



# Interactive Recommender Systems

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# Outline

- Introduction
- Use cases
  - Netflix
  - Spotify
- Challenges
- Deep Dive
  - Netflix
  - Spotify
- Insights
- Discussion

# **Introduction**



# What are Interactive RSs?

- Define Interactive:
  - Influencing or having an effect on each other.
  - Allowing a two-way flow of information
  - Responding to a user's input
- Forms of Interaction
  - Implicit vs explicit feedback
- User experiences



# Need for Interactive RSs?

- To better serve the user's (entertainment) needs
- Fill the gap between browse and search
  - Lean-back vs precise need
- To establish trust and credibility
- Instant gratification

# Interactive RS in practice?

- Most online services offer different levels of personalization
- Video: Netflix, YouTube, Hulu, Amazon Video, HBO, ...
  - Browse (homepage/genre) and search
- Music: Spotify, Pandora, Apple Music, Google Music, ...
  - Browse, **Radio**, Search
- Books/Apps/Shopping: Amazon, Apple, Google
- (Video and Image) Search: Google, Bing, Yahoo
  - Left rail suggestions (explore), search completion
- Travel: Booking.com, Kayak, Orbitz, Expedia, ...
  - **Guided experience**: Pick destination —> pick flight and hotel, arrange local transport, plan activities, go dining and sightseeing...

# Research on Interactive RS

- “A successful recommender system must balance the needs to **explore** user preferences and to **exploit** this information for recommendation.”
  - Exploration in Interactive Personalized Music Recommendation: A Reinforcement Learning Approach. X. Wang, Y. Wang, D. Hsu, Y. Wang (2013)
- Active learning / Multi-Armed Bandits ( $\varepsilon$ -greedy, UCB, Thompson sampling)
  - Papers at RecSys this year and in the past :)
- When do explicit taste preferences trump play data?
  - When we have **insufficient knowledge** about the user
  - When **context** changes
    - TasteWeights: A Visual Interactive Hybrid Recommender System. S. Bostandjiev, J. O’Donovan, T. Höllerer (RecSys 2012)
  - When the user has a **vague** idea of what they want
- IntRS: Workshop on Interfaces and Human Decision Making for Recommender Systems

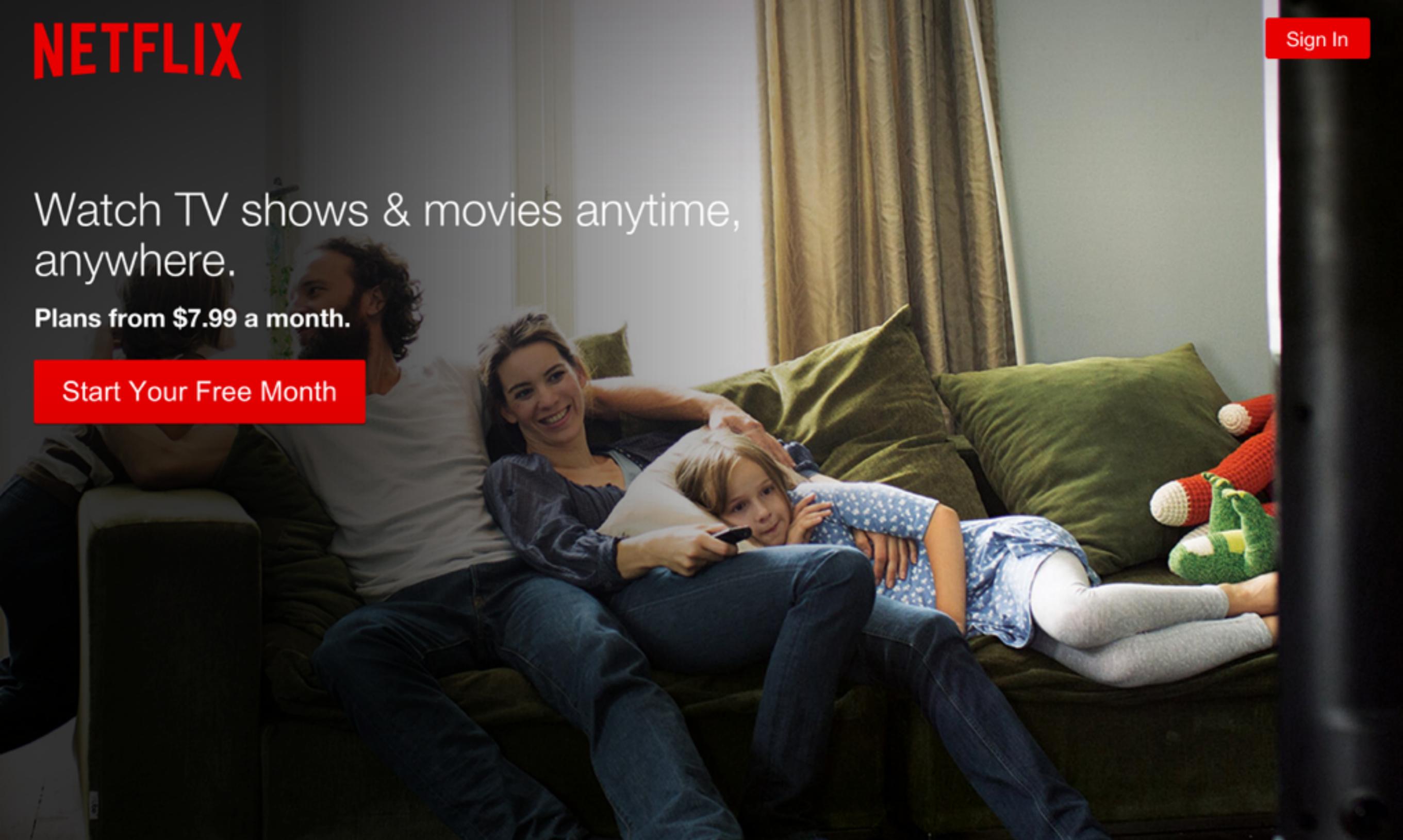
**Use-case:**

**NETFLIX**

Watch TV shows & movies anytime,  
anywhere.

Plans from \$7.99 a month.

[Start Your Free Month](#)



Watch on your smart TV, game console, PC, Mac,  
mobile, tablet and more.



TV shows & movies streamed instantly over  
the Internet.

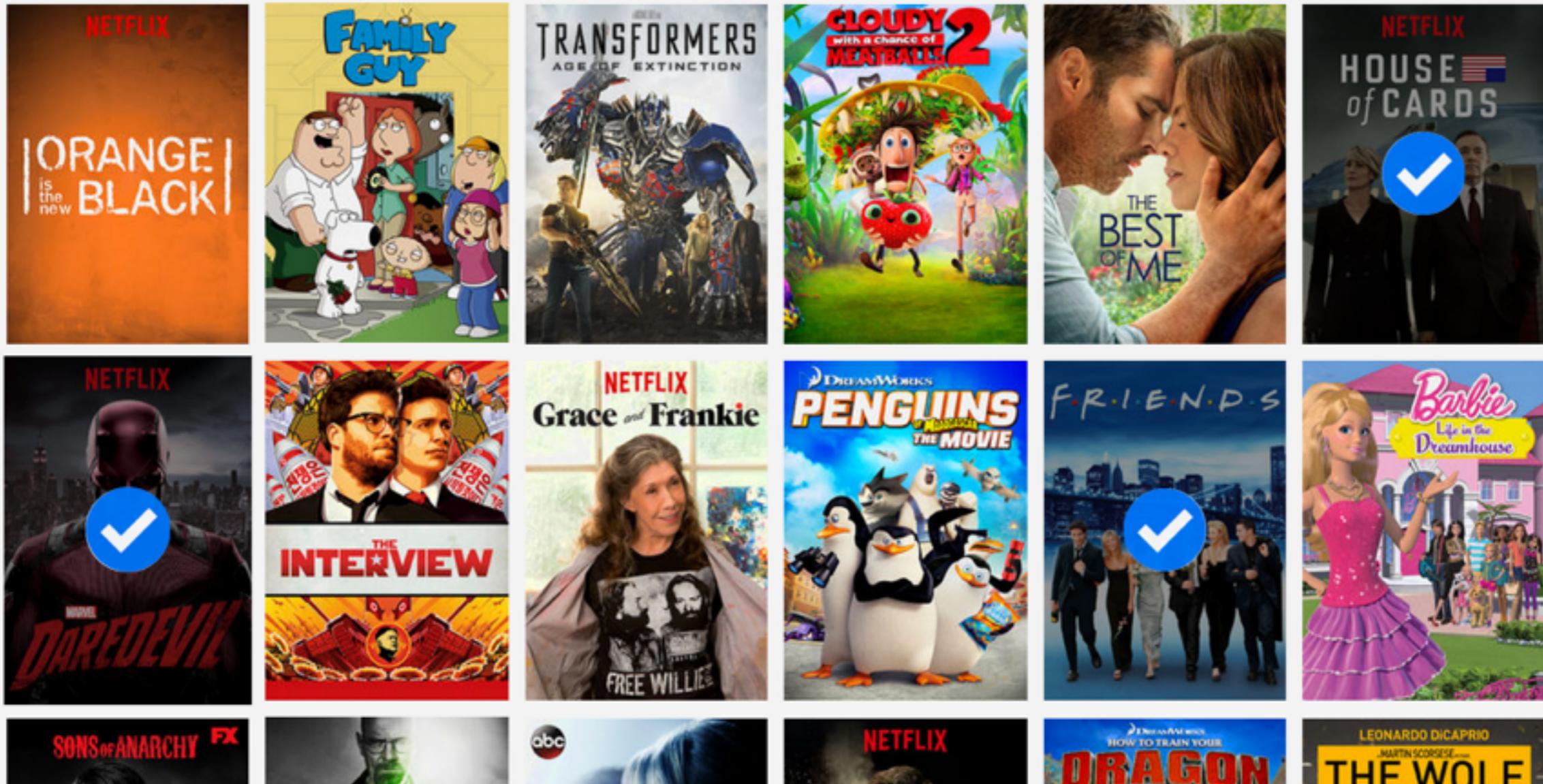


No pressure. Cancel anytime.

### ③ Roelof, choose 3 you like

It will help us find TV shows & movies you'll love! **Click the ones you liked!**

Continue



# NETFLIX ORIGINAL NARCOS

Watch All Episodes Now

First they got the coke. Then they got the money. Now the Colombian cartels want the power. Let the drug wars begin.

▶ PLAY

+ MY LIST



## Popular on Netflix



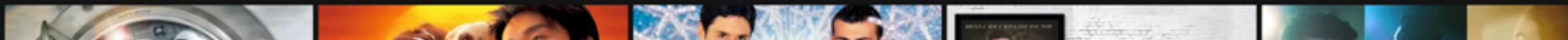
## Trending Now





Explore titles related to: Comedies

People: Guillaume Gallienne | Aurélien Recoing | Andy Comeau | Laurent Lafitte | Wendy Comes | Lodovica Comello



# Interactive RSs @ Netflix

- Help user's find a great video to watch as an alternative to browse and search.
  - Address browse fatigue; failed search experience; or user has vague notion of what to watch; watching with friends
  - Not for everyone, not all the time...
- Max - Rating Game
  - Select a topic, rate some videos, get recommendations
- Hot-or-Cold
  - Tell us what you're into, one video at a time
- Discover
  - Select one or more videos of interest to explore other similar options

# Max - Rating Game

## Grey's Anatomy

★★★★★ 2013 TV-14 10 Seasons HD

Neither their patients' problems nor their own relationships are black-and-white. It's all shades of grey.



Katherine Heigl won a Supporting Actress Emmy for the show, ranking in the top 10 for four seasons.

SEARCH & MENU

Continue Watching for HornerBaig



My List



# Hot or Cold Game

## Grey's Anatomy

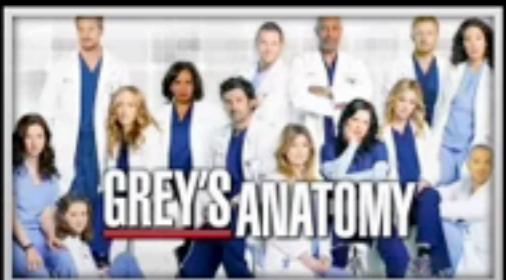
★★★★★ 2013 TV-14 10 Seasons HD

Neither their patients' problems nor their own relationships are black-and-white. It's all shades of grey.

Watched by these friends:



Continue Watching for HornerBaig



My List



# Discover App

Roelof

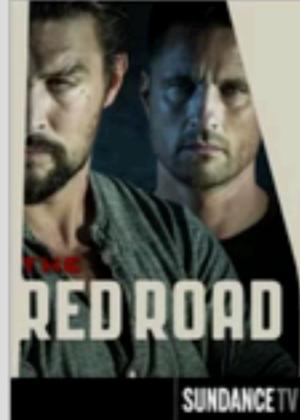
Netflix [www.netflix.com/WiHome?linkctr=mhWN](http://www.netflix.com/WiHome?linkctr=mhWN)

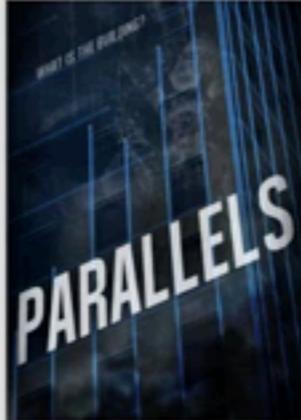
Search [US](#)

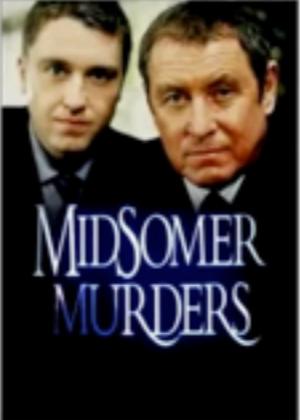
NETFLIX [Browse](#) [DVDs](#) [Discover](#)

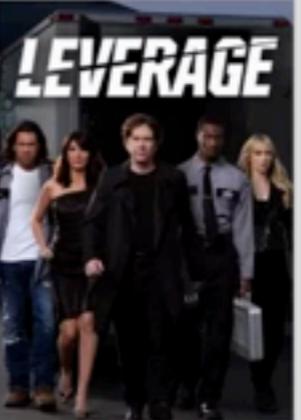
Recently Watched [My List](#) [See All](#)

 [Doc Martin](#)  
Added 6 days ago

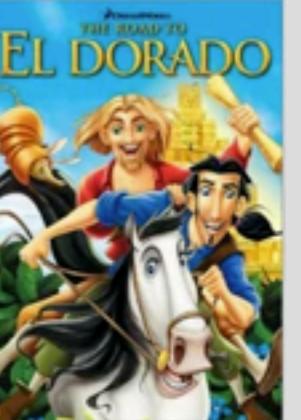
 [THE RED ROAD](#) [SUNDANCE TV](#)  
Added 1 week ago

 [PARALLELS](#)

 [MIDSOMER MURDERS](#)

 [LEVERAGE](#)

 [WAREHOUSE 13](#)  
THE UNKNOWN HAS AN ADDICT

 [THE ROAD TO EL DORADO](#)

 [LONGMIRE](#)

[Recommend](#)

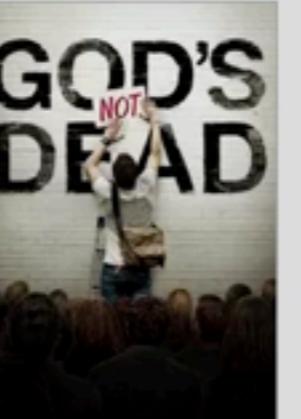
Trending Now

 [MR. PEABODY & SHERMAN](#)

 [ONCE UPON A TIME](#)

 [HOW TO TRAIN YOUR DRAGON 2](#)

 [GILMORE GIRLS](#)

 [GOD'S NOT DEAD](#)

 [NETFLIX \*Richie Rich\*](#)

 [AND SO IT GOES](#)

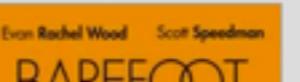
 [CHEF](#)

Top Picks for US

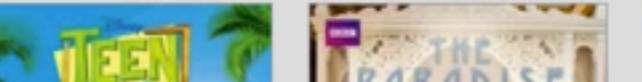
 [TANGLED](#)

 [SPY KIDS](#)

 [NO ONE IS WHAT THEY SEEM](#)

 [Eva Rachel Wood Scott Speedman RAREFOOT](#)

 [TEEN BEACH](#)

 [THE PARROT'S LAMENT](#)

 [PRINCESS DIARIES 2](#)

# Use-case:



MAIN

- Browse
- Activity
- Radio

YOUR MUSIC

- Songs
- Albums
- Artists
- Local Files

PLAYLISTS

- Find them Next
- Discover Weekly Finds
- Discover Weekly
- Current Rotation
- The Smashing Pumpkins ...
- The Smashing Pumpkins ...
- Best of Jagjaguwar by Jagja...
- Starred
- 90s Jam
- Something Satanical by Ne...
- patio
- climbing music by Jesse Ro...
- Pitchfork 2015: Best New ...
- Festivals
- Discover Weekly (old)
- Recently Saved
- Stereogum's Favorite New...
- DP - Control
- smartbox-ch1
- electronic
- DiscoveredPLs
- New Playlist
- Party Talk Craft Spells

Search

# Browse

OVERVIEW CHARTS GENRES & MOODS NEW RELEASES DISCOVER

Afternoon vibes...

AFTERNOON ACOUSTIC

Afternoon Acoustic

Unwind and let the afternoon unfold in all its acoustic glory.

Esntl Electronic Golds

Essential Electronic

Timeless electronic hits and house favorites!

SOUL REVIVED

Soul Revived

Updated takes on some of the most classic RnB/Soul tunes.

#ThrowbackThursday

#ThrowbackThursday

Can you guess each song's original decade? If so, you'll know... #spotifytbt...

Afternoon Groove

Get in your groove with some chilled ambient and electronic focus music.

Jazztronica

Where jazz meets electronic music.

CHARTS

Global Top 50, United States Top 50, United States Viral 50

NEW RELEASES

Travis Scott, Iron Maiden, Troye Sivan

DISCOVER WEEKLY

Discover Weekly

Recommended for you

GENRES & MOODS

Mood

Party

Pop

Chill

Workout

Hip hop

Chris Johnson

Evan Shrubsole  
Wildflower Beach House

Luc Succes  
Flicker Porter Robinson

Daniel Setlowan  
Turtles All the Way Down Sturgill Simpson

Kurt Jacobson  
Deep Inside - Low Steppa Remix Harddrive

Martin Sandberg  
Ave Maria Johann Sebastian Bach

Kate Mendenhall  
I Need Never Get Old Nathaniel Rateliff & The Night Sweats

Charlie Pastuszak  
Cushioned Caging Palehound

Jessica Gifford  
Glow Lights & Motion

Bilxt  
A Horse With Children's Feet Philip James de Vries

Becky Sandler  
La basse et les shakers Domenique Dumont

Ben Schumer  
Comme ça

LYRICS

2:43 3:40

# Spotify in Numbers



- Started in 2006, now available in 58 markets
- 75+ million active users, 20 million paying subscribers
- 30+ million songs, 20,000 new songs added per day
- 1.5 billion playlists
- 1 TB user data logged per day
- 1k node Hadoop cluster
- 10,000+ Hadoop jobs run every day



# Challenge: 20 Million songs... how do we recommend music to users?



# Discover Weekly

A screenshot of the Spotify desktop application. The main focus is the 'Discover Weekly' playlist, which is highlighted with a blue border. The playlist cover features a man in sunglasses and a suit. Below the cover, there are three buttons: 'PLAY', 'FOLLOWING' (which is highlighted in green), and a three-dot menu button. To the right of the buttons, it says 'FOLLOWERS 2'. A toggle switch labeled 'Available Offline' is turned off. The main content area shows a table of 30 songs with columns for Song, Artist, Album, Last Played, and Duration. Each song row has a plus sign icon on the left. At the bottom of the screen, there's a navigation bar with icons for back, forward, play/pause, volume, and other controls. The bottom right corner shows the current track at 0:25 and the total duration at 2:51.

# Discover

Search

Chris Johnson

MAIN

Browse

Activity

Radio

YOUR MUSIC

- Songs
- Albums
- Artists
- Local Files

PLAYLISTS

- Find them Next
- Find them Next
- Discover Weekly Finds
- Discover Weekly
- Current Rotation
- The Smashing Pumpkins ...
- The Smashing Pumpkins ...
- Best of Jagjaguwar by Jagja...
- Stared
- 90s jam
- Something Satirical by Ne...
- patlo
- climbing music by Jesse Ro...
- Pitchfork 2015: Best New ...
- Festivals
- Discover Weekly (old)
- Recently Saved
- Stereogum's Favorite New...
- DP - Control
- smartbox-ch1
- electronic

+ New Playlist

From the Morning He +  
Craft Spells

0:25

OVERVIEW CHARTS GENRES & MOODS NEW RELEASES DISCOVER

## Browse

### TOP RECOMMENDATIONS FOR YOU

LOWER DENS & NOOTROPICS REMIXED

The Beautiful Moon

Nootropics Remixed

Song for the Lovers

Closer

VOGUE DOTS

TOSKA

Toska

Vogue Dots

MAJICAL CLOUDZ

YOUR EYES

Y-R-E-E-  
J-AL-L-Z  
Y-E  
Y-E-S  
M-I-Z  
Y-S

Your Eyes

Majical Cloudz

Dreamlover

Roses

ROSES

Dreamlover

Roses

### NEW RELEASES FOR YOU

Poison Season

ZABA (Deluxe)

Frozen Throne LP

Live at 9:30

Horizons

Nocturnes

Glass Animals

Glass Animals

Groundslave

Animal Collective

Painted Palms

Willis Earl Beal

Nocturnes

Willis Earl Beal

### SUGGESTED FOR YOU BASED ON JOEY BADASS

HELL CAN WAIT

DANNY BROWN

DAPSY

Grand Quarters

BOLDY JAMES

From the Morning He +  
Craft Spells

0:25

LYRICS

351

# Related Artists

The screenshot shows a music streaming application interface. At the top, the search bar displays "Fleet Foxes". The main content area features the artist profile for Fleet Foxes, including a large photo of the band members, a "PLAY" button, a "FOLLOWING" button, and a "1,364,208 MONTHLY LISTENERS" stat. Below the profile, there are three tabs: "OVERVIEW", "RELATED ARTISTS" (which is currently selected), and "ABOUT". The "RELATED ARTISTS" section displays a grid of 18 smaller artist profiles, each with a thumbnail image and the artist's name. The artists listed are: Band of Horses, Bon Iver, Sufjan Stevens, Beirut, The Decemberists, The Shins, The National, Andrew Bird, Grizzly Bear, Iron & Wine, Midlake, Volcano Choir, From the Morning He, Craft Spells, and two other partially visible profiles.

Chris Johnson

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+ New Playlist

From the Morning He + Craft Spells

0:25 2:51 LYRICS

# Radio

The screenshot shows the Spotify desktop application interface. The main header features the word "Radio" in large white letters. The top navigation bar includes standard window controls (red, yellow, green), a search bar, and user information for "Chris Johnson".

**MAIN**

- Browse
- Activity
- Radio

**YOUR MUSIC**

- Songs
- Albums
- Artists
- Local Files

**PLAYLISTS**

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- electronic
- New Playlist

**SONIC YOUTH ARTIST RADIO**

**NEW STATION**

**PERSONALIZED STATIONS**

- Station One: No Joy, Warpaint, Ducktails, Ty Segall, Toro y Moi, Panda
- Station Two: Drake, J. Cole, Big Sean, Rick Ross, Kanye West, Joey
- Station Three: Queen, T. Rex, Lou Reed, Bob Dylan, Led Zeppelin,
- Station Four: Weezer, Nirvana, Pearl Jam, Veruca Salt, Foo Fighters,
- Station Five: Moe D, SCSI-9, San Soda, Kim Brown, Smallpeople,
- Station Six: Kins, Alvvays, Febueder, Only Real, Honeyblood, Yumi

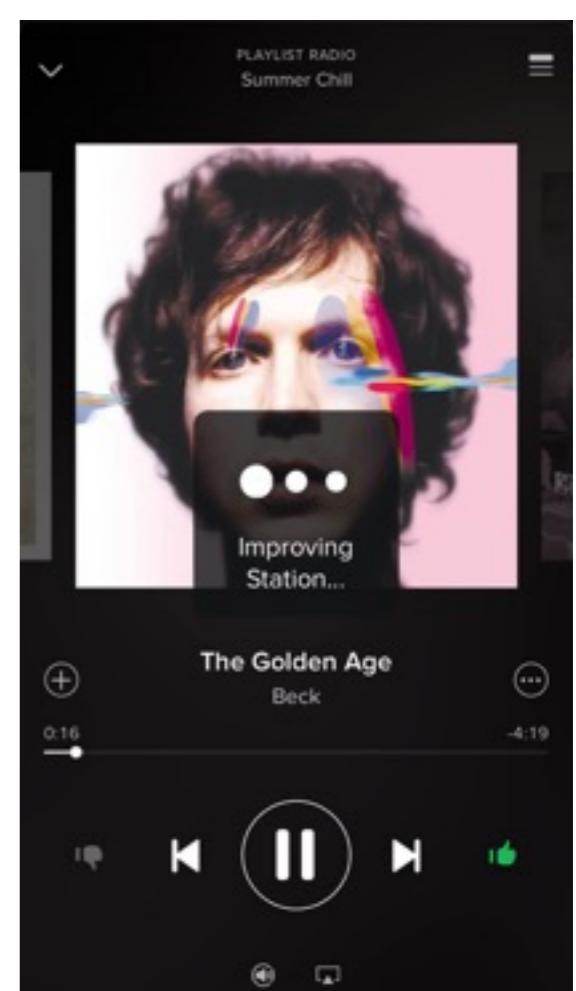
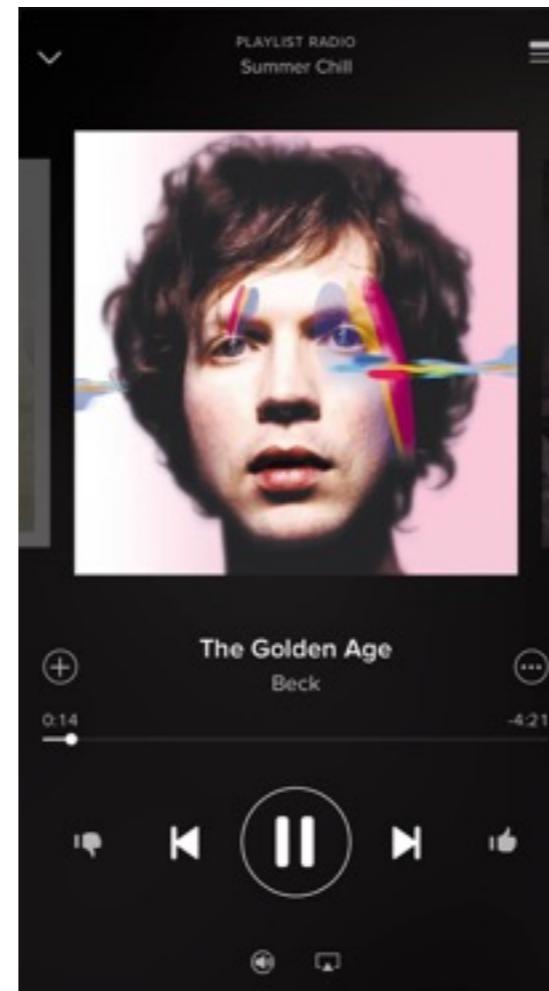
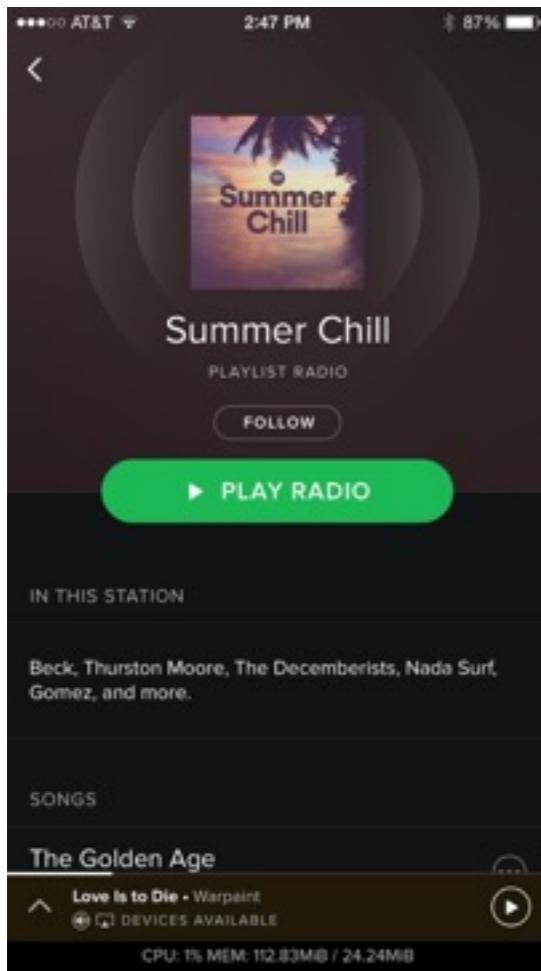
**YOUR STATIONS**

- From the Morning He Craft Spells

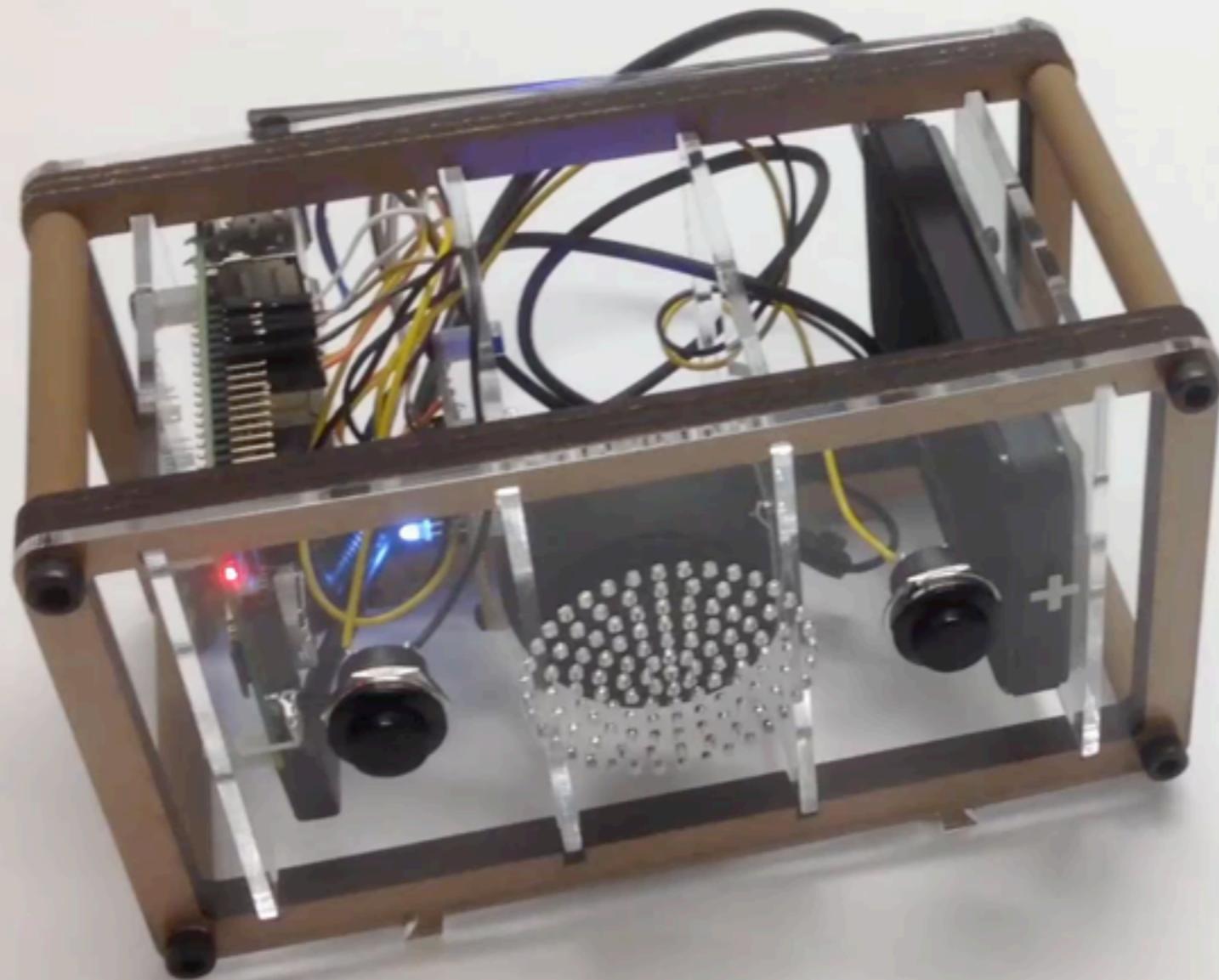
At the bottom, there is a playback control bar with icons for back, forward, play/pause, volume, and lyrics.

# Radio as an Interactive RS

- User has a vague idea of what they would like to listen to
  - User starts a radio station seeded by an Artist, Album, Song, Playlist, or Genre
  - Generally a lean back experience, but with the ability to tune recommendations with (+) and (-) feedback (   )



# SmartBox: fully interactive radio experience



# **Challenges**

# Challenges



<b>Understanding when to present interactive experience</b> - Binging, trying to find something new, experiencing browse fatigue	X	
<b>User Interaction Design</b> - UI affordance - Messaging task - Efficient mechanism to collect user input - Instant gratification - Choice penalty - Navigation options (user control)	X	X

# Challenges



## Workflow and Algorithmic Design

- Computational efficient
- Balancing relevancy, diversity and popularity of the recommendations
- Support user navigation
- Allow for both exploration and exploitation, e.g. avoid overfitting based on limited input from the user

X X

**Deep Dive: *Discover***

**NETFLIX**

# **Discover: Understanding the user**

# Meeting the users expectations

Introducing interactive RS as a full page experience or integrate with other rows on the homepage?

AND JUST LIKE THAT

BATES MOTEL

BEYOND SCARED STRAIGHT

BRICK MANSIONS

CARS TOON: MATER'S TALL TALES

HORNS

Barbie: Life in the Dreamhouse

Discover

Tell us what you're into...select a few titles you like.

It will help us find more movies and TV shows you'll love.

See suggestions

Restart

Recently Added

TYLER PERRY'S SINGLE MOMS CLUB

ADRIEN BRODY

# Meeting the users expectations

Introducing interactive RS as a full page experience or integrate with other rows on the homepage?

- Avoid conflict: browse vs discovery mode
- Browsing on the homepage is a lean-back experience
- Discover, is interactive... that means work

# Understanding the user's need

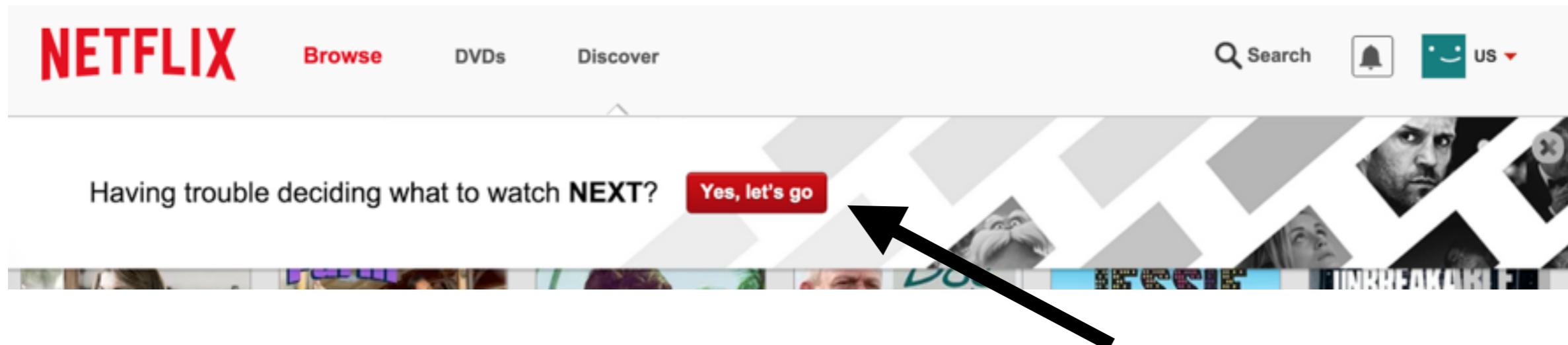
- Introducing Discover feature as a new destination



- Allow users to quickly navigate to feature

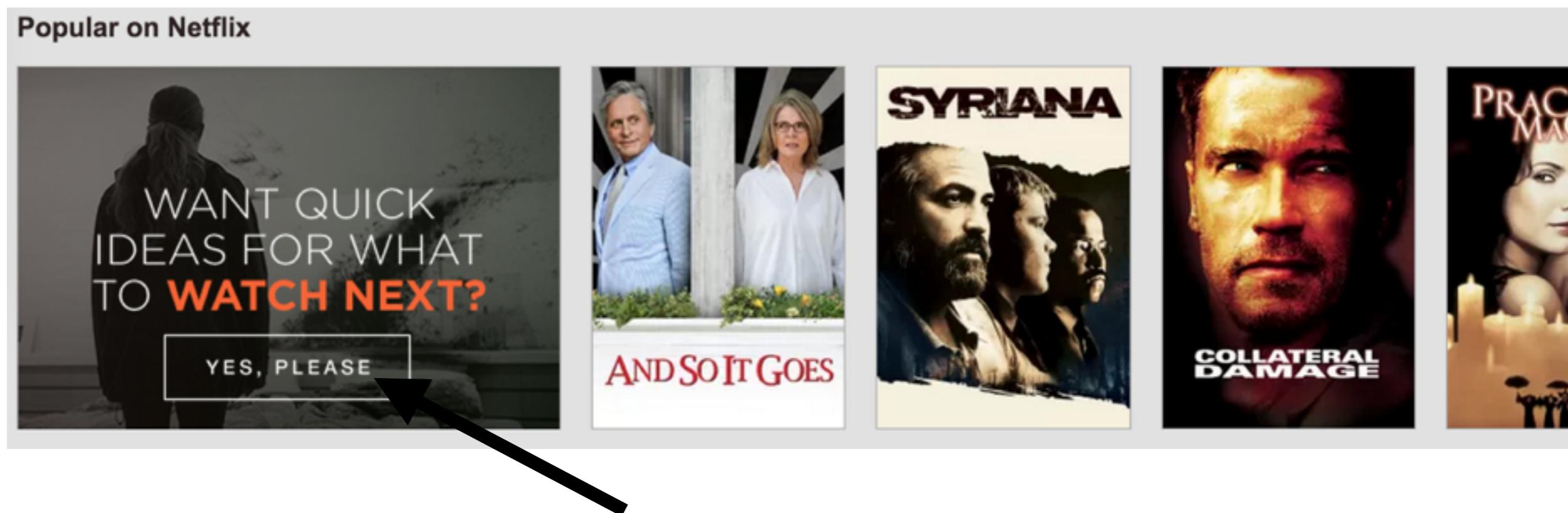
# Understanding the user's need

- Introducing Discover feature as a new destination
- Help users find new feature through
  - messaging at top of homepage
    - At session start
    - After scrolling X rows down
    - After 45 secs



# Understanding the user's need

- Introducing Discover feature as a new destination
- Help users find new feature through:
  - messaging at top of homepage
  - invitation in row on homepage



# Understanding the user's need

- Introducing Discover feature as a new destination
- Help users find new feature through:
  - messaging at top of homepage
  - invitation in row
  - row-based invitation
    - In position of N<sup>th</sup> row or as last row on homepage



# Understanding the user's need

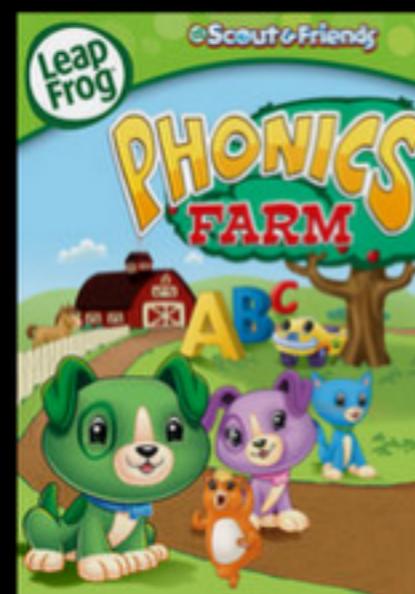
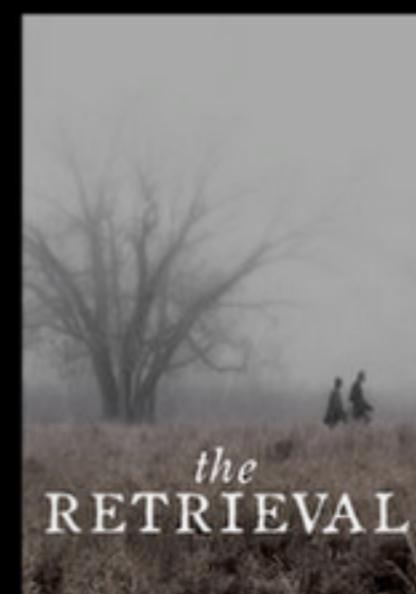
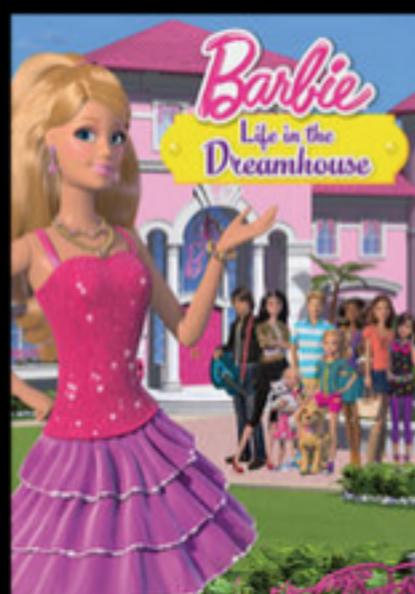
- Context is crucial for the success of the integration of interactive experiences into the product
- Never interrupt a user that knows what they want
  - Message at start of user session
- Showing the invitation at the right moment (and place) is crucial
  - Allow the user to explore options on the homepage first
- Challenge is to find the right trade-off between rate at which user tries the interactive experience, versus success
  - Success rate can vary from 30-70%
  - Not a goal to reach all users, just need to reach those who need help

# **Discover: Inside the interactive RS**



Tell us what you're into...select a few titles you like.

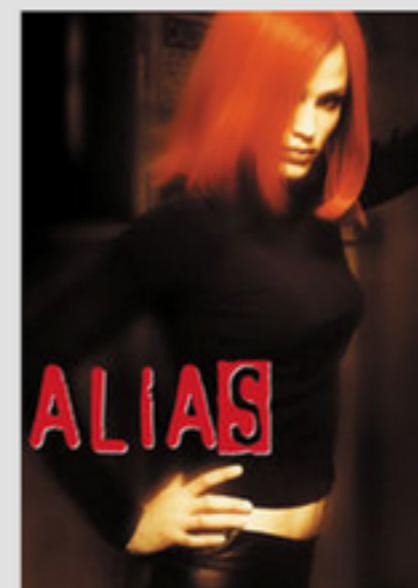
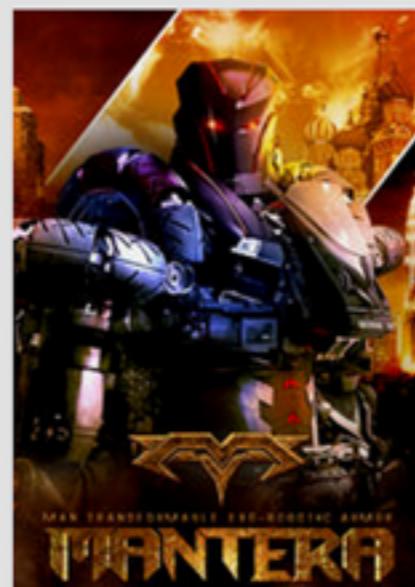
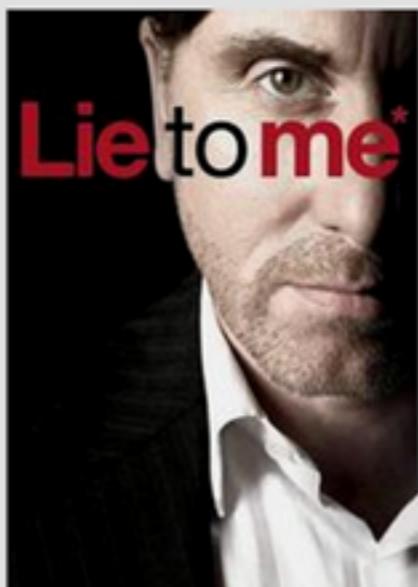
*It will help us find more movies and TV shows you'll love.*

[See Suggestions](#)[Restart](#)

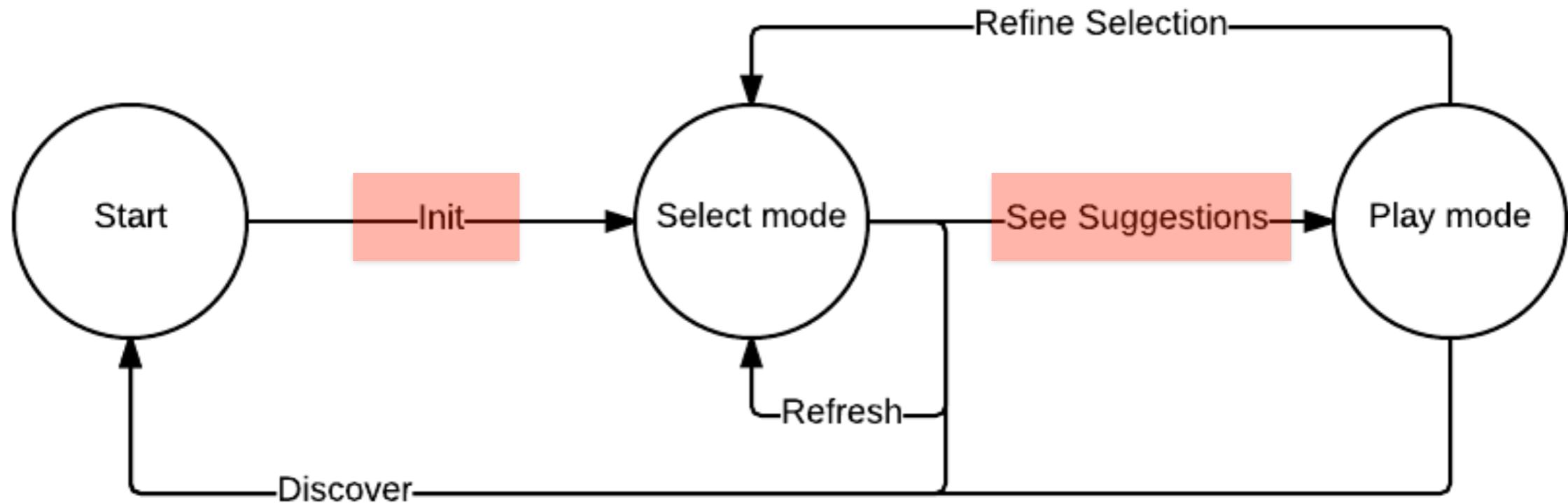


Here are some suggestions we think you'll like

Click below to refine your selection or choose the refresh button to start over.

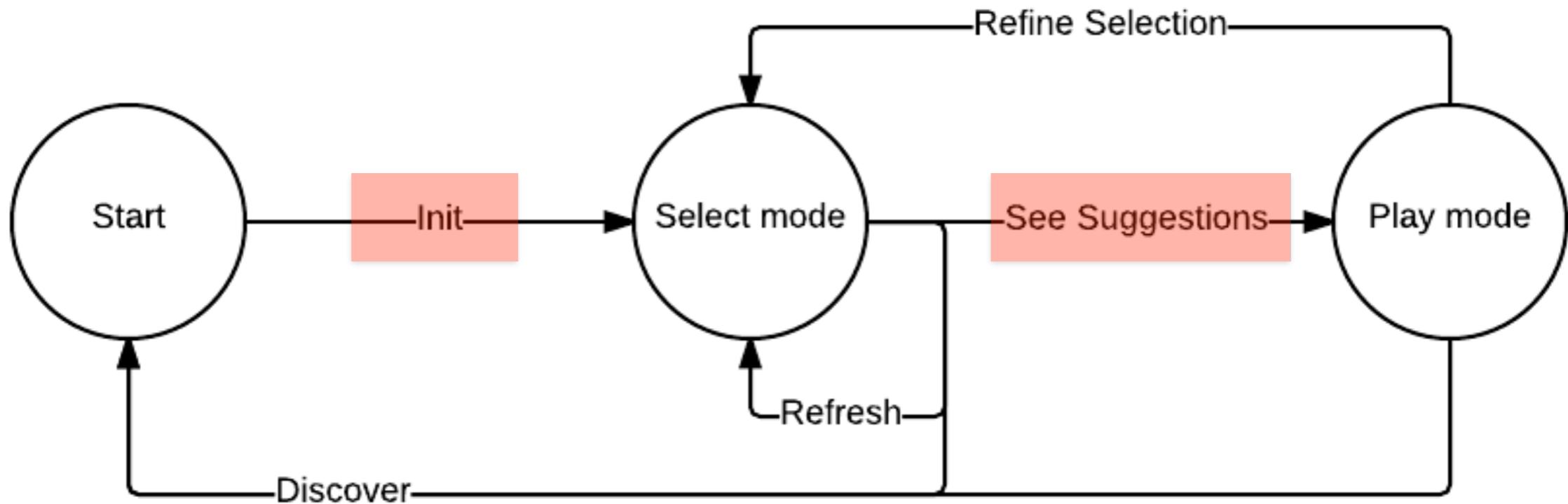
[Edit selection](#)[Restart](#)

# Interaction Workflow for Discover



- **Init** - At start of new session, create an initial seed of videos to show to the user
- **See Suggestions** - After receiving input from the user (selected videos), compute recommendations

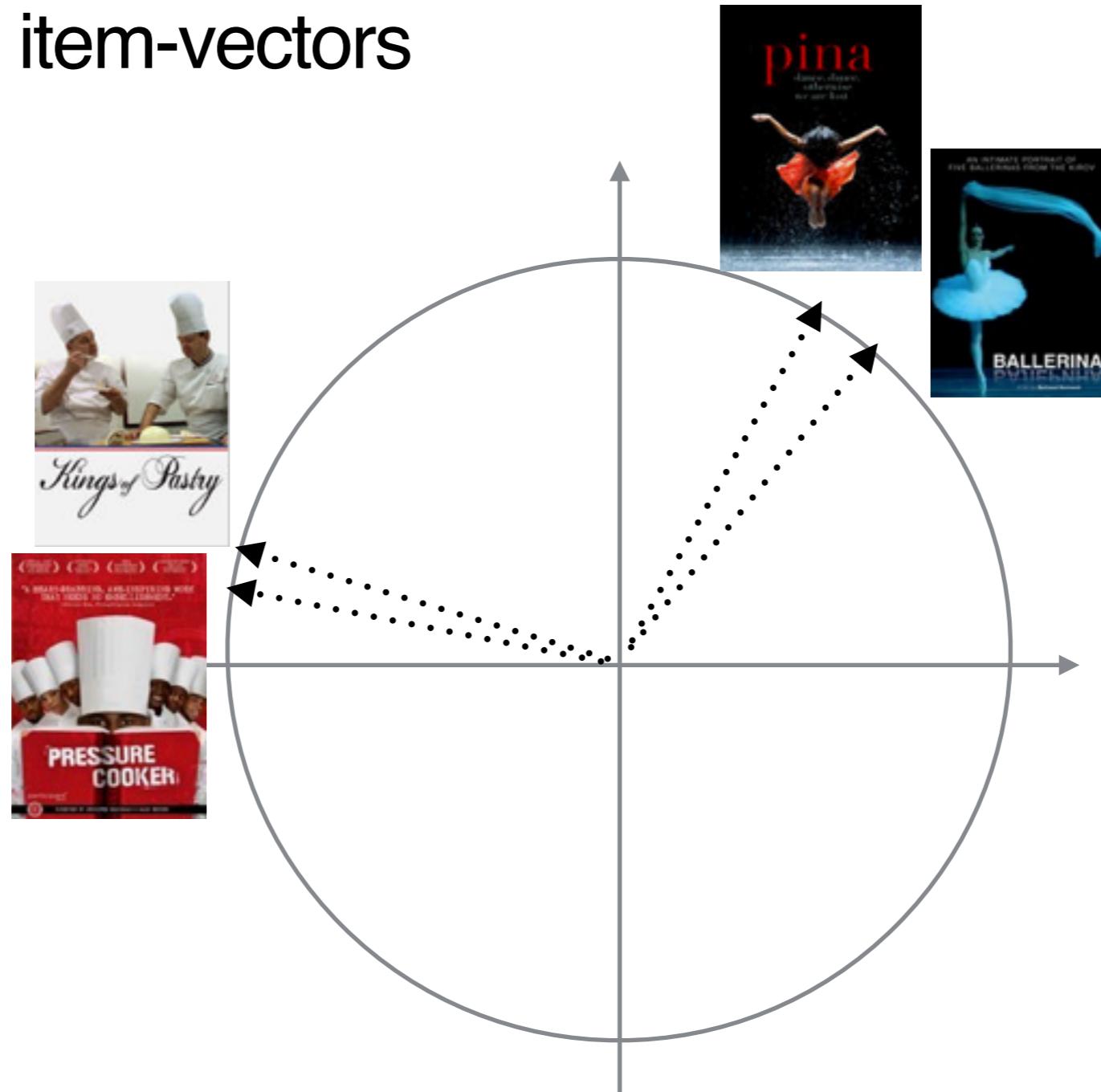
# Interaction Workflow for Discover



Need to find balance between relevancy, diversity and popularity of the videos shown to the user

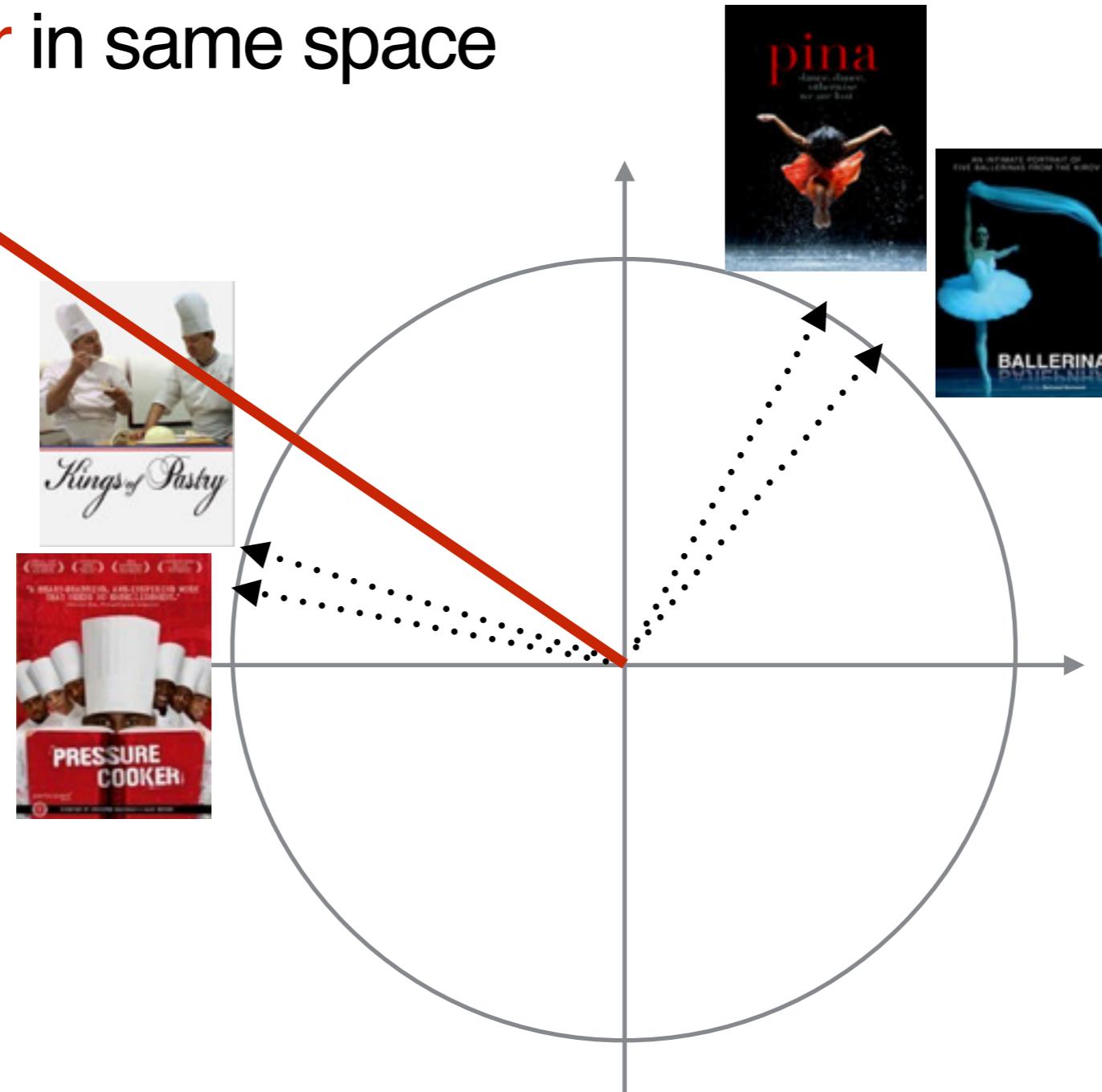
# Videos in a Latent Space Representation

- normalized item-vectors



# Videos in a Latent Space Representation

- user-vector in same space



# Relevance Score

$$\text{rel}(i, u) = \vec{p}_i \cdot \vec{u}$$

$$\vec{u} = \sum_{j \in \mathcal{U}} \vec{q}_j$$

# Diversity Score

$$\text{div}(i, j) = \|\vec{p}_i - \vec{p}_j\|^2$$

note:

$$\begin{aligned}\|\vec{p}_i - \vec{p}_j\|^2 &= \vec{p}_i^2 + \vec{p}_j^2 - 2\vec{p}_i \cdot \vec{p}_j \\ &= 2(1 - \vec{p}_i \cdot \vec{p}_j)\end{aligned}$$

# Popularity Score

$\text{pop}(i) = \# \text{ plays, } \# \text{ clicks, etc of item } i$

# “See Suggestions” step

Score of item  $i$ :

$$\text{score}(i|u, \mathcal{S}) = \min_{j \in \mathcal{S}} \left\{ \text{pop}(i)^\beta \cdot \text{rel}(i, u) \cdot \text{div}(i, j)^\alpha \right\}$$

- $\alpha, \beta$  for adjusting the balance
- $\text{score}(i)$  determined by “closest” item  $j$  in  $S$
- “diminishing returns”

# “See Suggestions” step

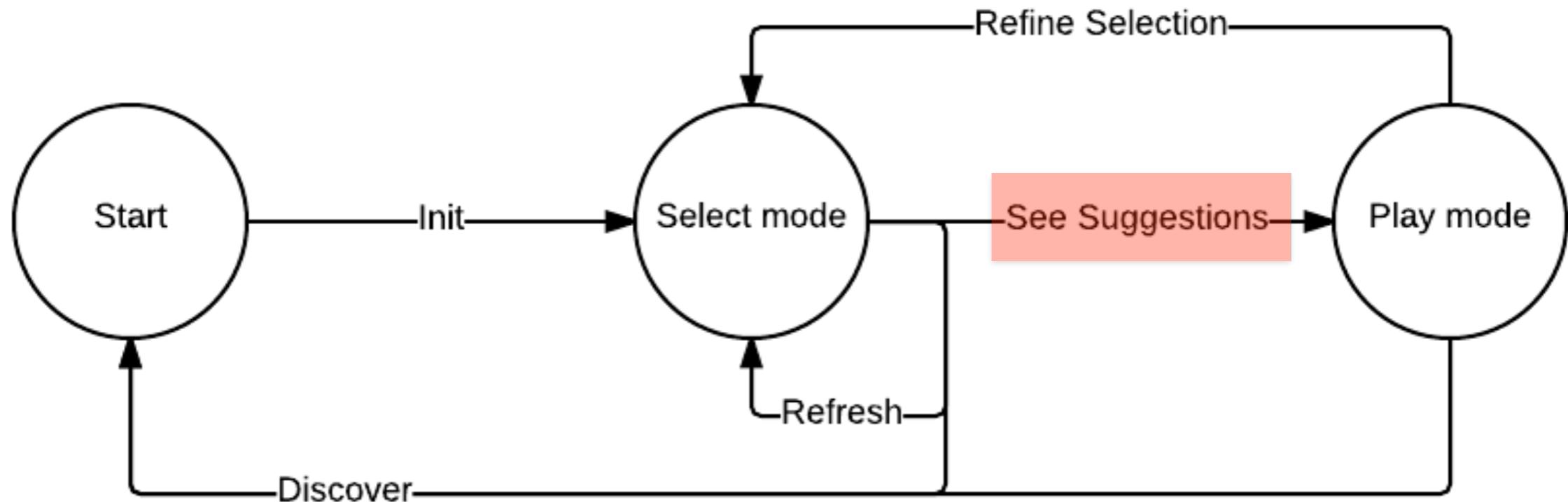
- Greedy computation of recommendation set  $S$ :

iterate :

$$i^* \leftarrow \operatorname{argmax}_i \text{ score}(i|u, \mathcal{S})$$

$$\mathcal{S} \leftarrow \mathcal{S} \cup \{i^*\}$$

# Interaction Workflow for Discover



**See Suggestions** - After receiving input from the user (selected videos), compute recommendations

**What if the selected videos cover more than 1 genre?**

# User may select diverse set of videos

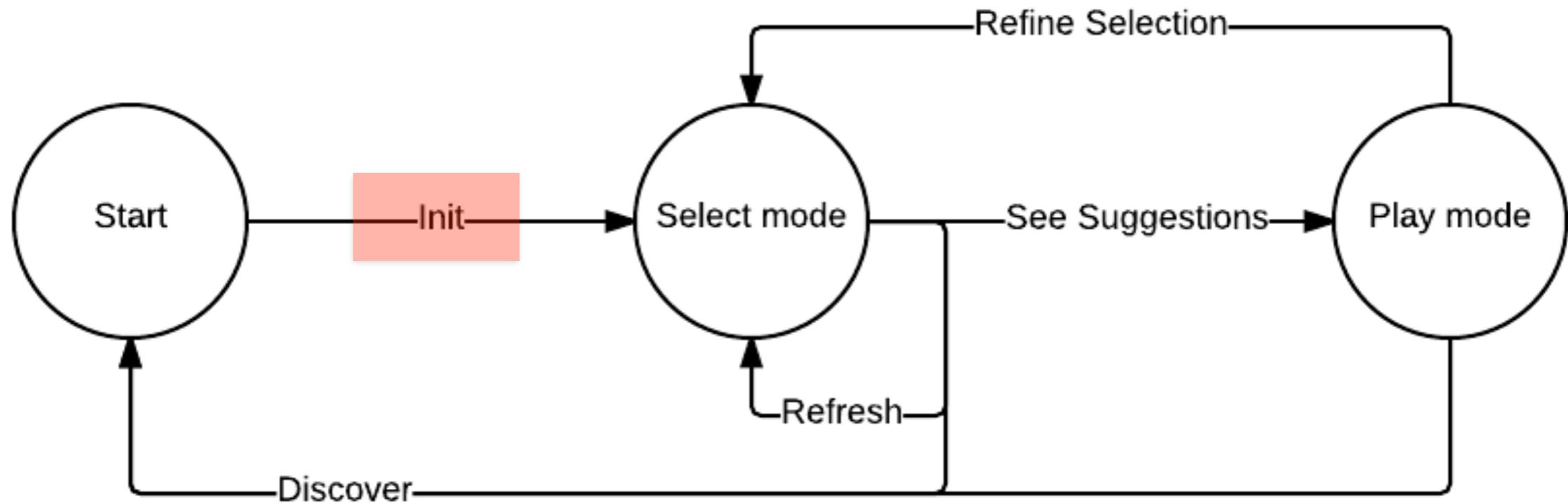
## Challenge:

- Recommendations should reflect all genres of the shows selected by user

## Solution:

- Multiple user-vectors, one per selected group of similar shows (clustering)
- Compute recommendations for each user vector
- Display clusters in separate rows, or combine via reciprocal rank aggregation

# Interaction Workflow for Discover



**Init** - At start of new session, create an initial seed of videos to show to the user

**Show diverse set of recognizable videos that are familiar to the user, and which is fresh across sessions**

# Producing the initial set of videos

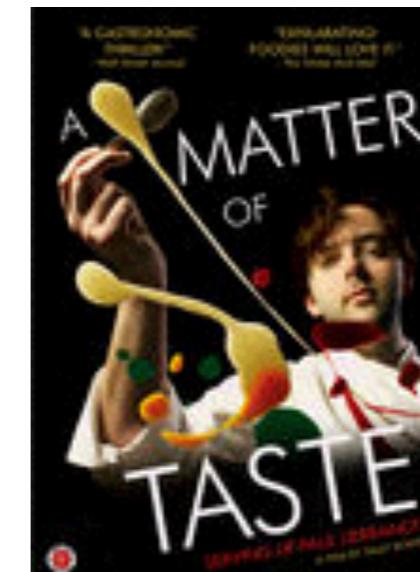
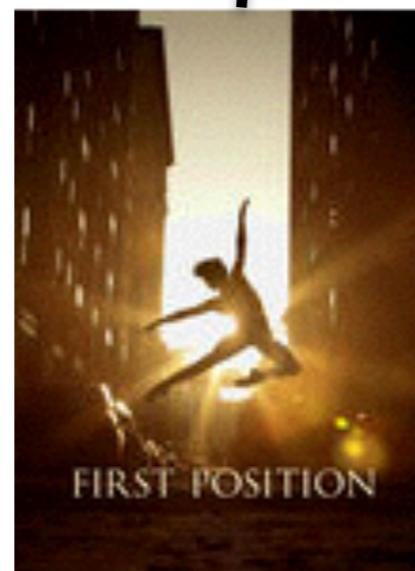
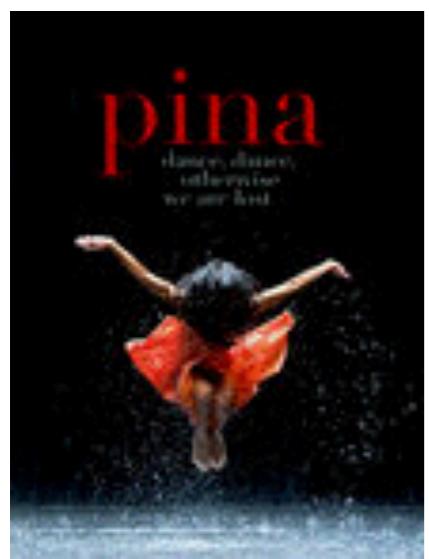
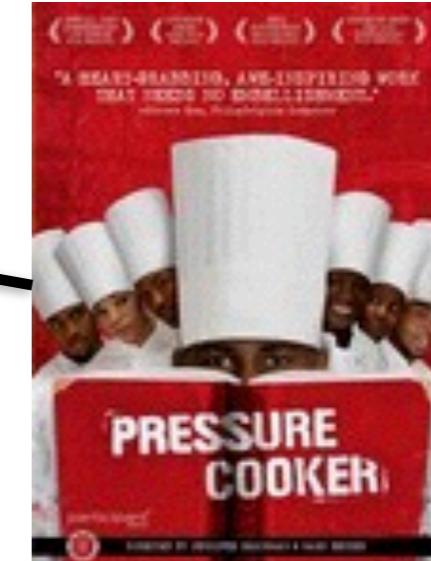
- Objective: Show diverse set of recognizable videos that are familiar to the user, and which is fresh across sessions
- How?
  - Sample videos from user's play history
    - score: no popularity & relevance component
  - Sample shows from catalog with popularity bias
    - score: no relevance component
  - Randomize initial set for freshness

# **Learning the Latent Vectors**

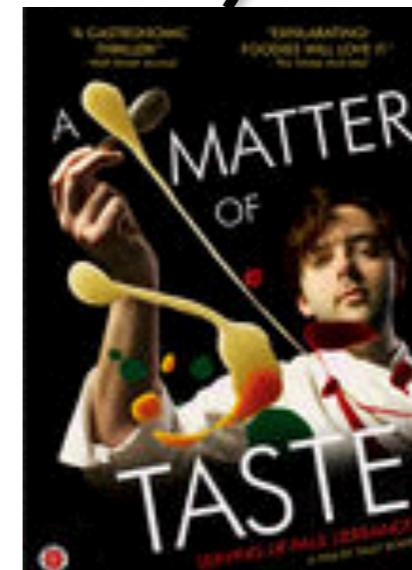
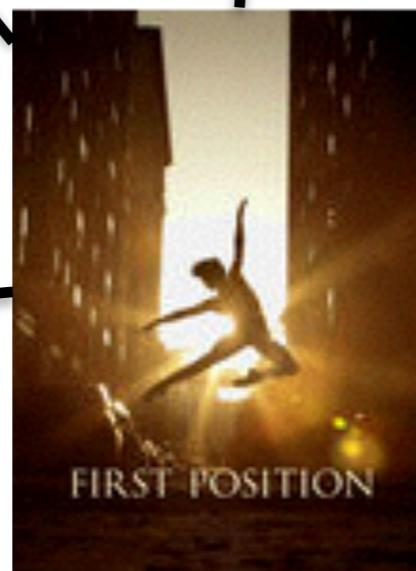
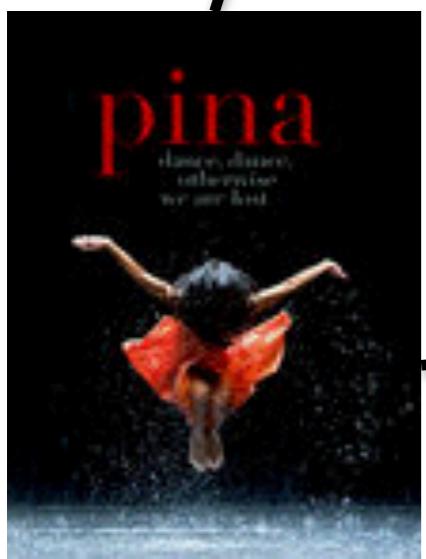
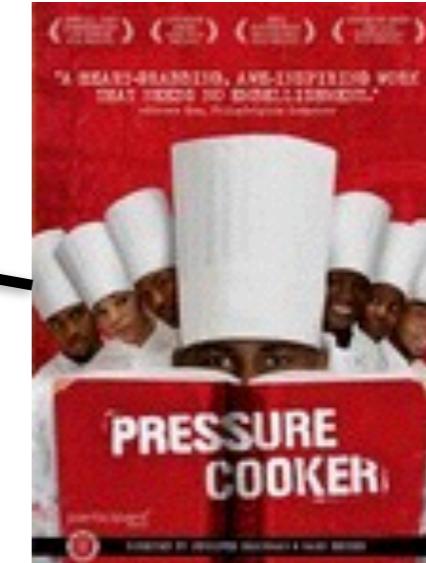
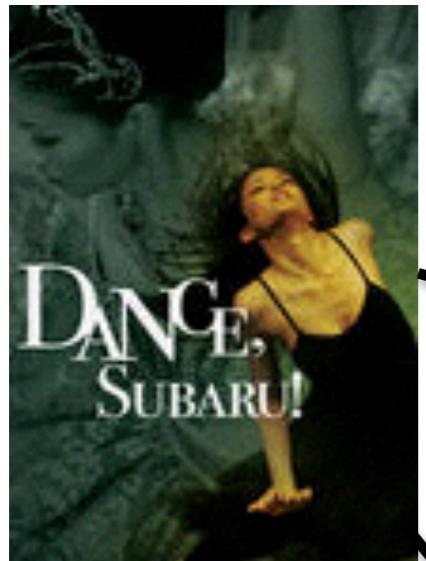
# Learning the Latent Vectors

- Use implicit feedback data
  - Compute item-item similarity matrix:
    - covariance matrix
    - transition matrix
    - ...
- Train (spectral) matrix factorization model

# Graph Cut—Simplistic Example



# Graph Cut—Simplistic Example



# Graph Cut—Simplistic Example



# **Graph Cut → Spectral Clustering**

1. Graph → Affinity Matrix  $A$

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- $D$  ... diagonal matrix,  $D_{ii} = \text{sum}_j (A_{ij})$

# Graph Cut → Spectral Clustering

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5. (kmeans) clustering of latent vectors

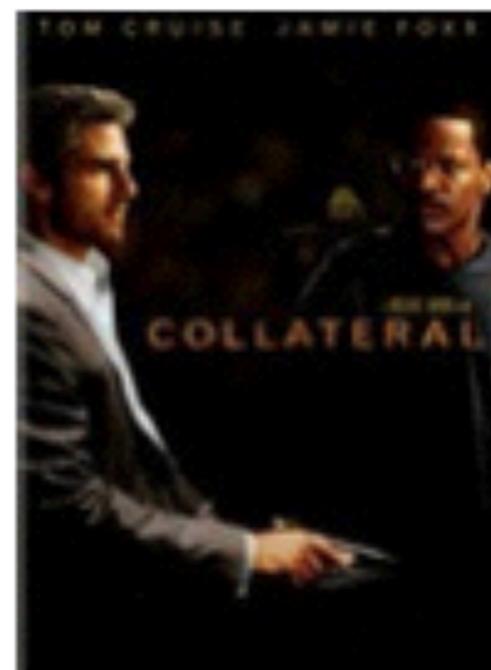
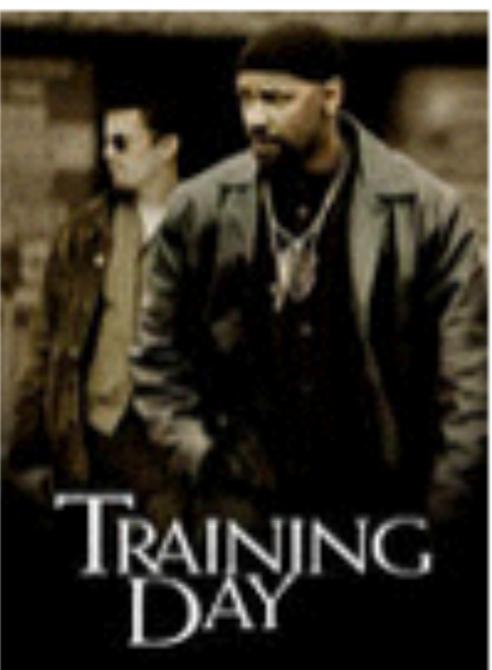
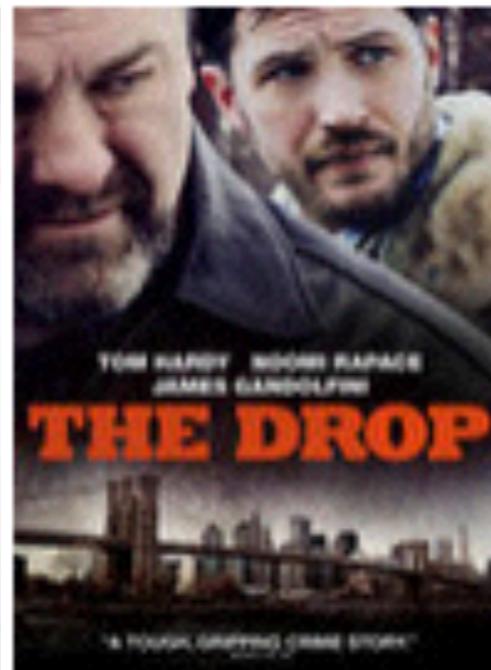
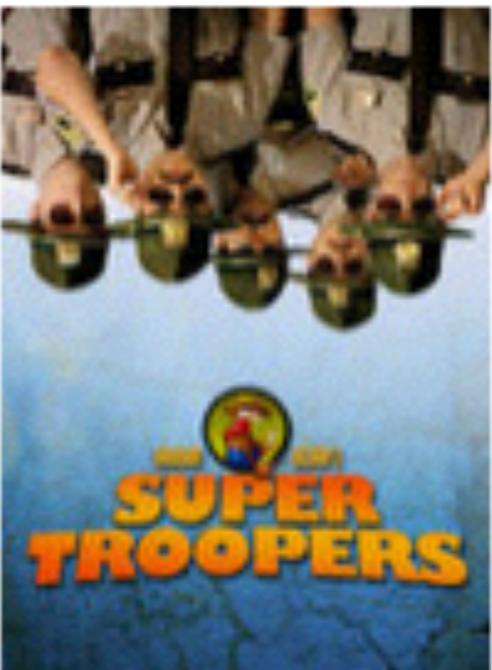
# Example: *Django*

Movies similar to:

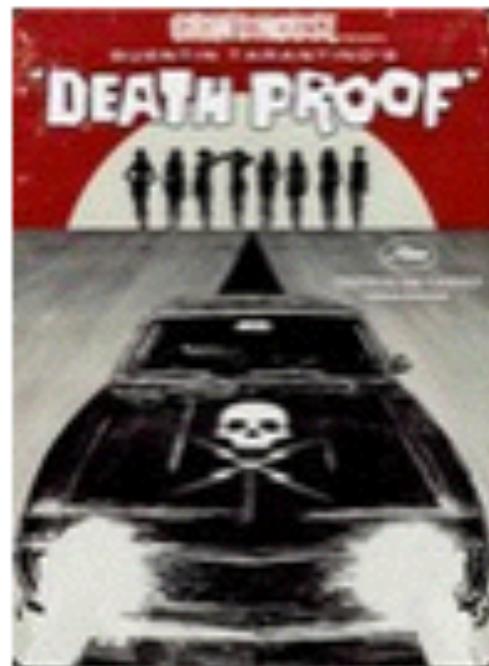
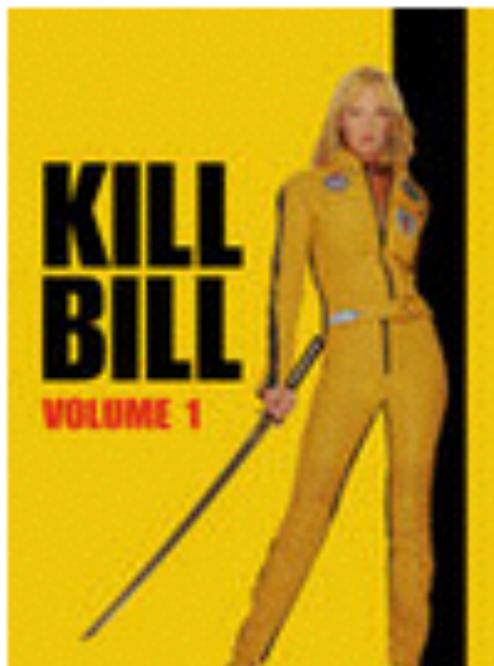
- Viennese-born Christoph Waltz won Oscar for best supporting role
- only play-data used, no content information



# Similar to *Django* via basic MF



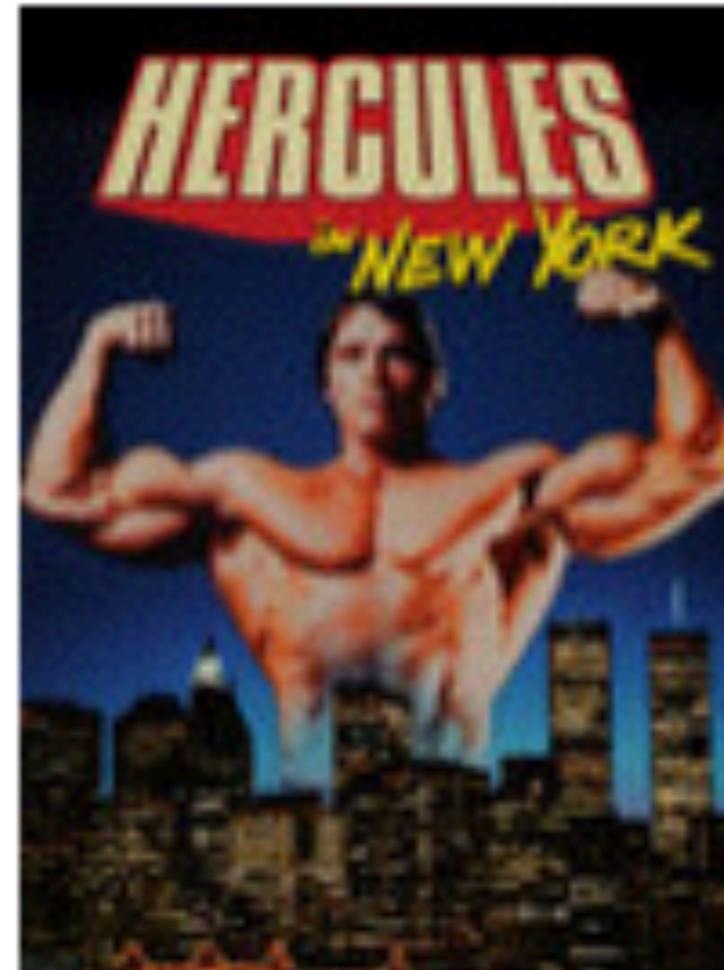
# Similar to *Django* via spectral MF



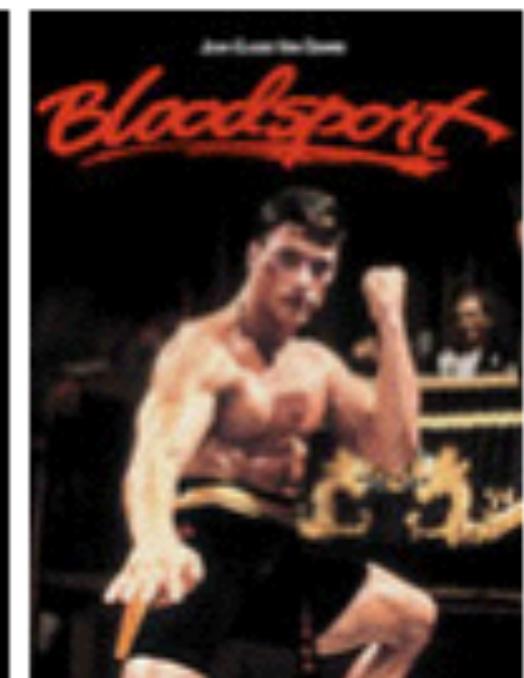
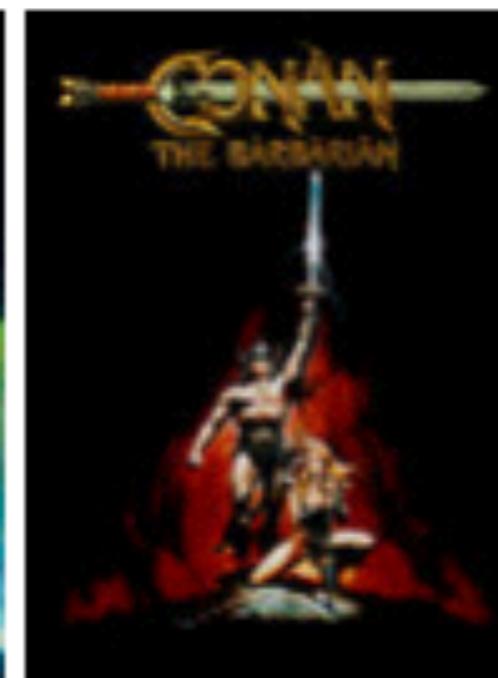
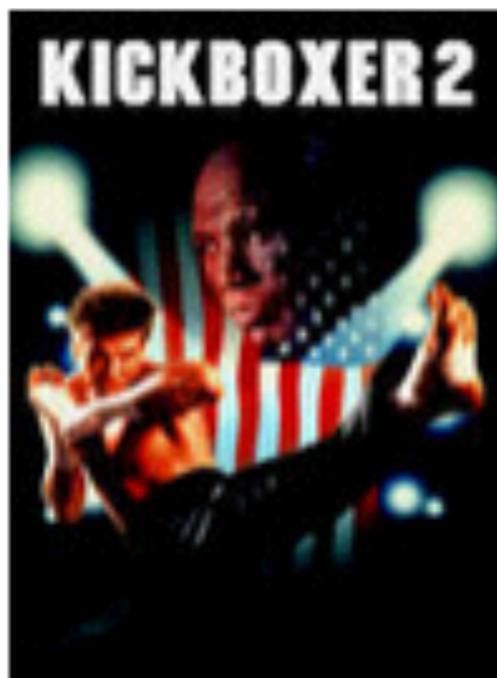
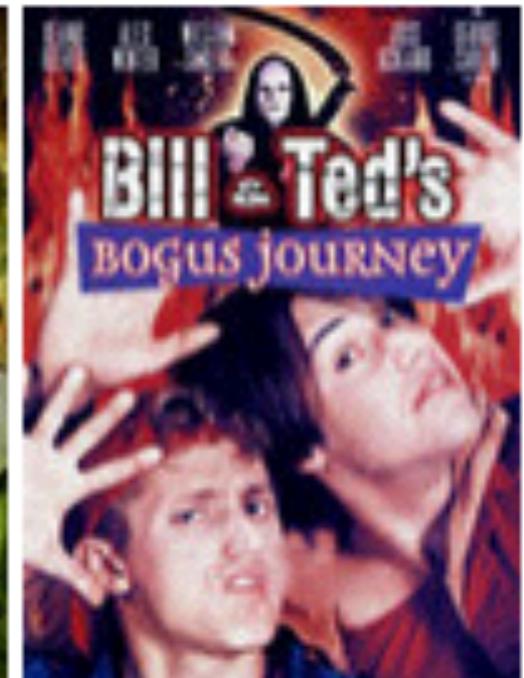
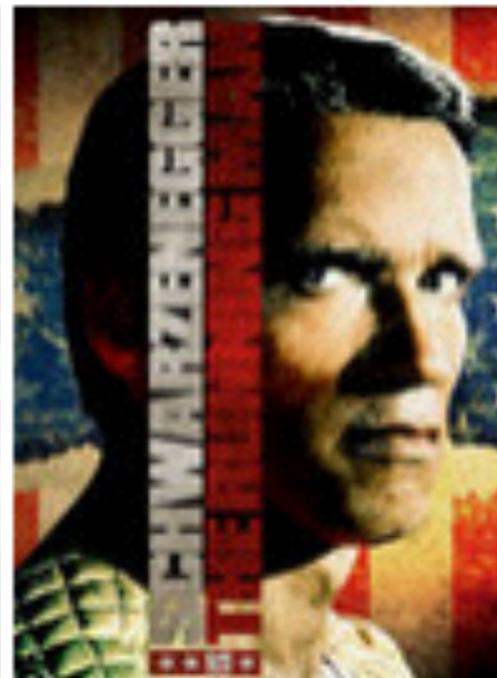
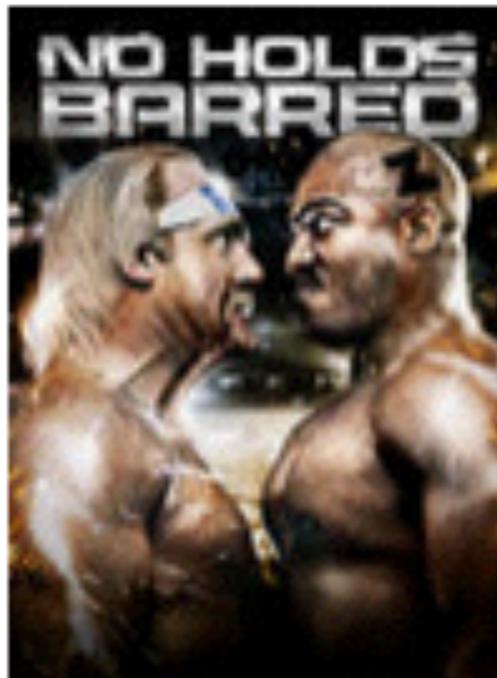
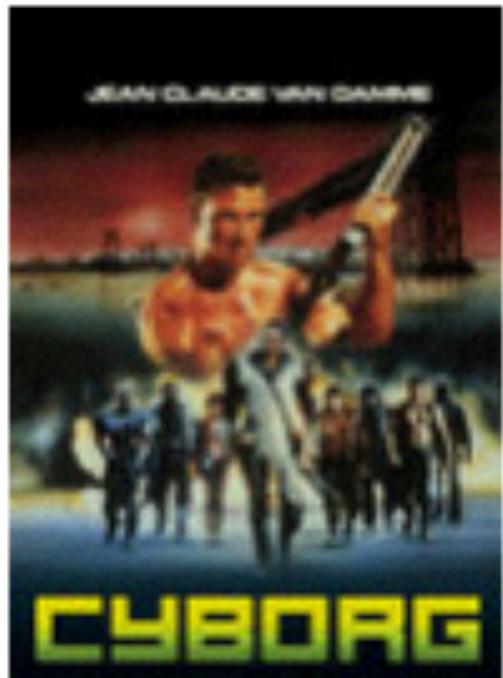
# Example: *Hercules in New York*

Movies similar to:

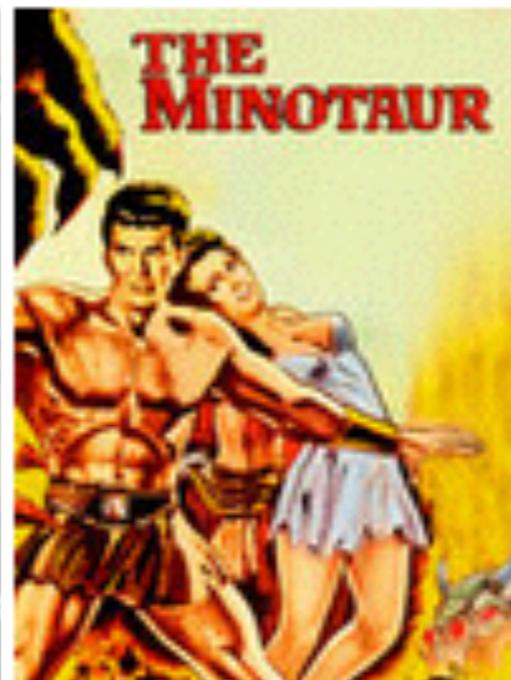
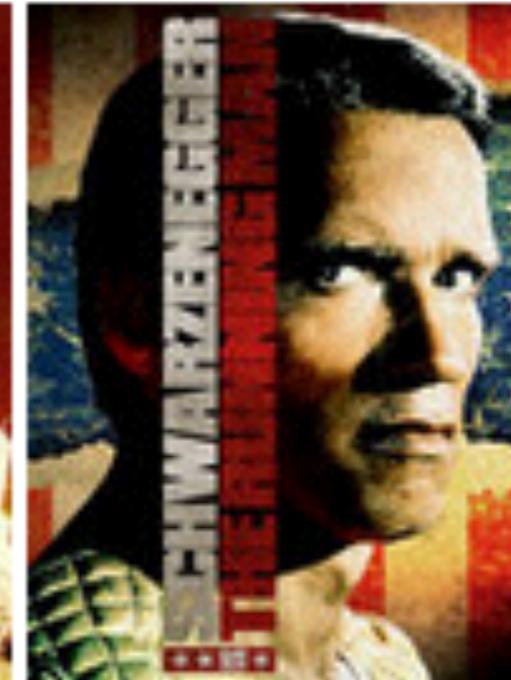
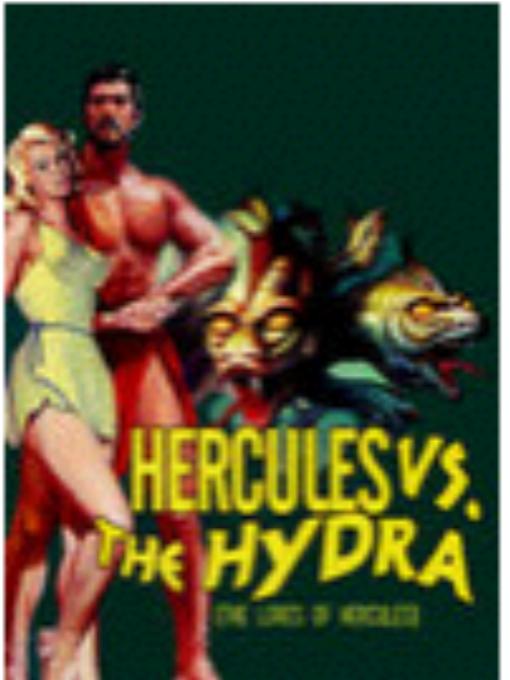
- Austrian-born Arnold Schwarzenegger's debut movie
- only play-data used, no content information



# Similar to *Hercules in NY* via basic MF



# Similar to *Hercules in NY* via spectral MF

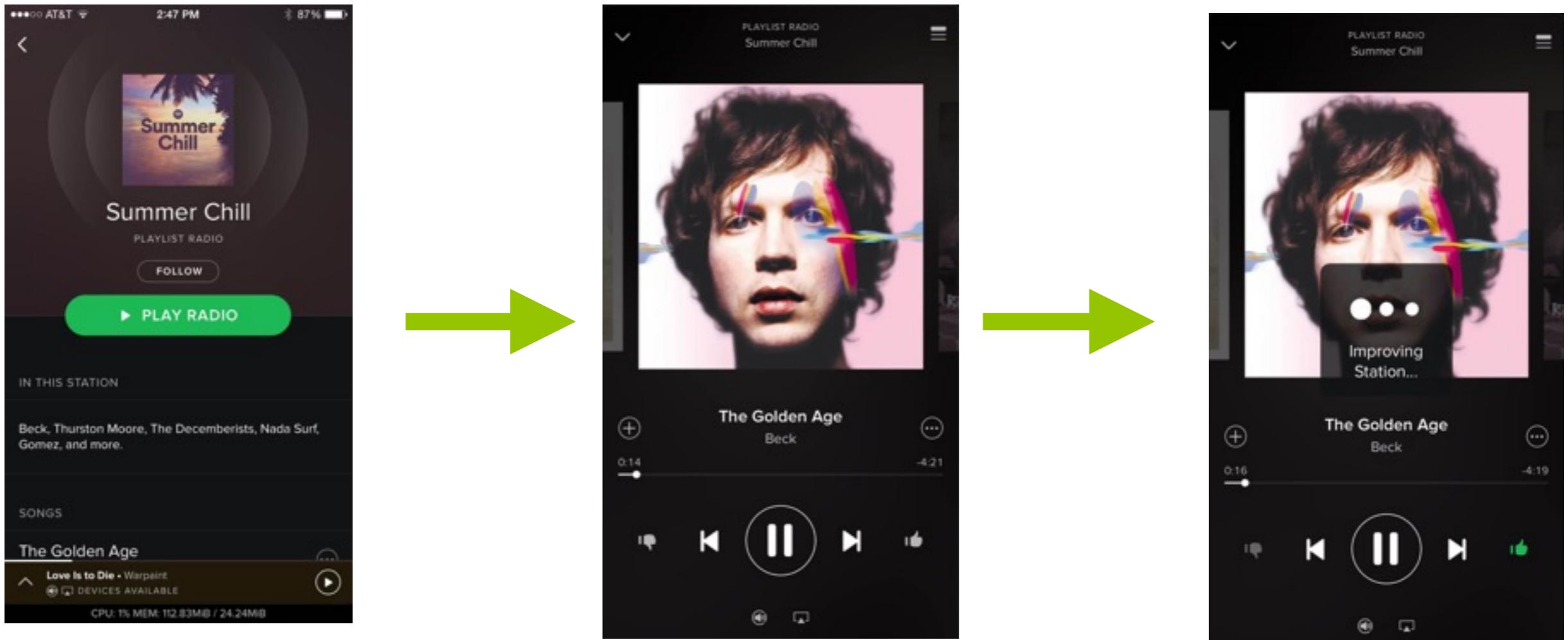


# Deep Dive: *Radio*

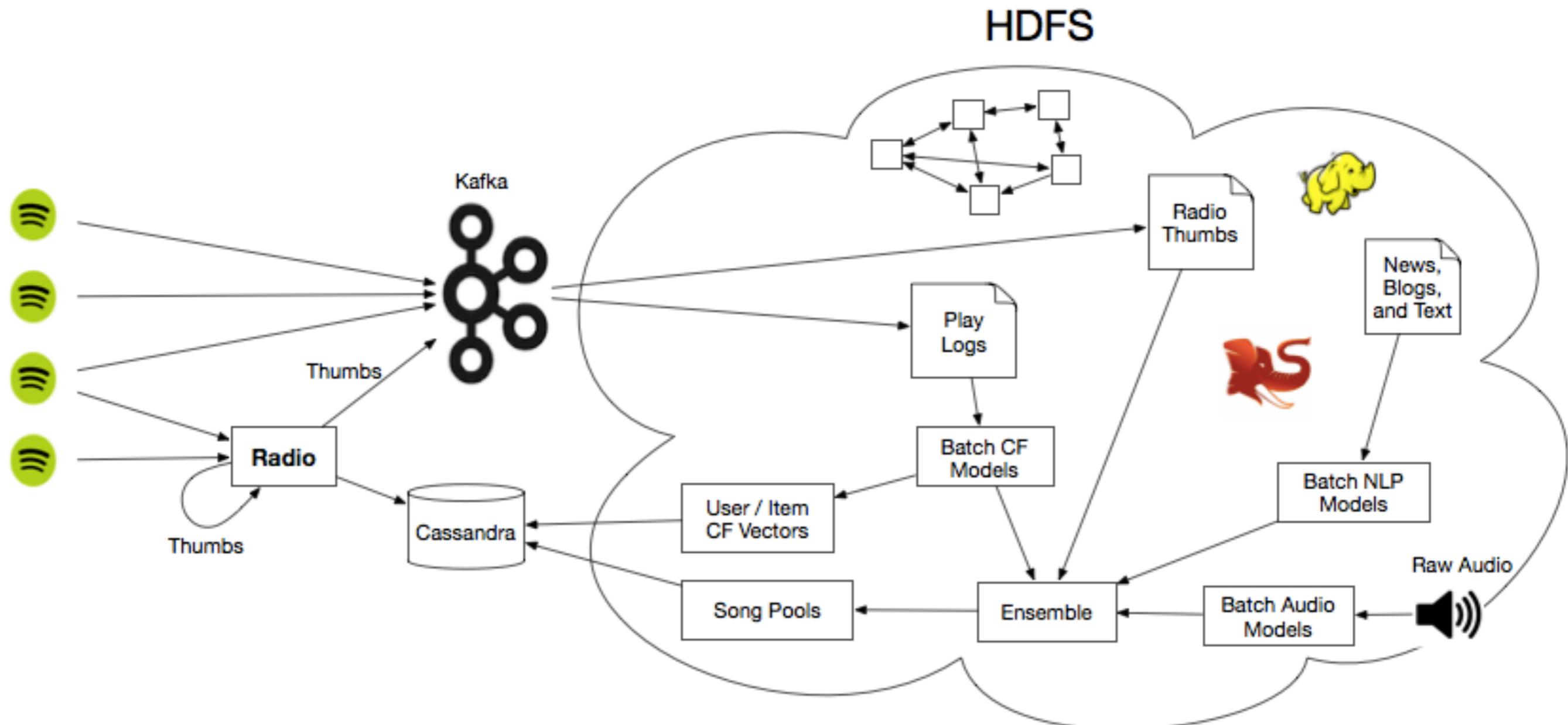


# Radio as an Interactive RS

- User has a vague idea of what they would like to listen to
  - User starts a radio station seeded by an Artist, Album, Song, Playlist, or Genre
  - Generally a lean back experience, but with the ability to tune recommendations with (+) and (-) feedback (   )



# Overview of Radio Dataflow





**Step 1:**

**Train batch recommendation models**

# Implicit Matrix Factorization [1]

- Aggregate all (**user**, **track**) streams into a large matrix
- Goal:** Approximate binary preference matrix by inner product of 2 smaller matrices by minimizing the weighted **RMSE** (root mean squared error) using a function of plays, context, and recency as weight

Users  $\begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \end{pmatrix}$   $\approx \underbrace{\begin{pmatrix} x \\ f \end{pmatrix}}_{\text{Songs}} \left( \begin{array}{c} Y \\ \vdots \end{array} \right) \}$   $f$

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

- $p_{ui} = 1$  if user  $u$  streamed track  $i$  else 0
- $c_{ui} = 1 + \alpha r_{ui}$
- $x_u$  = user  $u$ 's latent factor vector
- $y_i$  = item  $i$ 's latent factor vector
- $\beta_u$  = bias for user  $u$
- $\beta_i$  = bias for item  $i$
- $\lambda$  = regularization parameter

# Can also use Logistic Loss! [2]

- Aggregate all (user, track) streams into a large matrix
- Goal:** Model probability of user playing a song as **logistic**, then maximize **log likelihood** of binary preference matrix, weighting positive observations by a function of plays, context, and recency

Users

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \end{pmatrix} \approx \underbrace{\begin{pmatrix} X \\ Y \end{pmatrix}}_f \{ f \}$$

Songs

$$\max_{X,Y} \sum_{u,i} \alpha r_{u,i} \log(\sigma(x_u \cdot y_i + \beta_u + \beta_i)) + \log(1 - \sigma(x_u \cdot y_i + \beta_u + \beta_i)) - \lambda (\sum_u \|x_u\|^2 + \sum_i \|y_i\|^2)$$

- $x_u$  = user  $u$ 's latent factor vector
- $y_i$  = item  $i$ 's latent factor vector

- $\beta_u$  = bias for user  $u$
- $\beta_i$  = bias for item  $i$
- $\lambda$  = regularization parameter

# NLP models on News, Blogs, and Text

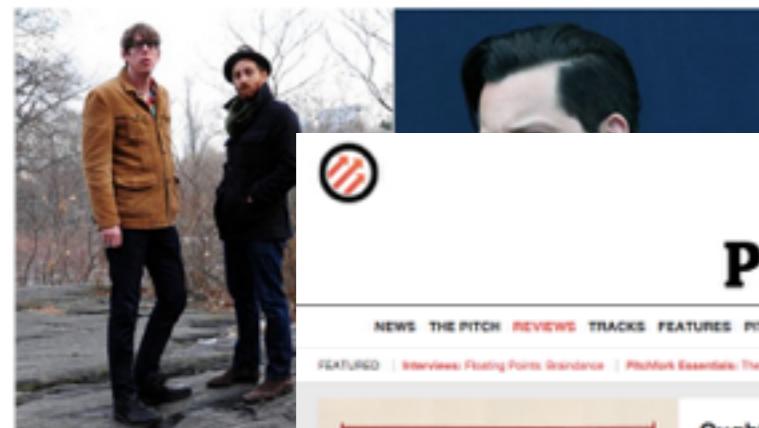
The screenshot shows the Rolling Stone website. At the top, there are social sharing icons for Like, Flickr, Google+, and YouTube. The main navigation menu includes links for MUSIC, POLITICS, TV, MOVIES, CULTURE, SPORTS, REVIEWS, LISTS, RS COUNTRY, and COVERWALL. A search bar is located at the top right. Below the menu, the headline reads "Jack White vs. the Black Keys: A Beef History". A sub-headline states: "As feud between rival blues-rock camps makes headlines again, we look back at story so far". The author is listed as "BY ANDY GREENE, KORY GROW, BRITTANY SPANOS, PATRICK DOYLE, HANK SHTEAMER September 14, 2015". Below the headline are social sharing buttons for Facebook, Twitter, Google+, and Email. To the left of the text is a photograph of two men standing outdoors. To the right of the text is a sidebar titled "RELATED" with links to "10 Craziest Beefs in MTV VMA History", "The 10 Wildest Rap Beefs of All Time", and "15 Biggest Feuds of 2014".

## Jack White vs. the Black Keys: A Beef History

As feud between rival blues-rock camps makes headlines again, we look back at story so far

■ BY ANDY GREENE, KORY GROW, BRITTANY SPANOS, PATRICK DOYLE, HANK SHTEAMER September 14, 2015

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"Tis the season of the beef. Just this week, Nicki Minaj took an "oh, no" acceptance speech. And last night, Jack White reignited their ongoing n

The screenshot shows the Pitchfork website. The top navigation bar includes links for NEWS, THE PITCH, REVIEWS, TRACKS, FEATURES, PITCHFORK.TV, PUNK RADIO, BEST NEW MUSIC, STAFF LISTS, ARTISTS, FESTIVALS, and TMR. Below the navigation is a "FEATURED" section with links to "Interview: Floating Points' Residence", "Pitchfork Essentials: The Golden Dawn: L.A. Beat Scene Origins", "The Out Beat: Summer 2015 Experimental Records Roundup", and "Unearthing the Punk". The main content area features a review for "Ought" with the title "Sun Coming Down" and the subtitle "Constellation; 2015". The review is written by Stuart Berman on September 15, 2015, and has a rating of 8.0. It includes a link to "Find it at: Amazon MP3 & CD". Below the review is a section titled "MUSIC FROM THIS RELEASE" with links to "Ought: 'Beautiful Blue Sky' (via SoundCloud)" and "Ought: 'Men for Miles' (via SoundCloud)". A paragraph discusses the song "Beautiful Blue Sky". To the right of the review is a "PLAYING NEAR YOU" section for "OUGHT" with a "Full Schedule" button. Below this is a "Most Read Album Reviews" section with filters for 7 DAYS, 30 DAYS, and 60 DAYS. At the bottom is a photograph of the album cover for "Sun Coming Down".

## Distributed Representations of Words and Phrases and their Compositionality

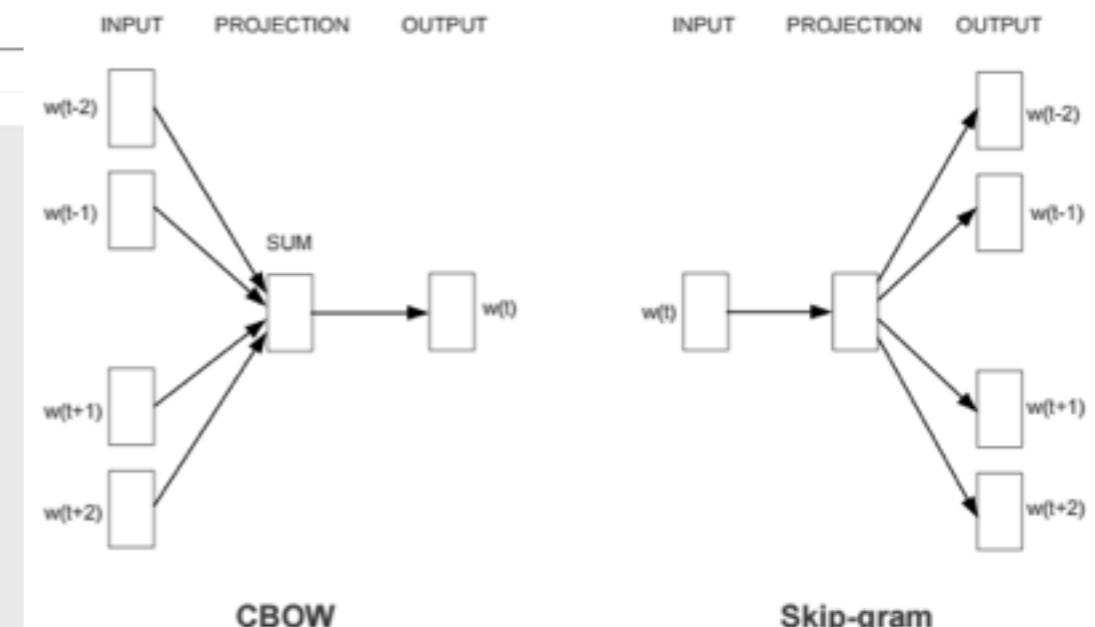
Tomas Mikolov  
Google Inc.  
Mountain View  
mikolov@google.com

Ilya Sutskever  
Google Inc.  
Mountain View  
ilyasut@google.com

Kai Chen  
Google Inc.  
Mountain View  
kai@google.com

Greg Corrado  
Google Inc.  
Mountain View  
gcorrado@google.com

Jeffrey Dean  
Google Inc.  
Mountain View  
jeff@google.com



# NLP models also work on playlists!

Playlist itself is a document

PLAYLIST

## SHOEGAZE

Celebrating The Scene That Celebrates Itself; effect heavy, shatteringly loud, sky-sweeping tracks from shoegazers then and now. [Follow for more \[PIAS\] playlists!](#)

FOLLOWERS 4,257

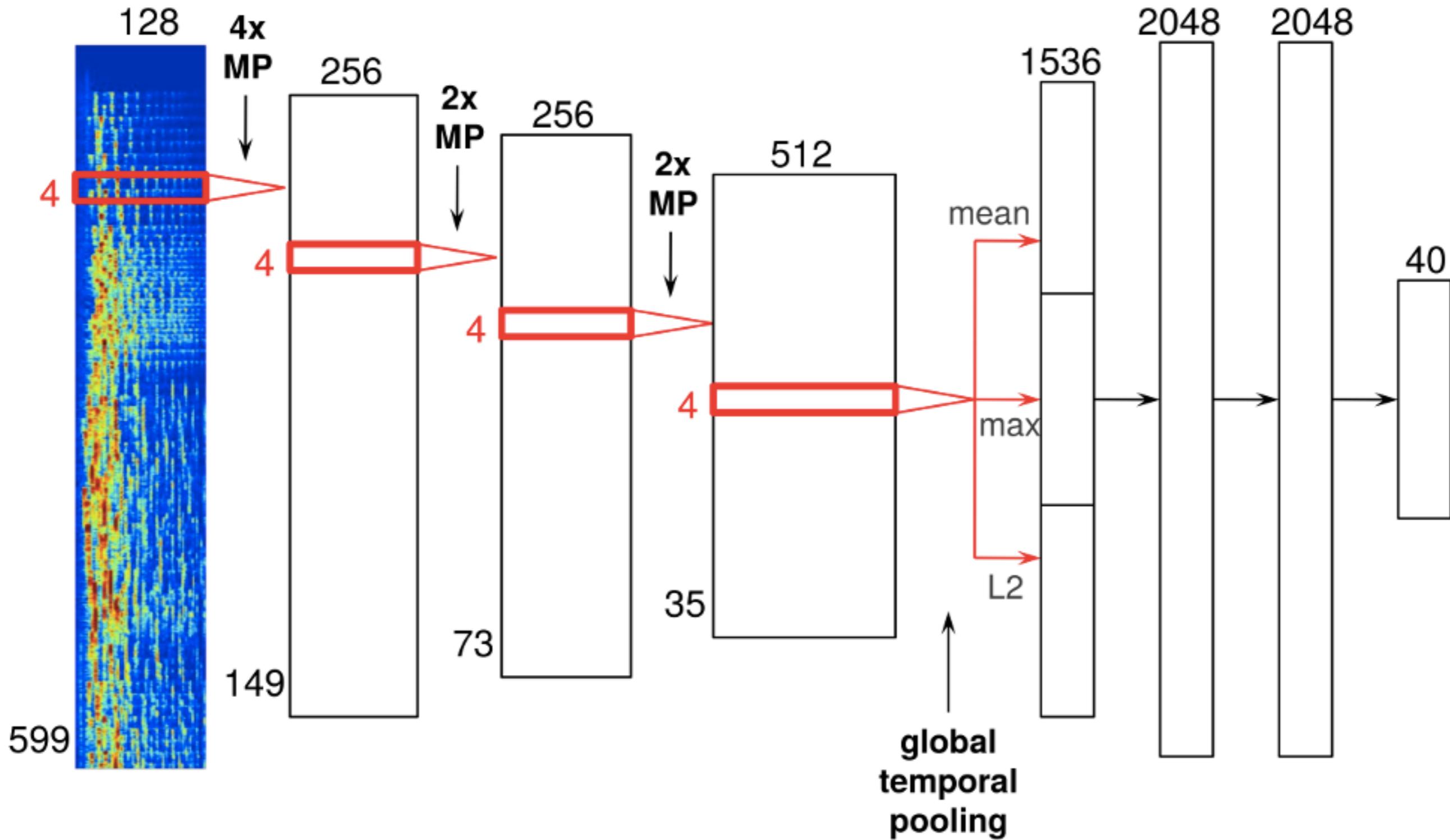
Created by: [PIAS] Playlists • 47 songs, 3 hr 24 min Available Offline

SONG	ARTIST	ALBUM	DATE	DURATION
+ Only Shallow - Remastered Ver...	My Bloody Valentine	Loveless	2015-03-05	4:18
+ Are You Ready?	Mercury Rev	Are You Ready?	2015-08-06	3:47
+ Sparks	Beach House	Sparks	2015-07-02	5:21
+ Somebody Call a Doctor	Sunflower Bean	Show Me Your Seve...	2015-07-27	3:56
+ Desire	DILLY DALLY	Desire	2015-07-27	3:36
+ Waves	Echo Lake	Era	2015-06-23	6:25
+ Wonderlust	Kid Wave	Wonderlust	2015-06-17	2:55
+ Cannabis	Slim Twig	Cannabis	2015-06-17	5:33
+ ILL	Fews	ILL	2015-06-02	8:17
+ Heroin	Gengahr	Heroin	2015-04-27	3:04

Songs in  
playlist are  
words

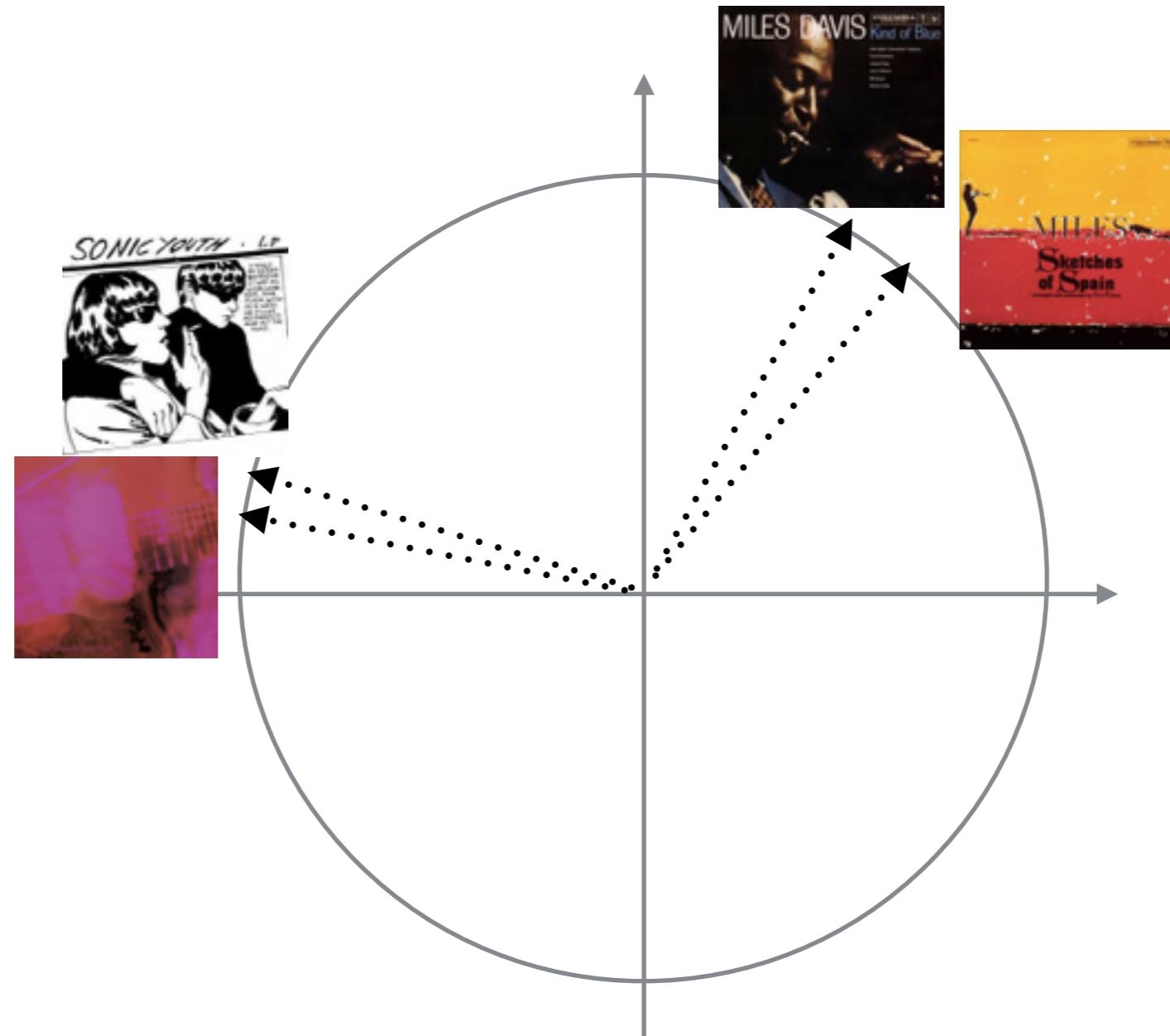
# Deep Learning on Audio [3]

82



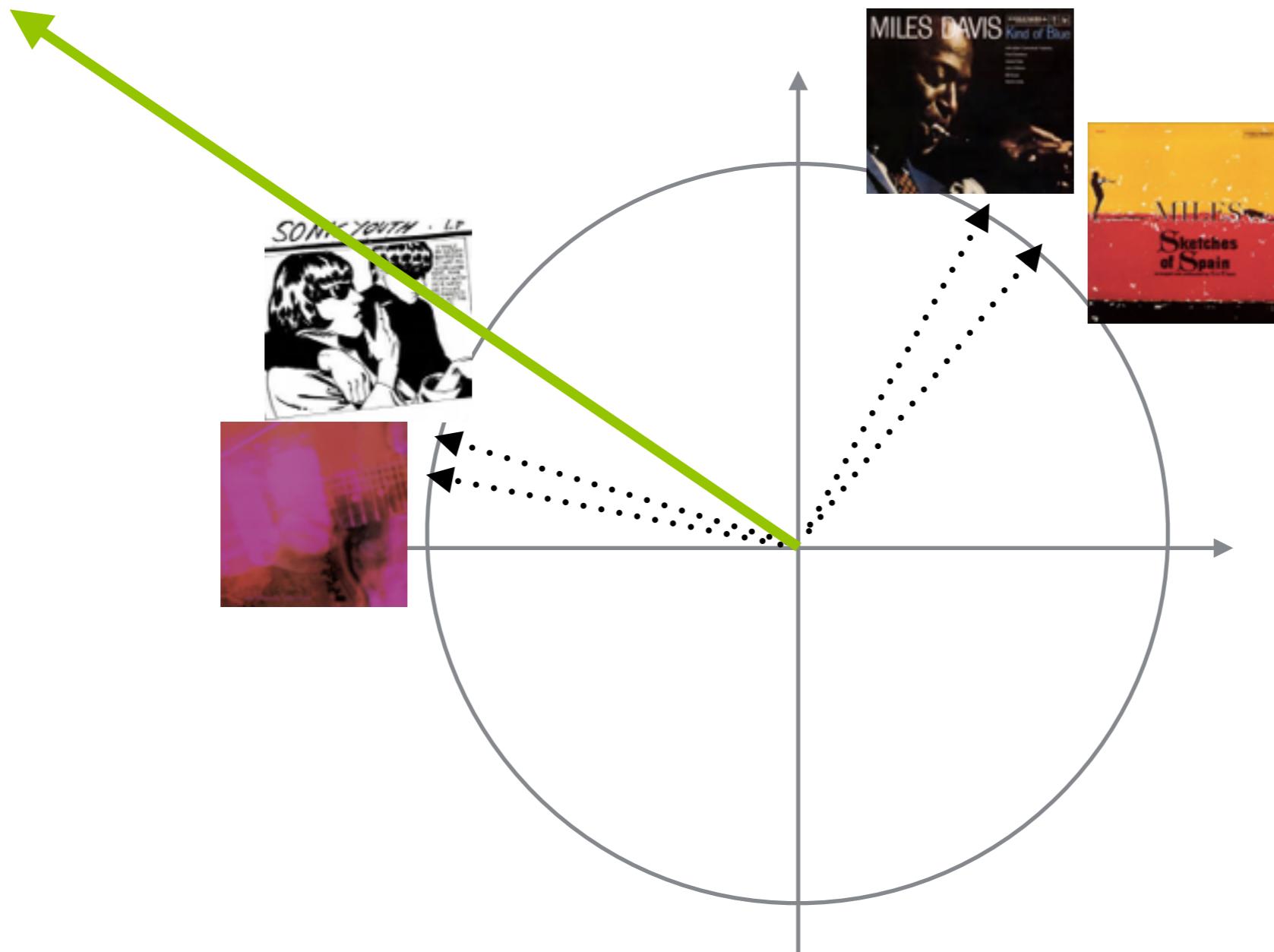
# Songs in a Latent Space Representation

- normalized item-vectors



# Songs in a Latent Space Representation

- **user-vector** in same space

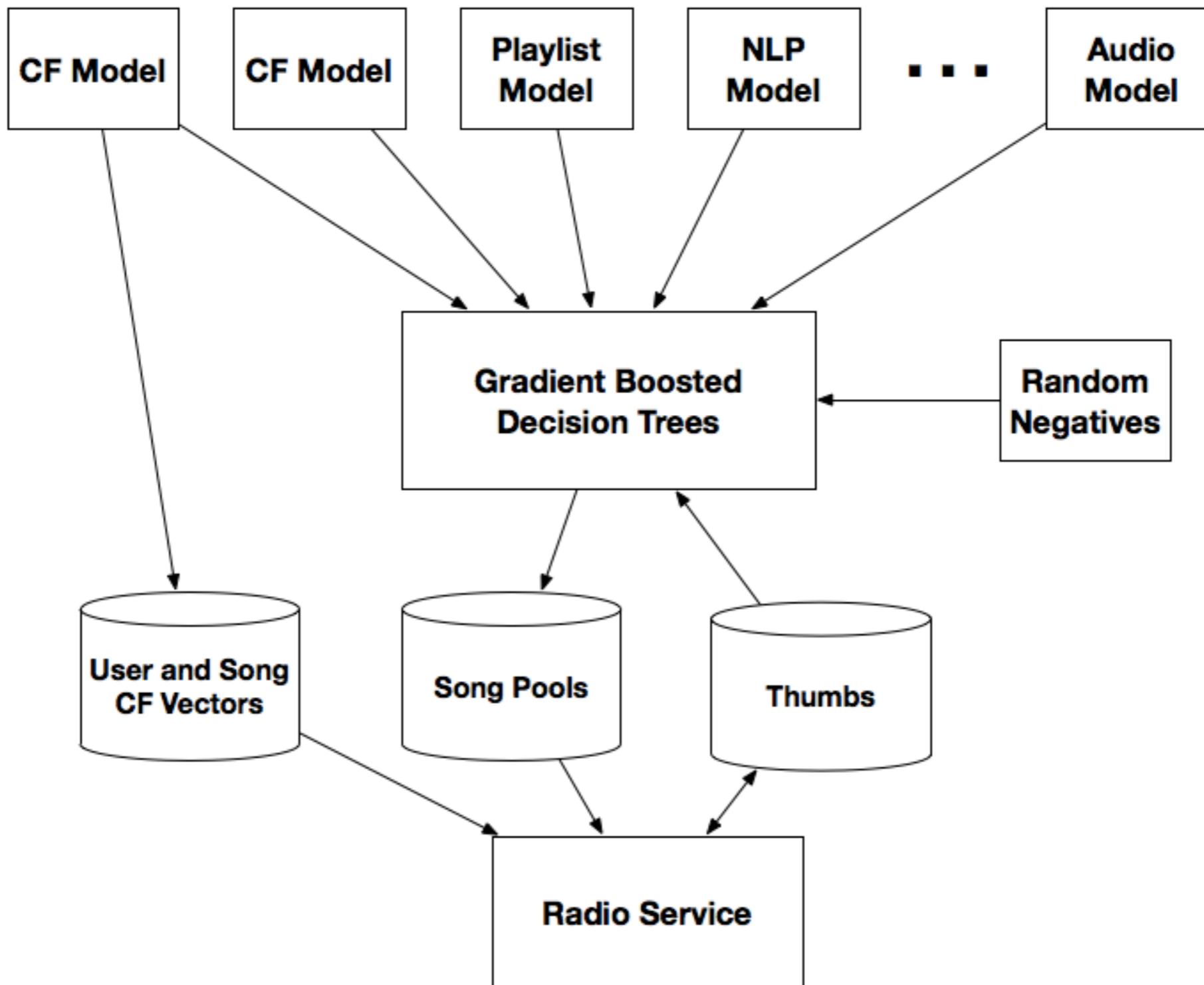


## Step 2:

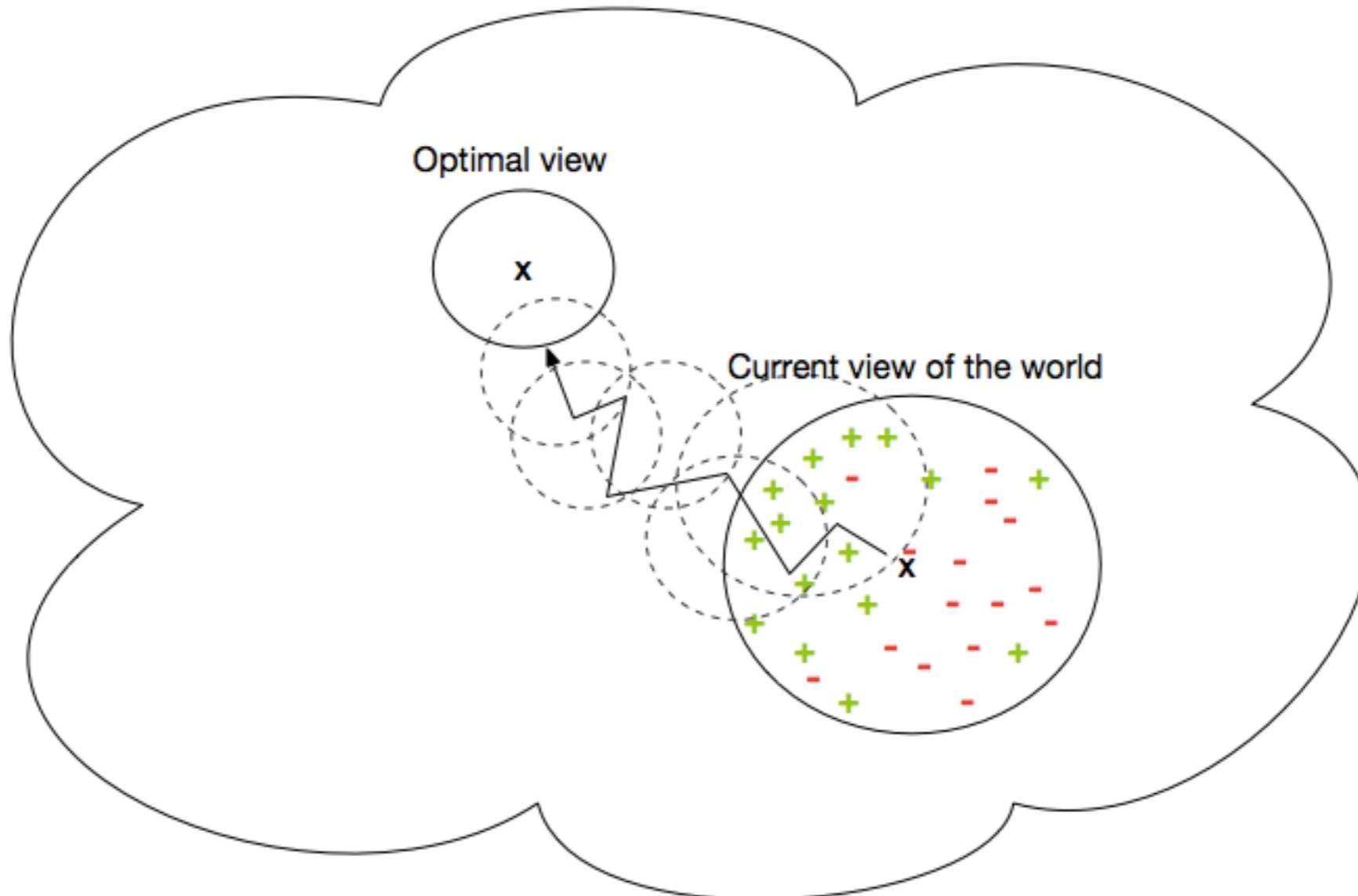
**Ensemble of batch models using  
explicit thumbs data**



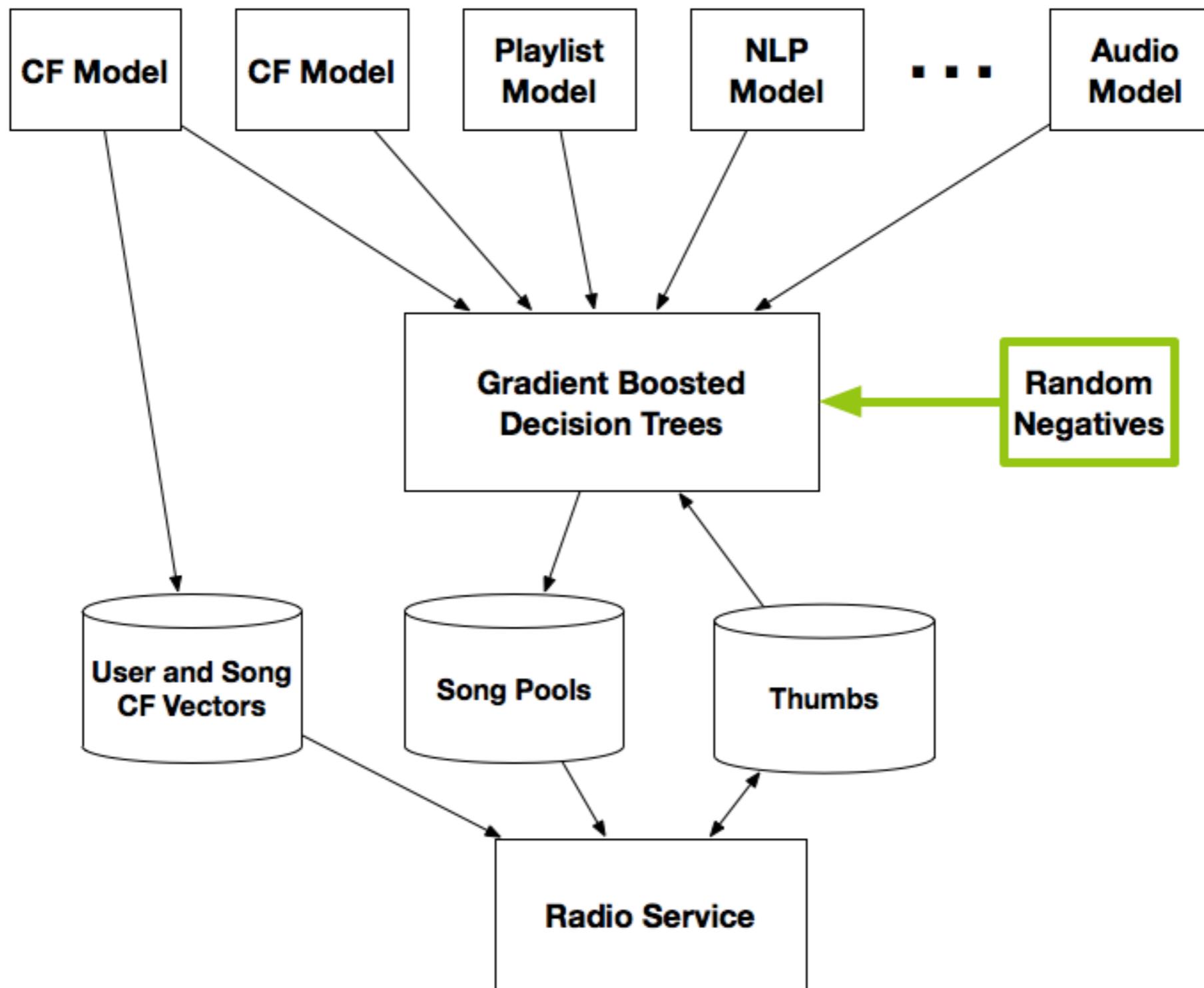
# Ensemble of Batch Models



# Explicit feedback at the expense of presentation bias...

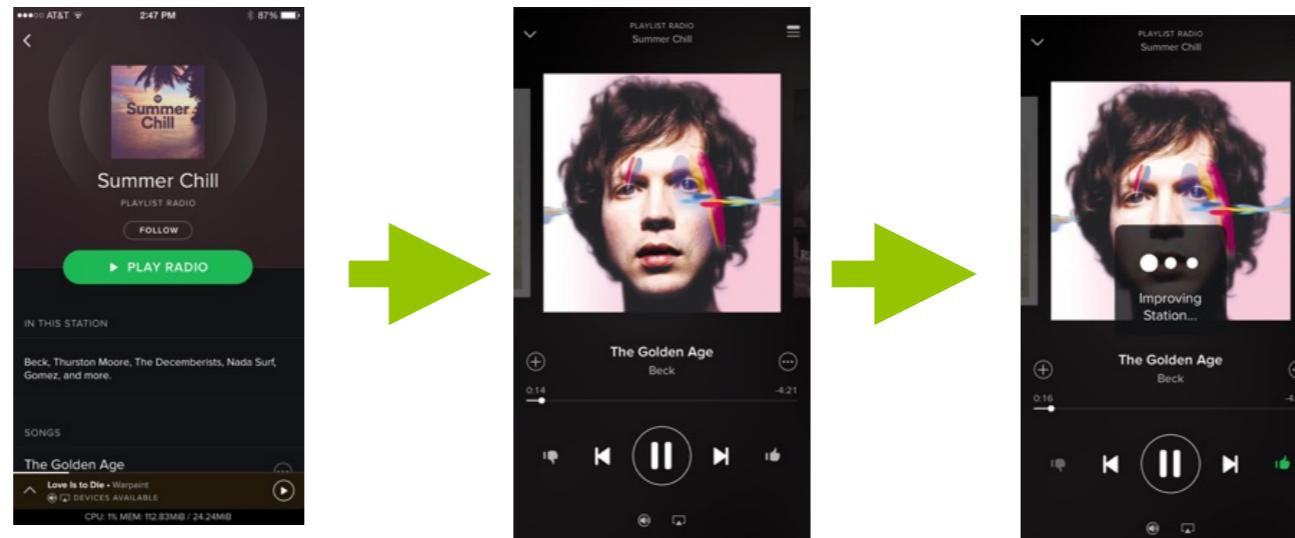


# Augment explicit feedback with random negatives



# Thumbs also carry a subjective bias...

- Thumbs used to personally tune a user's station

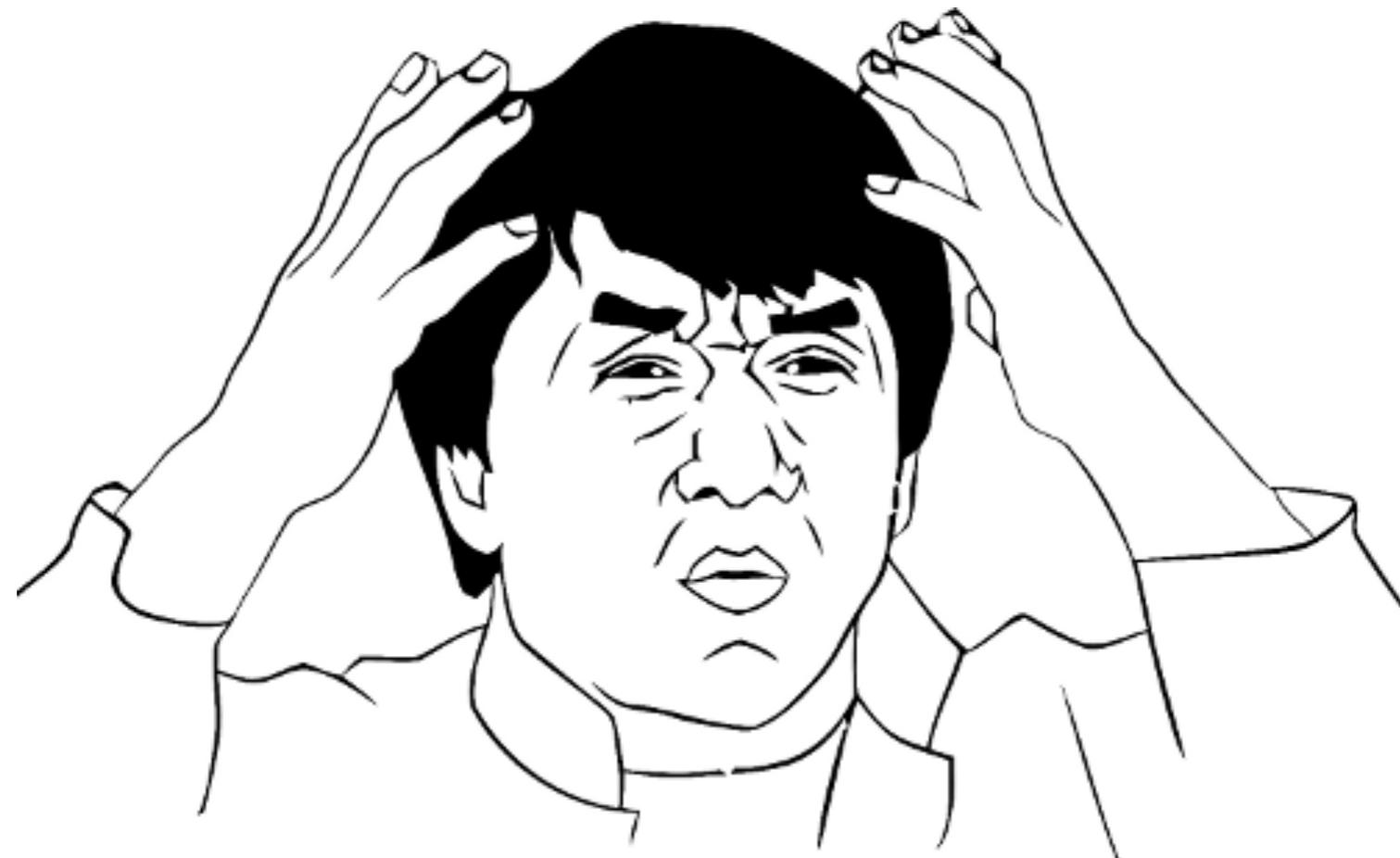


- But with enough data, they're a pretty good signal



# Interesting fact...

**Ratio of  to  does not always correlate with user engagement!**

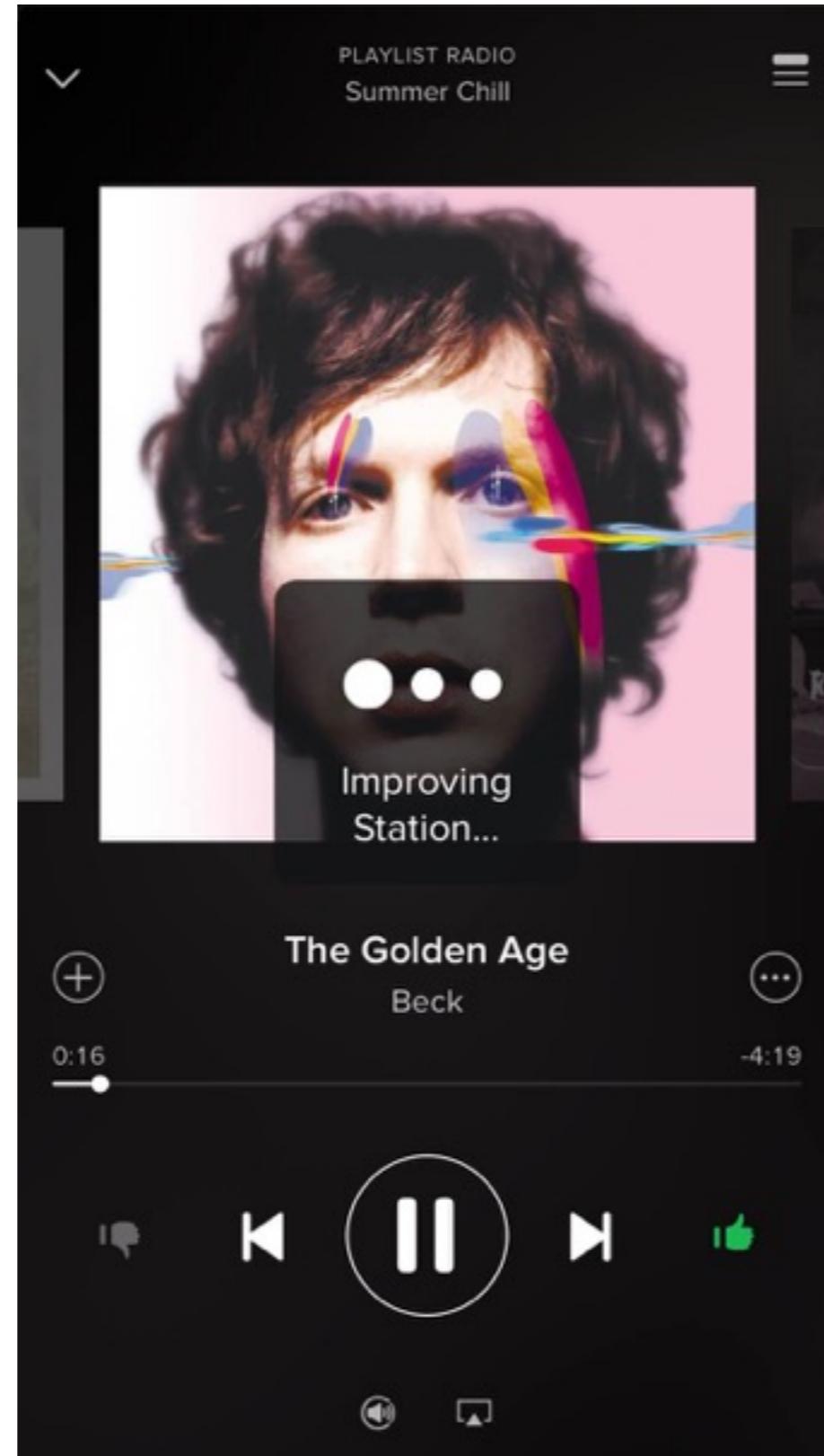


## **Step 3:**

**Static song pools adaptively  
personalized as user interacts**



# Should be **Simple**, **fast**, and **instantly gratifying**



# Adaptive personalization

- Probability of choosing song  $i$  given user  $u$ , station  $S$ , at time  $t$

$$\Pr(\text{play}(i \mid u, S, t)) = f(\text{rank}(i, S), \text{rel}(u, i), \text{thumb}(u, i), \text{div}(u, i, t))$$

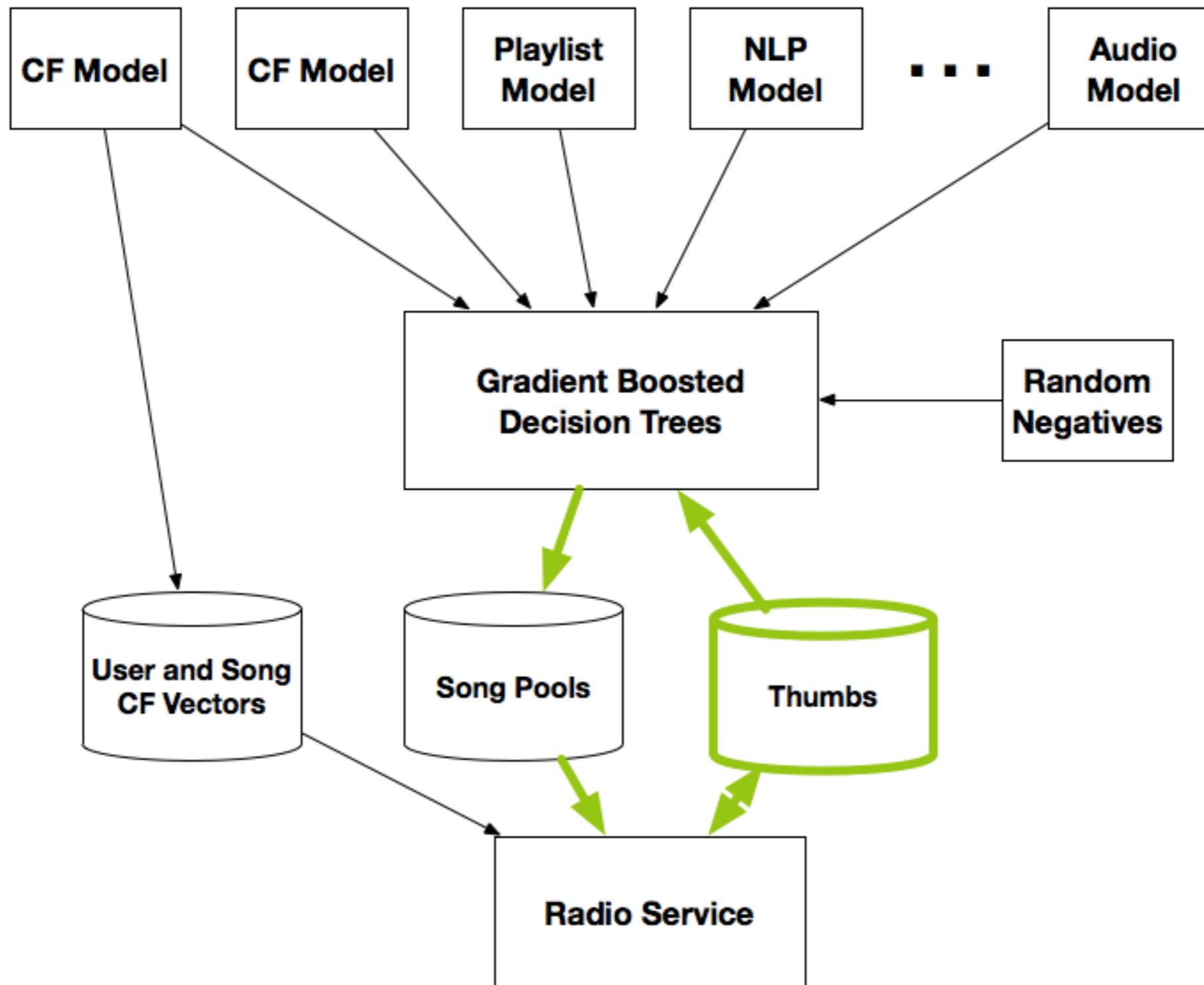
- $\text{rank}(i, S)$  = global rank of track in song pool
- $\text{rel}(u, i)$  = relevancy to user based on implicit CF vector
- $\text{thumb}(u, i)$  = relevancy to user based on explicit thumbs
- $\text{div}(u, i, t)$  = diversity of artist and album within radio session

## **Step 4:**

**Radio thumbs feed back into ensemble!**



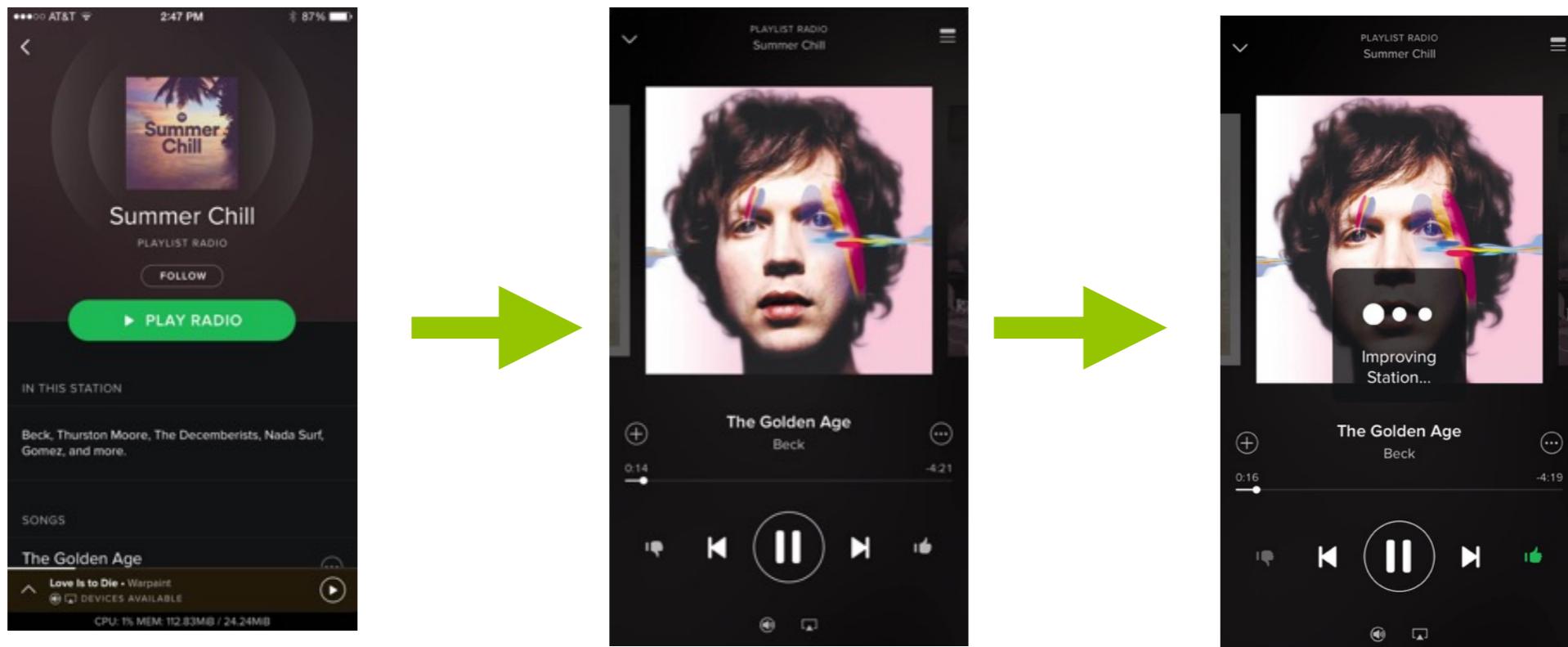
# Interactive feedback loop



# Key Take Aways



- Implicit feedback used to train batch recommendation models
- Explicit feedback is augmented with random negatives and used as training data to combine batch models (feedback loop)
- Adaptive shuffling is a function of song pool rank, user's implicit CF relevancy, user's thumbs relevancy, and diversity of artist and album
- Interaction needs to be simple, fast, and instantly gratifying to the user



# Insights

# Insights - User perspective

- Positioning of interactive RS in a product is crucial to success
  - Natural transition from browse and search to interaction
- Interactive RS needs to be lightweight..
  - Most users prefer lean-back experience
  - Interaction means work —> instant gratification
  - Evidence helps build trust and transparency
- Choice penalty
  - How much input is needed and how many results to return

# Insights - Algorithmic perspective

- Need to balance ***popularity***, ***relevancy***, and ***diversity*** of the recommendations during different phases of the interactive workflow.
- Real-time scoring vs offline computation of recommendations
- Video and music domain share many algorithmic characteristics, yet the application requires vastly different implementation
- On using implicit vs explicit feedback:
  - **What users say they like is not always what they watch/listen**

A close-up, low-angle shot of a person's hands playing an acoustic guitar. The person is wearing a dark-colored shirt and a gold ring on their left hand. They are using a wooden mallet to strike the strings. The background is blurred, showing warm colors like red, orange, and yellow.

Discussion