erik Hassle, C...
No Words (Re...
5:08
Input
I Will Wait
Aaron Krause
I Will Wait
3:54
Context
Lost
Ficci
Lost
4:07
Falling Short (DarkO Remix)
Låpsley, DarkO
Falling Short (...
4:12
Self Defined
Maya Payne
The Lucky On...
3:54
Escape
Tongues.
Kitsuné Hot S...
3:07

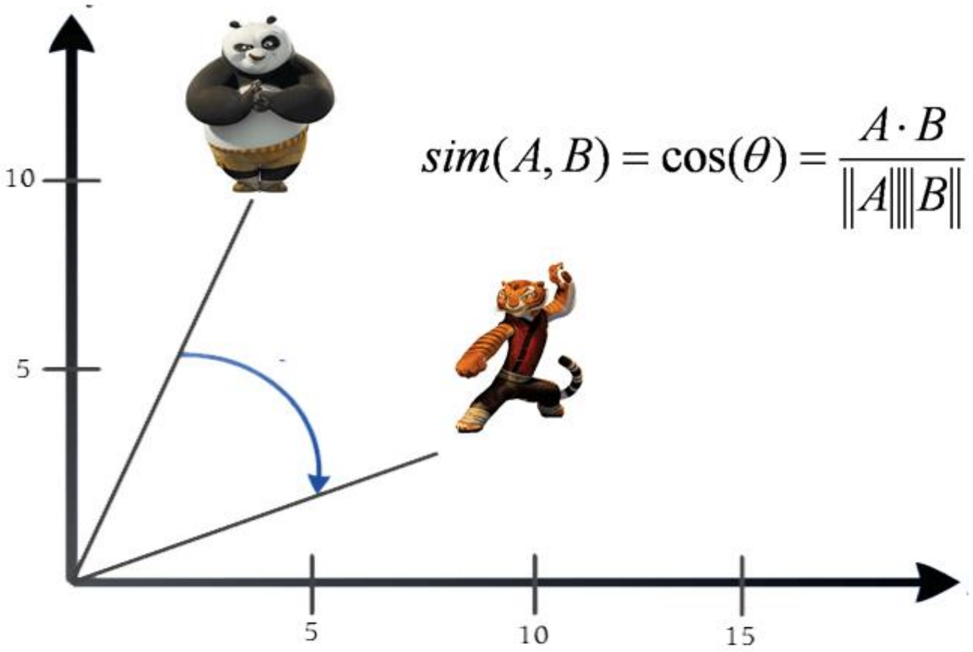
Song2Vec



Picture Credit: https://towardsdatascience.com/using-word2vec-for-music recommendations-bb9649ac2484

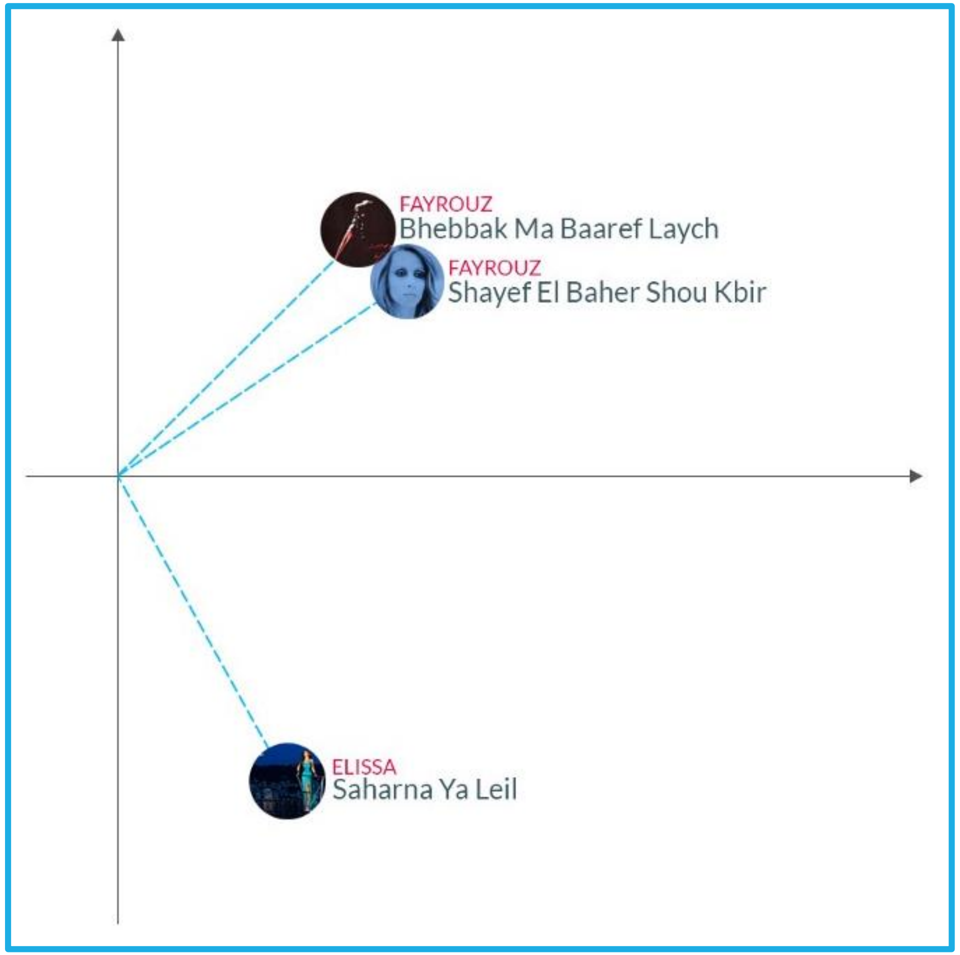
Song2Vec : Use Case

- Transformed problem of finding song similarity into mathematical numbers.
- Weights as coordinates in a high dimensional space.
- Each song being represented by a point in that space.
- Given a particular seed song, we can find *k* other similar songs (cosine similarity).



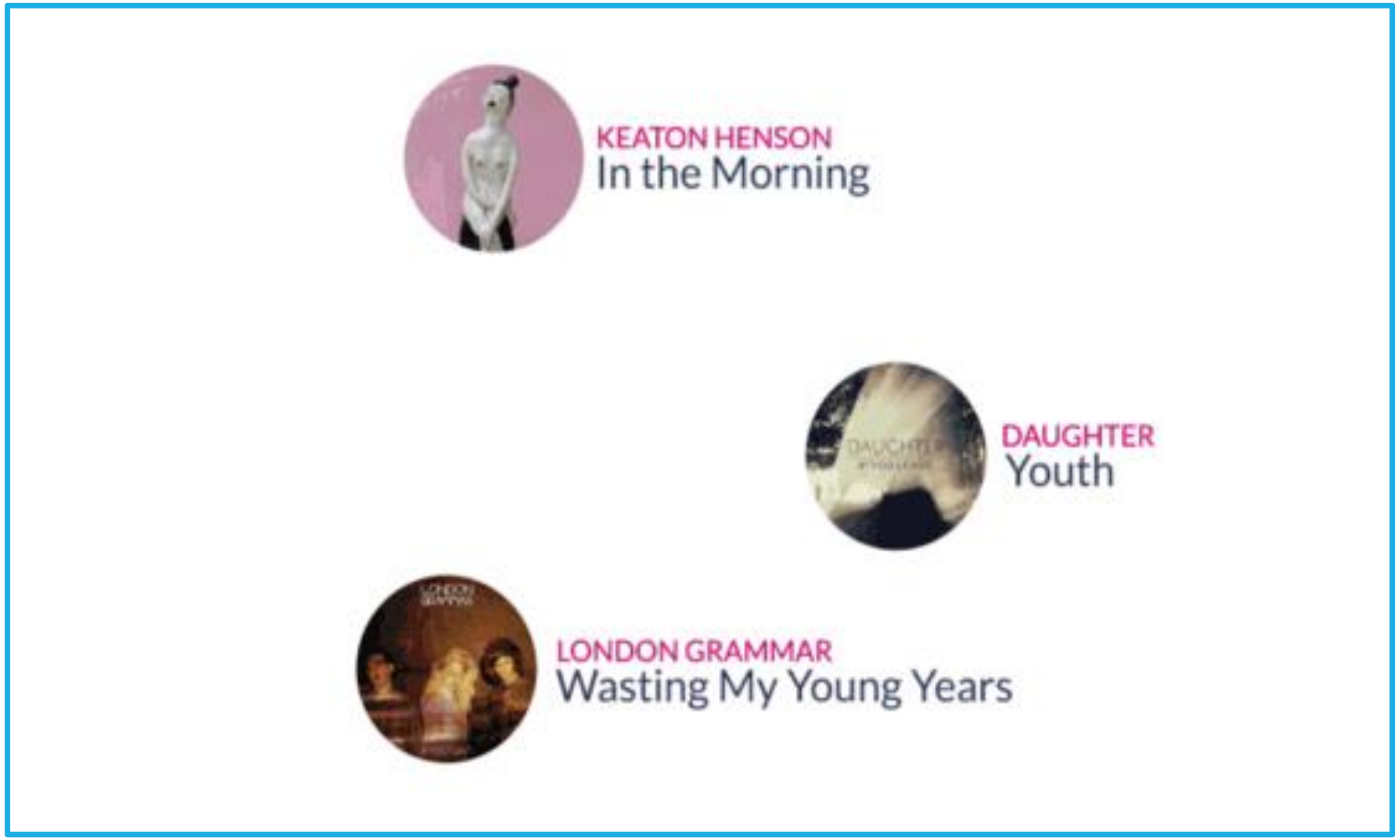
$$sim(A,B) = \cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|}$$

Song2Vec : Use Case



Picture Credit: https://towardsdatascience.com/using-word2vec-for-music recommendations-bb9649ac2484

Song2Vec : *Top-n Recommendation*



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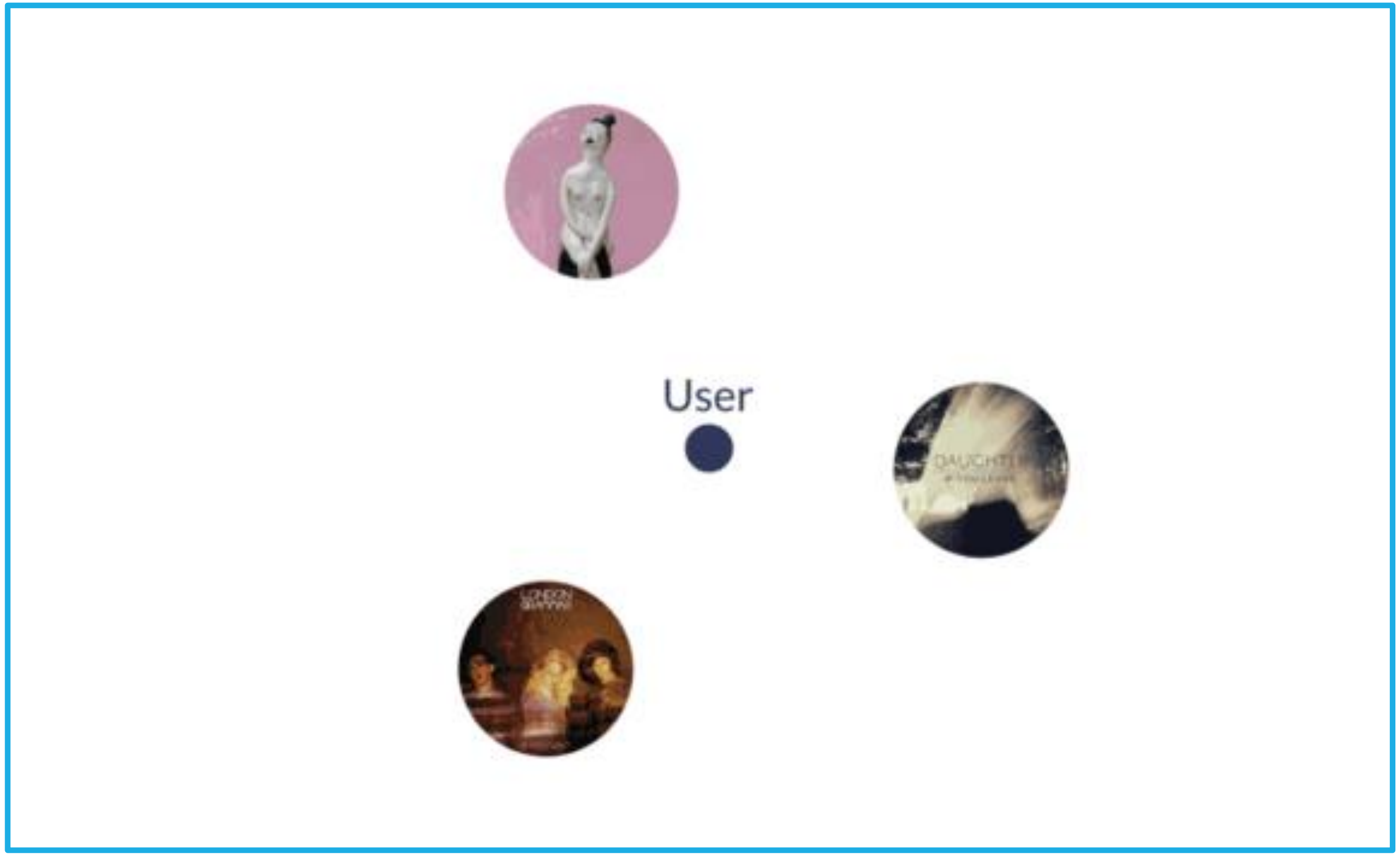
Song2Vec : *Top-n Recommendation*



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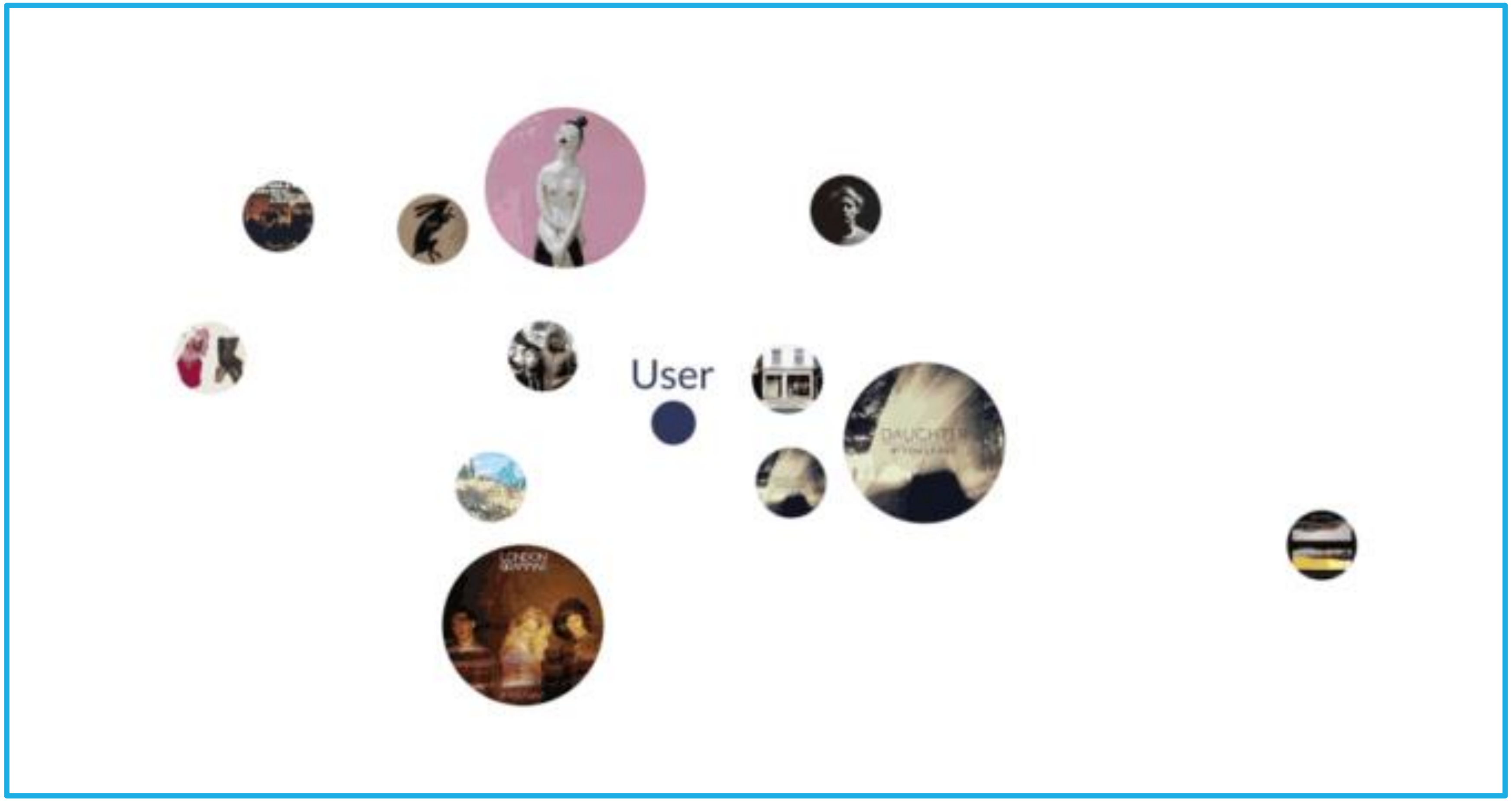
Song2Vec : *Top-n Recommendation*



Picture Credit: https://towardsdatascience.com/using-word2vec-for-music recommendations-bb9649ac2484

Final Objective Function

$$\min_{\boldsymbol{q}^*, \boldsymbol{p}^*, \boldsymbol{b}^*} \sum_{(\boldsymbol{u},\boldsymbol{i}) \in \boldsymbol{K}} \left(\boldsymbol{r}_{\boldsymbol{ui}} - \hat{\boldsymbol{r}}_{\boldsymbol{u},\boldsymbol{i}}\right)^2 + \frac{\alpha}{2} \sum_{i,j \neq i} \left(s_{i,j} - q_i^T q_j\right)^2 + \frac{\lambda}{2} \Omega(\Theta)$$

Song2Vec : Experimental Method

- Top-n recommendation
  - Given a song from the vocabulary, generate the top n recommended song for the user.
- Rating Prediction
  - Predict rating $\hat{r}_{u,i}$ (predicted rating of *u* song for *i* user)
  - Given d is the dimension of the latent feature vectors learned by MF, what is its effect on RMSE.

Results

- Top 6 recommendation for the song *"The Fox"*

```
get_song("The Fox")
```

```
Top 6 Songs for: The Fox

Name                        Similarity Score

Start Toge                  0.8167651891708374
Milkshake                   0.7961223125457764
Let'S Call                  0.795258641242981
Leave You                   0.7926040291786194
The End Of                  0.7861700057983398
One Song F                  0.7859086394309998
```

Results

- Top 6 recommendation for the song *"Bedragaren I Murmansk"*

```
get_song("Bedragaren I Murmansk")
```

```
Top 6 Songs for: Bedragaren I Murmansk

Name                         Similarity Score

Ännu Mera                    0.9780382513999939
Bilder Av                    0.9775434732437134
M Som I                      0.9768289923667908
Sån                  0.9757107496261597
Hur Många                    0.9739065170288086
Trösta Mig                   0.9728430509567261
```

Results

- Top 6 recommendation for the song *"A little Bit Of Pain"*

```
get_song("A Little Bit Of Pain")
```

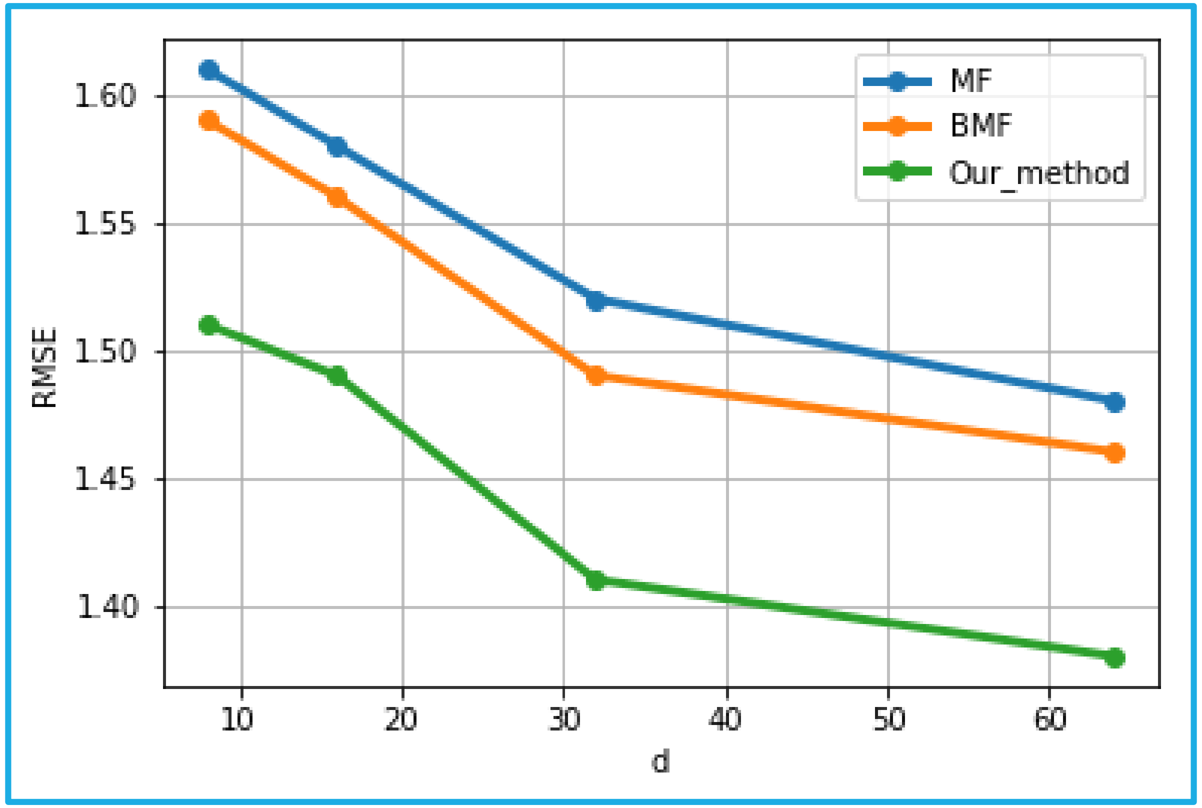
```
Top 6 Songs for: A Little Bit Of Pain

Name                         Similarity Score

Make You L                   0.964229261123657
Ilfracombe                   0.952248930931091З
Autumn'S H                   0.933212876319885З
Silent Tra                   0.932958483695983 9
I Would Fo                   0.924872159957885 7
Aphrodite                    0.921825289726257 3
```

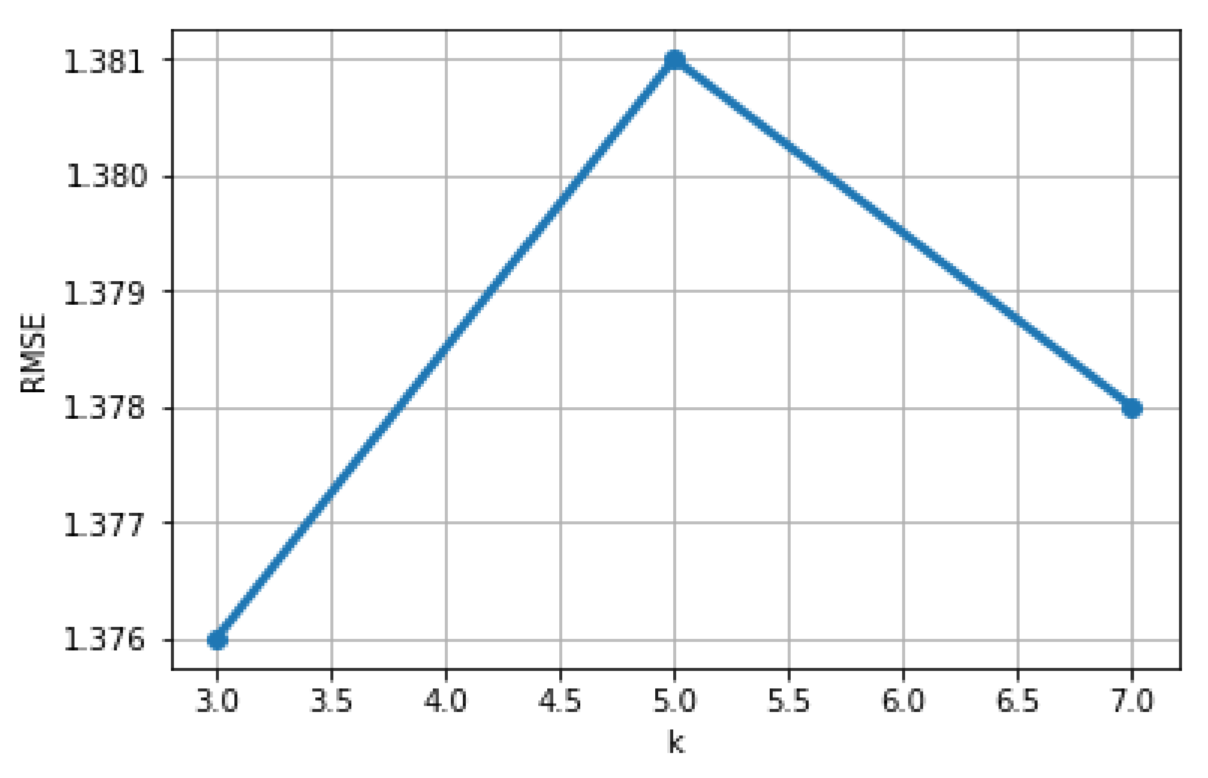
Results

- *RMSE vs d (No. of dimensions in latent factor space)*



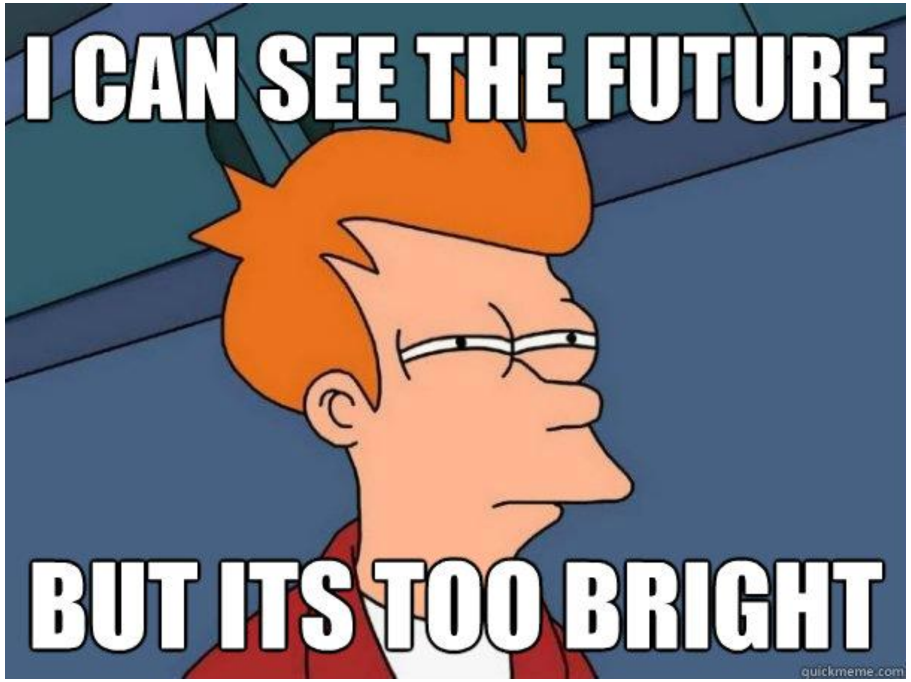
Results

- Variation of RMSE vs k (No. of nearest neighbors)



Future Direction

- Why not Artist2Vec ?
- Prediction based on lyrics.
- Develop dataset with more features like demographic information, language etc.



Picture Credit: https://scalerablog.files.wordpress.com/2015/12/dfd.jpg

References

1. Song2Vec: https://towardsdatascience.com/using-word2vec-for-music recommendations-bb9649ac2484
2. Matrix factorization: https://datajobs.com/data-science-repo/Recommender-Systems-[Netflix].pdf
3. [KeunhoChoia, DongheeYoob, GunwooKimc, YongmooSuha], A hybrid online-product recommendation system: Combining implicit rating-based collaborative filtering and sequential pattern analysis, Electronic Commerce Research and Applications, Volume 11, Issue 4, July–August 2012, Pages 309-317
4. Song2Vecimplementation: https://github.com/0411tony/Yue/blob/master/recommender/advanced/Song2vec.py
5. Create corpus for Song2Vec: https://github.com/WQtong/MusicRecsys/blob/master/create_song_corpus.ipynb

Thank You !

Picture Credithttps://pics.me.me/its-over-its-finally-over-26367283.png