Research Challenges in Recommenders

John Riedl, U of Minnesota
Todd Beaupre, Yahoo!
Jon Sanders, Netflix

GroupLens Research

Structure

- Introductions
- Eight Challenges
- John Riedl will define the Challenge
- Jon Sanders or Todd Beaupre will explain key issues
- Other panelist will respond
- Audience discussion of *that* Challenge

John Riedl

- Professor at the University of Minnesota
- Co-Leader of GroupLens Research
- Net Perceptions Founder, CTO, and Director, 1996-2004

- Your Friendly Moderator

Todd Beaupre

Yahoo!

Yahoo! is ranked among the top 3 sites in 26 key categories and #1 in 12 of them

Yahoo! Monthly Unique Visitors (000) Noted in Yellow

E-mail	Autos	Entertainment News	Local/Maps	Groups	Home Pages
1. Yahoo! Mail	1. eBay Motors U.S.	1. omg!	1. Google Maps	1. Facebook Groups	1. Yahoo! HP
2. Win. Live Hotmail	2. Yahoo! Autos	2. TMZ	2. Mapquest	2. Yahoo! Groups	2. Google HP
3. Google Gmail	3. KBB.com	3. People	3. Yahoo! Maps	3. Google Groups	3. Facebook HP
Y! UVs: 106,166	Y! UVs: 6,972	Y! UVs: 20,428	Y! UVs: 13,163	Y! UVs: 7,654	Y! UVs: 118,011

Games	Search	Finance	TV	News	IM
1. Yahoo! Games	1. Google Search	1. Yahoo! Finance	1. Yahoo! TV	1. Yahoo! News	1. Yahoo! Messenger
2. EA Games	2. Yahoo! Search	2. AOL Money & Finance	2. AOL TV	2. CNN	2. AIM.com/AIM App
3. Nickelodeon	3. ASK Network	3. MSN Money	3. MSN TV	3. MSNBC	3. MSN Msngr
Y! UVs: 18,797	Y! UVs: 90,191	Y! UVs: 21,671	Y! UVs: 15,085	Y! UVs: 48,433	Y! UVs: 38,140

Movies	Travel	Music	My (*Custom*)*	Sports	Portals
1. IMDB.com	1. TravelAd Network	1. AOL Music	1. My Yahoo!	1. Yahoo! Sports	1. Yahoo! Sites
2. Yahoo! Movies	2. Tripadvisor	2. MySpace Music	2. iGoogle	2. ESPN	2. Microsoft Sites
3. Moviefone	3. Yahoo! Travel	3. Yahoo! Music	3. My MSN	3. Fox Sports on MSN	3. AOL LLC
Y! UVs: 17,942	Y! UVs: 10,167	Y! UVs: 21,889	Y! UVs: 24,644	Y! UVs: 30,718	Y! UVs: 156,506

Shopping (*Comparison*)	Careers	Reference	Personals	Photos	Real Estate
1. Yahoo! Shopping	1. Careerbuilder	1. Wikimedia	1. Yahoo! Personals	1. Facebook.com Photo	1. Move Network
2. Shopzilla.com	2. Yahoo! HotJobs	2. Yahoo! Answers	2. SingelsNet	2. Photobucket	2. Yahoo! Real Estate
3. Shopping.com	3. Monster	3. Answers.com	3. PlentyofFish	3. FLICKR.COM	3. AOL Real Estate
Y! UVs: 22,901	Y! UVs: 16,697	Y! UVs: 43,164	Y! UVs: 3,330	Y! UVs: 24,686	Y! UVs: 7,525

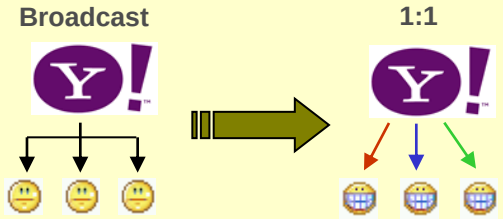
Source: comScore Media Metrix, July 2009
Base: P2+ U.S. data, Note: Homepages is not a traditional category in comScore's service
*Not Shown: Yahoo! Green ranks #2 in Environment, Yahoo! Health ranks #3 in Health
Monthly figures unless otherwise indicated

I think our clear strength is 'relevance' – whether that means knowing what weather to give you or serving up headlines you'll be interested in. It's all about really getting you **and we have more work to do in that area.**

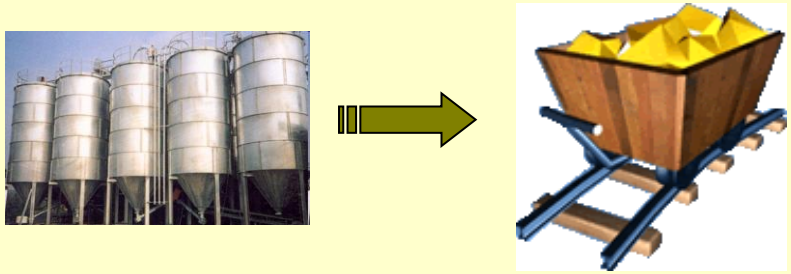
- Carol Bartz, CEO, Yahoo!

Make Yahoo! the most ***relevant experience*** on the Web by recommending the **right content** and products to the **right user** at the **right time**

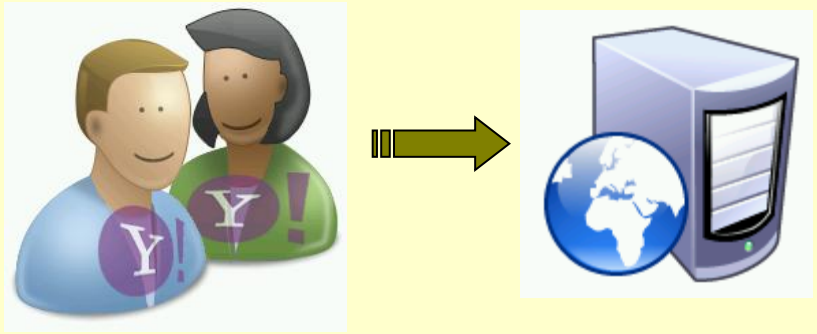
- **Fundamentally shift** Yahoo!'s content programming and serving paradigm from broadcast to 1:1



- **Break down data silos** to extract more value from our behavioral data goldmine



- **Automate content programming** in global markets where editorial headcount is not available



Most Popular

"What's most engaging overall?"

Personalized Recommendations

"What's most relevant to me based on my interests and attributes?"

Related Items

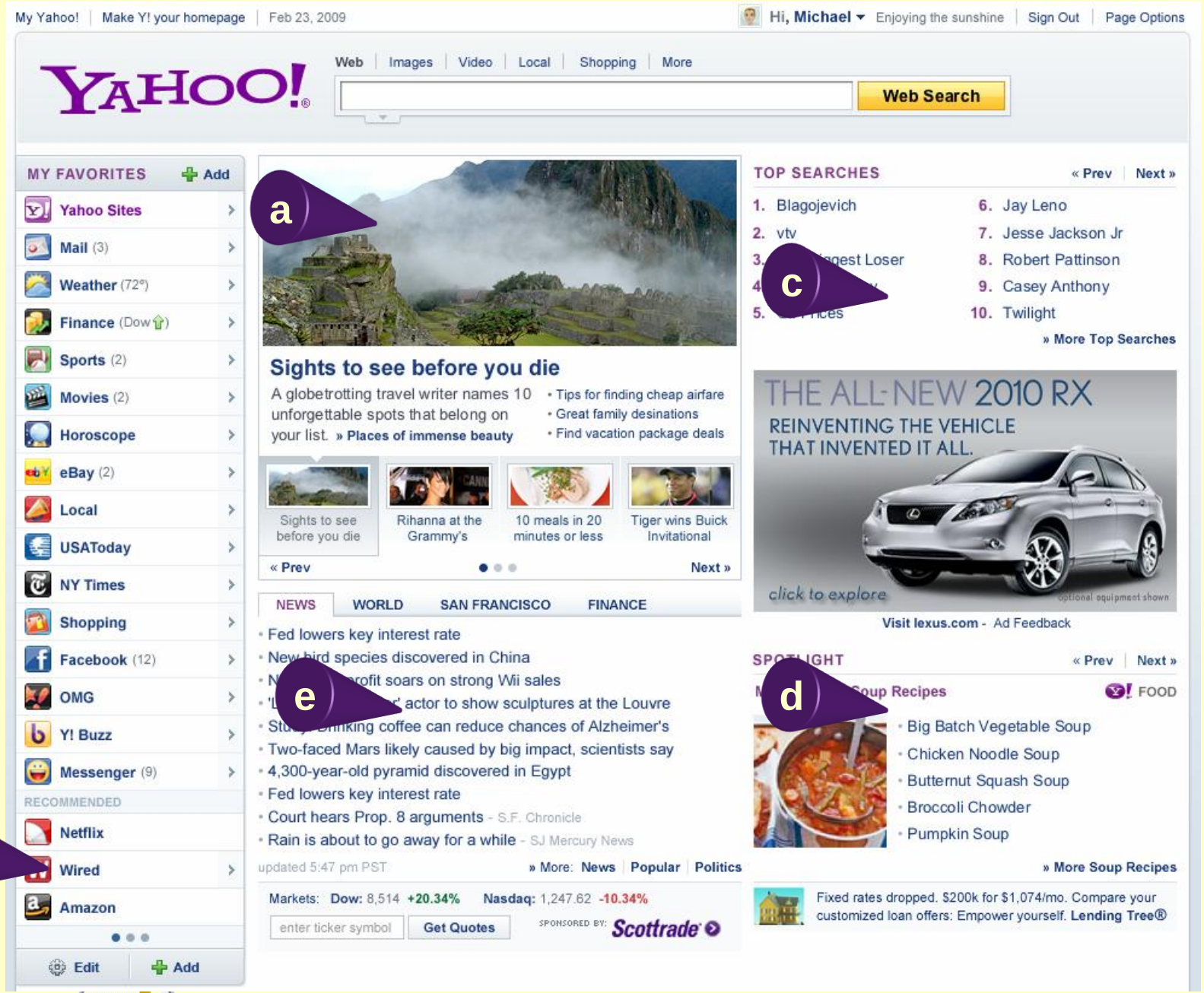
Behavioral Affinity:
People who did X, did Y

Similarity: Based on metadata

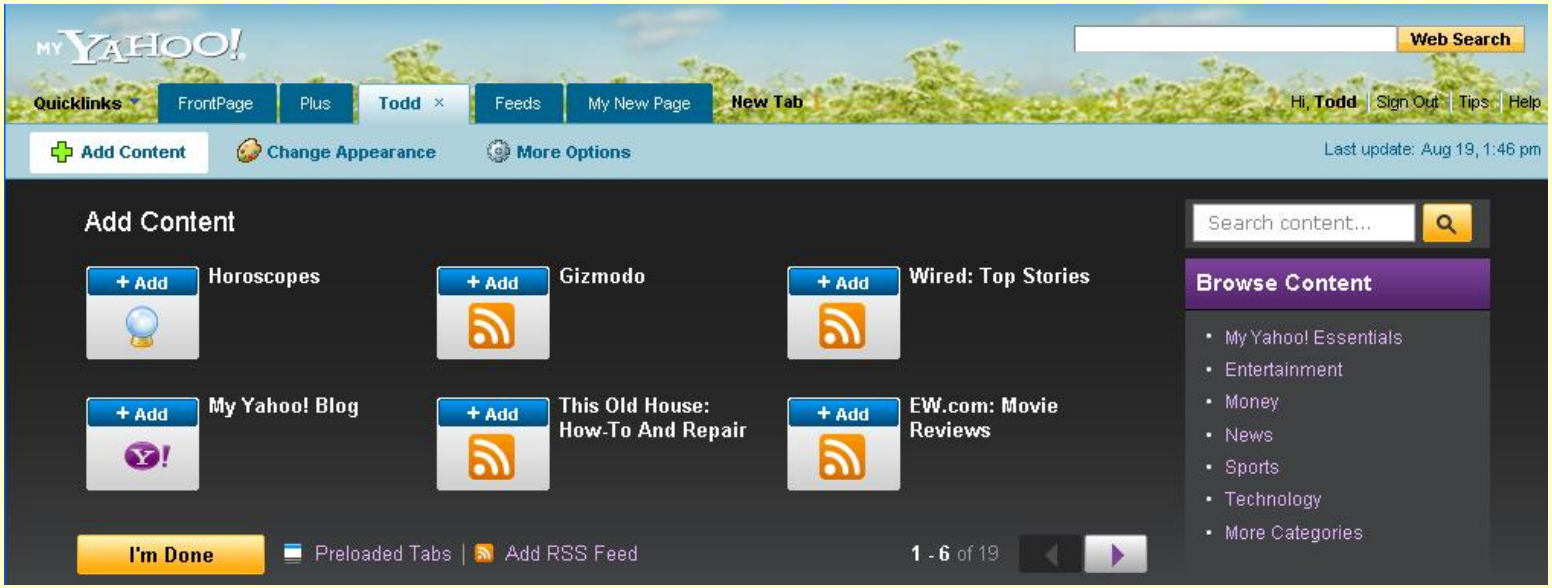
Voice and Business Rules

Real-time Dashboard

Business Optimization


My Yahoo! | Make Y! your homepage | Feb 23, 2009
Hi, Michael | Enjoying the sunshine | Sign Out | Page Options
YAHOO!
Web | Images | Video | Local | Shopping | More
Web Search
MY FAVORITES
Add
Yahoo Sites
Mail (3)
Weather (72°)
Finance (Dow)
Sports (2)
Movies (2)
Horoscope
eBay (2)
Local
USAToday
NY Times
Shopping
Facebook (12)
OMG
Y! Buzz
Messenger (9)
RECOMMENDED
Netflix
Wired
Amazon
Edit
Add
a
Sights to see before you die
A globetrotting travel writer names 10 unforgettable spots that belong on your list. » Places of immense beauty
• Tips for finding cheap airfare
• Great family desinations
• Find vacation package deals
Sights to see before you die
Rihanna at the Grammy's
10 meals in 20 minutes or less
Tiger wins Buick Invitational
« Prev
Next »
NEWS
WORLD
SAN FRANCISCO
FINANCE
• Fed lowers key interest rate
• New bird species discovered in China
• N rofit soars on strong Wii sales
• ' actor to show sculptures at the Louvre
• St inking coffee can reduce chances of Alzheimer's
• Two-faced Mars likely caused by big impact, scientists say
• 4,300-year-old pyramid discovered in Egypt
• Fed lowers key interest rate
• Court hears Prop. 8 arguments - S.F. Chronicle
• Rain is about to go away for a while - SJ Mercury News
updated 5:47 pm PST
» More: News | Popular | Politics
Markets: Dow: 8,514 +20.34% Nasdaq: 1,247.62 -10.34%
enter ticker symbol
Get Quotes
SPONSORED BY: Scottrade
TOP SEARCHES
« Prev | Next »
1. Blagojevich
2. vtv
3. gest Loser
4.
5. ices
6. Jay Leno
7. Jesse Jackson Jr
8. Robert Pattinson
9. Casey Anthony
10. Twilight
» More Top Searches
THE ALL-NEW 2010 RX
REINVENTING THE VEHICLE THAT INVENTED IT ALL.
click to explore
optional equipment shown
Visit lexus.com - Ad Feedback
SPOTLIGHT
« Prev | Next »
oup Recipes
FOOD
• Big Batch Vegetable Soup
• Chicken Noodle Soup
• Butternut Squash Soup
• Broccoli Chowder
• Pumpkin Soup
» More Soup Recipes
Fixed rates dropped. $200k for $1,074/mo. Compare your customized loan offers: Empower yourself. Lending Tree®
b
c
d
e

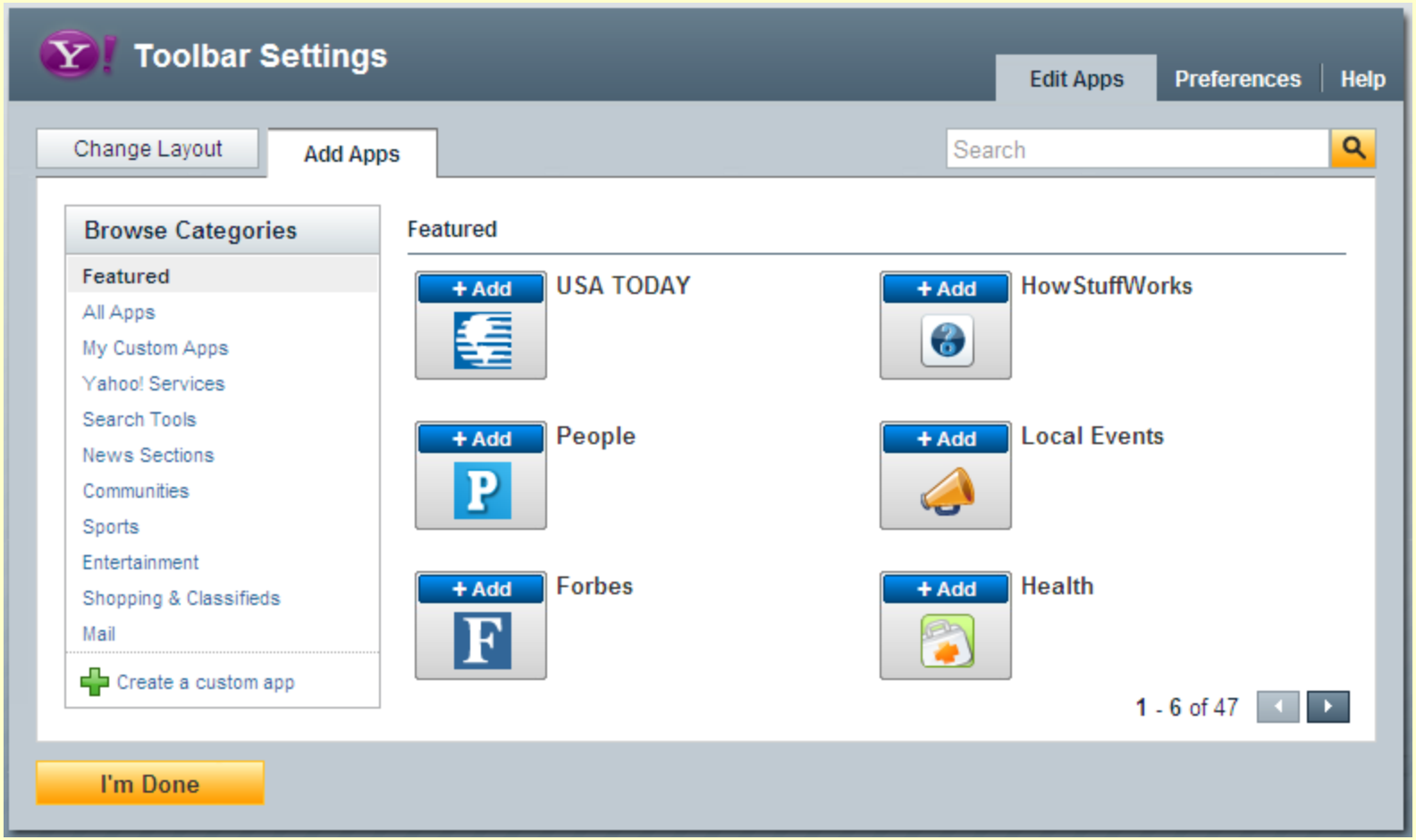
My Yahoo!: Module and Feed Recommendations



- **Personalized based on Age, Gender, Location, BT, and module subscriptions**

YAHOO! TOOLBAR

Recommended Apps and Buttons



Personalized based on BT profiles

YAHOO! TRAVEL

Destination Recommendations

Today's Picks for *Todd Beaupré

Traveling from: Sunnyvale, CA [Change Location]

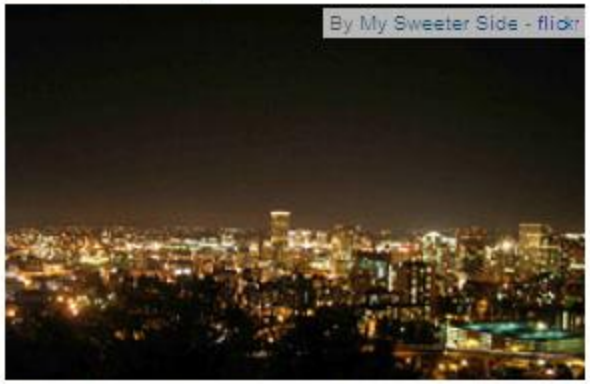
SHOW ME ▸ My Recommendations

Salem, OR »

The main – and perhaps the only – reason to visit SALEM is to see the modern, white Vermont-marble State Capitol ... More

Photos | Hotels | Things To Do | Map

Portland, OR »



Having been spared the kind of aggressive, remorseless development that many Seattle residents have come to loathe, PORTLAND ... More

Photos | Hotels | Things To Do | Map

Showing Recommendations 1 - 2 of 10

YAHOO! GAMES

Most popular by category

TOP 5 CARD GAMES

1		Hold 'Em Poker
2		Pyramids
3		HOT UNO - Undercover
4		HOT Aloha Solitaire
5		Super Solitaire Turbo

YAHOO! AUTOS

Most popular by category

Yahoo! Autos User's Picks

Most Viewed SUVs on Yahoo! Autos

1 2009 Honda CR-V

MSRP $21,245 - $28,945

Avg. Rating (38 reviews)

"This is my 2nd CRV and it's as good as the last. Super reliable, love..." more

by Heath

2 2009 Volkswagen Tiguan

3 2009 Nissan Rogue

4 2009 Jeep Patriot

5 2010 Mercedes-Benz GLK-Class

Search affinity

Similar Searches

People that searched for Nissan Murano also searched:

Nissan Maxima

Nissan Pathfinder

Nissan Altima

Honda Accord

Toyota Camry

Toyota RAV4

Infiniti FX35

Honda CR-V

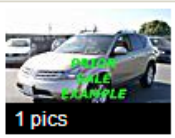
Toyota Highlander

Toyota 4Runner

Listing & M/M/T Affinity

Other People Also Viewed

People that viewed the **2005 Nissan Murano SL** listing also viewed these vehicles.

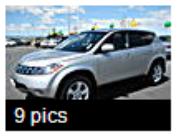


2006 Nissan Murano

$15,800 / 27,472 miles

Dealer : Alameda County Auction

Dublin CA



2004 Nissan Murano

$12,784 / 80,304 miles

Dealer : Tracy Mazda

Tracy CA

2004 Nissan Murano

$13,988 / 71,302 miles

Dealer : Formula #1 Motors

Hayward CA

YAHOO! REAL ESTATE

Related Listings (Behavioral & Metadata)

People who viewed 1103 Lund Ter also viewed

29% also viewed

521 Porpoise Bay Ter
Sunnyvale, CA
Beds: 3 | Bath: 2.50
$658,000
Save

27% also viewed

722 Saranac Dr
Sunnyvale, CA
Beds: 5 | Bath: 2.50
$1,035,000
Save

20% also viewed

1118 Breezewood Ct
Sunnyvale, CA
Beds: 3 | Bath: 2
$440,000
Save

19% also viewed

1071 Mango Ave
Sunnyvale, CA
Beds: 3 | Bath: 2
$1,049,000
Save

YAHOO! TV

Similar Shows

SIMILAR SHOWS

- The Apprentice (NBC)
- Big Brother: All-Stars
- The Real World 18 - Denver
- American Idol
- Project Runway

YAHOO! SHOPPING

Recommended Products

Apple iPod touch, 32GB MP3 Player
$339.99 - $339.99
51 ratings | 8 reviews

Apple iPod classic 80GB - Black ...
$299.95 - $299.95
109 ratings | 10 reviews

Garmin nuvi 360 GPS Receiver
$139.95 - $362.99
31 ratings | 13 reviews

Related Products

Shoppers who viewed this product also viewed:

Garmin Nuvi 660 GPS Receiver
$459.95 - $459.95
90 ratings | 23 reviews

Garmin nuvi 760 GPS Receiver
$189.99 - $532.99
20 ratings | 2 reviews

Garmin nuvi 360 GPS Receiver
$139.95 - $362.99
31 ratings | 13 reviews

YAHOO! SMALL BUSINESS **(Stores)**

You may also be interested in these items:

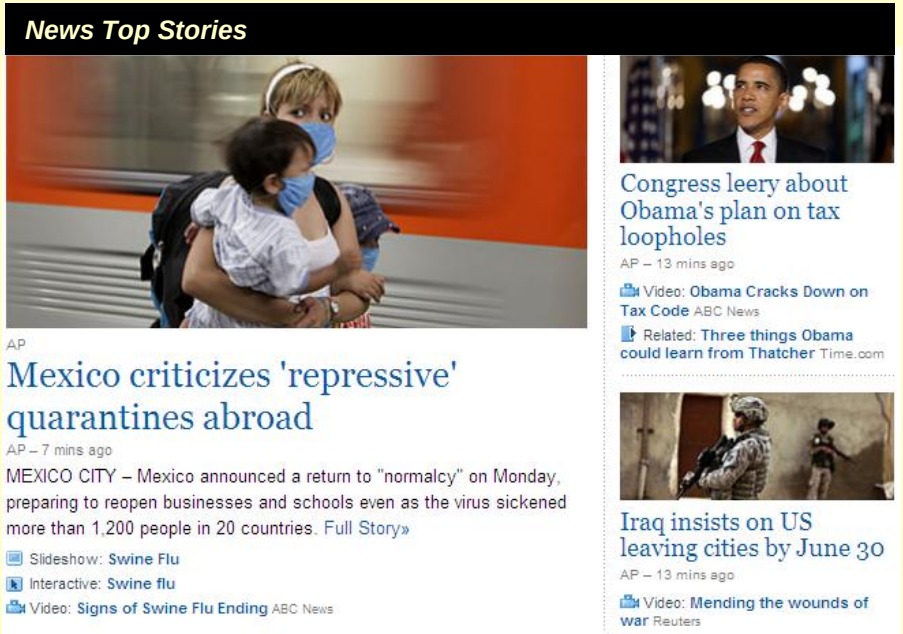
fingerprint-proof rectangular recycler
$179.99

40 liter / 10.5 gallon fingerprint-proof semi-round step can
$139.99

40 liter / 10.5 gallon fingerprint-proof round step can
$99.99

Across the network

- **News Top Stories**



Across the network

- News Top Stories
- **Finance Top Stories**

News Article Related content

Without state budget, California readies "IOUs"

Featured

Michael Jackson

Yahoo! News' complete coverage includes latest news and videos.
» Slideshow

Eyes on the prize

Canadian author Alice Munro wins the Man Booker Prize in The Week in Photos.

Education

Careers That Fight Recession

These fields offer strong careers that stay in demand during an economic slowdown.

Surprising Stay-Home Salaries

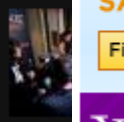
Working from home is more popular than ever. See the most lucrative stay home careers.

Entertainment

Daily Features

All Comics »

Hayden Panettiere Opens Up



LAUNCH A WEB SITE FOR YOUR BUSINESS.
SIGN UP TODAY AND SAVE 35%.
Find Out More
REPLAY
YAHOO! SMALL BUSINESS

More from Yahoo! Entertainment »

U.S. Video

AP Top Stories AP

In Hot Water FOX News

After-school Attack
FOX News

Squatters clash with Peruvian police
Reuters

More U.S. Video »

Also on Yahoo! News

- Today in History
- Obituaries
- Corrections
- News by Region (Yahoo! Directory)
- Yahoo! News & Media Sites

Photo Highlight

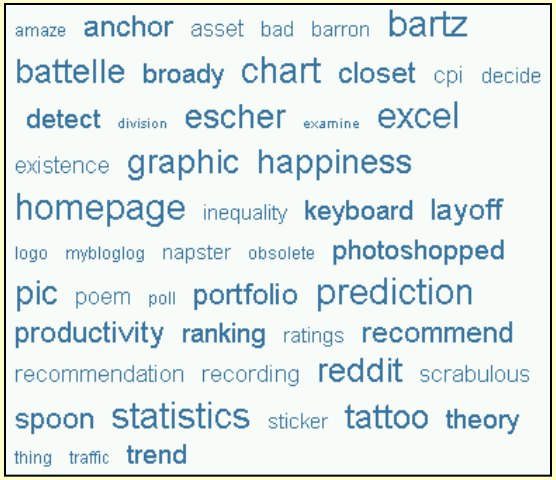
Photo Highlight Slideshow
A boy jumps while playing football in a field near Pretoria. AFP/Yasuyoshi Chiba

Across the Network

- News Top Stories
- Finance Top Stories
- Related News content
- **Buzz Ranking**

Best of the Web

+



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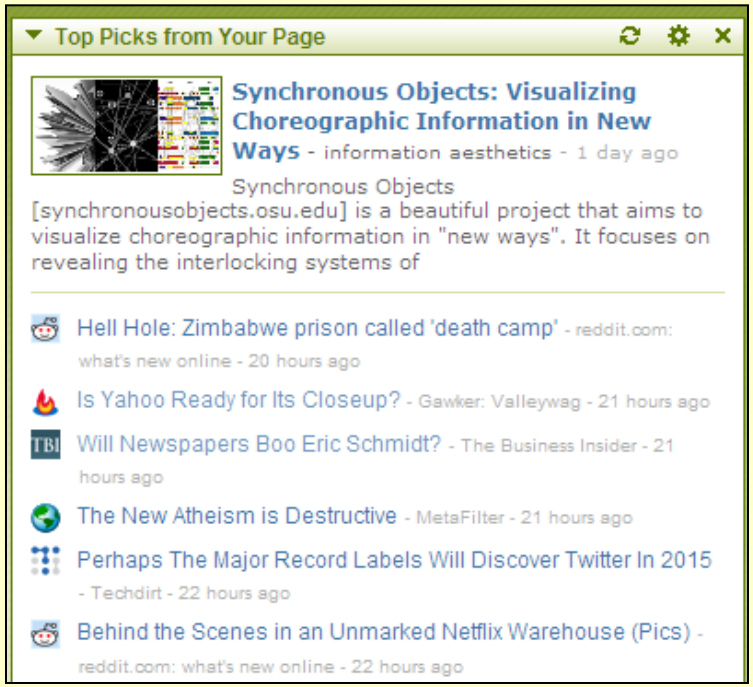


	Today	Future
Learns from…	My Yahoo! views/clicks	On- and off-network activity
User profiles are…	Sources, keywords	Sources, keywords, entities, topics
Content pool pulls from…	Subscribed feeds	All feeds, no setup required

Jon Sanders

Netflix

Personalizing Netflix

(in 10 minutes)

Jon Sanders
Recommendation Systems Engineering
Netflix
Los Gatos, CA
jsanders @ netflix.com

NETFLIX

Fun facts about Netflix

World's largest online movie rental service
Founded 1997

#1 in customer satisfaction
Video rental companies (Consumer Reports)
Online retail (ForeSee)

With more than…
10M subscribers, $1B revenue
100K DVD titles, 50 distribution centers
12K streaming movies & TV episodes
1.5B minutes streamed to 1M Xbox360's
3B movie ratings, 200 per member

On a typical day
2M DVDs shipped
3M movie ratings received
30B ratings predicted

60% of movies selected based on personalized recommendations

Connecting people with movies they'll love

Recommender domain

Customers
Paid subscription
Long term relationship
Households
Seeking entertainment
Unlimited consumption

Products
Long-lived
Finite, growing catalog
Rich metadata
Single-use
Varied external demand generation
Varied inventory constraints

Primary interactions
Subscribe
DVD queue/ship/return
Stream play/shuttle/stop
Rate movies/categories

In the beginning…

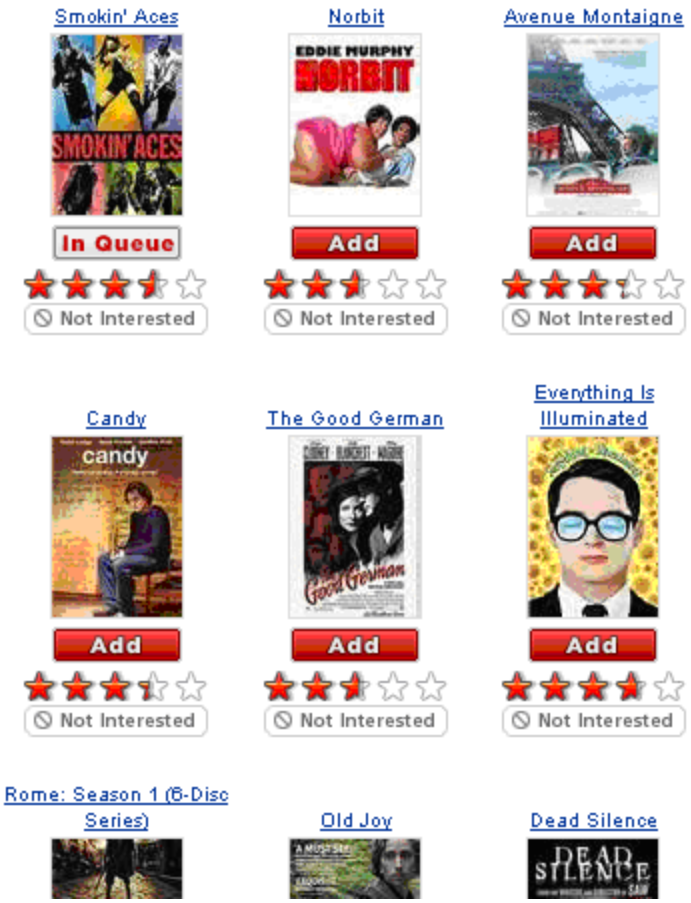
Everyone sees the same site

Evolve methodically

The rating widget

- Ask about & predict movie Enjoyment
- User-similarity collaborative filter
- Recommendations fuel discovery

Score & sort any movie



Combine popularity & enjoyment prediction

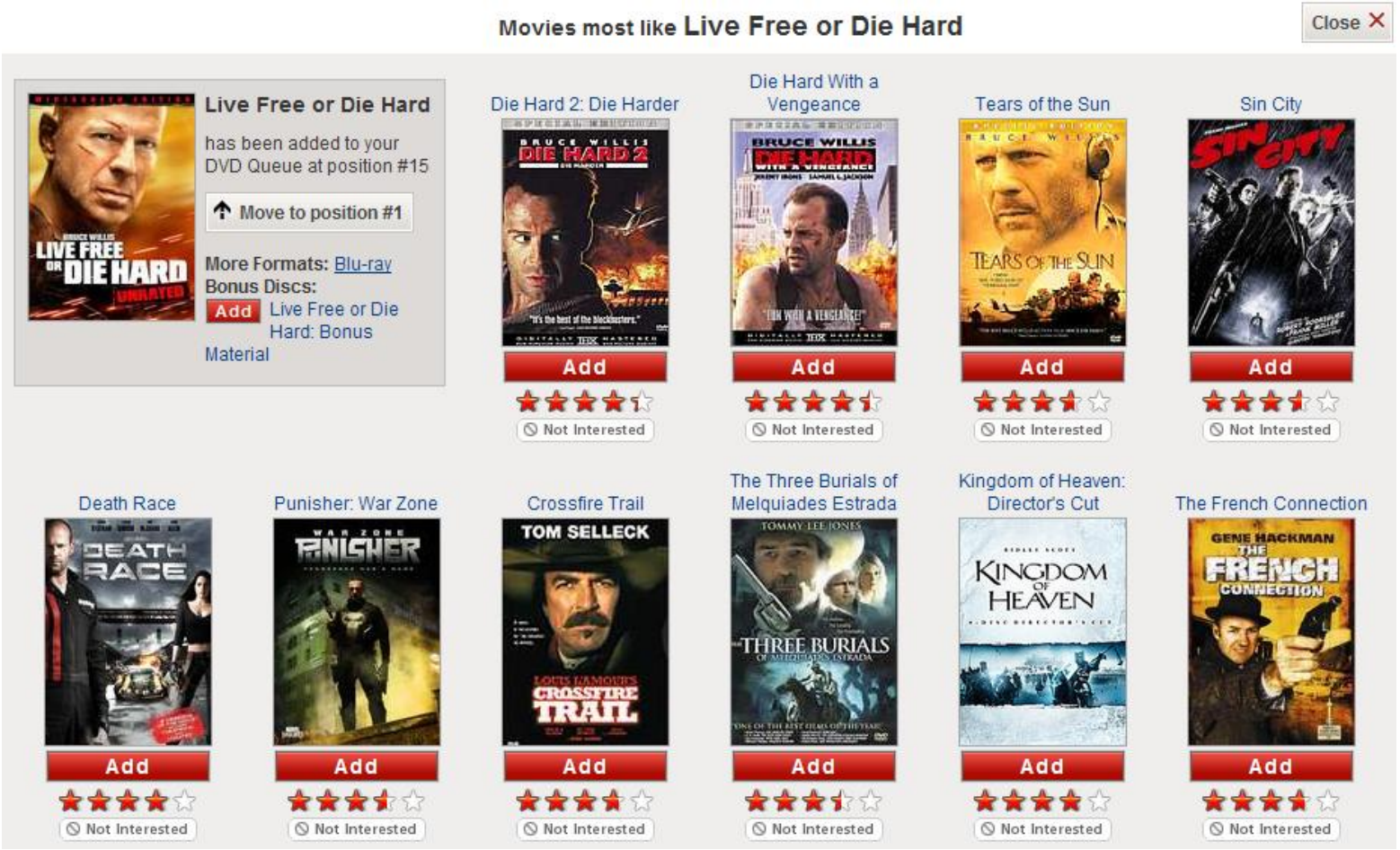
Tune recommendations

- Movie-similarity collaborative filter
- K-nearest-neighbor algorithm
- More credible connections

WHY IS THIS RECOMMENDED

Die Hard 2: Die Harder	★★★★★
Beverly Hills Cop II	★★★★★
Bad Boys II	★★★★★
Live Free or Die Hard	★★★★★
The Rock	★★★★★
The Fast and the Furious	★★★★★
Die Hard With a Vengeance	★★★★☆
Demolition Man	★★★★☆

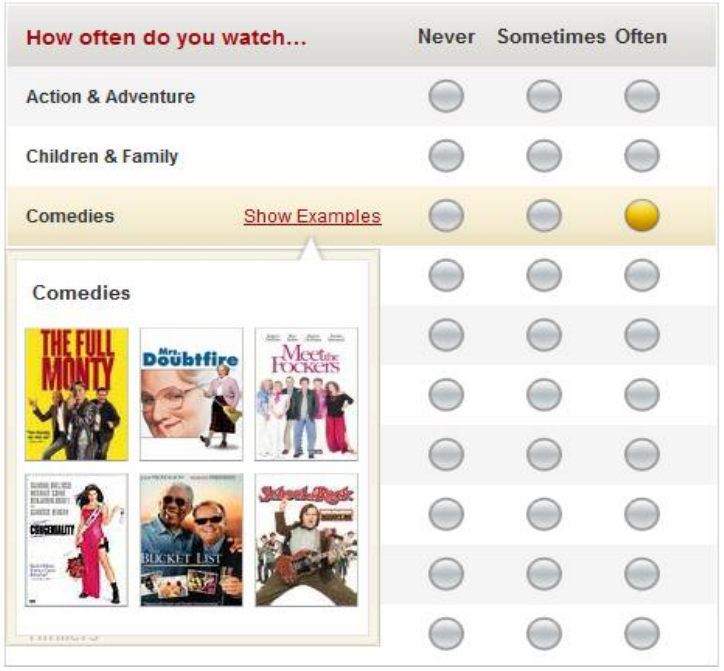
Interest-based discovery

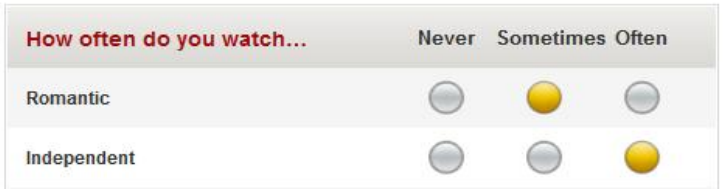


Metadata connections: actor, director, genre, …

Ask about Interest

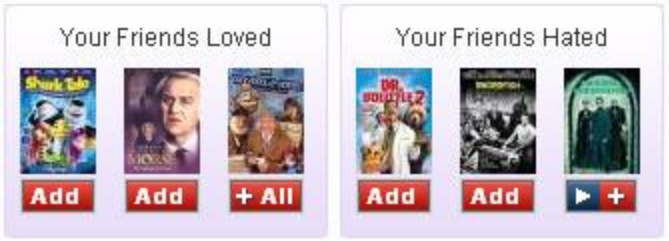
Jennifer, take a minute to create a personalized Netflix website.





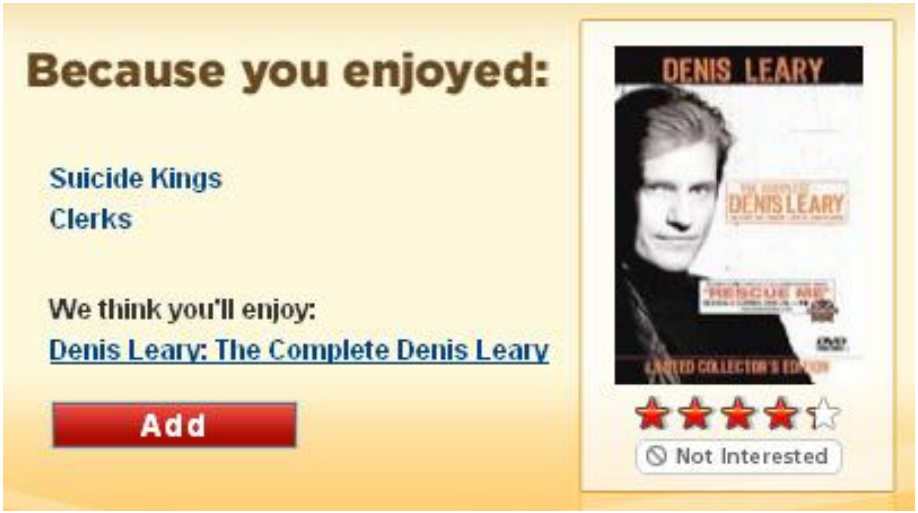
Prioritize catalog areas

Ask other people



Community offers decision support

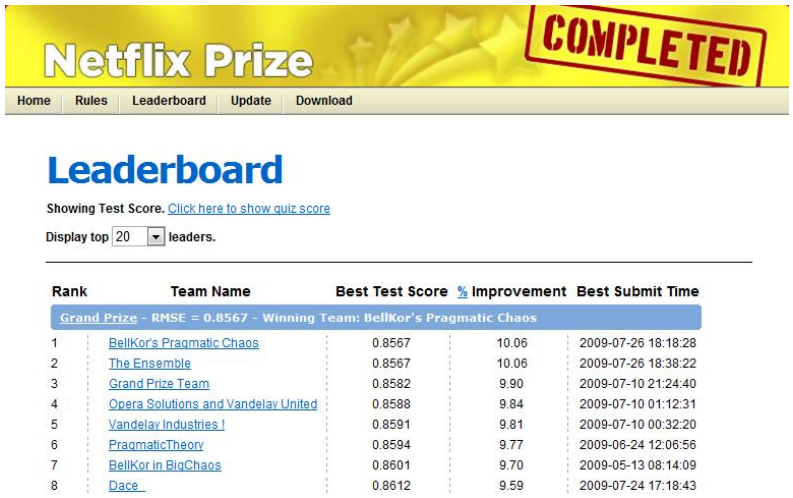
Explain why



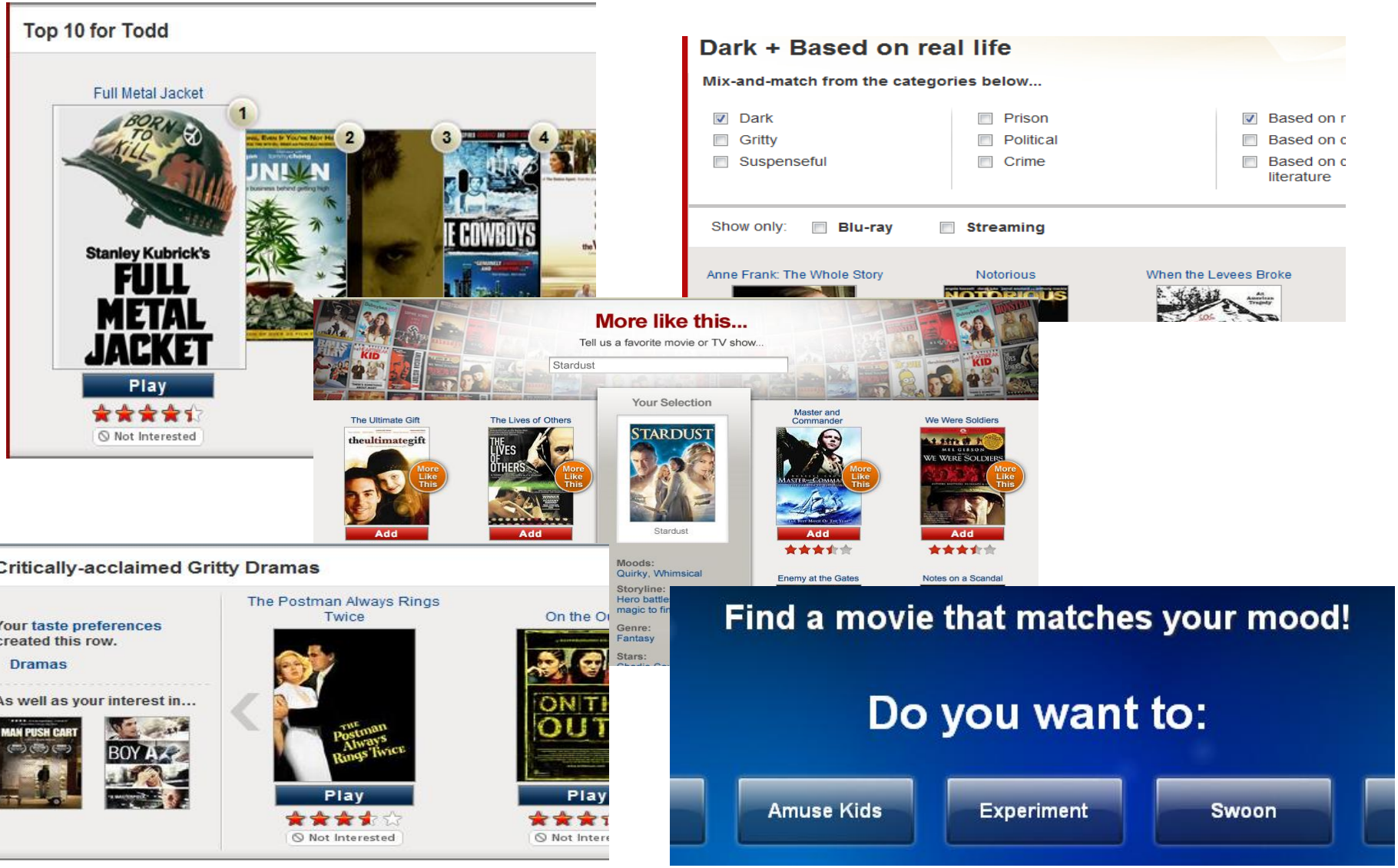
Build trust with reflected evidence

Netflix Prize

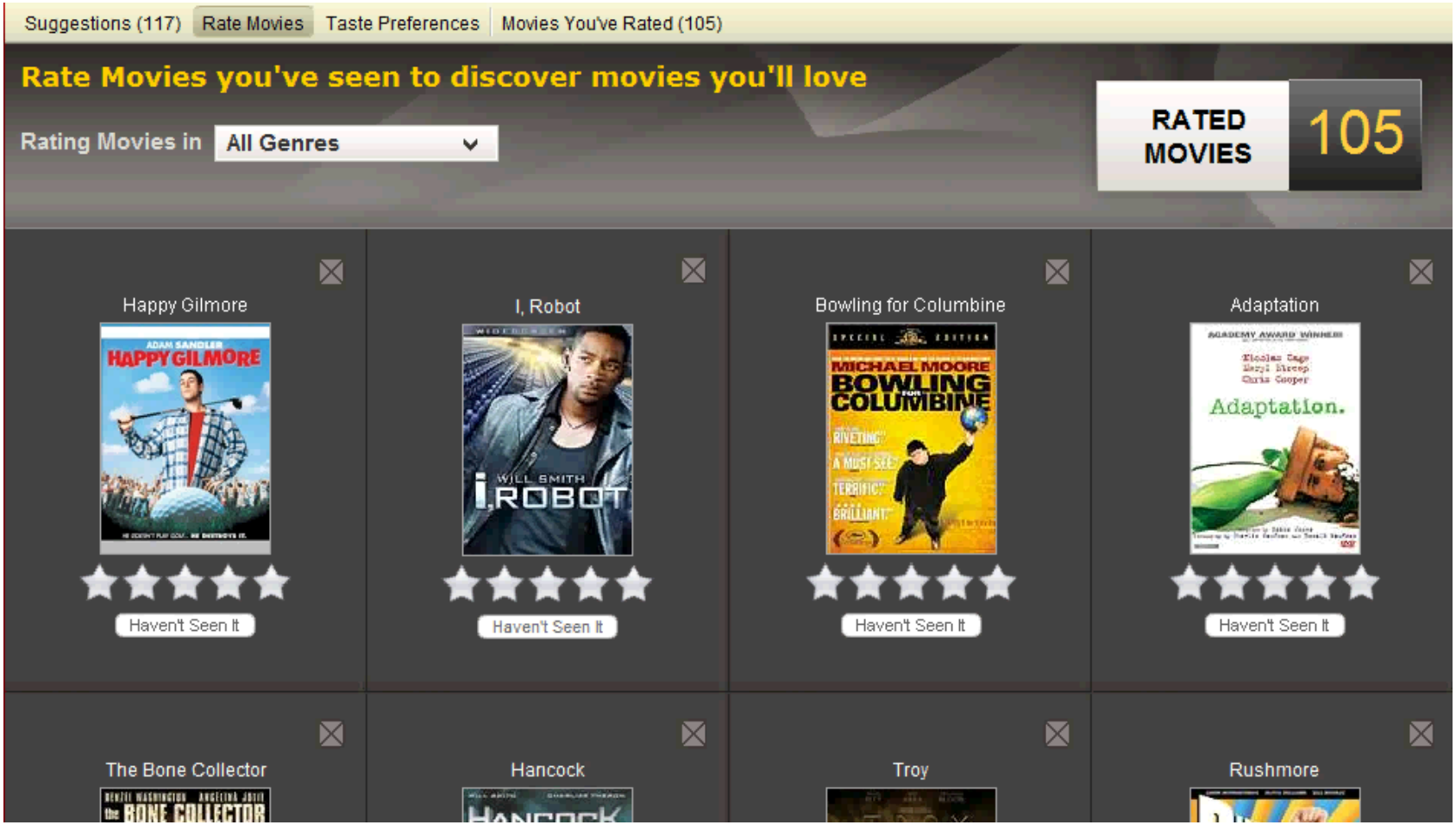
- Improve accuracy of Enjoyment predictions
  - 100M ratings
  - Achieve 10% better than Netflix RMSE
- Innovative, engaged research community
- Highly relevant results
  - Global and time-based corrections
  - SVD, RBM models
  - Blending predictors



Experiment


Top 10 for Todd
Full Metal Jacket
Stanley Kubrick's
FULL METAL JACKET
Play
Not Interested
Dark + Based on real life
Mix-and-match from the categories below...
Dark
Gritty
Suspenseful
Prison
Political
Crime
Show only:
Blu-ray
Streaming
Anne Frank: The Whole Story
Notorious
When the Levees Broke
More like this...
Tell us a favorite movie or TV show...
Stardust
Your Selection
The Ultimate Gift
The Lives of Others
Master and Commander
We Were Soldiers
Add
Critically-acclaimed Gritty Dramas
Your taste preferences created this row.
Dramas
As well as your interest in...
The Postman Always Rings Twice
Moods:
Quirky, Whimsical
Genre:
Fantasy
Enemy at the Gates
Notes on a Scandal
Find a movie that matches your mood!
Do you want to:
Amuse Kids
Experiment
Swoon

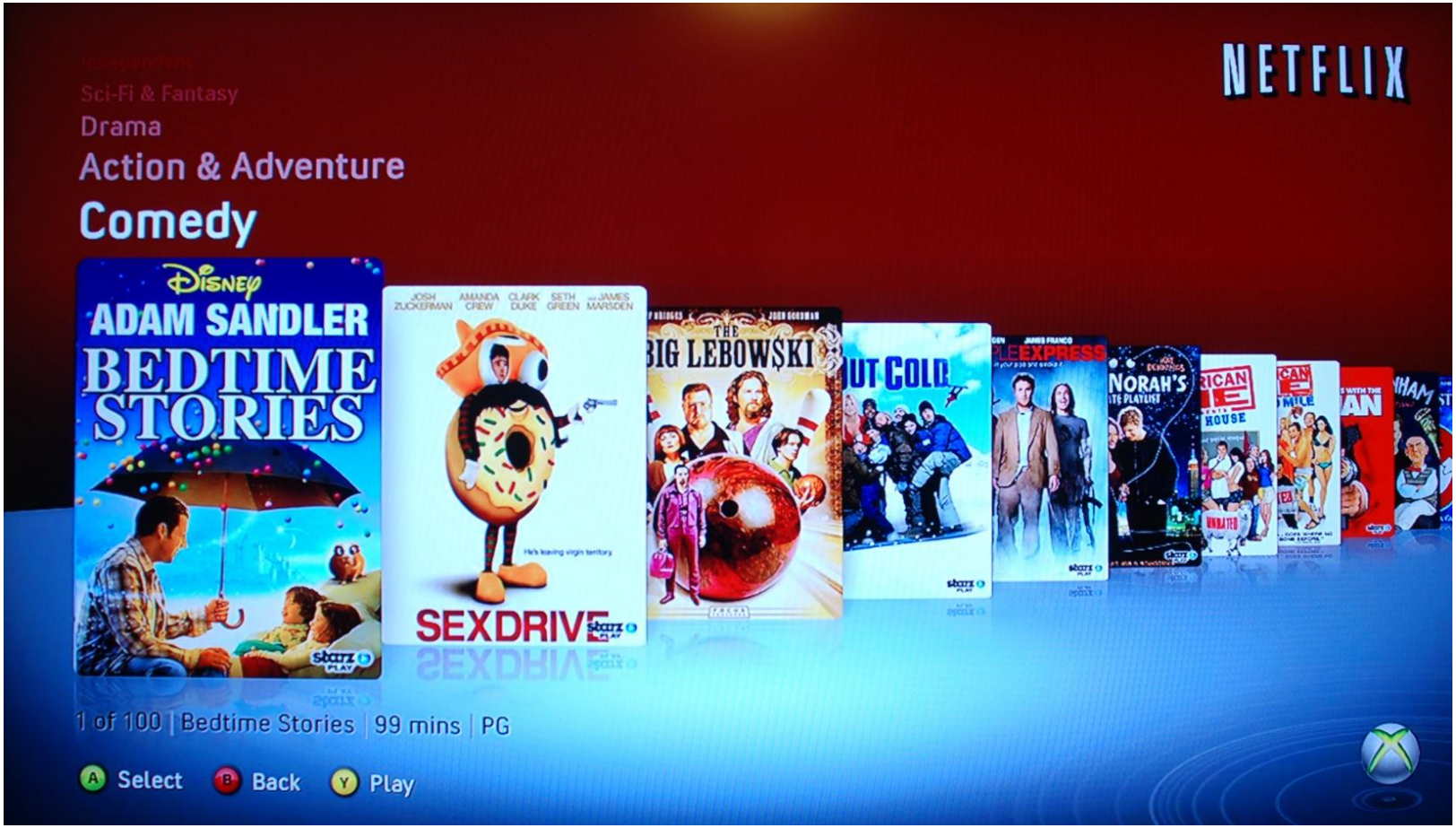
Optimize, optimize



Test everything

A website for each subscriber

Personalizing the TV



Just beginning

- So many opportunities
- Streaming-specific personalization

- Collaborative Filtering is a component of personalization
- Offer discovery, focus and decision support

Connecting people with movies they'll love

Key Challenges

1. Transparency
2. Exploration versus Exploitation
3. Guided Navigation
4. Time Value
5. User Action Interpretation
6. Evaluating Recommenders
7. Scalability
8. **Academic/Industry Partnerships**

Missing Challenges

- Information Diet
- Serendipity
- Privacy
- Balkanization
- Driving Traffic Strategically
- Combining Content and Collaborative Recommenders

Ground Rules: Be Nice!

- NO "My 1993 paper solved this problem …".
- NO: "What's the answer?"
- YES: "What would a solution look like?"
- YES: "How would the solution be different between Yahoo! and Netflix?"

1. Transparency

We recommend Fargo because it is tagged with ***quirky***, ***dark comedy***, and ***Coen Brothers***, and we believe you like movies with these tags."

- Convince a user to accept a recommendation
- Help a user make a good decision
- Help a user fit a goal or mood
- What types of transparency are valuable?
- **Jon Sanders Lead**

1. Transparency

- Explaining “Why” increases engagement

- Where?
- When?
- How?

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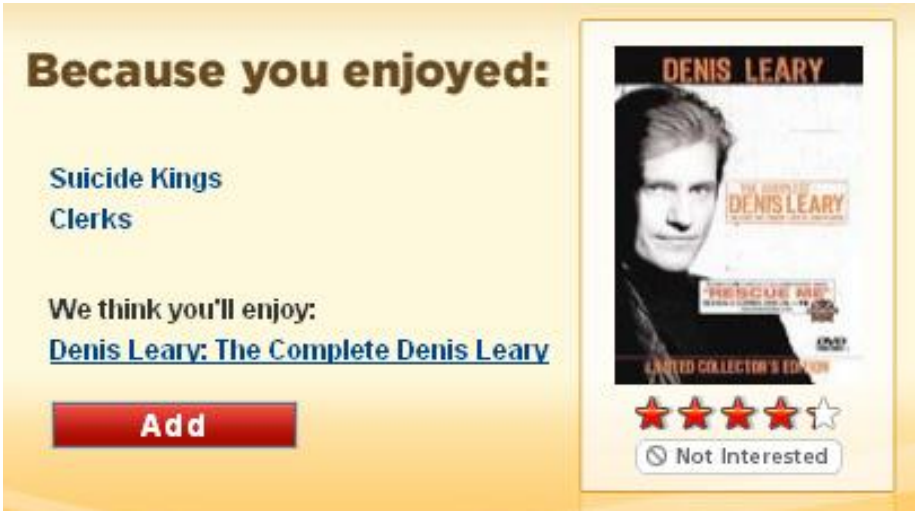

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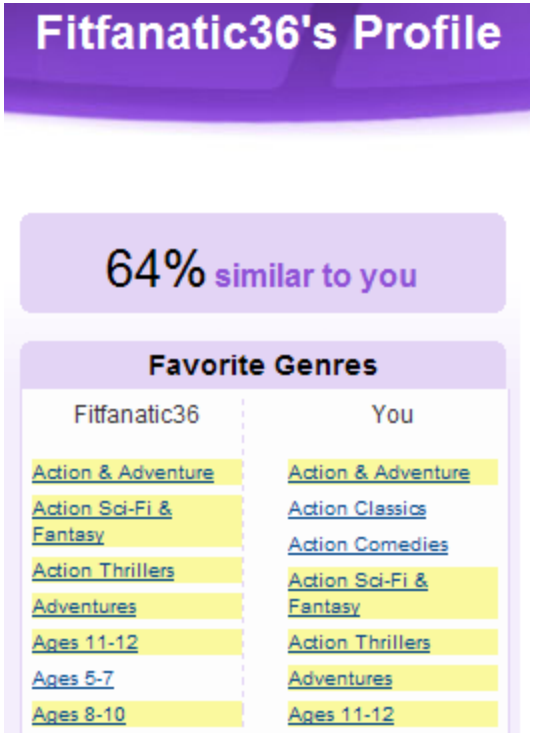

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2. Exploration versus Exploitation

- Cold start problems
  - For new items
  - For new users
- Choosing what questions to ask users
  - Trade-off between optimizing for *this* user vs. for all users
- How can meta-data on user or item help?
- **Todd Beaupre Lead**

2. Exploration versus Exploitation

• Pick the top four stories from a pool of ~20 editorially programmed stories for each user visit to the Front Page in order to maximize clicks in the Today Module

In general, one may want to pick *m* **items** from a set of *K* **items** to maximize some easily observable metric

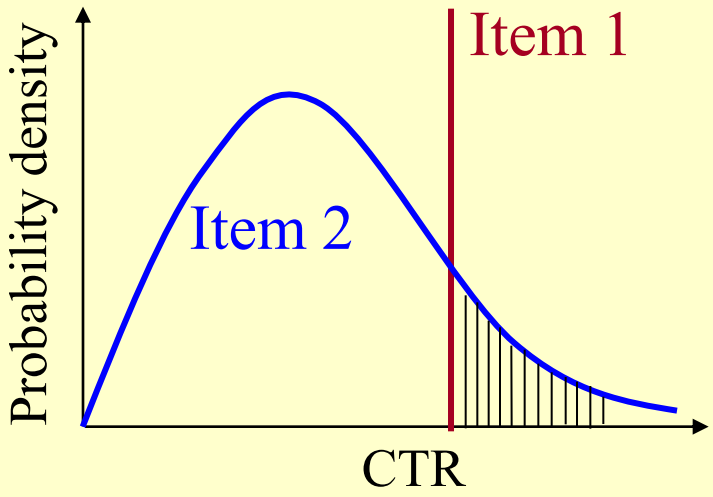
Items: Articles, ads, modules, configuration parameters of page layout

2. Exploration versus Exploitation

- Only consider the first position
  - ~ 2/3 clicks happen at the first position
  - Pick the best ***one*** from *K* items (stories)
- Tradeoff between explore and exploit
  - We want to show the item currently having the highest CTR
  - We need to explore every available item (using some fraction of traffic) to estimate its CTR
    - Explore too little → Unreliable CTR estimates
    - Explore too much → Little traffic to show the highest CTR item
- We want make the optimal decision: What fraction of page views should we give to each item for each small time interval in order to maximize the expected total number of clicks over a long period?

2. Exploration versus Exploitation

Simplified setting: Two items with the CTR of one exactly known



If we only make a decision once,
give item 1 100% page views

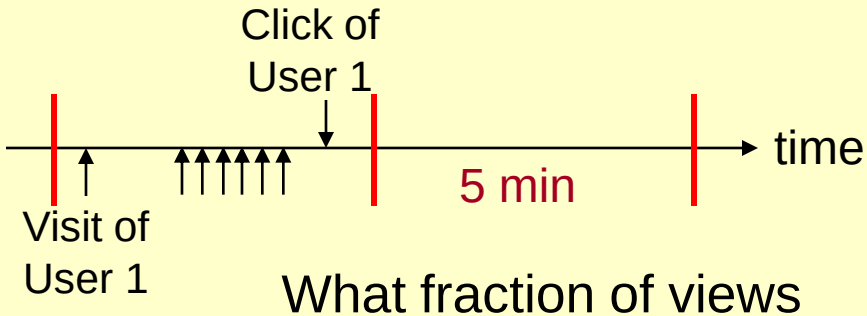
If we make multiple decisions in the future
explore item 2 since it can be
potentially better than item 1

We know the CTR of Item 1 exactly (shown 10M times)
We are uncertain about the CTR of item 2 (only 100 times)

2. Exploration versus Exploitation

- Non-stationary CTR
  - CTR of an item can change dramatically over time
- Dynamic set of items
  - Items come and go with short lifetimes (hours)
  - Asymptotically optimal policies may fail to achieve good performance when item lifetimes are short
- Batch serving
  - For scalability reasons,

    click-through data is processed in batches (one batch per 5 min)
  - Delayed click feedback



What fraction of views should be given to item *i*

2. Exploration versus Exploitation

p_1

p_2

p_3

Bandit "arms"

(unknown payoff probabilities)

- Goal: Pull arms sequentially to maximize the total expected reward; achieve the best trade-off between
  - Exploit: Use estimates of payoff probabilities $\{p_i\}$
  - Explore: Don't be misguided by uncertainty in estimates; play arms that are potentially good

2. Exploration versus Exploitation

- ***Bandit policy*** : Sequential scheme to play arms
- *Regret of a policy* = Expected loss relative to best policy that plays the best arm at all times
  - Best arm: The arm with the highest success probability
  - Of course, the best arm is not known
  - Hence, the regret is the price of exploration
  - Low regret implies quick convergence to the best
- Two lines of research in the literature
  - Bayesian: Seek to find the Bayes optimal solution to a Markov decision process (with assumptions about distributions)
  - Minimax: Seek to find a policy that incurs bounded regret (with no or mild assumptions about distributions)
- Traffic volume per interval
- # of items to explore
- Lifetime of items

2. Exploration versus Exploitation

- Explore/exploit is an effective strategy to maximize CTR in a content display system
- Bayesian solution provides superior performance
- Ongoing research
  - Explore/exploit for personalized recommendation
    - Hierarchical explore/exploit
    - Explore/exploit based on feature-based models
    - Exploring items vs. exploring users
  - Explore/exploit for multiple positions and page layout optimization
    - Positional effects not uniform over time and items
  - Explore/exploit in the presence of constraints

3. Guided Navigation

- Providing a guide over a vast body of content
  - UI design + intelligent algorithms
  - User's intent or mood

- **Jon Sanders Lead**

3. Guided Navigation

- Exploring the unknown
- Intent
- Approach
- UI
- Familiarity, serendipity, freshness
- Simple vs comprehensive

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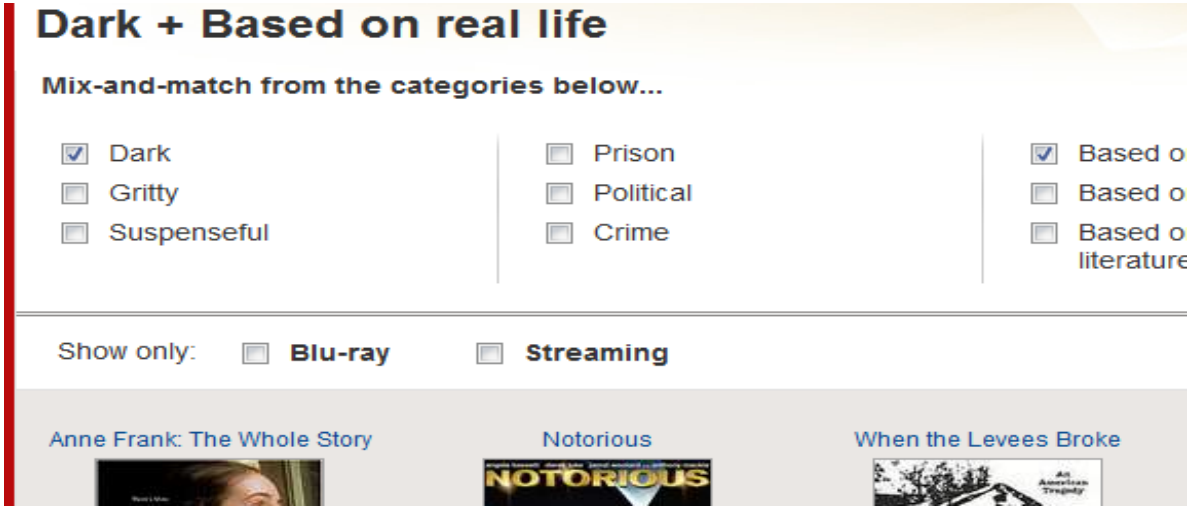

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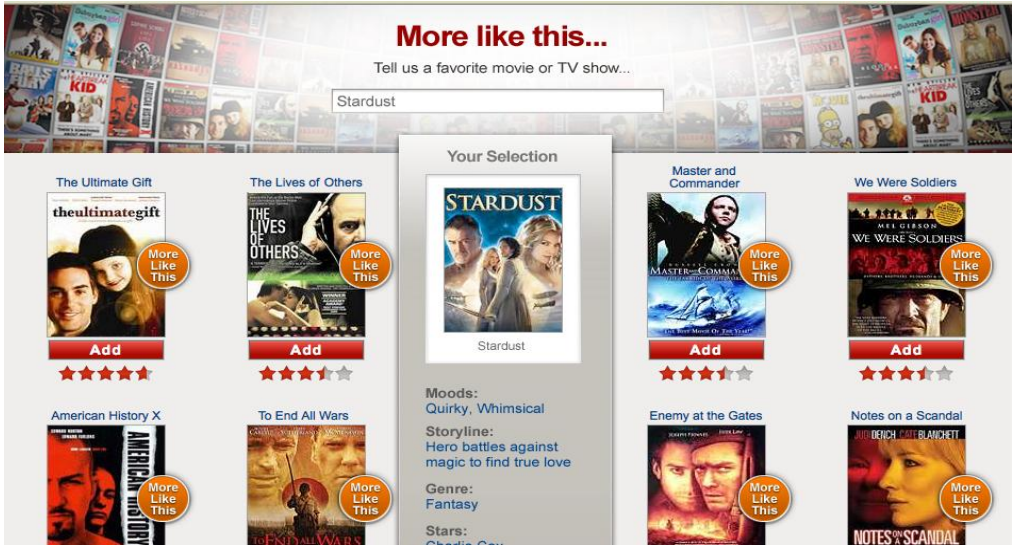
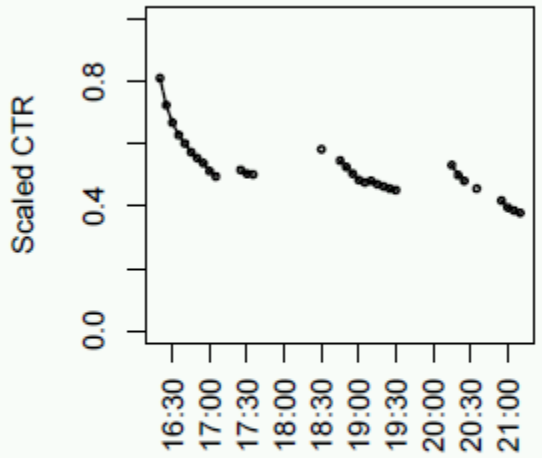


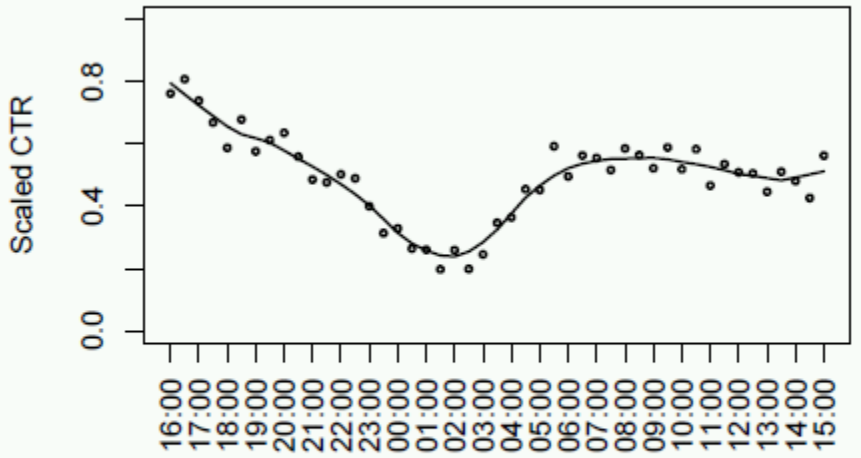
4. Time Value

- Does value of user input decay with time?
- Do items change in relevance with time?
- How to adjust for recent user experience?
- **Todd Beaupre Lead**

4. Time Value

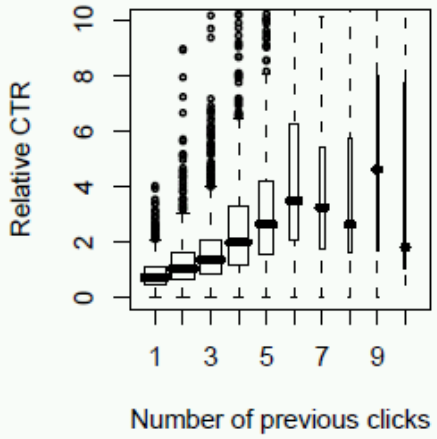


(a) CTR in the EMP Bucket

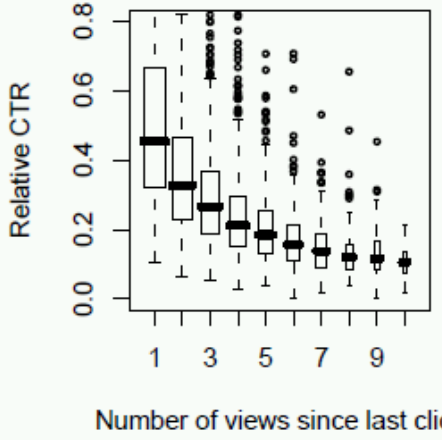


(b) CTR in the Random Bucket

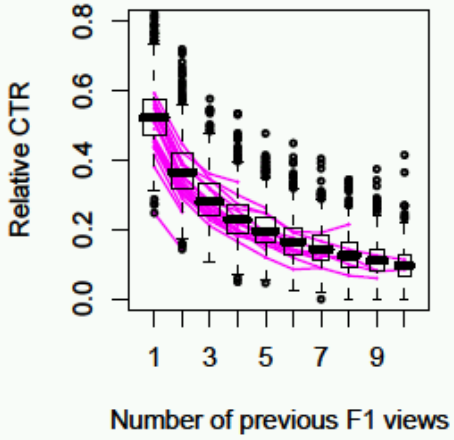
4. Time Value



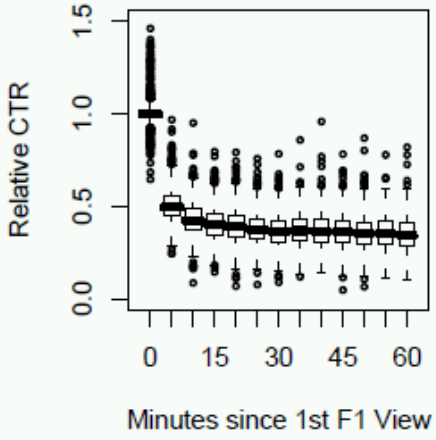
(a) Previous clicks



(b) Views since last click

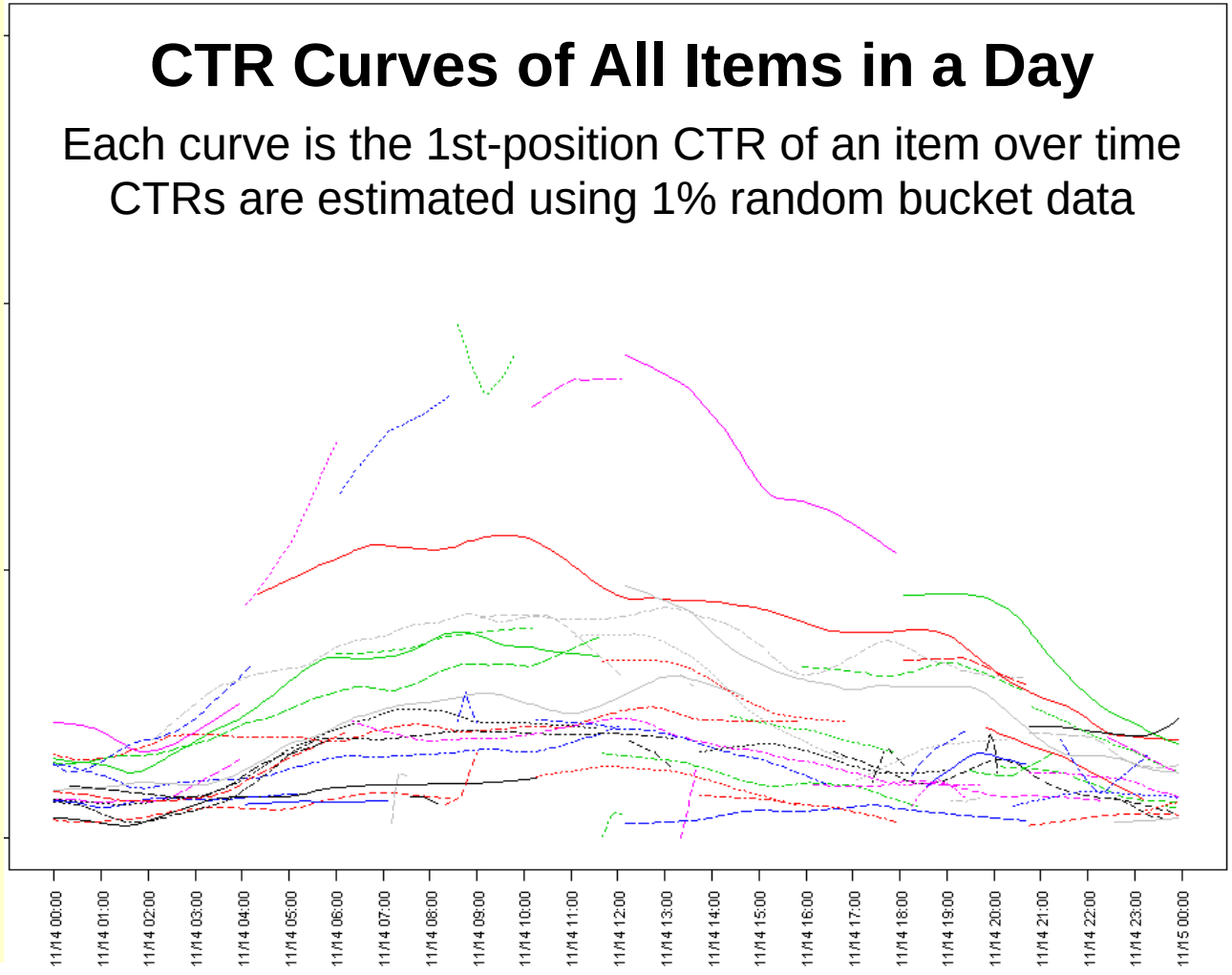


(c) Previous F1 Views



(d) Time since 1st view

4. Time Value


CTR Curves of All Items in a Day
Each curve is the 1st-position CTR of an item over time
CTRs are estimated using 1% random bucket data
11/14 00:00
11/14 01:00
11/14 02:00
11/14 03:00
11/14 04:00
11/14 05:00
11/14 06:00
11/14 07:00
11/14 08:00
11/14 09:00
11/14 10:00
11/14 11:00
11/14 12:00
11/14 13:00
11/14 14:00
11/14 15:00
11/14 16:00
11/14 17:00
11/14 18:00
11/14 19:00
11/14 20:00
11/14 21:00
11/14 22:00
11/14 23:00
11/15 00:00

4. Time Value

- Short-term (news, trip to Hawaii)
- Intermediate term (Olympics)
- Long-term (Chicago Cubs)
- Identify content structure
- Identify intents (news interest may vary across users, exploit vs. pigeonhole)
- The right mix, de-duplication

5. User Action Interpretation

- Ratings are valuable, but less frequent
- Positive & negative signal identification

- **Todd Beaupre Lead**

5. User Action Interpretation

- Ratings: Billions per year
- Pageviews: Billions per day
- Every action is opportunity to learn about user and content
- Engineering challenge to collect, store, model, serve in real-time
- Research challenge to model user intent on behavioral data

5. User Action Interpretation

- Click =~ Value (Scanning headlines)
- Hover (Weather)
- Negative learning is important to prevent positive feedback loops (Collaborative filtering)
- A view is a negative event, but not always a strong signal (Mail)
- Position and cross-position effects (Skips)

5. User Action Interpretation

- Two users, one browser
- Friend behavior
- False registration data
- Robot detection
- Malicious users

6. Evaluating Recommenders

- Evaluation of entire user experience
- Best practices for experiments
- Business metrics and Proxy metrics

- **Jon Sanders Lead**

6. Evaluating Recommenders

- Enjoyment Prediction is just part of a recommender experience
- RMSE? Even for predictions it’s not enough
- Intuition, offline replay/score, qualitative, A|B test
- Goal vs proxies
- Interpretation
- Performance
- Deploying Prize solutions

7. Scalability

- What are the key scalability features you would value?
- What parallelization structure is best?
- What "hidden" requirements prevent algorithm adoption?

- **Todd Beaupre Lead**

7. Scalability

- Large user bases (100s of millions)
- Large user event sets (10s of K per second)
- Large item pools with short lives (100s of K per day)
- Data can't fit into memory
- Many models require iterative computation
- Sync cost across map-reduce framework is high
- Clustering with local optimization is lossy
- Think real-time: 15ms

8. Academic/Industry Partnerships

- How can academic researchers participate in interface innovation?
- What types of partnerships are fruitful?
- Tension with compulsion to publish versus access rich business data
- How can we make research more accessible to industry?
- **Jon Sanders Lead**

8. Academic/Industry Partnerships

- Use large data
- Netflix Prize
- Build experiences with Netflix API
- Design datasets & challenges
- Recs for groups

8. Academic/Industry Partnerships

- Data sharing with WebScope
- 19 data sets, including Music, Movies, Delicious
- http://webscope.sandbox.yahoo.com/
- Key Scientific Challenges
- Graduate students send proposals, Y! grants $5k, invites 20-25 for summit.
- http://labs.yahoo.com/ksc
- Faculty Research Engagement Program
- Faculty send proposals around problem, come to our labs in summer. Up to $25k grants.
- http://labs.yahoo.com/Academic_Relations/Faculty
- Internships
- Universities invite Industry Partners to research showcases
- http://research.yahoo.com/node/2742

Research Challenges in Recommenders

John Riedl, U of Minnesota
Todd Beaupre, Yahoo!
Jon Sanders, Netflix

GroupLens Research