

NLP for Music (use cases)

Sergio Oramas (Pandora)

Automated Knowledge Base Construction

Knowledge Bases

- **Knowledge Base:** Repository of knowledge organized in a taxonomic or ontologic structure.
 - Handcrafted: WordNet, DBpedia, BabelNet, Freebase
 - Fully automatic: NELL, ReVerb
- Music Knowledge Bases (or databases)
 - Handcrafted: MusicBrainz, Discogs
 - Fully automatic: -

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Music Knowledge Bases: why should we care?

- Structured information about music is incomplete
 - (almost) Only popular artists and western music
 - (almost) Only editorial and some biographical information



Music Knowledge Bases: why should we care?

Huge amount of music information remains implicit in unstructured texts

- * Artists biographies, articles, reviews, web pages, user posts.

last.fm

SONGFACTS

Wikipedia

The screenshots show how structured data like artist profiles and detailed articles can be derived from unstructured text sources like social media posts and web pages.

last.fm screenshot details:

- Profile for David Bowie: Overview, Tracks, Albums, Photos. Metrics: 160.7M Scrobbles, 3.1M listeners.
- Bottom navigation: rock · glam rock · classic rock · 80s · 70s · alternative.
- Text: "David Bowie (born David Robert Jones on 8th January 1947 in Brixton, London, UK) was an English songwriter, musician, and actor. Active during six decades of popular music and frequently changing image, Bowie is widely regarded as an innovator, particularly for his work in the 1970s. Shortly after the release of his studio album *Blackstar*, it was announced Bowie died on 10 January 2016, following an eighteen-year battle with cancer."
- Text: "As a multi-instrumentalist, he is famous... read more"
- Top Tracks table:

1	Ziggy Stardust	707,902
2	Space Oddity	665,605
3	Life on Mars?	644,354
4	Changes	631,515
5	"Heroes"	582,657
- Bottom navigation: Startman

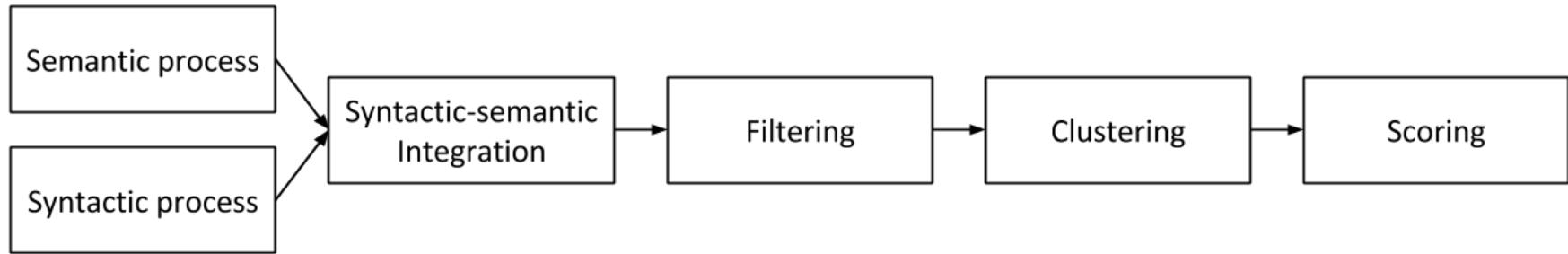
SONGFACTS screenshot details:

- Article about Bob Marley's tour.
- Text: "Marley developed a powerful stage presence on this tour, and added musicians like Family Man Barrett and Al Anderson to sweeten the sound. The audiences on the tour where the live version was recorded were evenly mixed between black and white people. Marley was one of the few artists to have mass appeal that transcended race. The song became a highlight of Marley's concerts as the crowd always joined in. It is very easy to sing along to."
- Text: "The original line of the song is "No, Woman, Nah, cry." Nah is Jamaican for "don't," so what is meant by the line is that she is leaving and reassuring her that the place they live in won't get her down, that everything will be alright and "she" will be there for her."
- Text: "The original version on *Natty Dread* was nothing like the live performances. It was shorter and sped-up, with little of the original instrumentation. According to Rolling Stone magazine, the "Government yard in Trench Town" refers to the Jamaican public-housing project where Marley grew up."
- Text: "According to Rolling Stone magazine, the "Government yard in Trench Town" refers to the Jamaican public-housing project where Marley grew up."
- Text: "Marley wrote this, but gave a composer credit to Vincent "Tanner" Ford, one of his friends from Jamaica who helped him out and ran a soup kitchen in Kingston. By giving Ford the credit, Marley was helping out an old friend by trying to divert royalty checks to him. Marley's original output was often freestyle, and Marley may have initially considered giving all the royalties to Ford for helping him out with his own royalties (it's unclear how much money ever made it to his friend). Ford is also listed as "Rastman Vibrations."
- Text: "The female vocals were by backing group the I-Threes, made up of Judy Mowatt, Marcia Griffiths, and Bob's wife, Rita Marley. The song "Electric Boogaloo," which became a line dance favorite in America."
- Text: "Peter Tosh and Bunny Wailer left the group the year before this was released. They were upset at the way Marley was given sole credit for the song."
- Text: "This was included on *Legend*, a compilation album released three years after Marley's death. It was a #1 album in the UK."
- Text: "Dakota Moon's lead singer and guitarist, Ty Taylor, appeared on the reality TV series *Rockstar INXS* and did a cover of this song."
- Text: "The Brazilian Tropicalia singer Gilberto Gil recorded this for his 1979 album *Realice*, putting a Bossa Nova twist on it. Gil later Minister of Culture, Brazil, Bertrand - Paris, France)"

Wikipedia screenshot details:

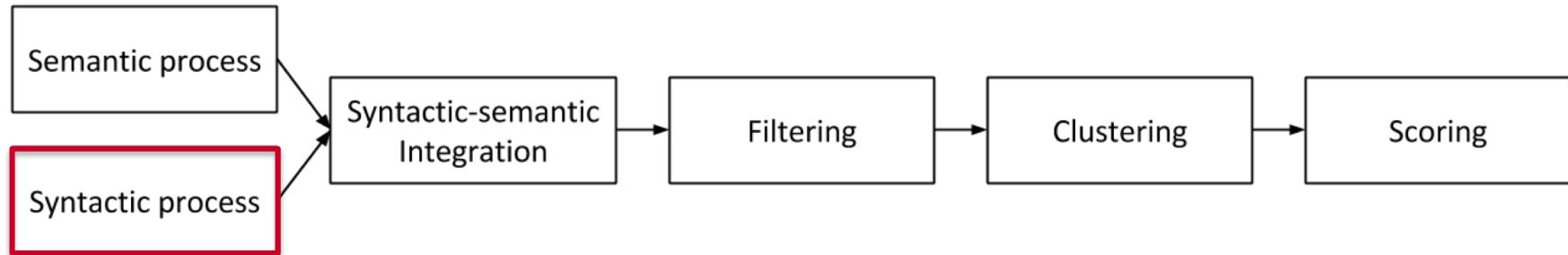
- Article about Bad Religion.
- Text: "American punk rock band formed in Los Angeles, California in 1979. The band makes extensive use of soaring three-part vocal harmonies (which they refer to in their album liner notes as the 'Holy Trinity'), guitar solos and lyrics that often contain religious and political commentary. Their lyrics often relate to matters of social responsibility. The band's lineup has changed several times over its lifespan, with the current members being Greg Graffin (the only constant member), Jay Bentley, and Jay Gourley. To date, Bad Religion has released ten studio albums, two live albums, and one compilation album, *True North* (one of which is composed of covers of Christmas songs) and two DVDs (which were both recorded live). They are considered to be one of the most influential and successful American punk rock acts of all time.^[1] Having sold over 15 million records worldwide, Bad Religion had built an underground following in the United States with their early albums before signing to Atlantic Records in 1993. They rose to fame that same year with their seventh studio album *Recipe for Hate*, which peaked at number 34 on *Billboard's* *Heatseekers* chart.^[2] *Recipe for Hate* was followed a year later by *Stranger Than Fiction*, which spawned their biggest hits "Infected" and the re-recorded version of "21st Century (Digital Boy)".^[3] and was certified gold in both the United States and Canada. Shortly before the release of *Stranger Than Fiction*, Gourley left Bad Religion to focus on his latest Epiphany, and was replaced by Brian Baker. Since the return of Gourley in 2001, the band has undergone a resurgence in popularity, with their sixteenth studio album *True North* (2013) becoming Bad Religion's first album to crack the top 20 on the *Billboard* 200 chart, where it peaked at number 13.^[4] The band is expected to release their seventeenth studio album in 2017.^[5]
- Table of contents:
 - 1 History
 - 2 Discography
 - 3 Live performances
 - 4 Awards
 - 5 Controversy
 - 6 References
 - 7 External links

Automated Knowledge Base Construction

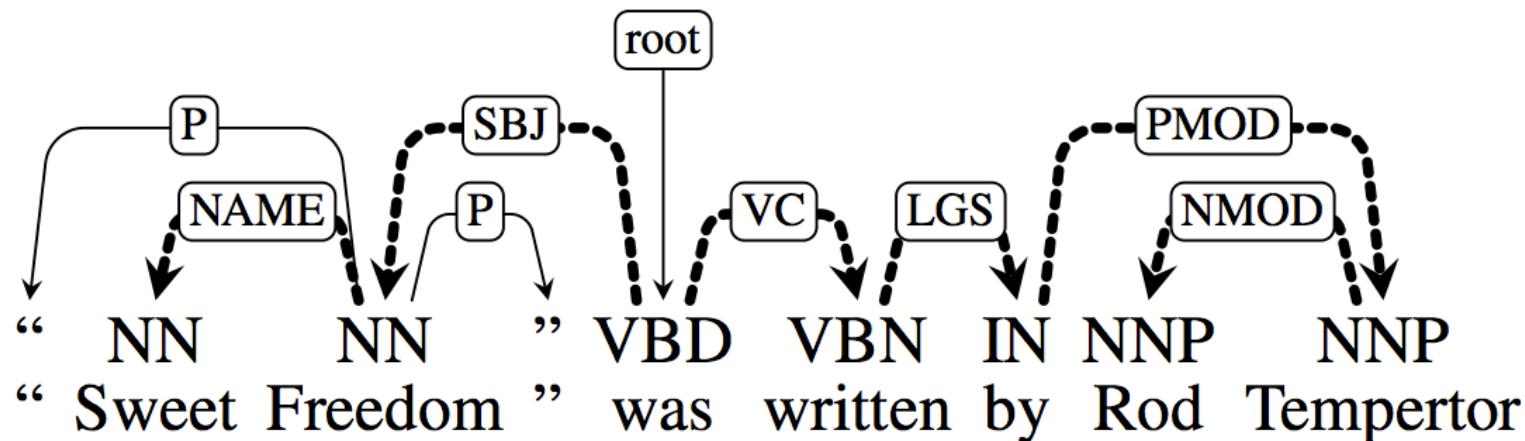


Oramas S., Espinosa-Anke L., Sordo M., Saggion H. & Serra X. (2016). Information Extraction for Knowledge Base Construction in the Music Domain. Data & Knowledge Engineering, Volume 106, Pages 70-83.

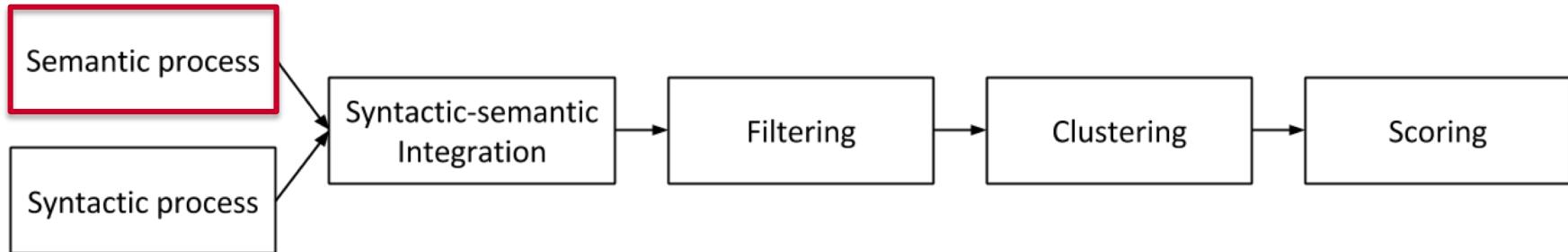
Automated Knowledge Base Construction



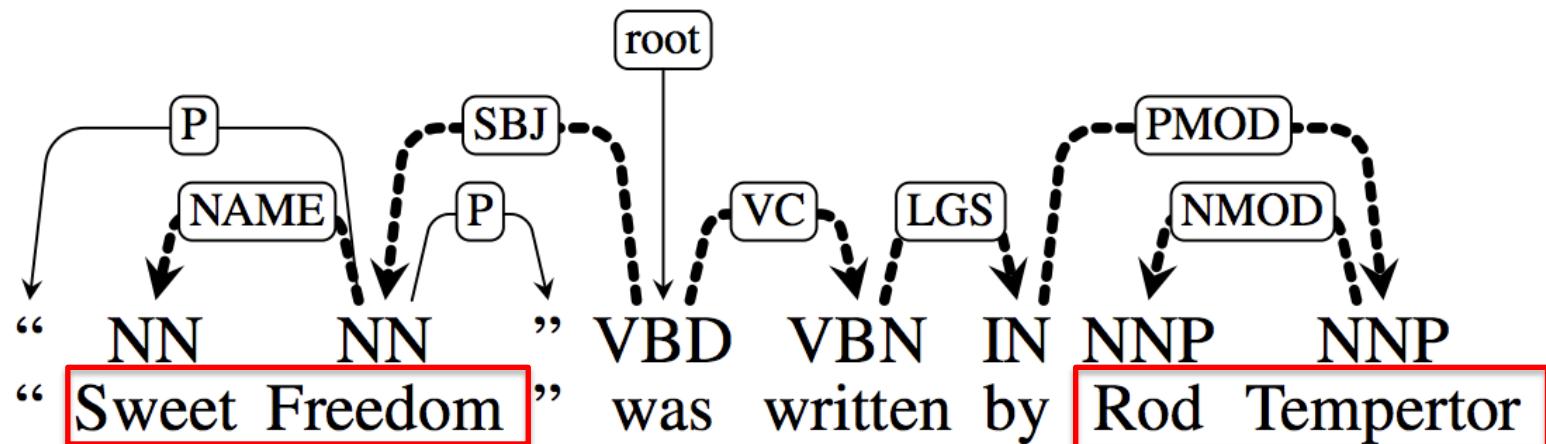
- **Dependency Parsing:** MATE Tools (Bohnet 2010)



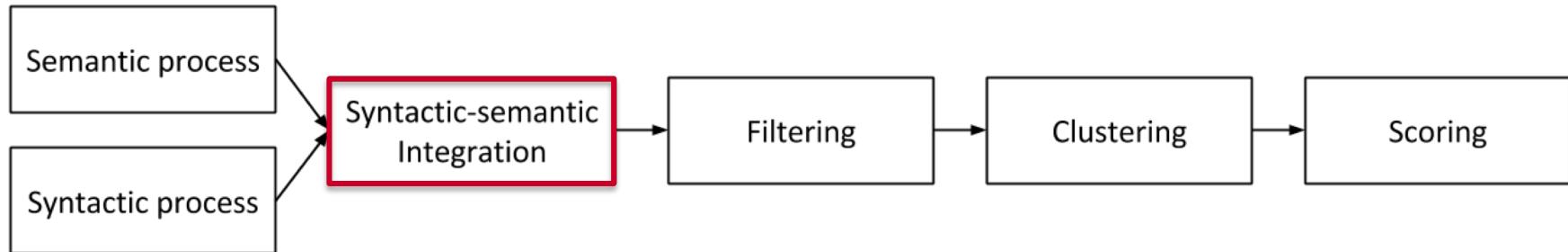
Automated Knowledge Base Construction



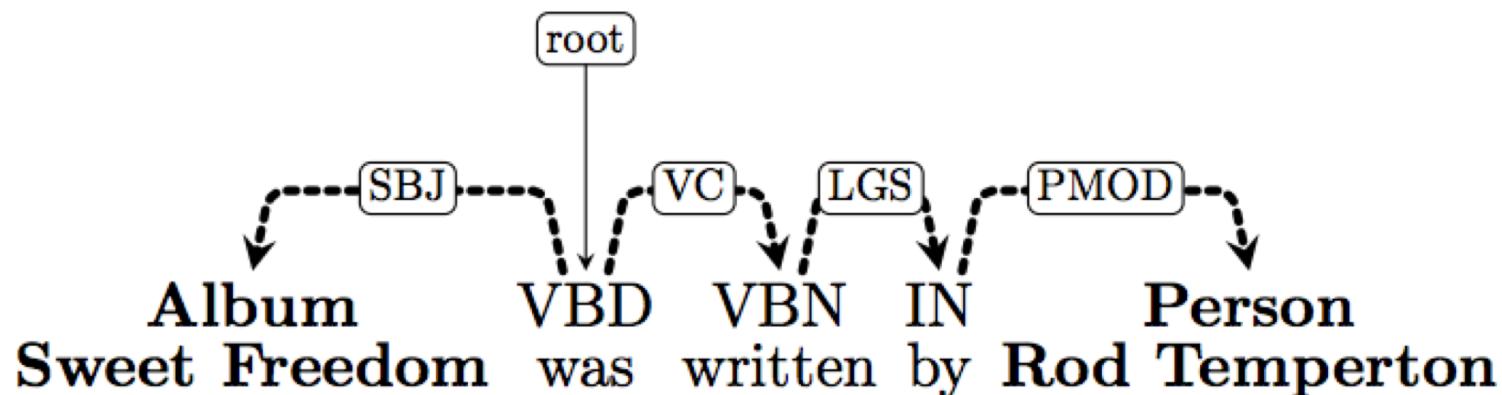
- Entity Linking: DBpedia Spotlight



Automated Knowledge Base Construction



- Group entity nodes
- Find shortest path between entities

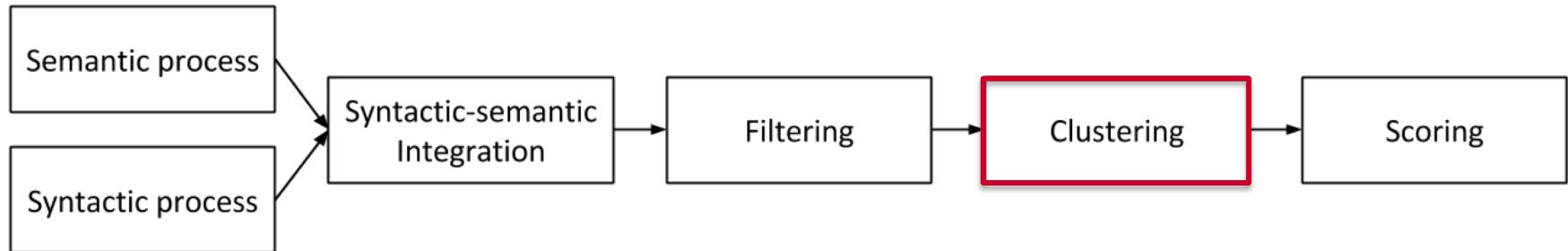


Automated Knowledge Base Construction



- Shortest path is prone to errors
- **Filtering:** Regular expressions
 - **Lexical:** Word lemmas
 - **Syntactical:** Dependency functions
 - **Morphological:** Part-of-speech tags

Automated Knowledge Base Construction



- Group different relations with similar meaning
- Simplify the knowledge base

was written by artist

was written by frontman

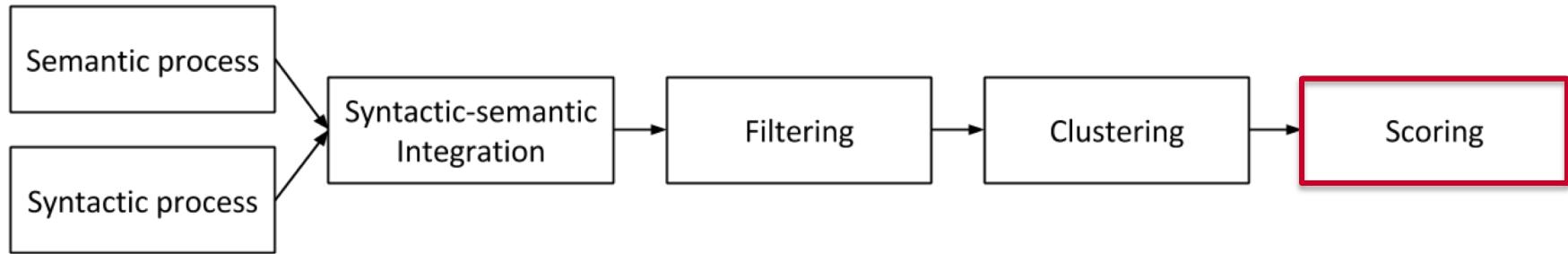
was written by guitarist

was written by singer



was written by

Automated Knowledge Base Construction

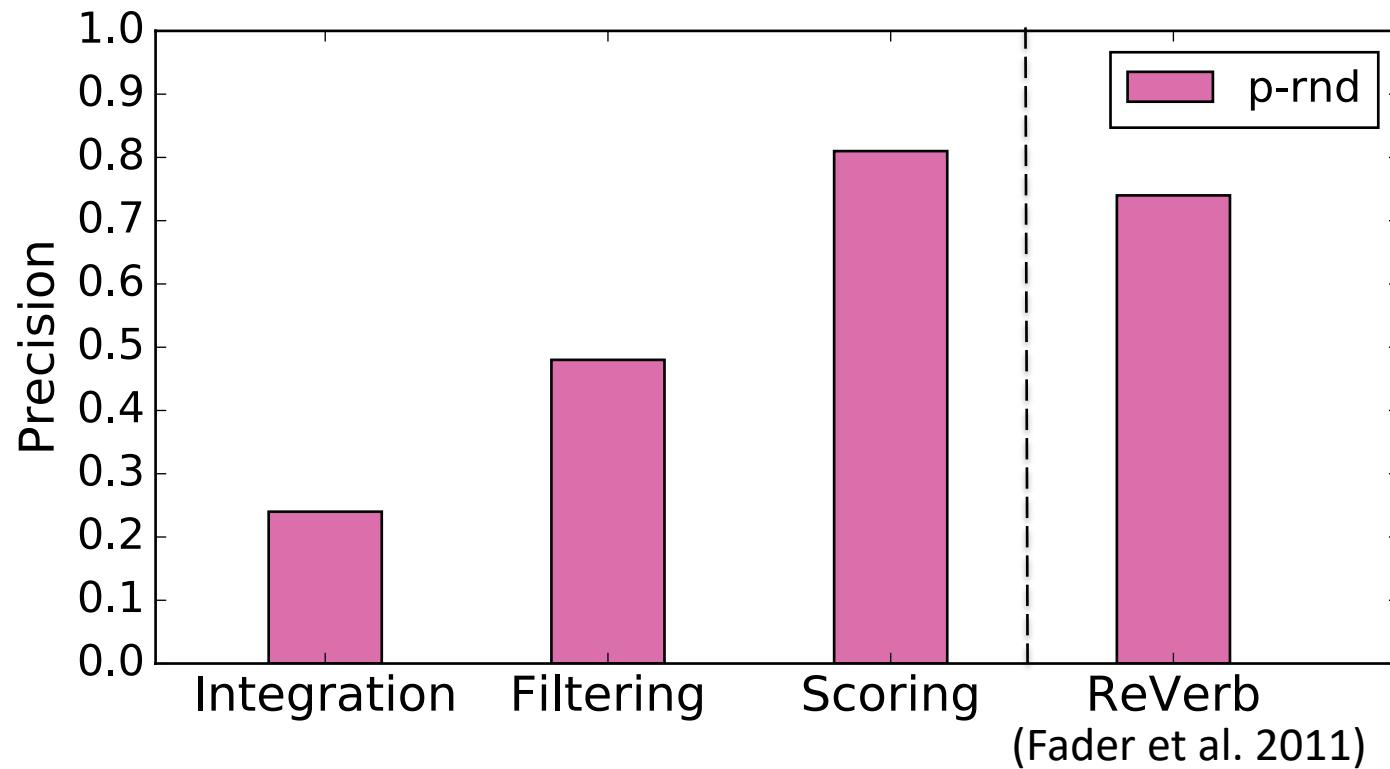


- Confidence measure of extracted relations
- Based on statistical analysis of all extracted relations

Experiment

- Task: Automated creation of a Music Knowledge Base (KBSF)
- Text corpora
 - Stories about 30k songs gathered from songfacts.com
- Evaluation
 - Quality evaluation: 2 annotators in random relations
 - Coverage evaluation: Comparison between KBs
 - Application evaluation: Explaining Recommendations

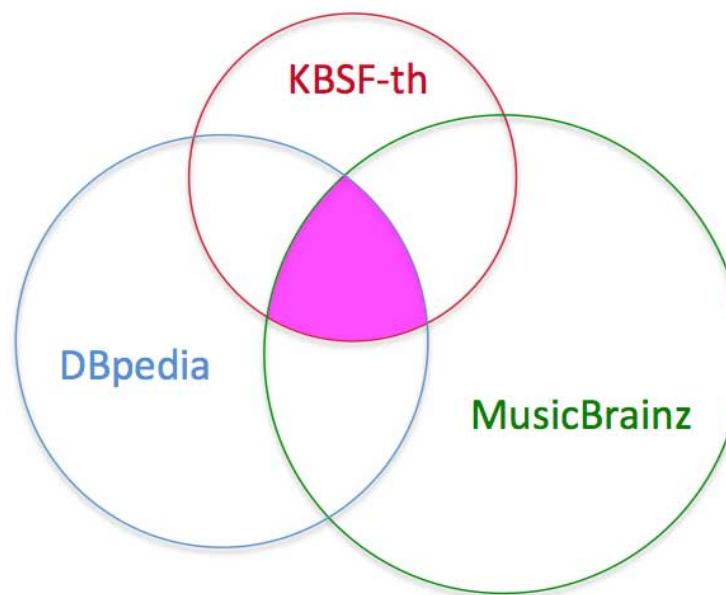
Quality Evaluation



Coverage Evaluation

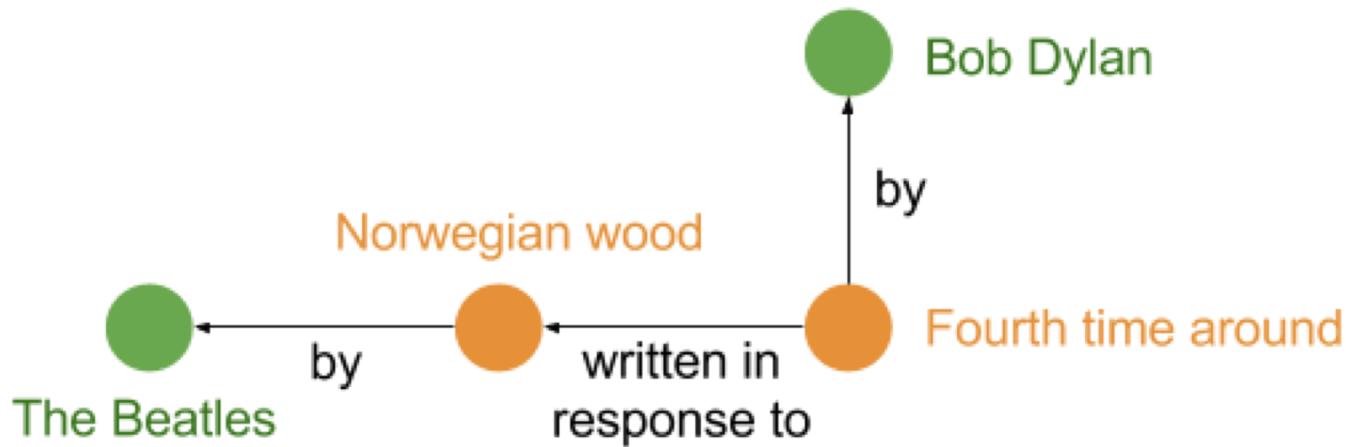
- Number of relations between entities present in all KBs

	KBSF-th	MusicBrainz	DBpedia
#Relations	3633	1535	1240



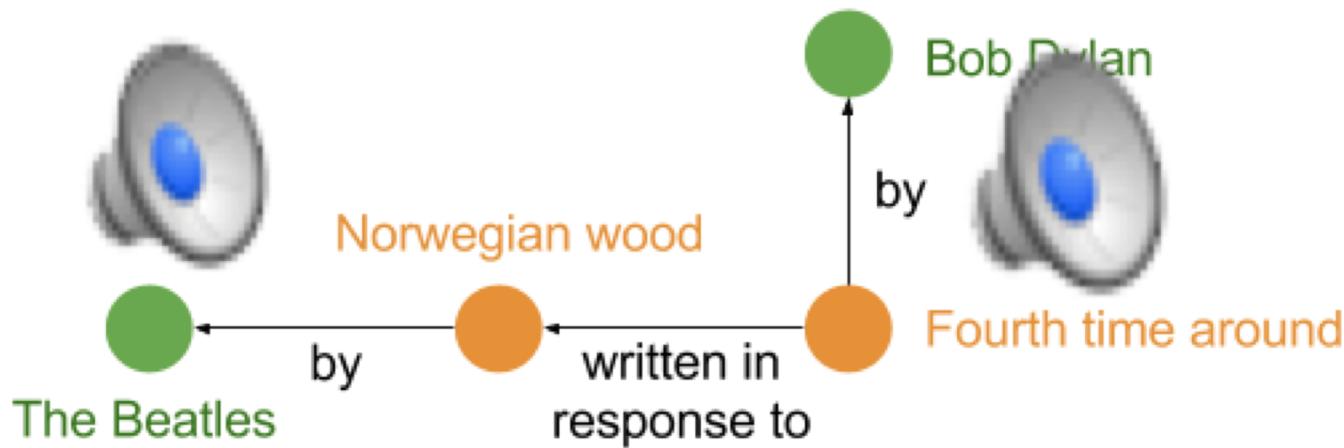
Explaining Recommendations

Norwegian Wood (The Beatles) -> Fourth Time Around (Bob Dylan)



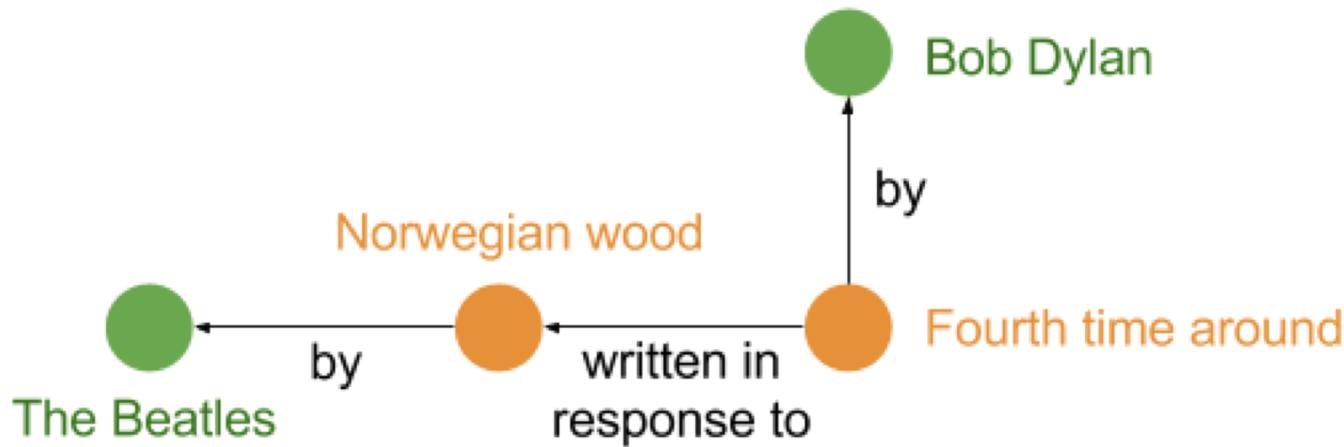
Explaining Recommendations

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Explaining Recommendations

Norwegian Wood (The Beatles) -> Fourth Time Around (Bob Dylan)



Fourth Time Around was written in response to Norwegian Wood by The Beatles, since it is similar, both melodically and lyrically.

Explaining Recommendations

- User Experiment with 35 subjects
 - Recommendations provided with different types of explanations
 - Users rated recommendations between 1 to 5
- Results
 - Explanations using original sentences improve ratings by 5% with respect to recommendations without explanations
 - Higher differences in ratings on musically untrained subjects

Music Recommendation with Knowledge Graphs

Semantic Enrichment via Entity Linking

Elvis Presley covered Guitar Man with Reed

Semantic Enrichment via Entity Linking

https://en.wikipedia.org/wiki/Elvis_Presley

https://en.wikipedia.org/wiki/Jerry_Reed

Elvis Presley covered **Guitar Man** with Reed



WIKIPEDIA

[https://en.wikipedia.org/wiki/Guitar_Man_\(song\)](https://en.wikipedia.org/wiki/Guitar_Man_(song))

Semantic Enrichment via Entity Linking

Singers from Tennessee
American rockabilly musicians
1935 births

American country singer-songwriters
American country guitarists
Musicians from Atlanta
https://en.wikipedia.org/wiki/Jerry_Reed

https://en.wikipedia.org/wiki/Elvis_Presley

Elvis Presley covered **Guitar Man** with Reed



WIKIPEDIA

[https://en.wikipedia.org/wiki/Guitar_Man_\(song\)](https://en.wikipedia.org/wiki/Guitar_Man_(song))
1967 singles
Jerry Reed songs
RPM Country Tracks number-one singles

Enriched Graph

“[Gorillaz](#) are a [British](#) virtual band formed in 1998 by [Damon Albarn](#) of [Blur](#), and [Jaime Hawelett](#), co-creator of the comic book [Tank Girl](#).”

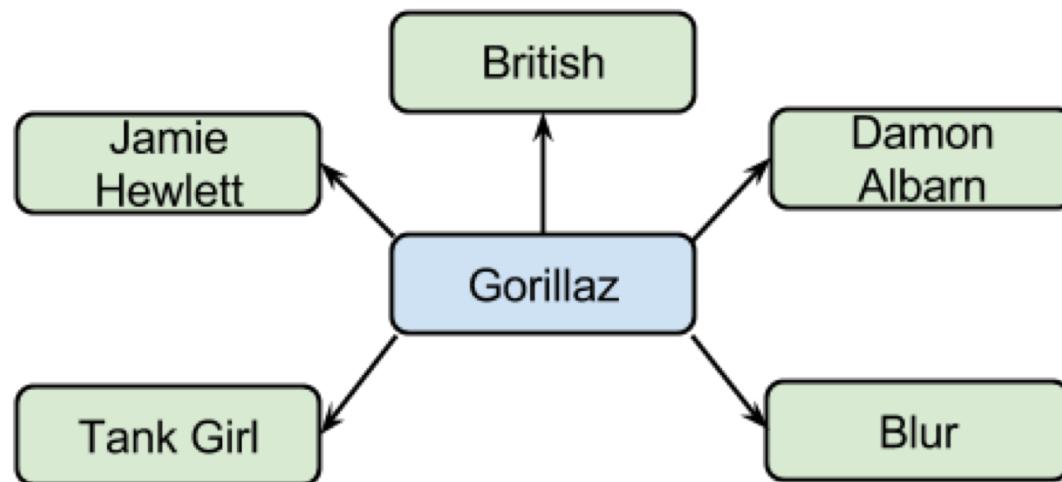
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Gorillaz

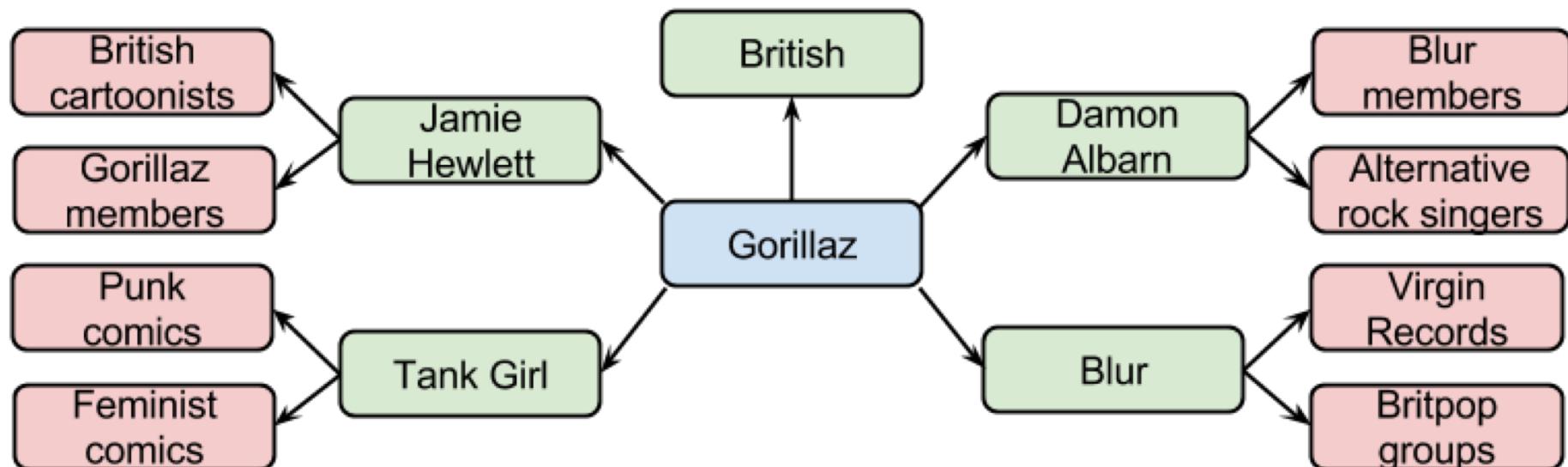
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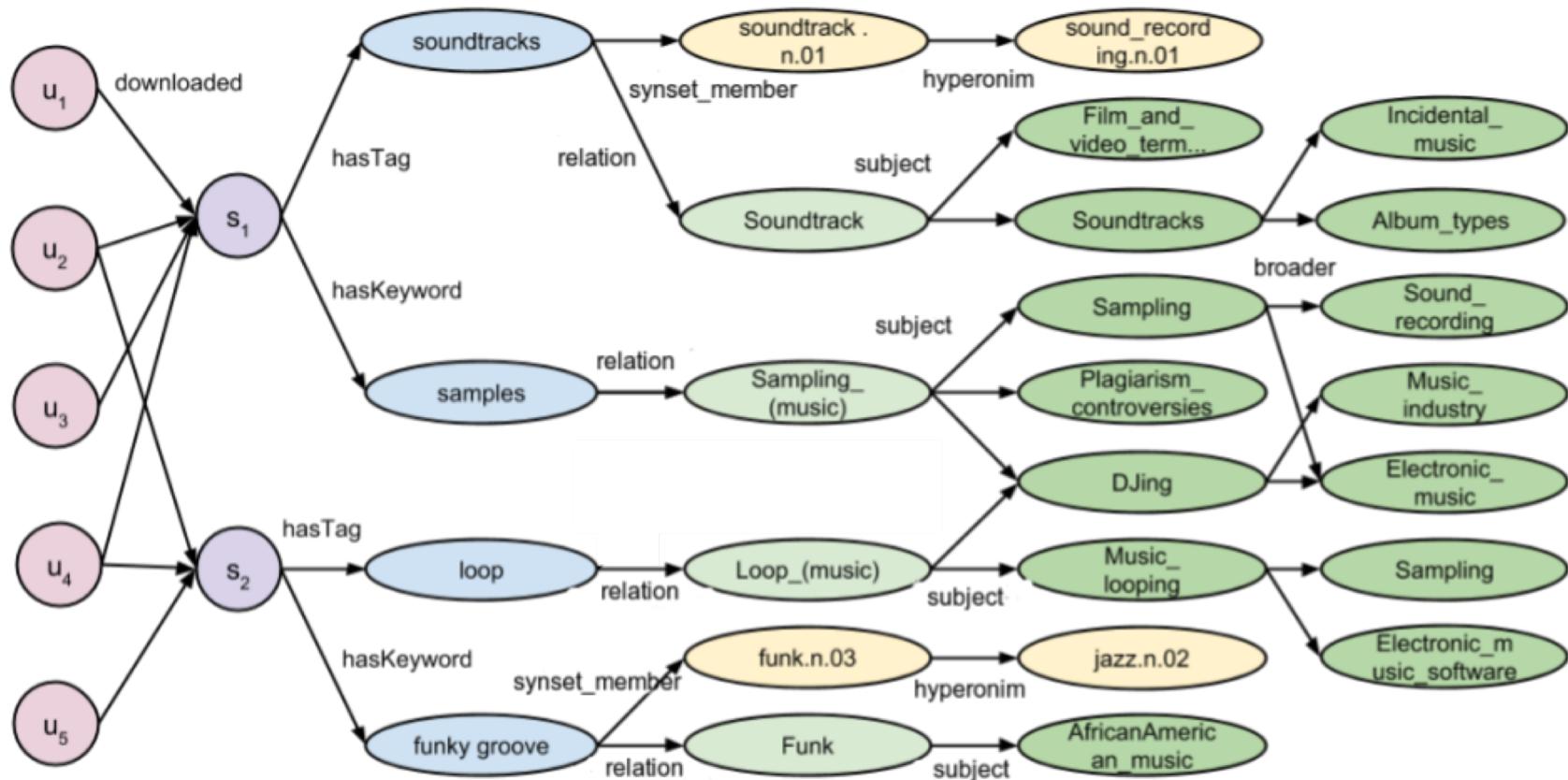


Enriched Graph

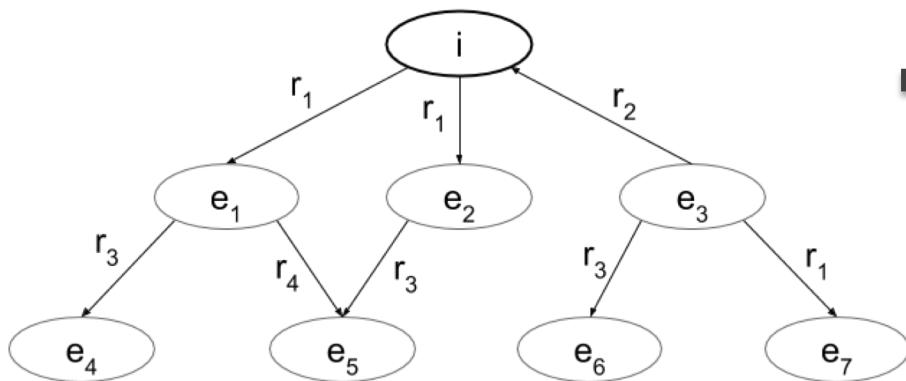
“[Gorillaz](#) are a [British](#) virtual band formed in 1998 by [Damon Albarn](#) of [Blur](#), and [Jaime Hawelett](#), co-creator of the comic book [Tank Girl](#).”



Knowledge Graph



Graph Embedding

Item Graph**Feature vector**

$$\varphi_i = (w_1 e_1, w_2 e_2, \dots, w_t e_t)$$

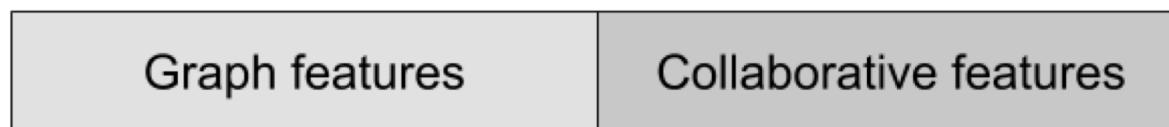
Weights (w_i):

- Distance to the root
- Number of in-links
- Frequency and inverse frequency

- Entity-based embedding
- Path-based embedding

Music Recommendation Approach

- **Semantic enrichment** via Entity Linking to build an **Enriched Graph** of every item
- Embed each Enriched Graph into a **feature vector**
- Recommend using a **hybrid** feature-combination approach
 - Train a linear model for each user to predict recommendations



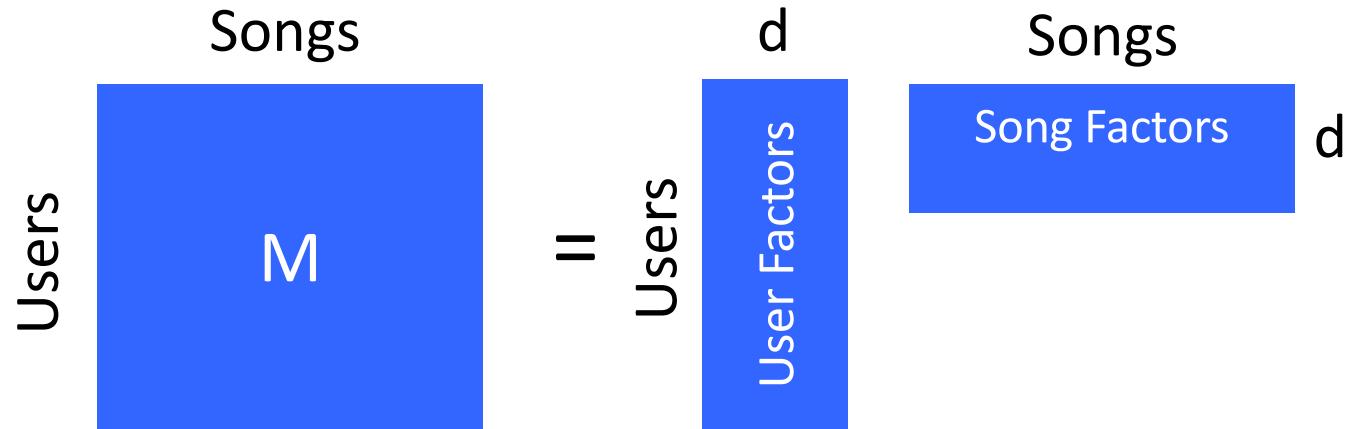
Oramas S., Ostuni V. C., Di Noia T., Serra, X., & Di Sciascio E. (2016). Music and Sound Recommendation with Knowledge Graphs. ACM Transactions on Intelligent Systems and Technology, Volume 8, Issue 2, Article 21.

Results

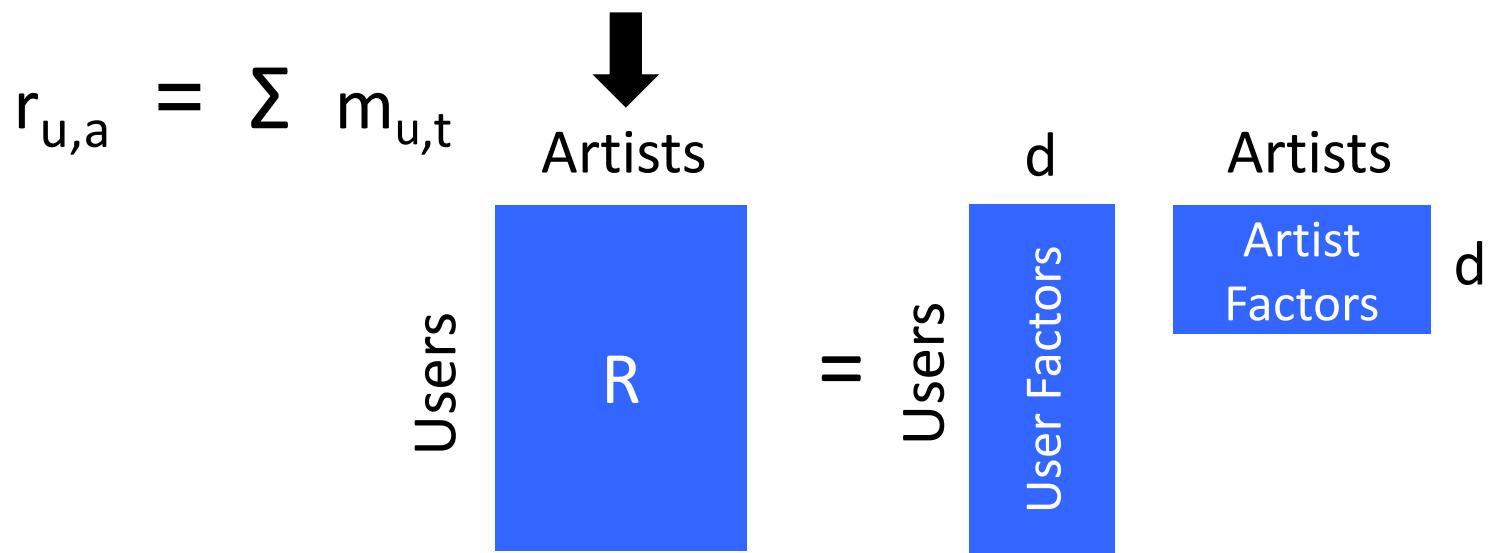
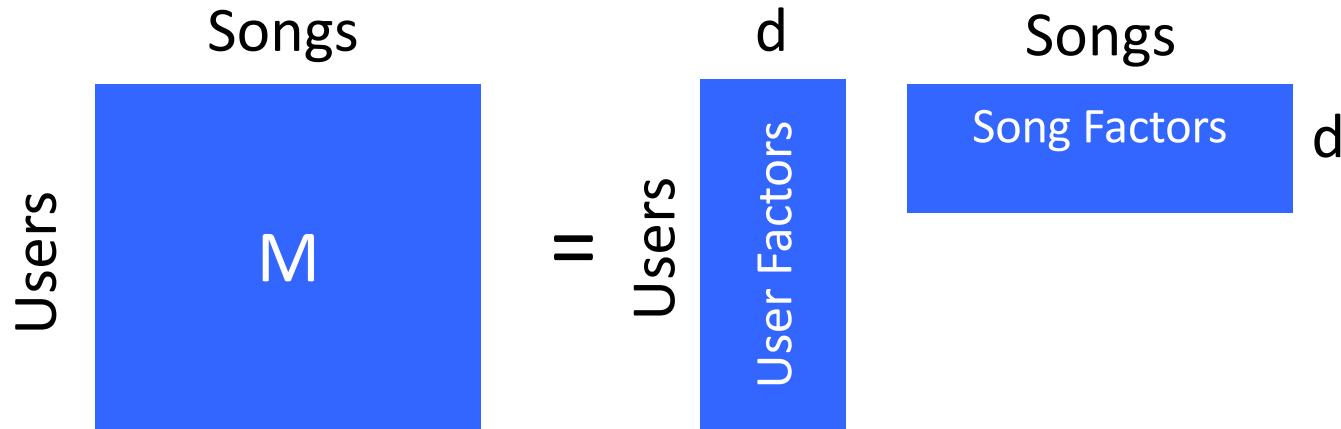
Approach	Exploitation	Exploration
Collab		
Collab + Tags		
Collab + Enriched Graph		
Enriched Graph only		

Multimodal Cold-start Music Recommendation

Matrix Factorization (WMF)



Matrix Factorization (WMF)



Semantic Enrichment via Entity Linking

Singers from Tennessee
American rockabilly musicians
1935 births

https://en.wikipedia.org/wiki/Elvis_Presley

American country singer-songwriters
American country guitarists
Musicians from Atlanta
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WIKIPEDIA

Elvis Presley covered **Guitar Man** with Reed

[https://en.wikipedia.org/wiki/Guitar_Man_\(song\)](https://en.wikipedia.org/wiki/Guitar_Man_(song))

1967 singles
Jerry Reed songs
RPM Country Tracks number-one singles

Text-based Approach: Enriched Description

Singer, songwriter and certified guitar player Jerry Reed found his musical calling as a child. It's interesting, albeit a bit disconcerting, to hear Reed singing so far outside his earthier country sound, and the folk- and pop-flavored cuts haven't the swagger of his blues. Elvis Presley covered Guitar Man, with Reed reproducing the guitar break from this recording.

+

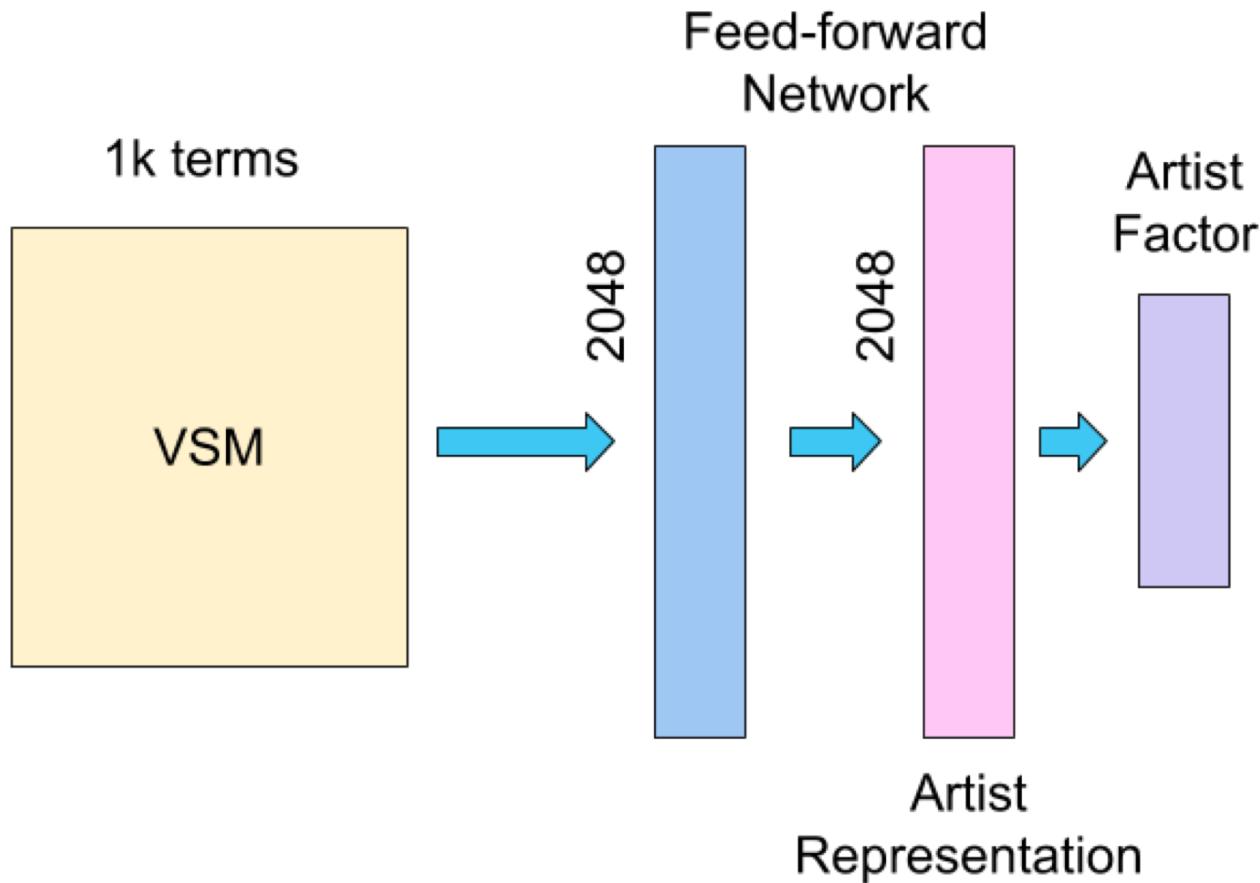
Singers_from_Tennessee,American_ro ckabilly_musicians,1935_births,Americ an_country_singer
songwriters,American_country_guitari sts,Musicians_from_Atlanta,20th- century_American_male_actors,Gram my_Award_winners

Item Description

VSM
tf-idf

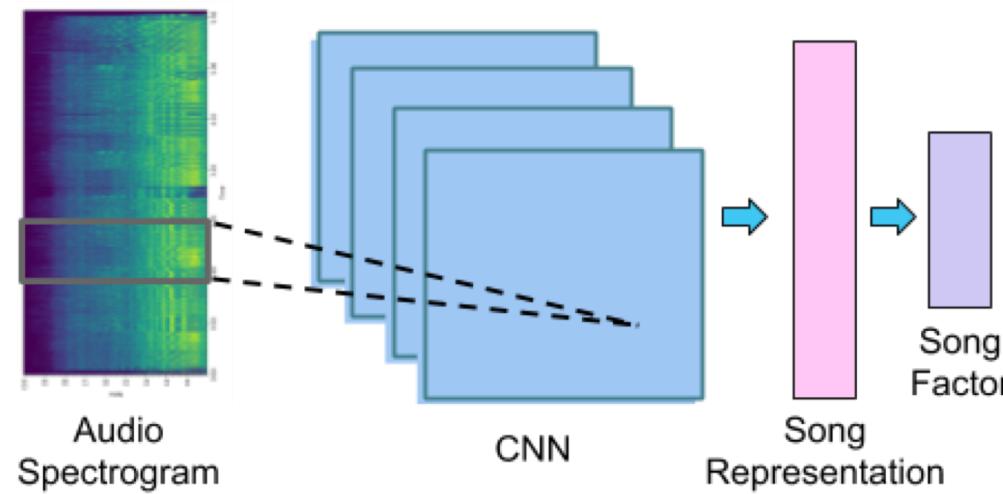
Semantic data

Text-based Learning Approach



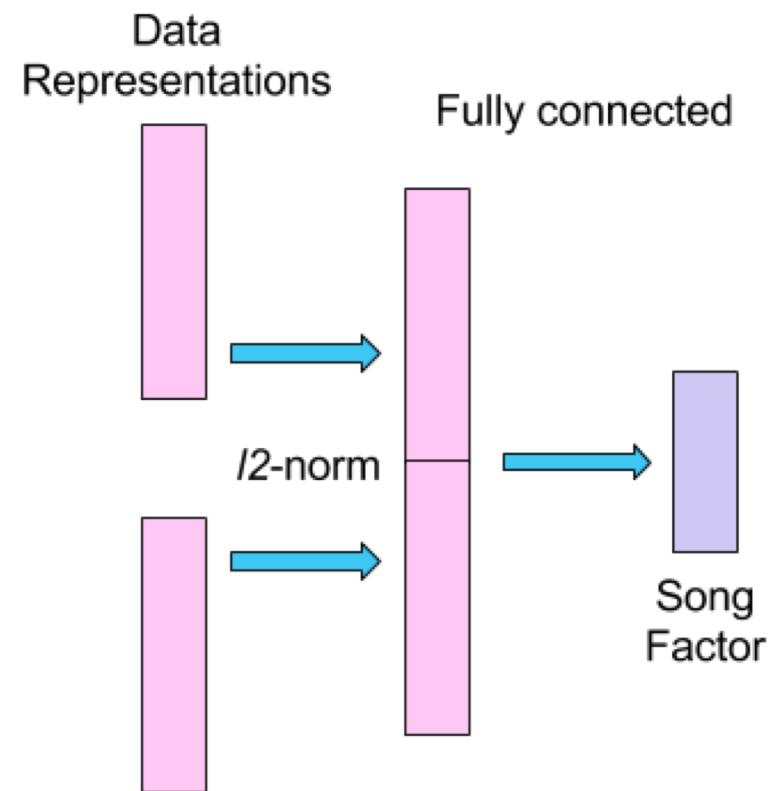
Audio-based Learning Approach

- Constant-Q audio spectrograms with 96 frequency bins
- 4 convolutional and max pooling layers
- Time domain filters (Van Den Oord et al. 2013)
- No dense layers

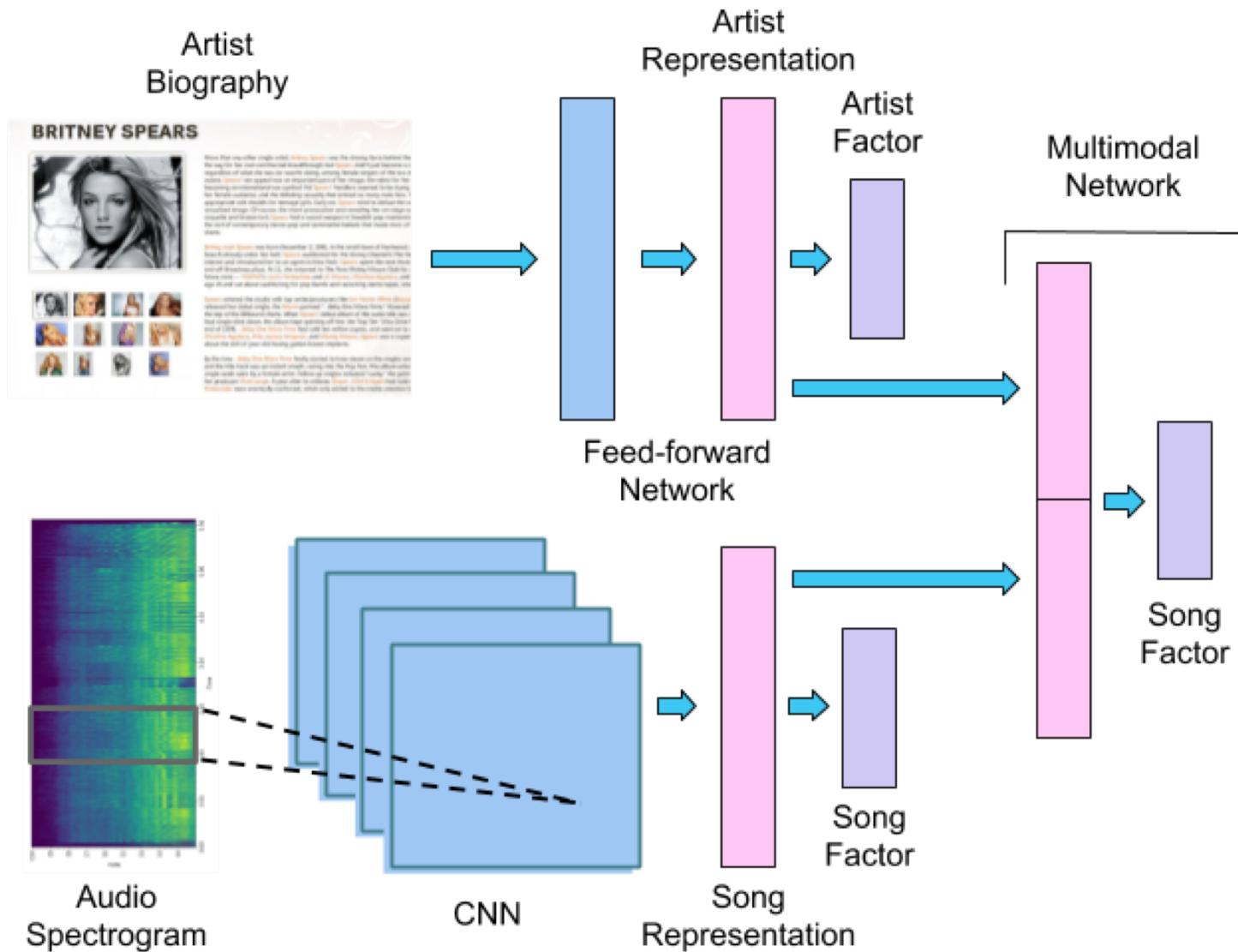


Multimodal Fusion

- ℓ_2 -norm
- Concatenate representations
- Linear model

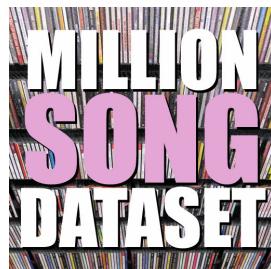


Learning Approach



Dataset

- MSD-A
 - 330k tracks
 - 24k artists
 - 1M users



+ last.fm

Audio and user feedback

Artists biographies and tags

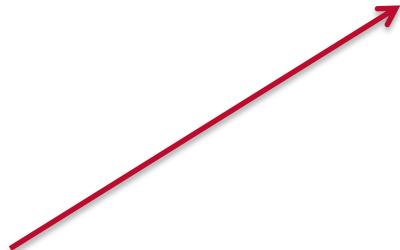
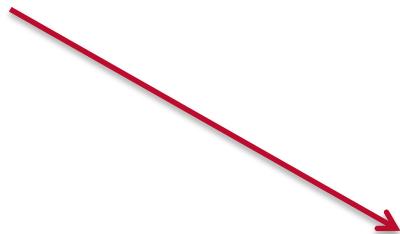
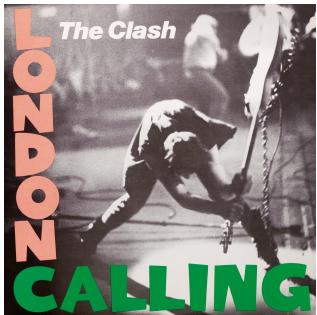
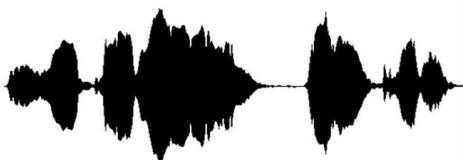
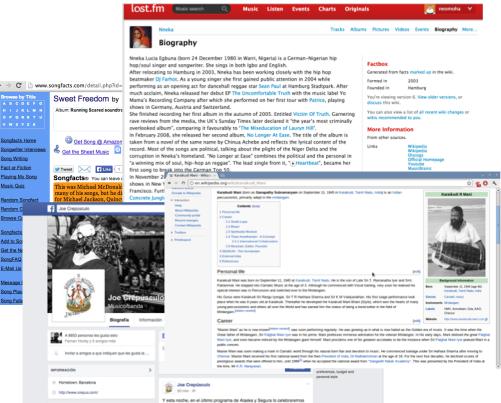
Experiments

- Artist Recommendation
 - Text-based approaches
- Song Recommendation
 - Audio, text, and multimodal approaches
- Splits: 80 train - 10 validation – 10 test
- **Different artists in each subset**
- Evaluation metric: MAP@500

Oramas, S., Nieto O., Sordo M., & Serra X. (2017). A Deep Multimodal Approach for Cold-start Music Recommendation. DLRS-RecSys 2017.

Multimodal Music Genre Classification

Music Genre Classification



electronic rock
female vocalists ambient
new age finnish
experimental symphonic metal alternative
dance Gothic pop heavy metal
folk rock ethereal Icelandic
medieval Prog rock
celtic Power metal
trip hop chillout
trance instrumental

Music Genre Classification

Music Genre Classification is a widely studied problem*

Music Genre Classification

Music Genre Classification is a widely studied problem but only with these characteristics:

- Audio-based
- Handcrafted features
- Single-label
- Few broad genres

Music Genre Classification

Music Genre Classification is a widely studied problem
but only with these characteristics:

- Audio-based → Multimodal
- Handcrafted features → Learned features
- Single-label → Multi-label
- Few broad genres → Hundreds of genres

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Single-label Music Genre Classification

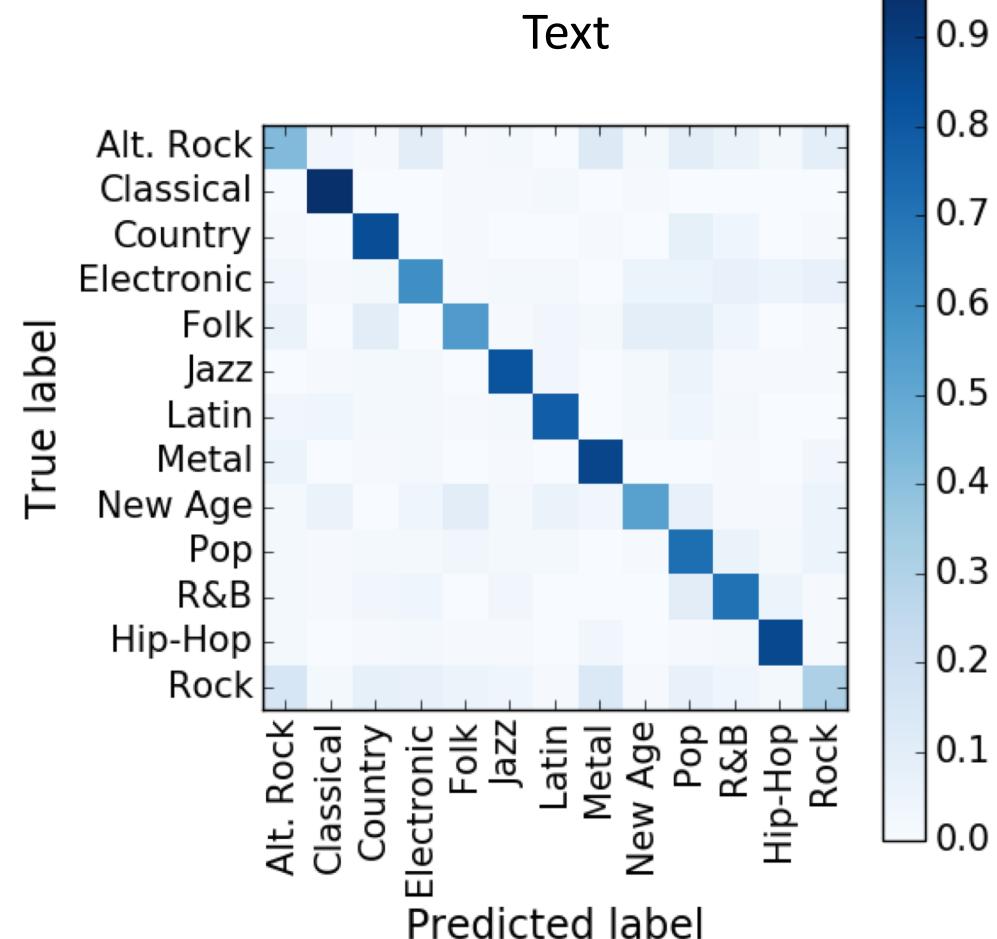
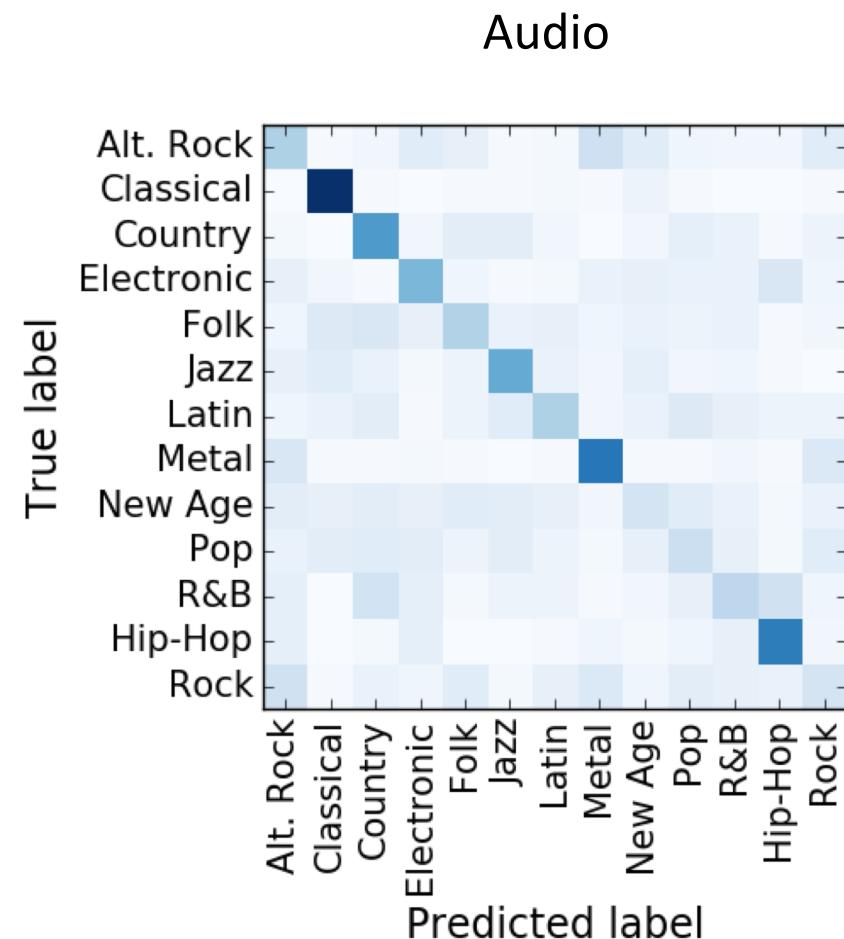
- MARD dataset
 - 1300 albums
 - 13 genres
 - Amazon reviews + AcousticBrainz audio features
- Features:
 - **Textual:** VSM of uni-grams and bi-grams
 - **Semantic:** Enriched description (Wikipedia categories)
 - **Acoustic:** Low-level audio features
- Classifier
 - SVM 5-fold cross validation

Oramas S., Espinosa-Anke L., Lawlor A., Serra X., & Saggion H. (2016). Exploring Music Reviews for Music Genre Classification and Evolutionary Studies. ISMIR 2016.

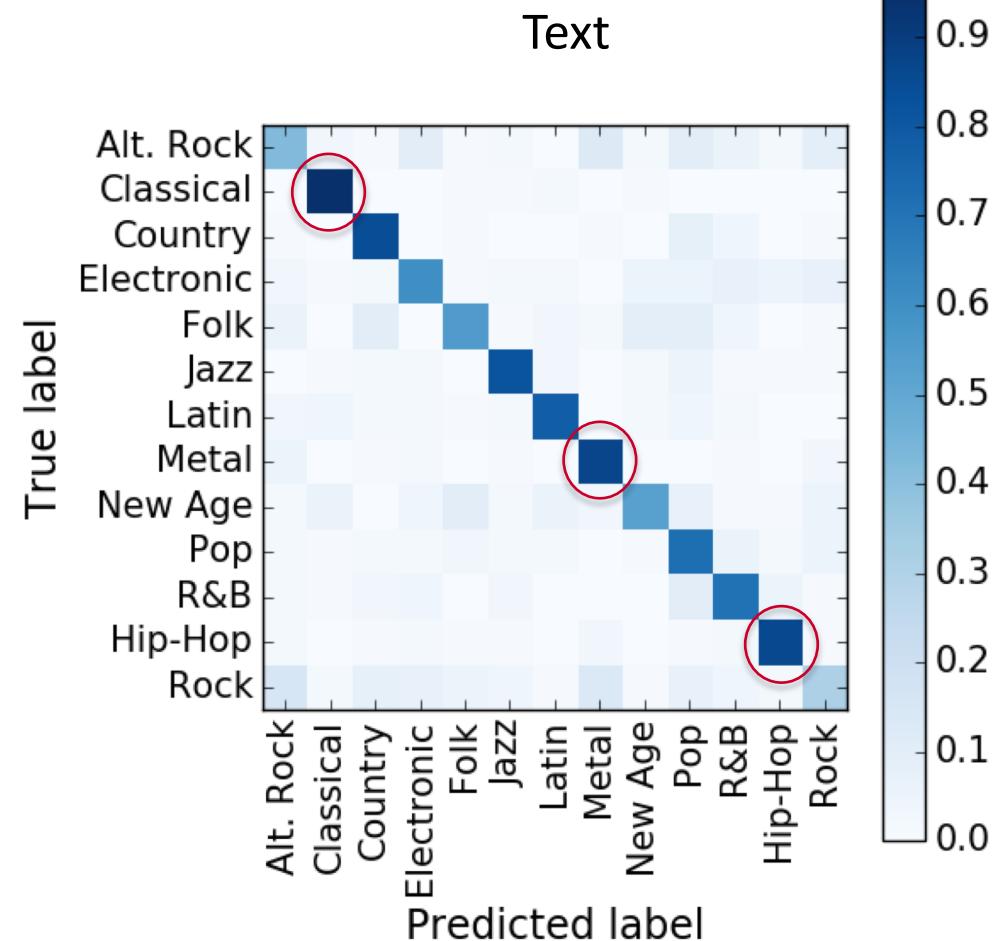
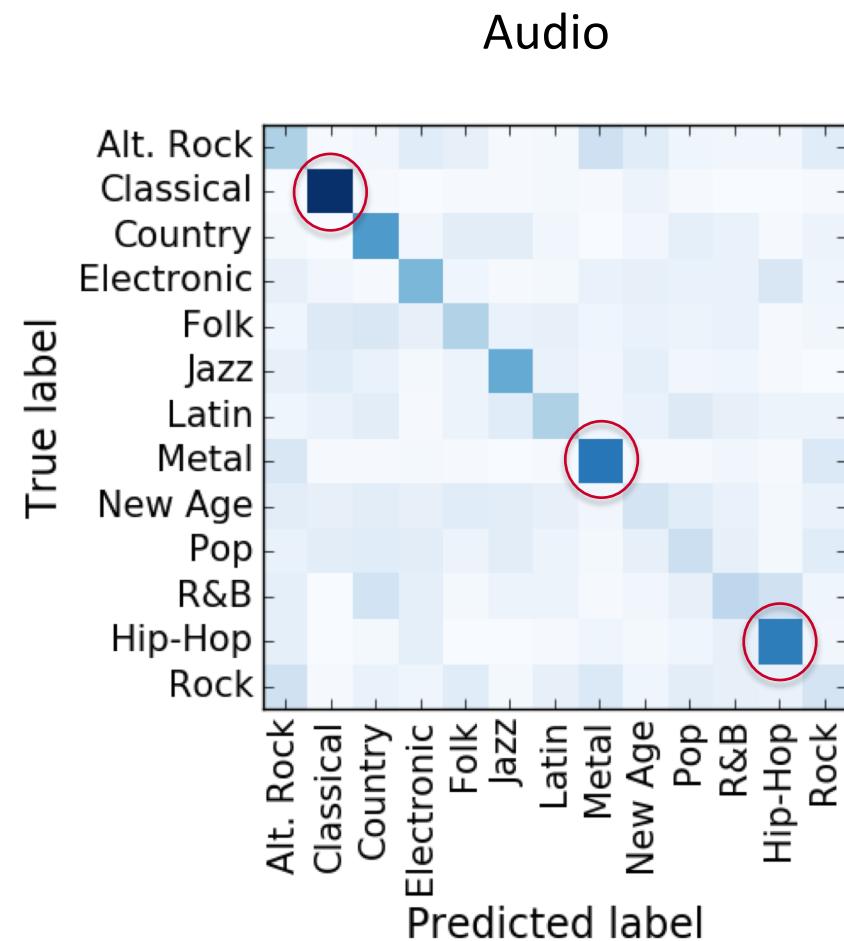
Single-label Music Genre Classification

	Accuracy
Text-based	62.9
Enriched Description	69.1
Text-based (Hu 2006)	55.0
Audio features	38.7

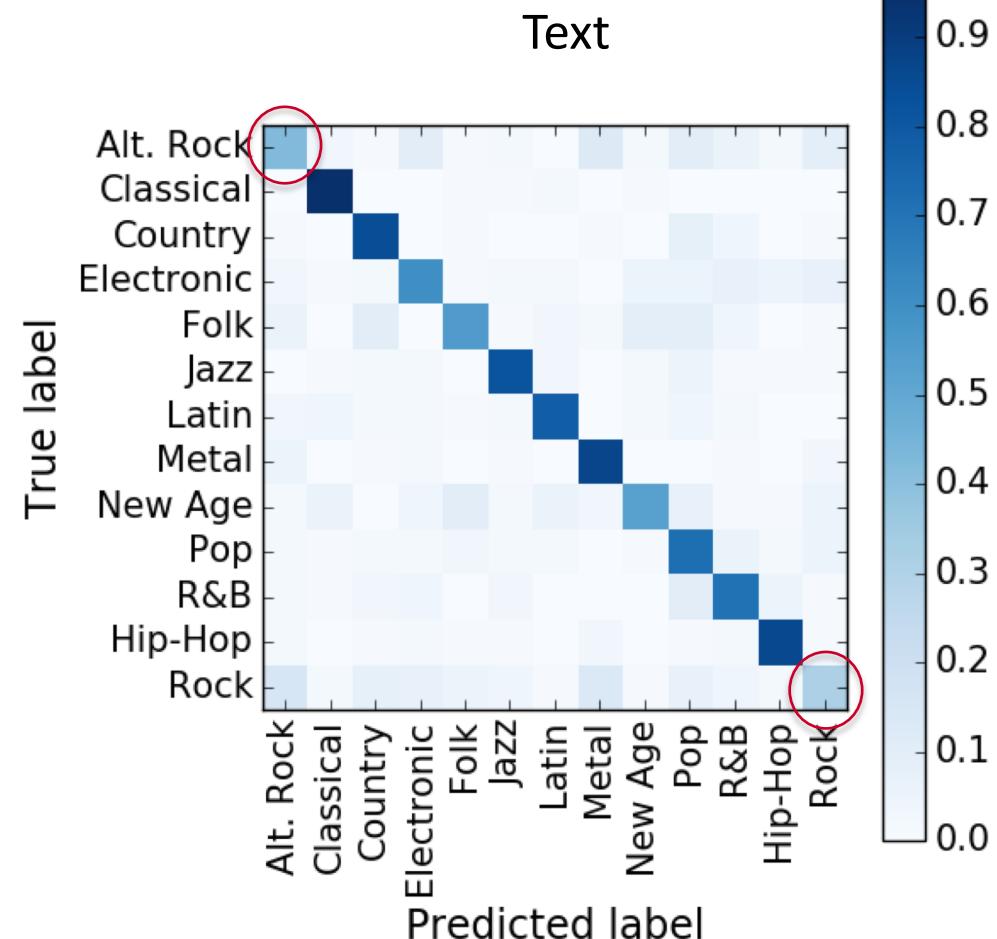
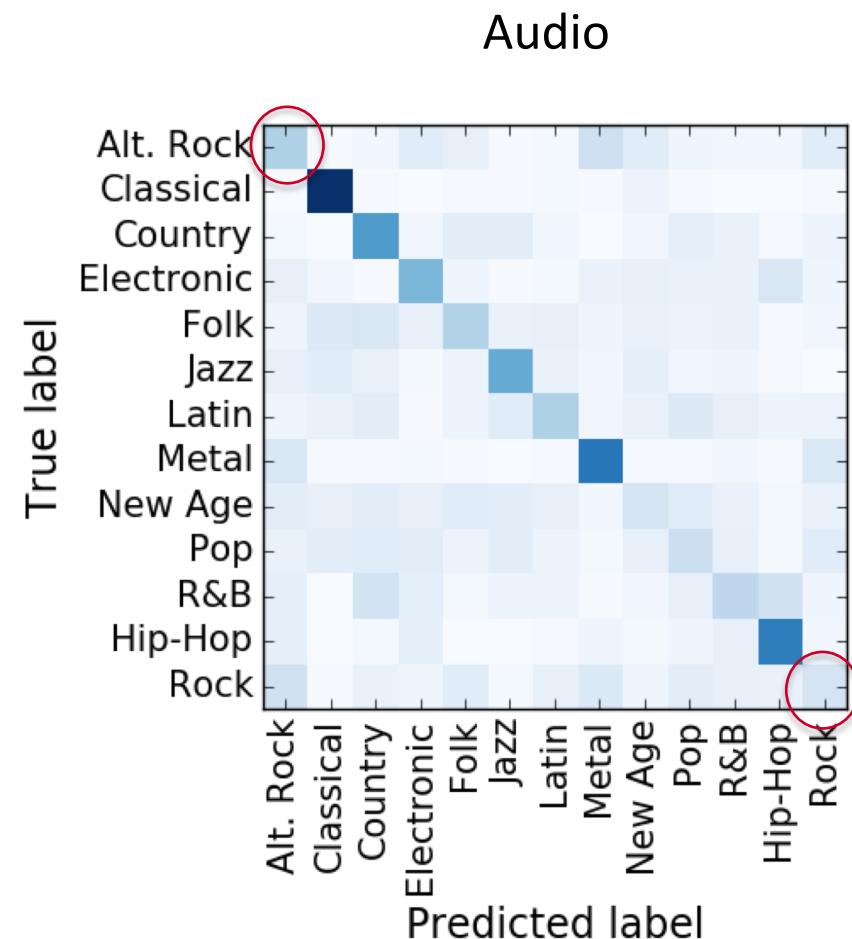
Single-label Music Genre Classification



Single-label Music Genre Classification



Single-label Music Genre Classification



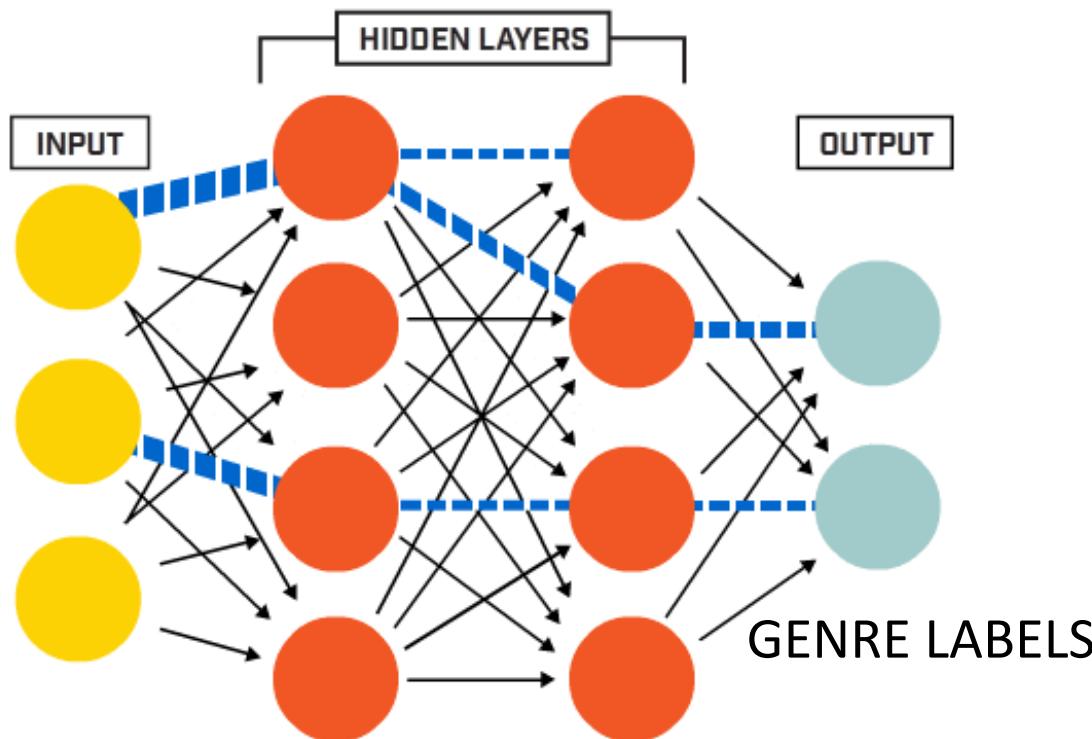
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- Single-label → **Multi-label**
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Multi-label Classification with Deep Learning

Logistic output

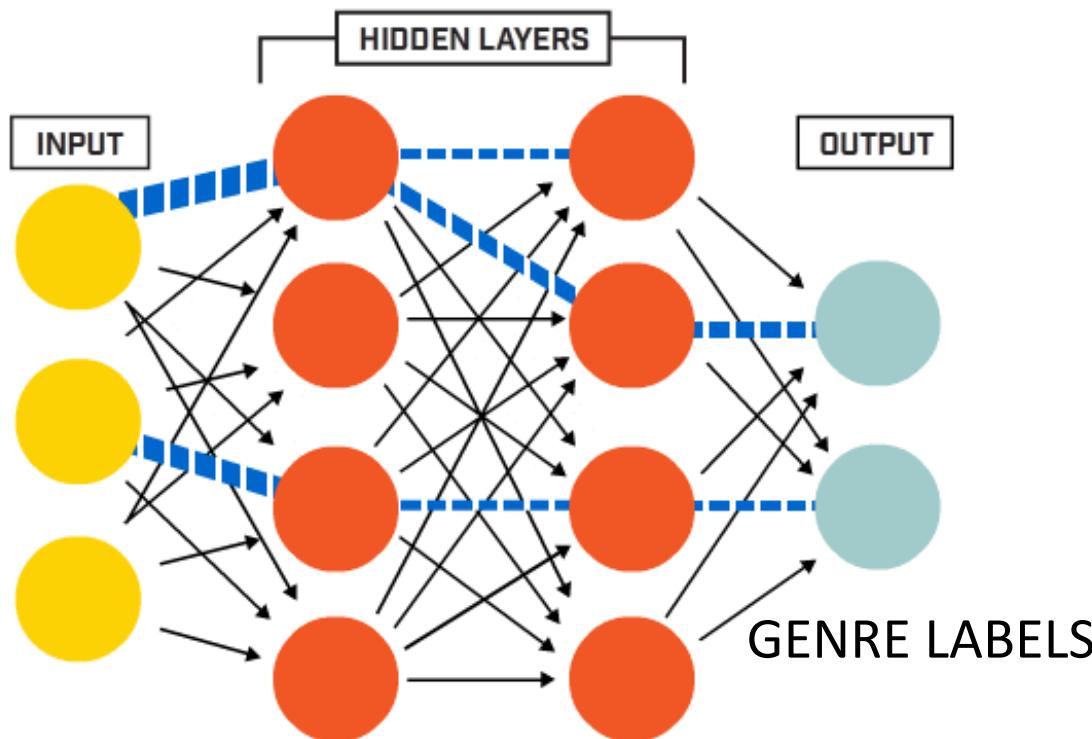


Output layer:

- 1 neuron per label
- Sigmoid activation
- Cross entropy loss

Multi-label Classification with Deep Learning

Logistic output



Output layer:

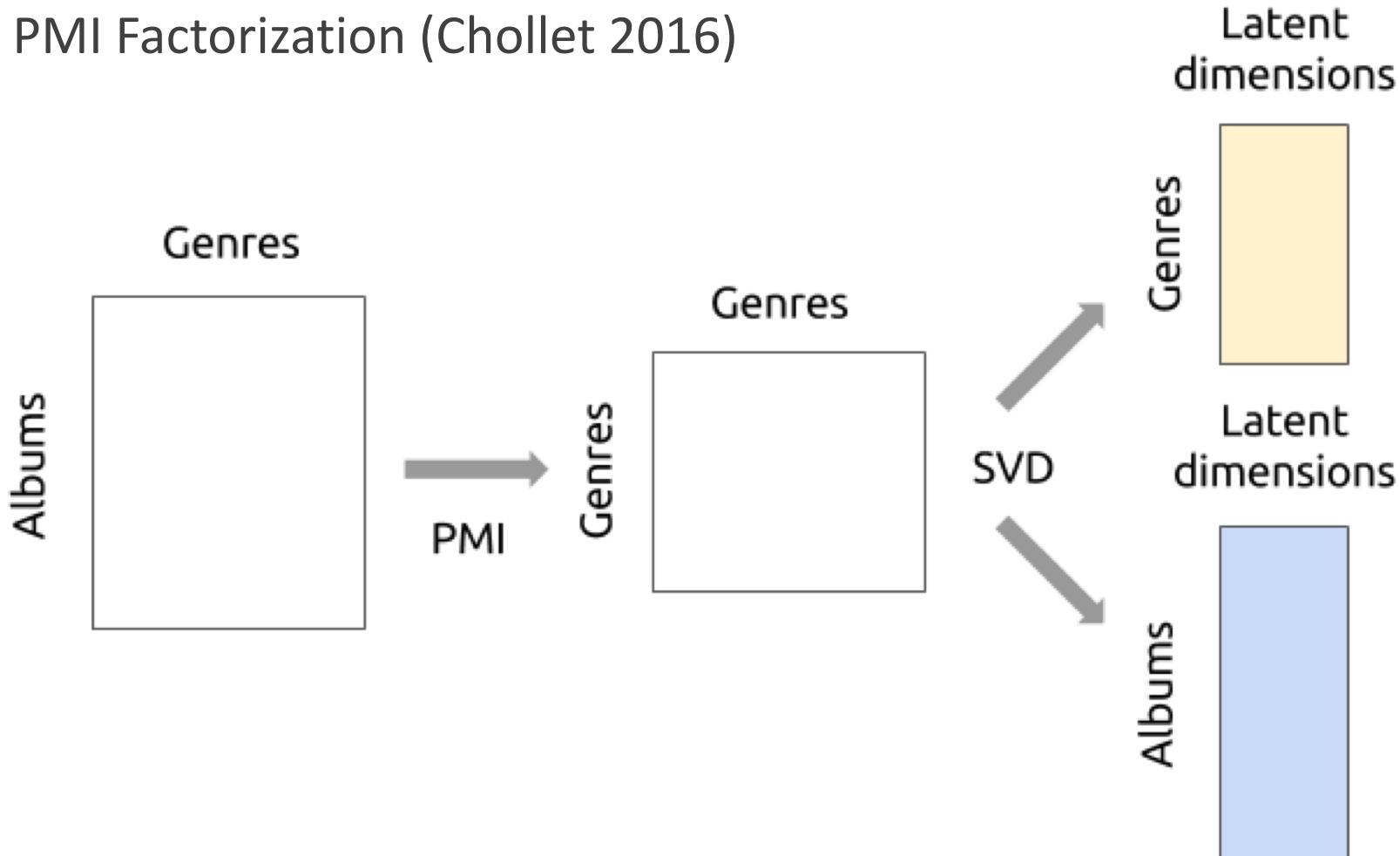
- 1 neuron per label
- Sigmoid activation
- Cross entropy loss

Cons:

- Assumption of mutual independence of labels
- High dimensionality

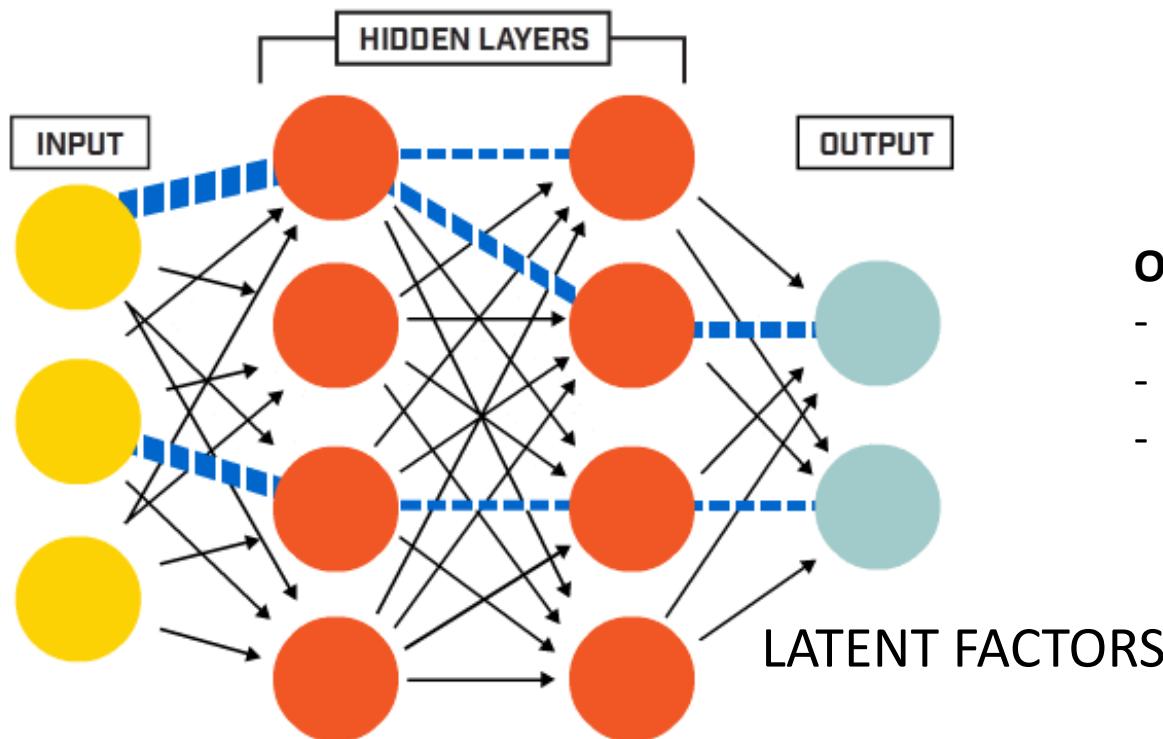
Dimensionality reduction

PMI Factorization (Chollet 2016)



Multi-label Classification with Deep Learning

Regression output

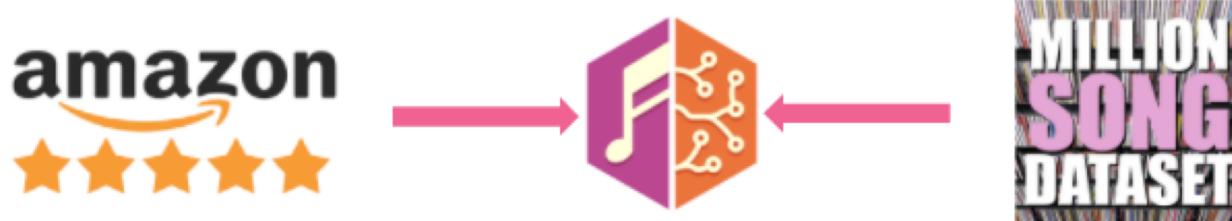


Output layer:

- 1 neuron per latent dim
- Linear activation
- Cosine proximity loss

Dataset

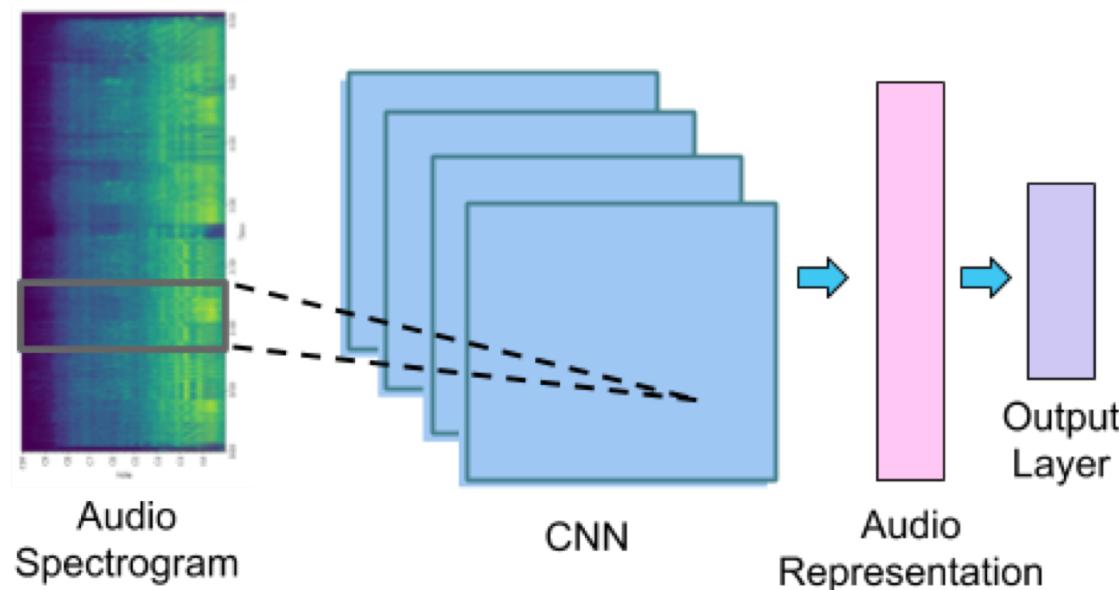
- MuMu Dataset
 - 31k albums with
 - Cover art images
 - 150k audio tracks
 - 450k album reviews
 - Multi-label genre annotations of 250 genres



Oramas, S., Nieto O., Barbieri F., & Serra X. (2017). Multi-label Music Genre Classification from Audio, Text and Images Using Deep Features. ISMIR 2017.

Audio-based approach

- Constant-Q spectrograms with 96 frequency bins
- 4 convolutional layers
- No dense layers



Audio-based classification results

Target	Input	AUC	ADiv@1
GENRE LABELS	Acoustic features	0.792	0.04
GENRE LABELS	CQT + CNN	0.871	0.05

Audio-based classification results

Target	Input	AUC	ADiv@1
GENRE LABELS	Acoustic features	0.792	0.04
GENRE LABELS	CQT + CNN	0.871	0.05
LATENT FACTORS	CQT + CNN	0.888	0.35

Qualitative Analysis

LATENT FACTORS

Dance & Electronic, Dance Pop, Electronica
Rock, Alternative Rock, Pop
Jazz, Bebop, Modern Postbebop
Jazz, Cool Jazz, Bebop
Jazz, Bebop, Cool Jazz
Jazz, Bebop, Cool Jazz
Blues, Traditional Blues, Acoustic Blues
Smooth Jazz, Soul-Jazz & Boogaloo, Jazz
Dance Pop, Dance & Electronic, Electronica
Rock, Alternative Rock, Metal
Rock, Pop, Singer-Songwriters
Dance & Electronic, Dance Pop, Electronica
Pop, Rock, World Music
Dance & Electronic, Dance Pop, Electronica
Alternative Rock, Indie & Lo-Fi, Indie Rock
Rock, Alternative Rock, Pop
Singer-Songwriters, Contemporary Folk, Folk
Metal, Pop Metal, Rock
Smooth Jazz, Soul-Jazz & Boogaloo, Jazz
Alternative Rock, Rock, American Alternative

LABELS

Pop, Dance & Electronic, Rock
Pop, Rock, Alternative Rock
Pop, Jazz, Rock
Pop, Jazz, Bebop
Jazz, Pop, Bebop
Pop, Jazz, Bebop
Pop, Rock, World Music
Pop, Jazz, R&B
Pop, Dance & Electronic, Dance Pop
Rock, Pop, Alternative Rock
Pop, Rock, Country
Dance & Electronic, Pop, Dance Pop
Pop, Rock, World Music
Pop, Rock, Dance & Electronic
Rock, Pop, Alternative Rock
Pop, Rock, Alternative Rock
Pop, Rock, Folk
Pop, Rock, Alternative Rock
Pop, Rock, Jazz
Pop, Rock, Alternative Rock

Qualitative Analysis

LATENT FACTORS

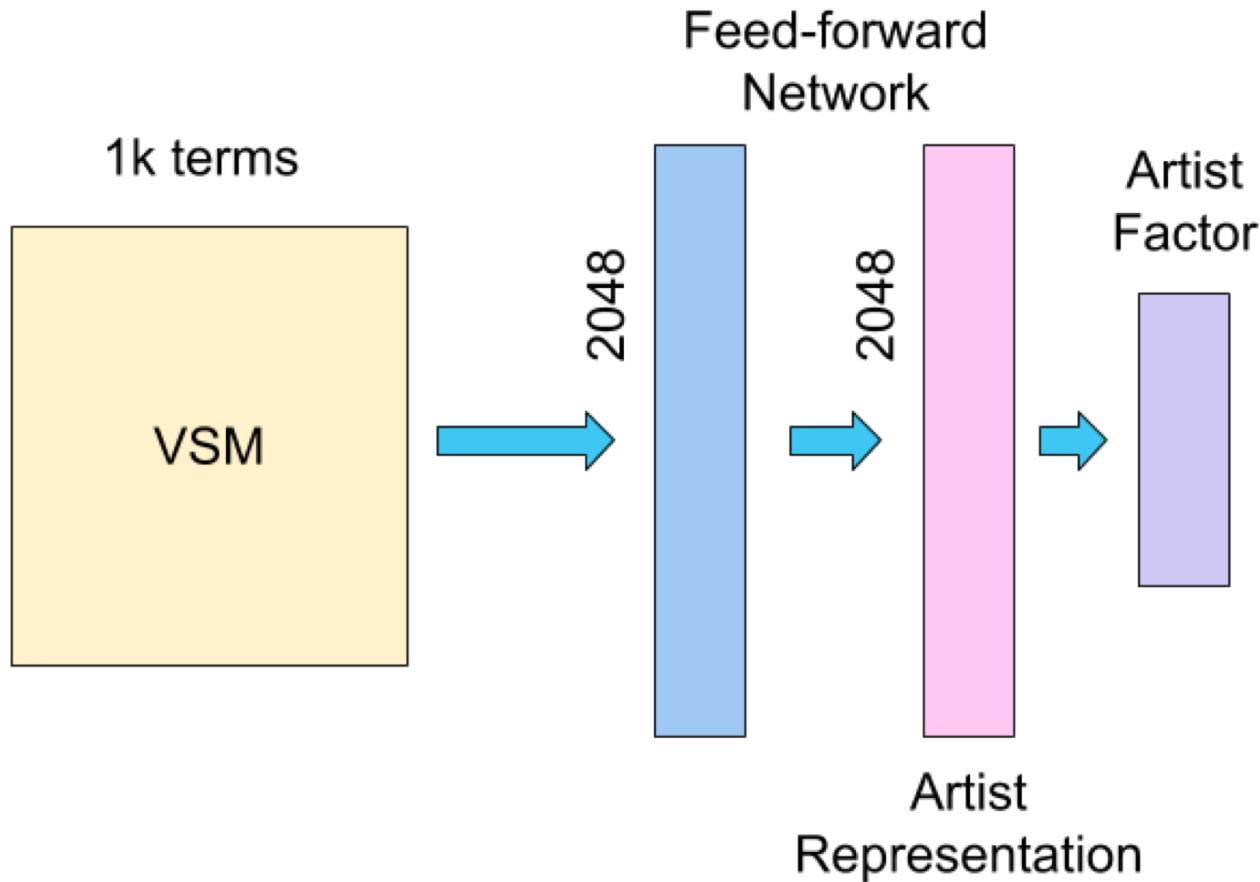
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Pop, Rock, Dance & Electronic
Rock, Pop, Alternative Rock
Pop, Rock, Alternative Rock
Pop, Rock, Folk
Pop, Rock, Alternative Rock
Pop, Rock, Jazz
Pop, Rock, Alternative Rock

Text-based Approach



Text-based classification results

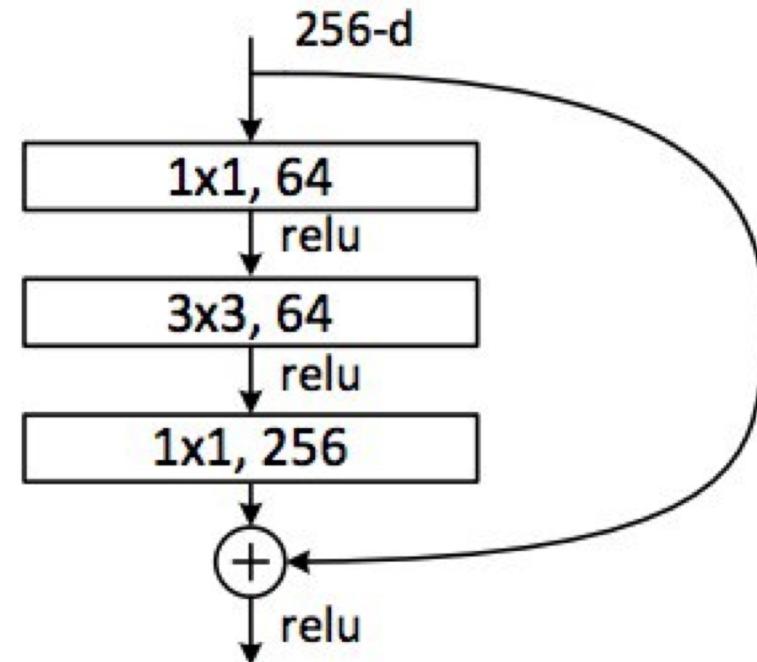
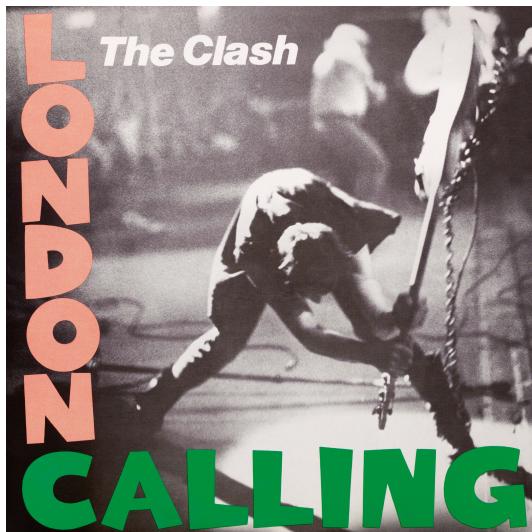
Target	Input	AUC	ADiv@1
GENRE LABELS	Text	0.905	0.08
GENRE LABELS	Enriched Text	0.916	0.10
LATENT FACTORS	Enriched Text	0.917	0.42

Information Gain

Rock	Pop	Metal	Hip Hop	Country
band	song	metal	hip	country
rock	songs	death	hop	Nashville
punk	euro	band	rap	her
bands	trade	black	rhymes	Waylon

Image-based approach

- Deep Residual Networks (ResNets)
- 101 layers
- Pretrained on ImageNet
- Fine-tuning in our task



Multimodal classification results

Modality	AUC
Audio	0.888
Text	0.917
Images	0.743

Multimodal classification results

Modality	AUC
Audio	0.888
Text	0.917
Images	0.743
A + T	0.930
A + I	0.900
T + I	0.921

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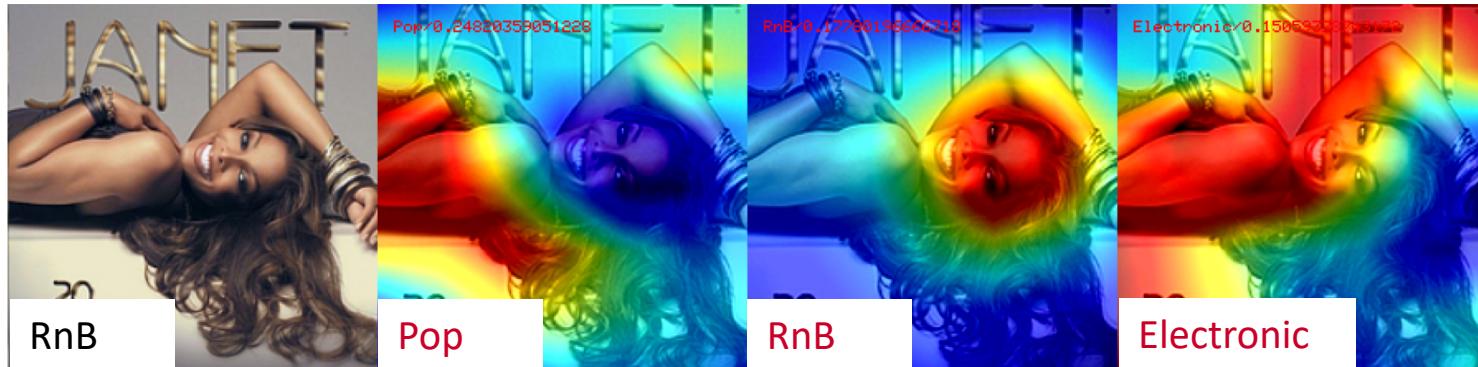
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A + T + I	0.936

Qualitative analysis: Attention heatmaps



NLP for Music Knowledge Discovery

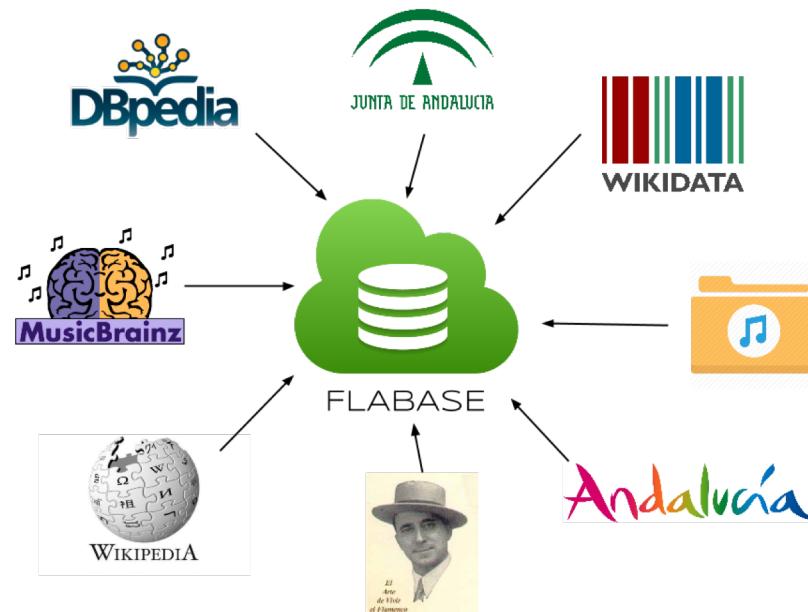
Knowledge Extraction for Musicology

- Musicologists have to read thousands of documents
- Automatic analysis of documents may help musicologists providing insights or novel hypothesis
- Two use cases:
 - Relevance of Flamenco artists
 - Evolution of Affective Language in Music Reviews

Oramas, S., Espinosa-Anke L., Gómez F., & Serra X. (2018). Natural Language Processing for Music Knowledge Discovery. *Journal of New Music Research*

Flamenco Knowledge Base

- ~1k artist biographies
- Ad hoc entity linking system



Graph of Entities

Camarón de la Isla

[...] He was noted for his collaborations with Paco de Lucía and Tomatito [...]

Vicente Amigo

[...] An admirer of Paco de Lucía since childhood, Amigo took part with him in the show “Legends of the Guitar” [...]

Graph of Entities

Camarón de la Isla

[...] He was noted for his collaborations with [Paco de Lucía](#) and [Tomatito](#) [...]

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Entity Linking

Graph of Entities

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Vicente Amigo

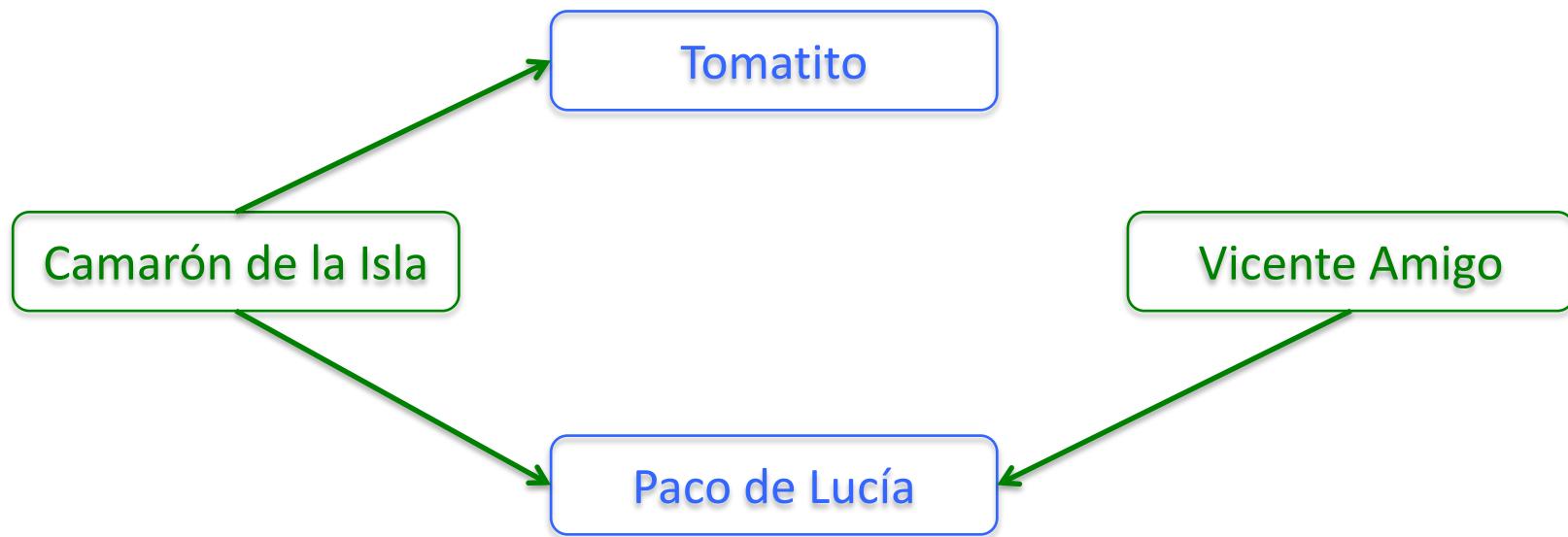
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Vicente Amigo

[...] An admirer of [Paco de Lucía](#) since childhood, Amigo took part with him in the show “Legends of the Guitar” [...]



Artist Relevance

- Flamenco expert manual evaluation

Algorithm	Precision@5
PageRank	0.93
HITS	0.60

PageRank Top-5

Cantaor (Singer)	Guitarist	Bailaor (Dancer)
Antonio Mairena	Paco de Lucía	Antonio Ruiz Soler
Manolo Caracol	Ramón Montoya	Rosario
La Niña de los Peines	Niño Ricardo	Antonio Gades
Antonio Chacón	Manolo Sanlúcar	Mario Maya
Camarón de la Isla	Sabicas	Carmen Amaya

Evolution of Affective Language in Music Reviews

- MARD Dataset: Amazon + MusicBrainz
 - 250k album customer reviews and ratings
 - 66k albums
 - 16 genres
 - Album and review publication date



Evolution of Affective Language in Music Reviews

- MARD Dataset: Amazon + MusicBrainz
 - 250k album customer reviews and ratings
 - 66k albums
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 - Album and review publication date
- Aspect-based Sentiment Analysis



+ 0.8

- 0.4

This album has **great guitar riffs** but the **vocals** are **shrill**

A blue curved arrow points from the text "great guitar riffs" to the "+ 0.8" above it. Another blue curved arrow points from the text "vocals are shrill" to the "- 0.4" above it.

Evolution of Affective Language in Music Reviews

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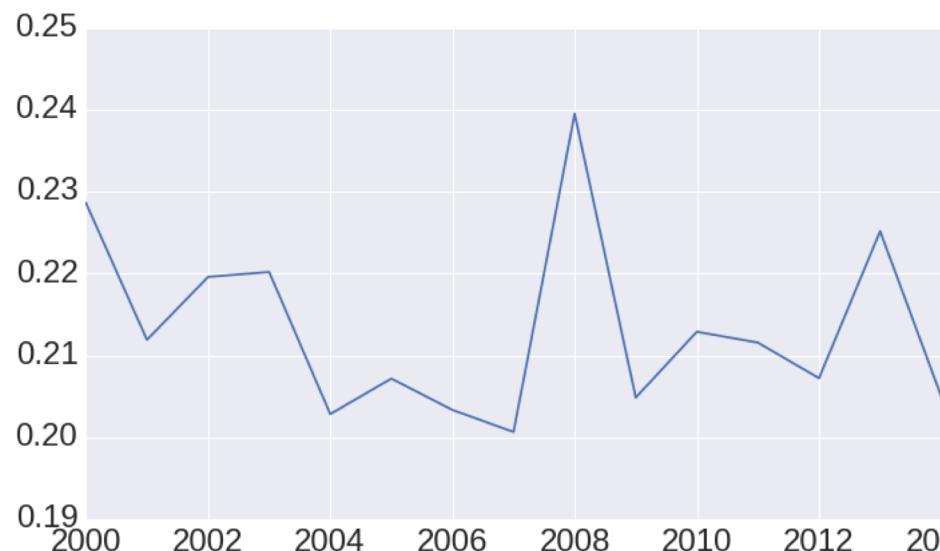
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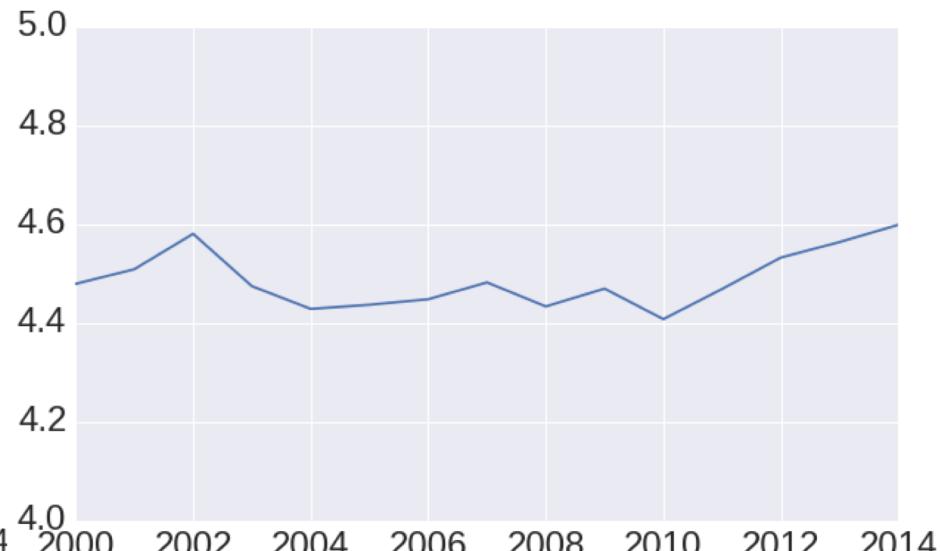
- Group and average scores by: review, album, date, genre

By review creation year

Average sentiment

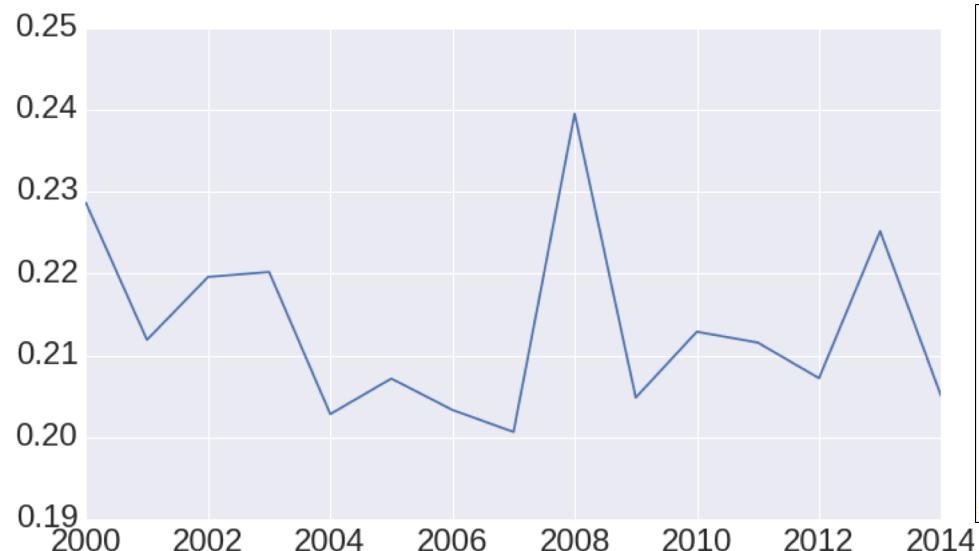


Average rating

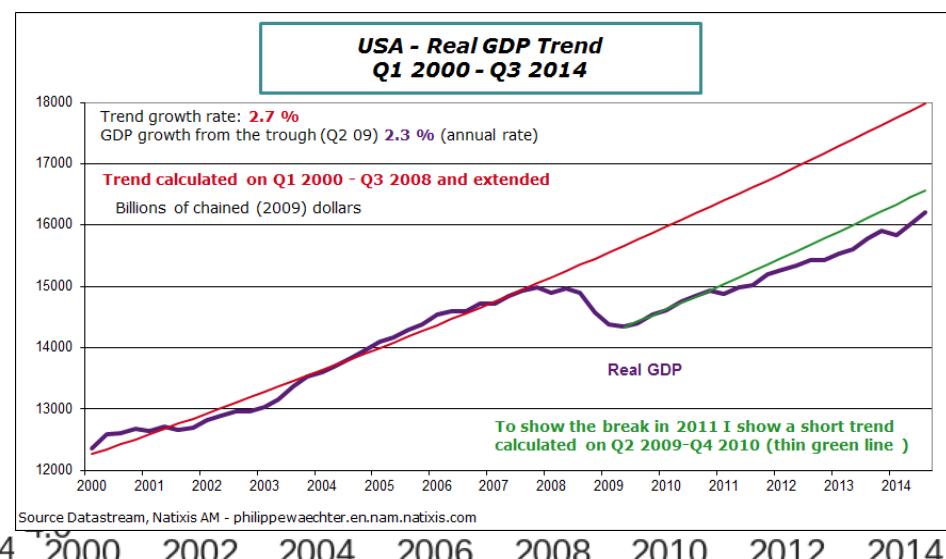


By review creation year

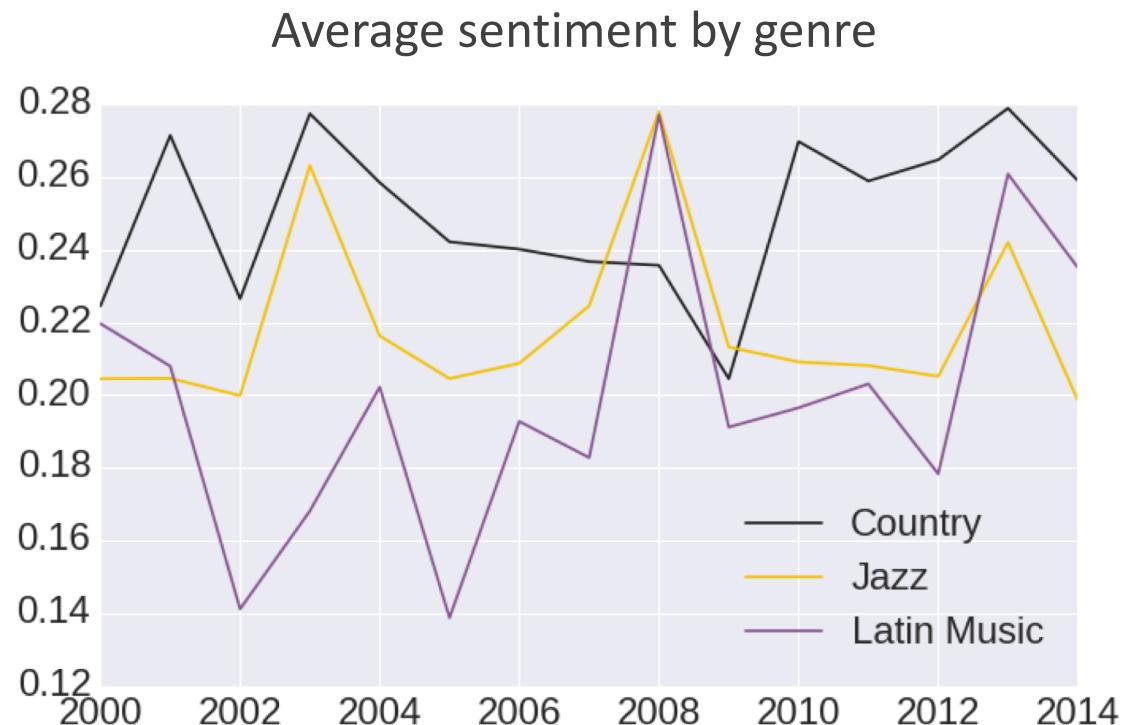
Average sentiment



USA GDP

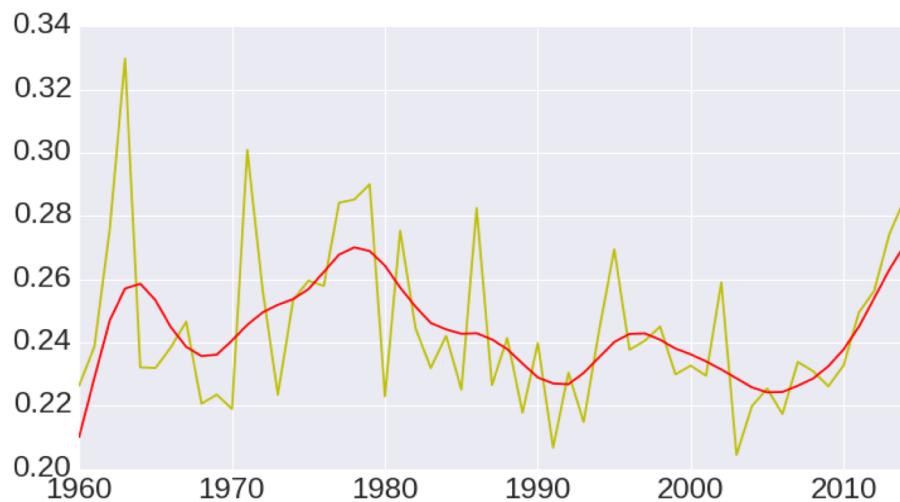


By review creation year

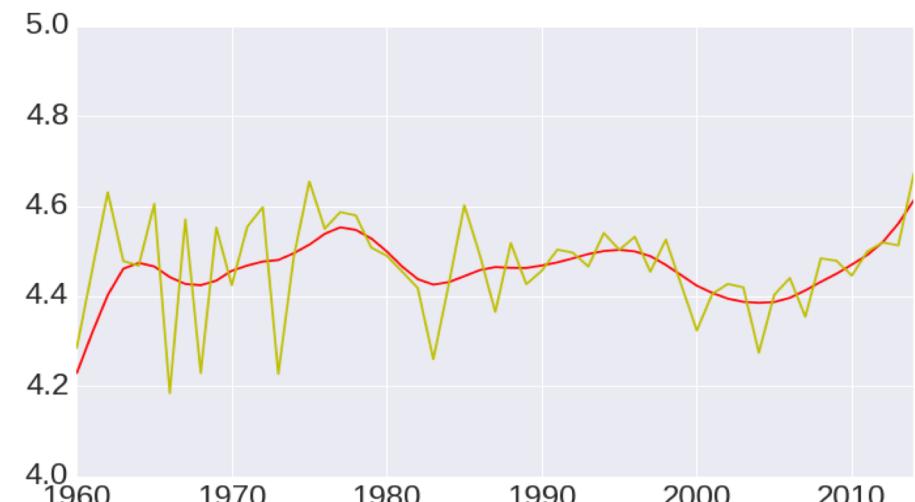


By album release year

Average sentiment



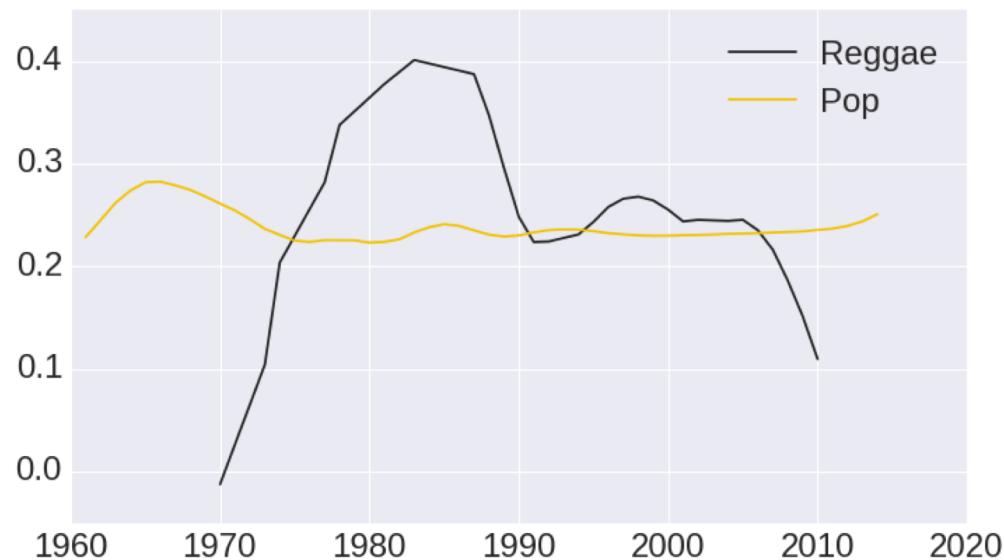
Average rating



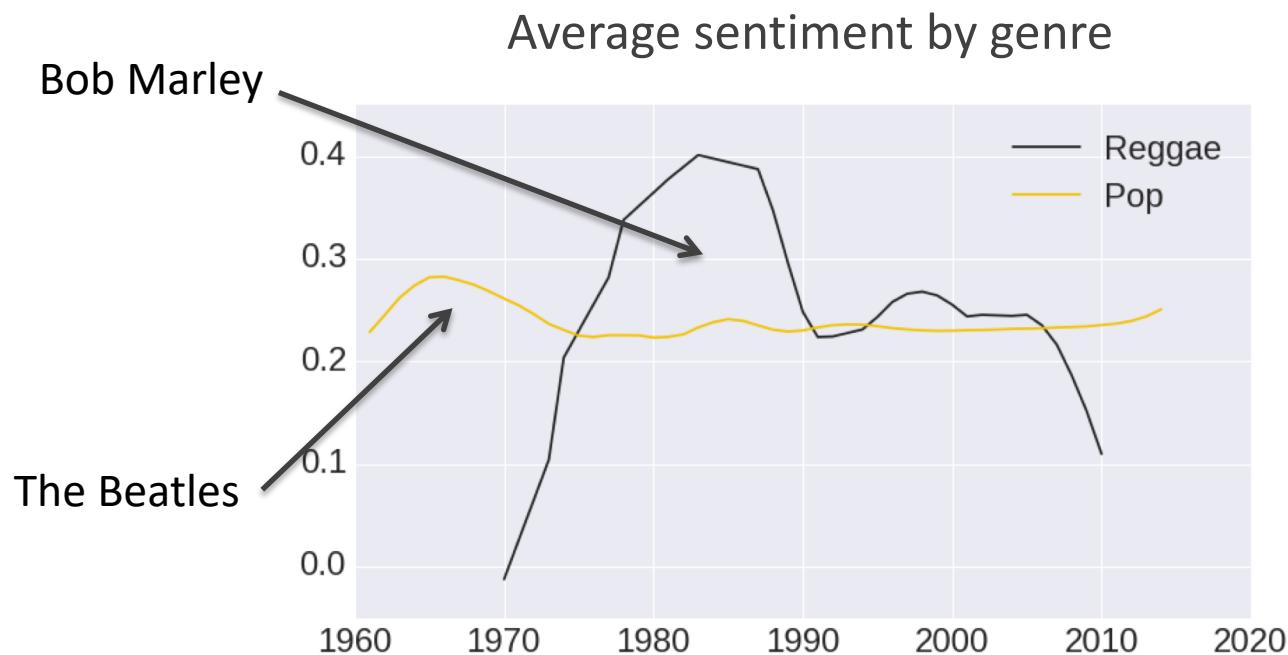
Pearson's correlation $r = 0.75$, $p \ll 0.001$

By album release year

Average sentiment by genre



By album release year



Future directions

- Creation of a large and extracted Music KB
- Deep learning for text: word embeddings, attention models
- Conversational systems or chatbots
- Multimodal retrieval using learned data representations
- Generative models: from one modality to another