



Using Image Fairness Representations in Diversity-Based Reranking for Recommendations

CHEN KARAKO & PUTRA MANGGALA

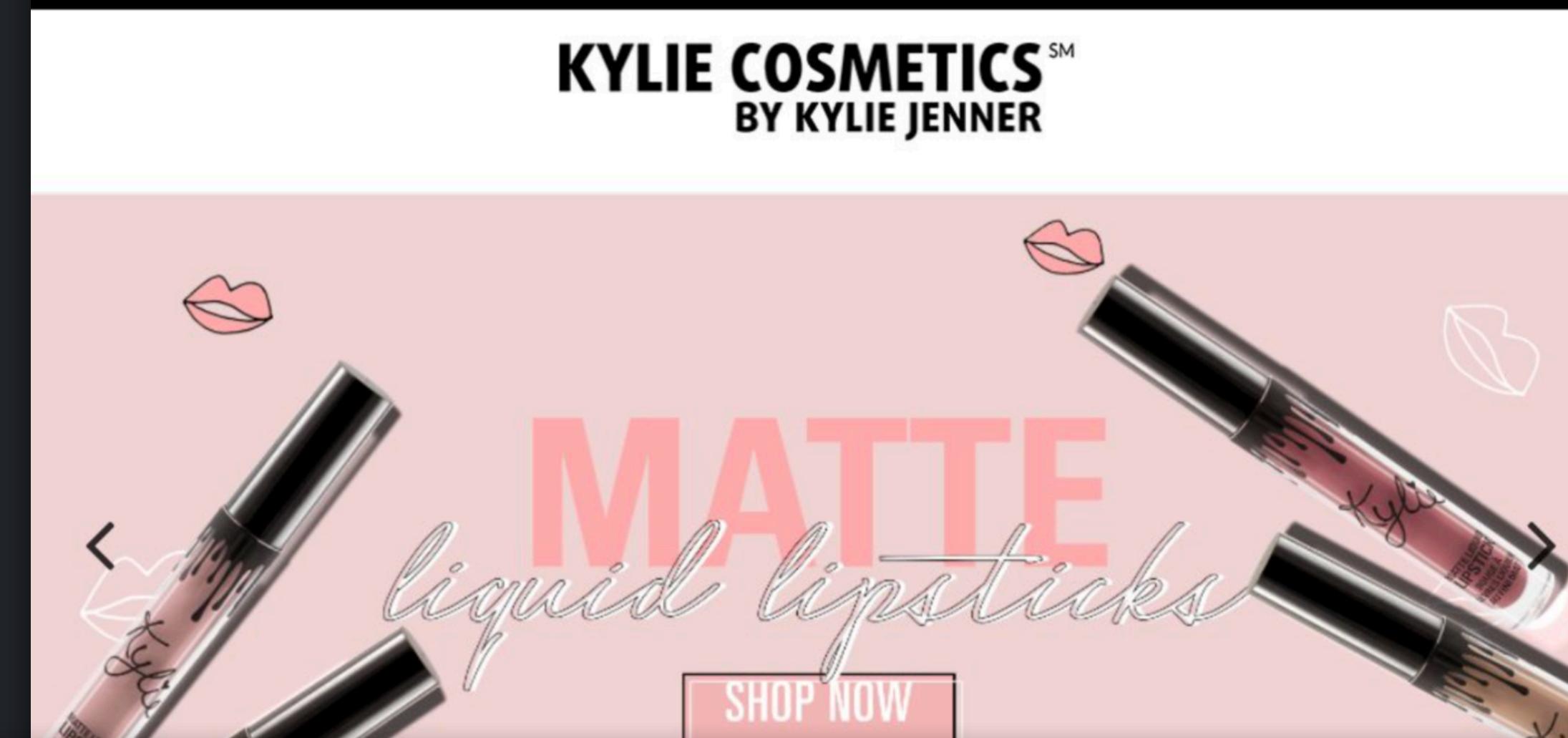
Discovery Algorithms @ Shopify

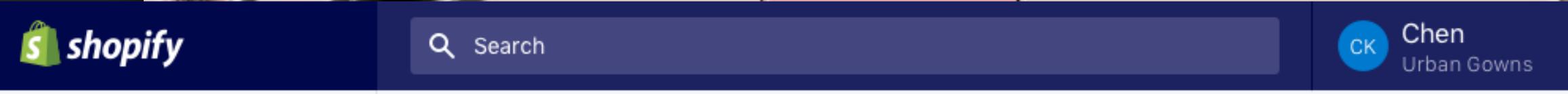
Discovery Algorithms @ *shopify*

Multi-channel commerce platform
powering 600k+ businesses in 175 countries.

Recommendations & Personalization

Personalized insights, actions, and tools
to help our merchants' businesses.

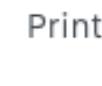




Good morning, Chen
Here's what's happening with your store today.

\$2,543 Today's sales	24 Today's orders	340 Today's visits
--------------------------	----------------------	-----------------------

Create and ship custom products with one of these top print on demand apps
Suggested based on pages you've looked at.

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Can we incorporate
fairness into search
results and
recommendations?

C

l

Image search

Google puppy

All Images Videos News Shopping More Settings Tools

cute teacup adorable pitbull fluffy tiny teddy bear cute baby pug pomeranian shih tzu

The Google Images search interface shows the word "puppy" in the search bar. Below it, there are tabs for All, Images (which is selected), Videos, News, Shopping, More, Settings, and Tools. A row of filters includes: cute, teacup, adorable, pitbull, fluffy, tiny, teddy bear, cute baby, pug, pomeranian, and shih tzu. Below these filters are two rows of puppy images.

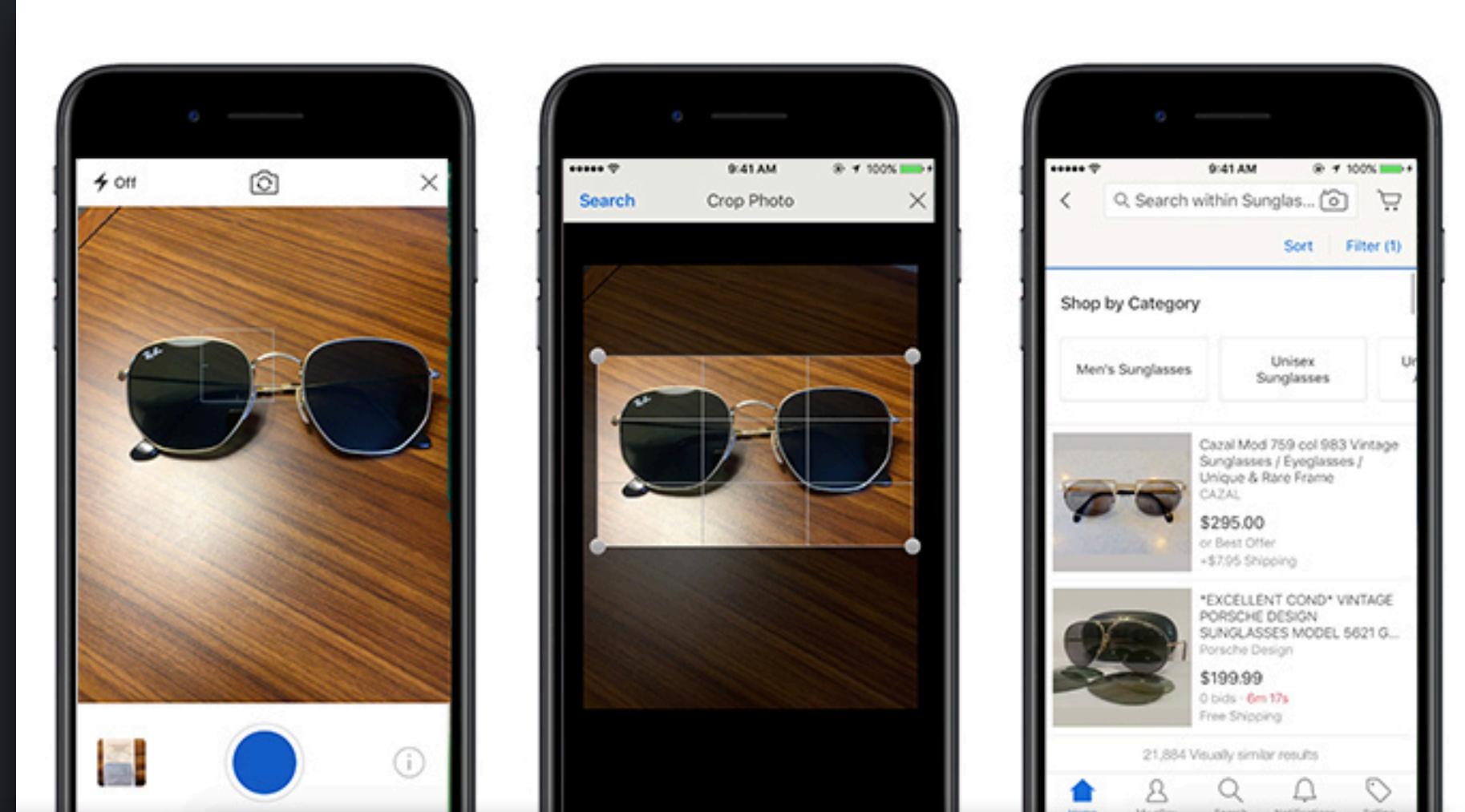
BURST workout

282 photos found for “workout”

Similar photos also found in these categories:

Fitness Women Men Sports Happy Shoes →

The BURST app interface shows a search bar with the word "workout". Below it, it says "282 photos found for ‘workout’". It then lists "Similar photos also found in these categories: Fitness, Women, Men, Sports, Happy, Shoes". Below these category names are small thumbnail images. The main area displays a grid of larger images related to fitness and sports, such as people exercising, climbing ropes, and boxing.



All

Images

News

Videos

Maps

More

Settings

Tools

SafeSearch ▾

snapchat

instagram

twitter

netflix

youtube

linkedin

tide

male

lamborghini

ferrari

rolls royce

bugatti

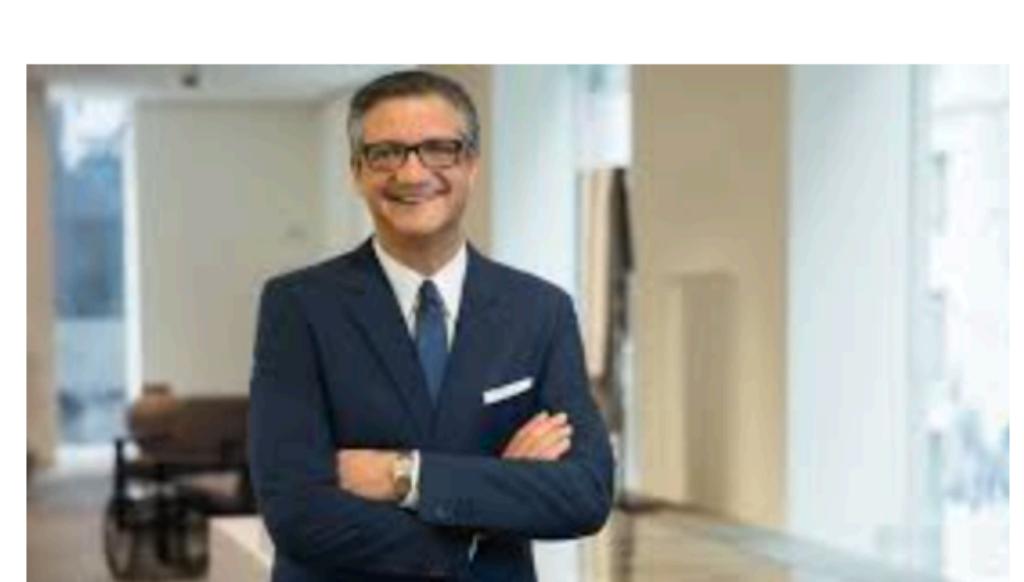
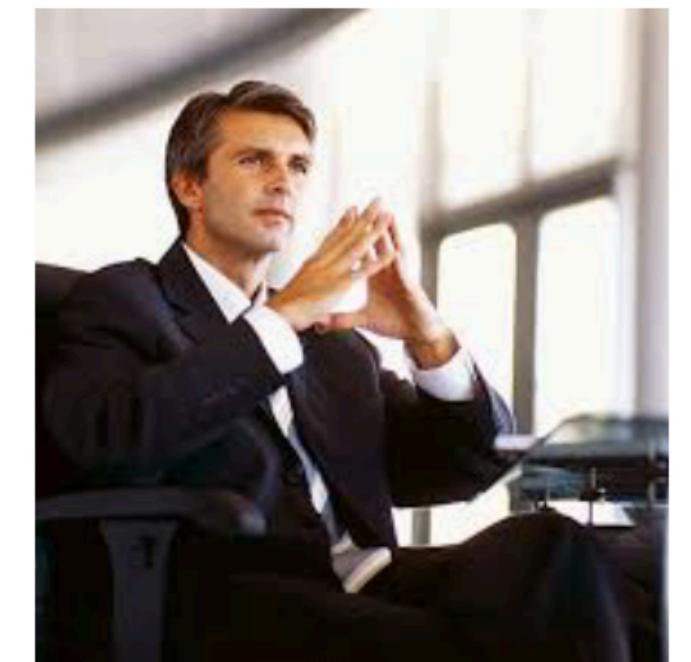
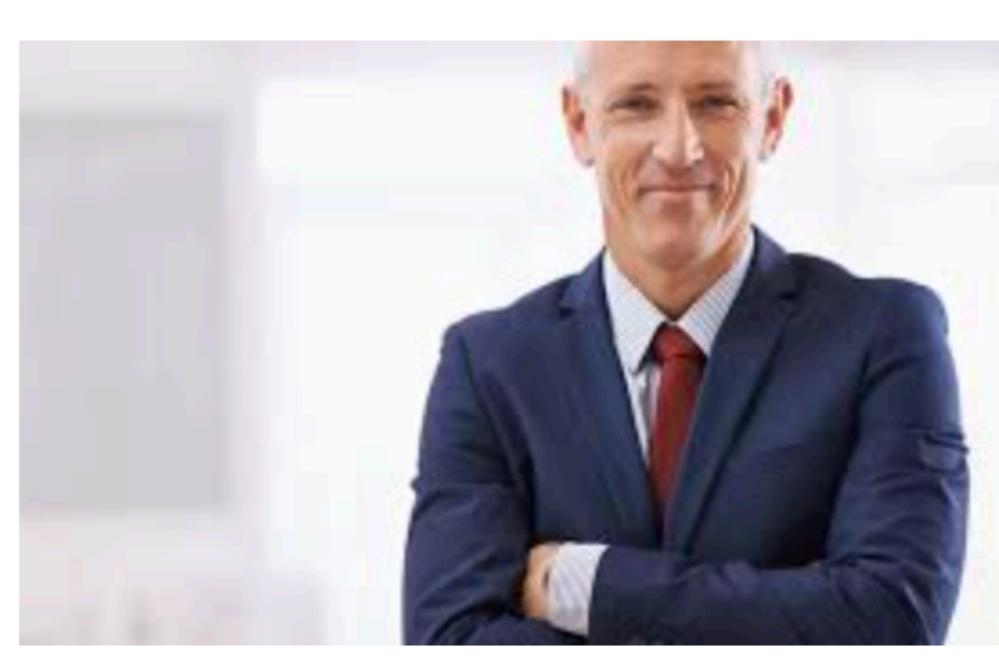
rich

vidcon

top 10

matthew harrigan

>





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Settings Tools

SafeSearch ▾

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Can we incorporate
fairness into search
results and
recommendations
via reranking?

C

l

Base relevance model

Google afghan

All Flights News Images Maps More Settings Tools

About 173,000,000 results (0.76 seconds)

Afghanistan - Wikipedia
<https://en.wikipedia.org/wiki/Afghanistan> ▾
Afghanistan officially the Islamic Republic of Afghanistan, is a landlocked country located within South Asia and Central Asia. Afghanistan is bordered by ...
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Afghanistan
Country in South Asia

Afghanistan, officially the Islamic Republic of Afghanistan, is a landlocked country located within South Asia and Central Asia. [Wikipedia](#)

Capital: Kabul
Capital and largest city: Kabul; 34°32'N 69°08'E / 34.533°N 69.133°E
Population: 34.66 million (2016) World Bank
President: Ashraf Ghani
Official languages: Pashto, Dari

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 Kabul  Herat  Kandahar  Band-e Amir Nati...  Zorkul

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Limitations

Google search results for "afghan":

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Afghan Hound
From Wikipedia, the free encyclopedia

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Contents [hide]

- 1 History
- 2 Description
- 3 Variants
- 4 Health

Afghan Hound

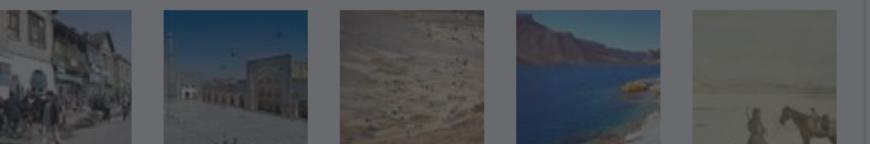
Afghan Hound, fully coated

exclusive video footage, photos and updated maps.

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Afghan (blanket)
From Wikipedia, the free encyclopedia

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An **afghan** is a woollen blanket or shawl, usually knitted or crocheted.^[1] It is sometimes also called a "throw" of indeterminate size. Afghans are often used as bedspreads, or as a decoration on the back of couches or chairs.^[2]

Etymology [edit]

The word **afghan** refers to the people of Central Asia. The use of **afghan** in the English language goes back to 1831, when Thomas Carlyle mentioned it in his *Sartor Resartus*.^[3] The first mention of the word referring to the woven rug was in 1877.^[4]

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Afghan Hound
Afghan Hound, fully coated

An afghan blanket

MMR re-ranking

- Used for increasing the diversity of a result set
- Objective function:

relevance

gain in diversity

MMR re-ranking

- Used for increasing the diversity of a result set
- Objective function:

$$\lambda \text{ relevance} + (1 - \lambda) \text{ gain in diversity}$$

MMR re-ranking

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$$\lambda \text{ relevance} + (1 - \lambda) \underbrace{\max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)}_{\text{gain in diversity}}$$

MMR re-ranking

- Done in a greedy iterative process to obtain the top-k results

$$\operatorname{argmax}_{i_{\text{new}} \in S_{\text{unchosen items}}} \lambda \text{ relevance}(i_{\text{new}}) + (1 - \lambda) \underbrace{\max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)}_{\text{gain in diversity}(i_{\text{new}})}$$

MMR re-ranking

1. Afghanistan
2. Afghanistan
3. Afghanistan
4. Afghanistan
5. Dog
6. Dog
7. Blanket

MMR re-ranking

- 1. Afghanistan
- 2. Afghanistan
- 3. Afghanistan
- 4. Afghanistan
- 5. Dog
- 6. Dog
- 7. Blanket



- 1. Afghanistan

MMR re-ranking

1. Afghanistan
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4. Afghanistan
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1. Afghanistan

MMR re-ranking

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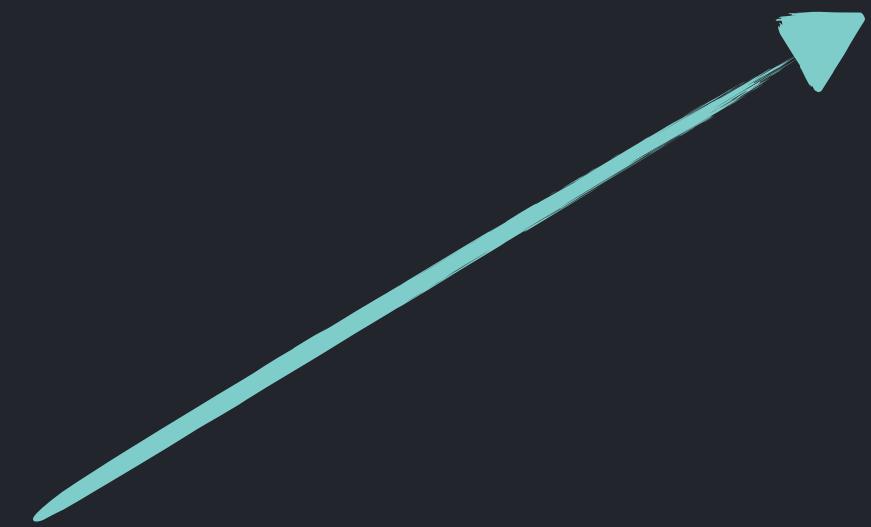
MMR re-ranking

1. Afghanistan
2. Afghanistan
3. Afghanistan
4. Afghanistan
5. Dog
6. Dog
7. Blanket

1. Afghanistan

MMR re-ranking

- 1. Afghanistan
- 2. Afghanistan
- 3. Afghanistan
- 4. Afghanistan
- 5. Dog
- 6. Dog
- 7. Blanket



- 1. Afghanistan
- 2. Dog

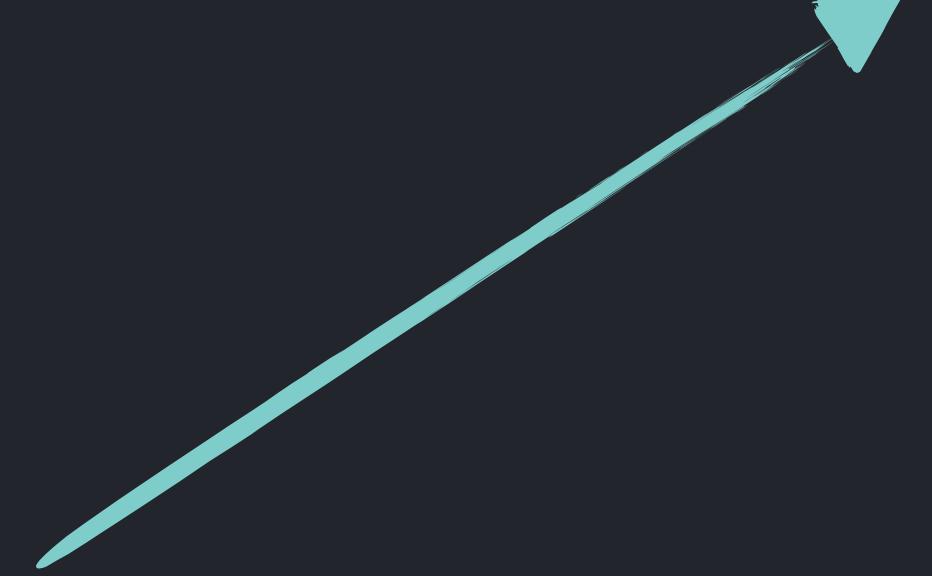
MMR re-ranking

1. Afghanistan
2. Afghanistan
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7. Blanket

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2. Dog

MMR re-ranking

1. Afghanistan
2. Afghanistan
3. Afghanistan
4. Afghanistan
5. Dog
6. Dog
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- 
1. Afghanistan
 2. Dog
 3. Blanket

MMR re-ranking

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4. Afghanistan
5. Dog
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- .
- .
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MMR re-ranking

Google afghan

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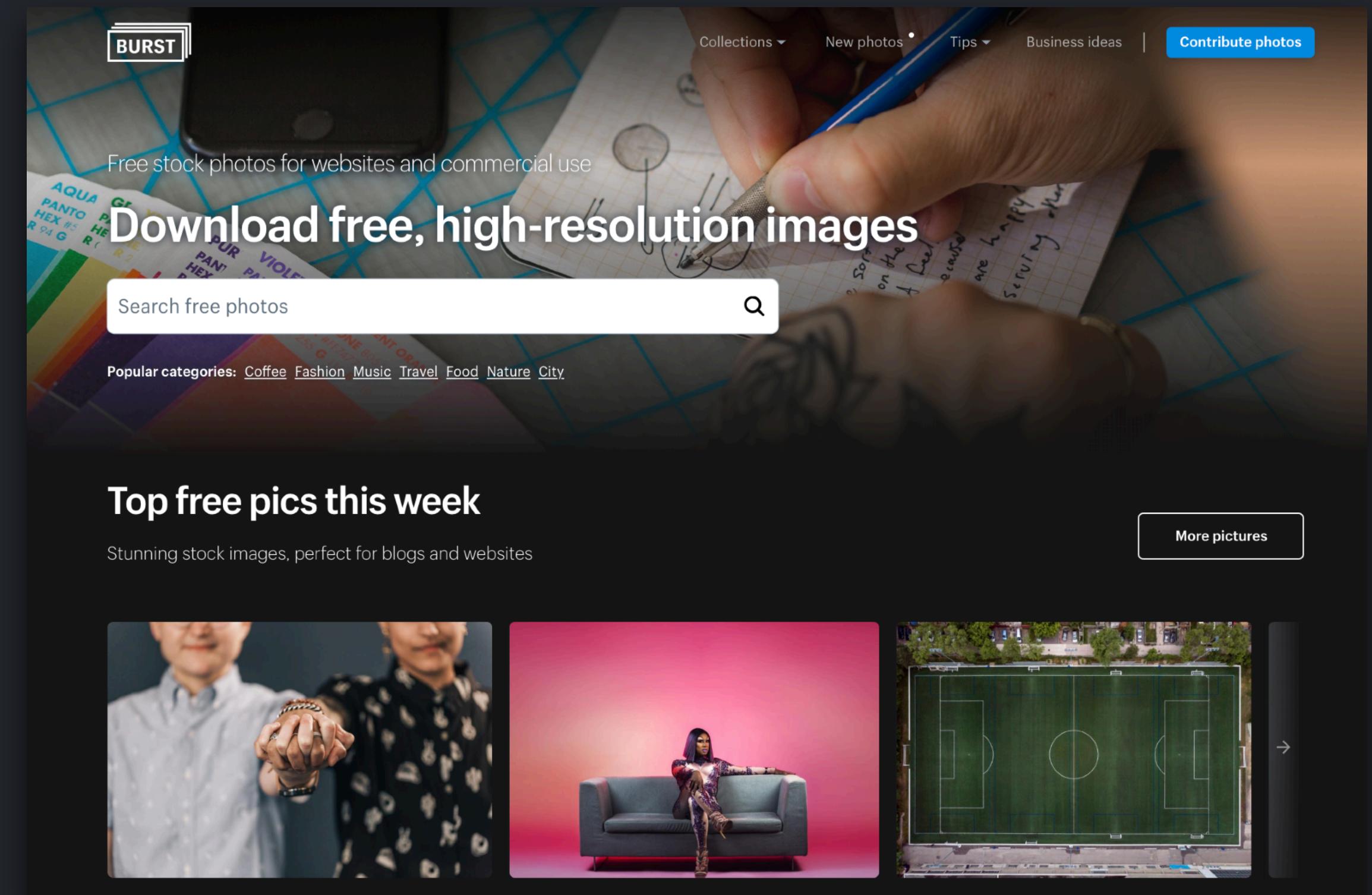
An afghan blanket

$$\text{gain in diversity} = - \max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)$$

Ex: Image search in Burst

Burst: stock photo website

Task: similar image search



<https://burst.shopify.com>

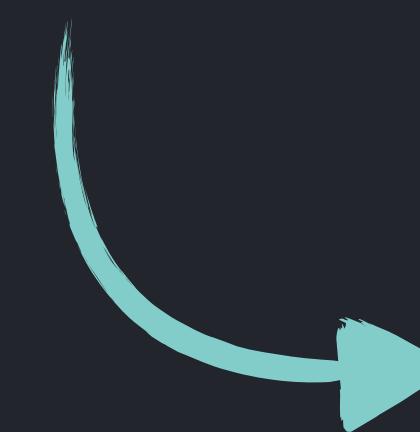
Related images: relevance

Query image



Related images: MMR

Query image



MMR reranking

Can we use this instead for fairness?

$$\lambda \text{ relevance} + (1 - \lambda) \text{ gain in diversity}$$

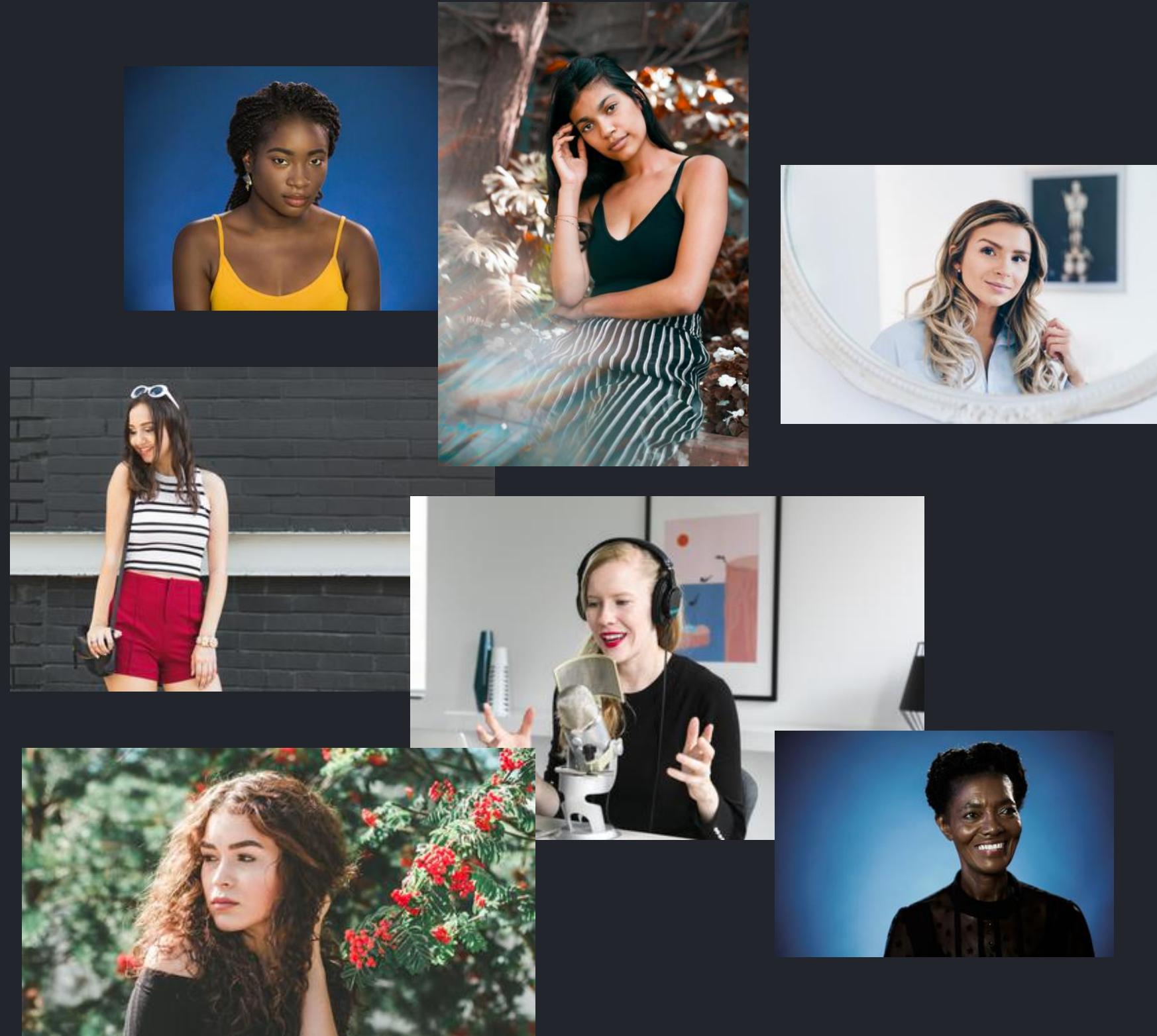
fairness

$$- \max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)$$

Image representations

- Richer representations of image content
- Inception-v3: pre-trained CNN
- Learns image representations: 2048-dimensional vectors
 - pairwise similarity

Image fairness representations



Inception



[0.1, 0.3, 2.4, ...]

[4.5, 1.7, 0.4, ...]

...

Average

$$\xrightarrow{\text{Average}} v_{\text{woman}} = [3.6, 0.8, 1.3, \dots]$$

[6.1, 0.5, 1.2, ...]

tag: 'woman'

Image fairness representations



tag: 'man'

Inception



[6.1, 2.3, 7.3, ...]

[1.5, 1.7, 0.5, ...]

...

Average



$v_{\text{man}} = [3.2, 1.8, 4.0, \dots]$

[2.0, 1.5, 4.2, ...]

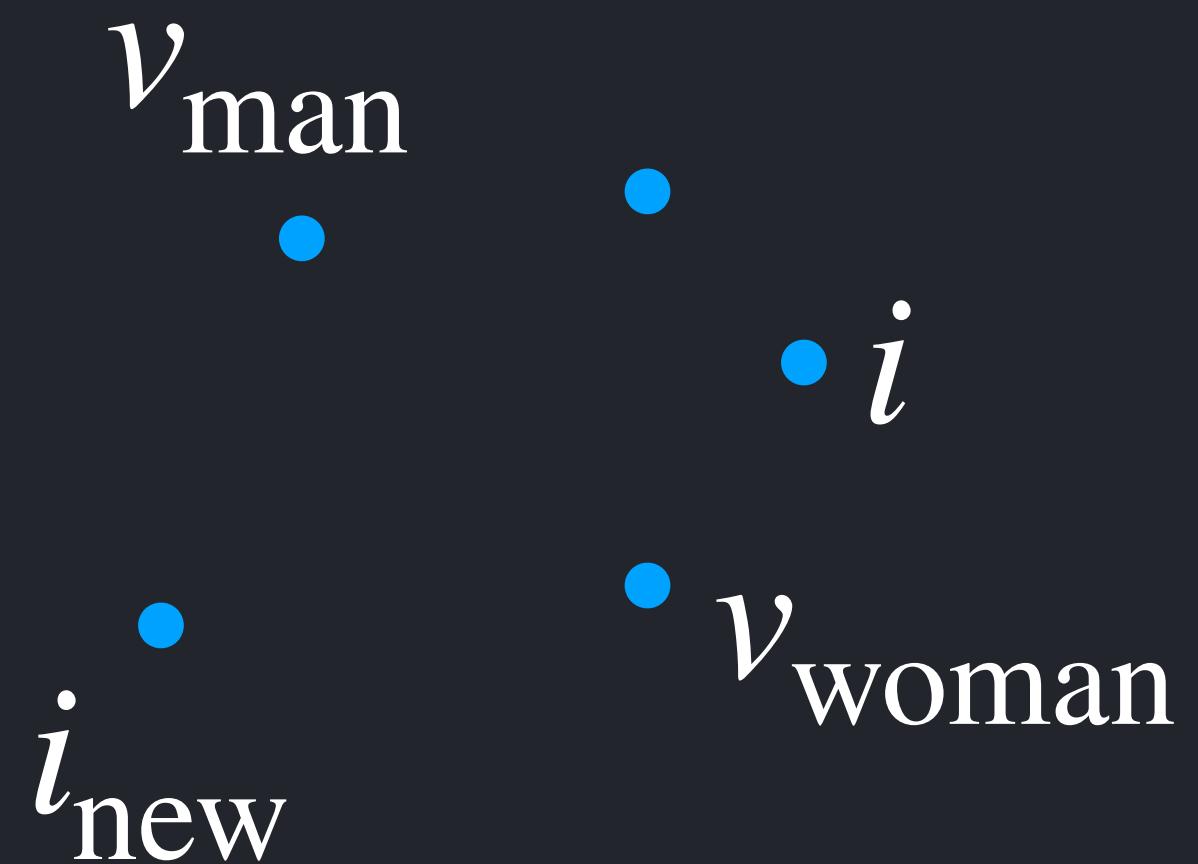
Fairness-aware MMR reranking (FMMR)

$$\lambda \text{ relevance} + (1 - \lambda) \text{ gain in fairness}$$
$$- \max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)$$

Fairness-aware MMR reranking

λ relevance + $(1 - \lambda)$ gain in fairness

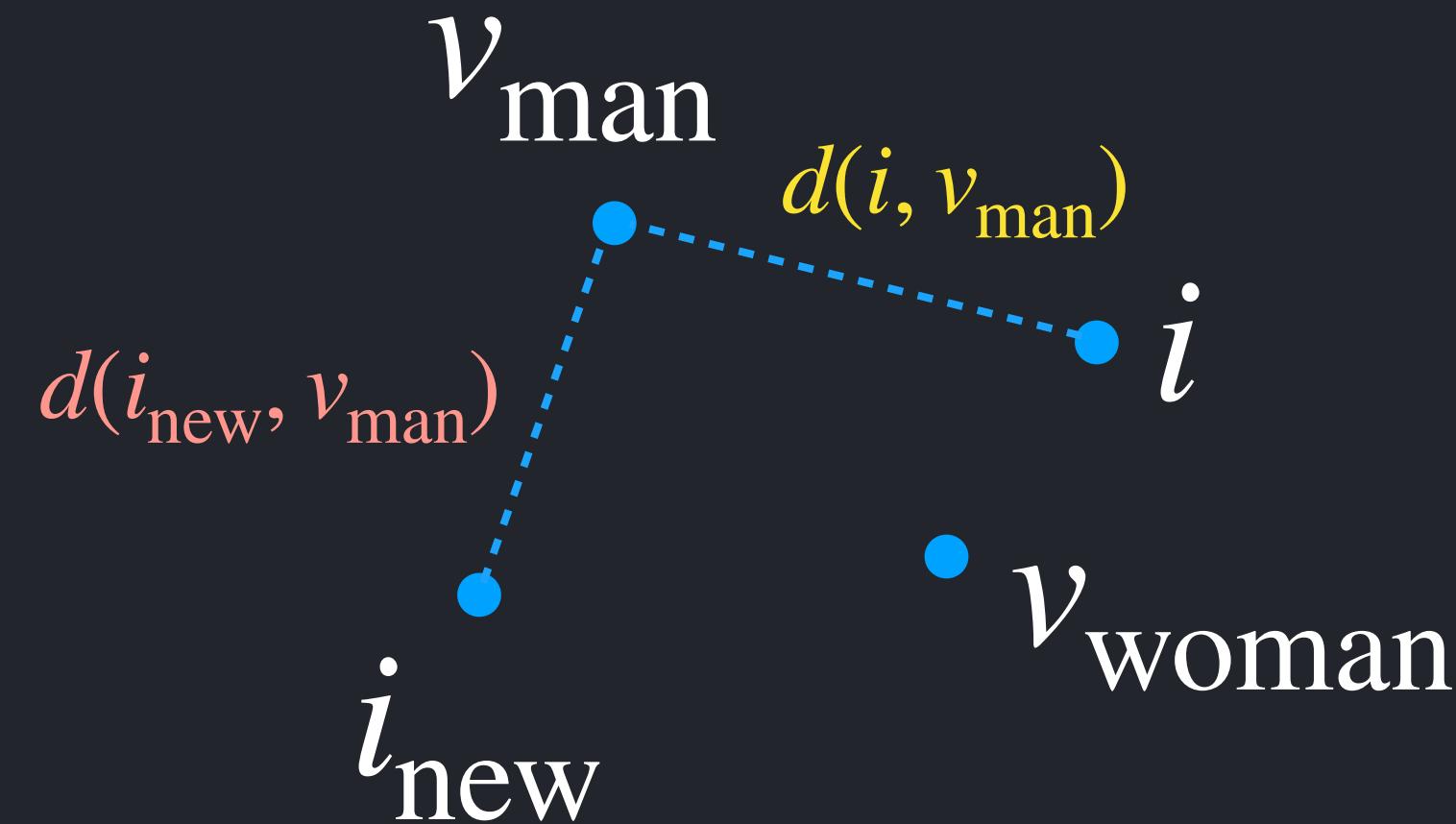
$\text{Sim}(i_{\text{new}}, i)$?



Fairness-aware MMR reranking

λ relevance + $(1 - \lambda)$ gain in fairness

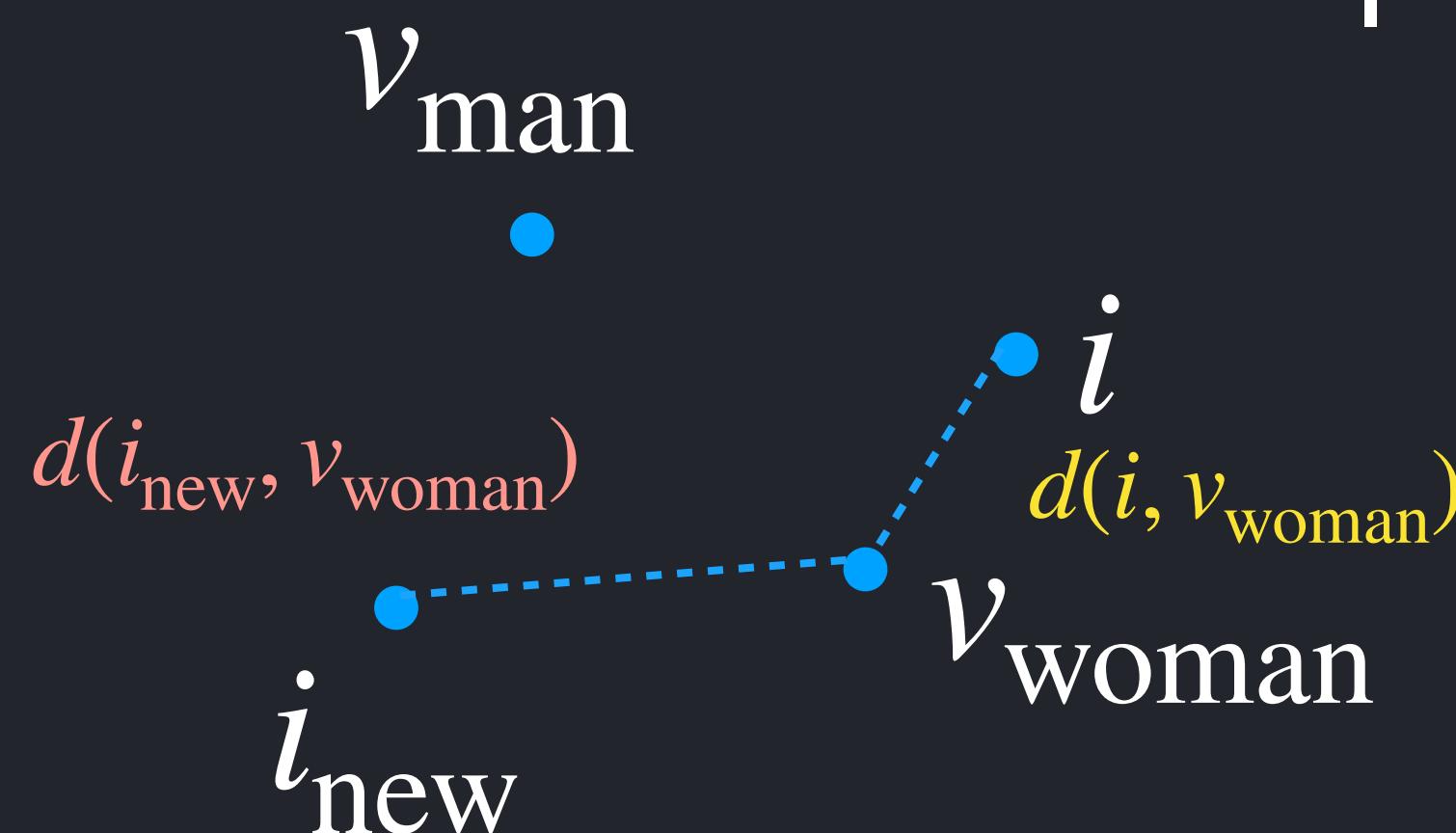
$$\text{Sim}(i_{\text{new}}, i) \ ? \quad - | d(i, v_{\text{man}}) - d(i_{\text{new}}, v_{\text{man}}) |$$



Fairness-aware MMR reranking

λ relevance + (1 - λ) gain in fairness

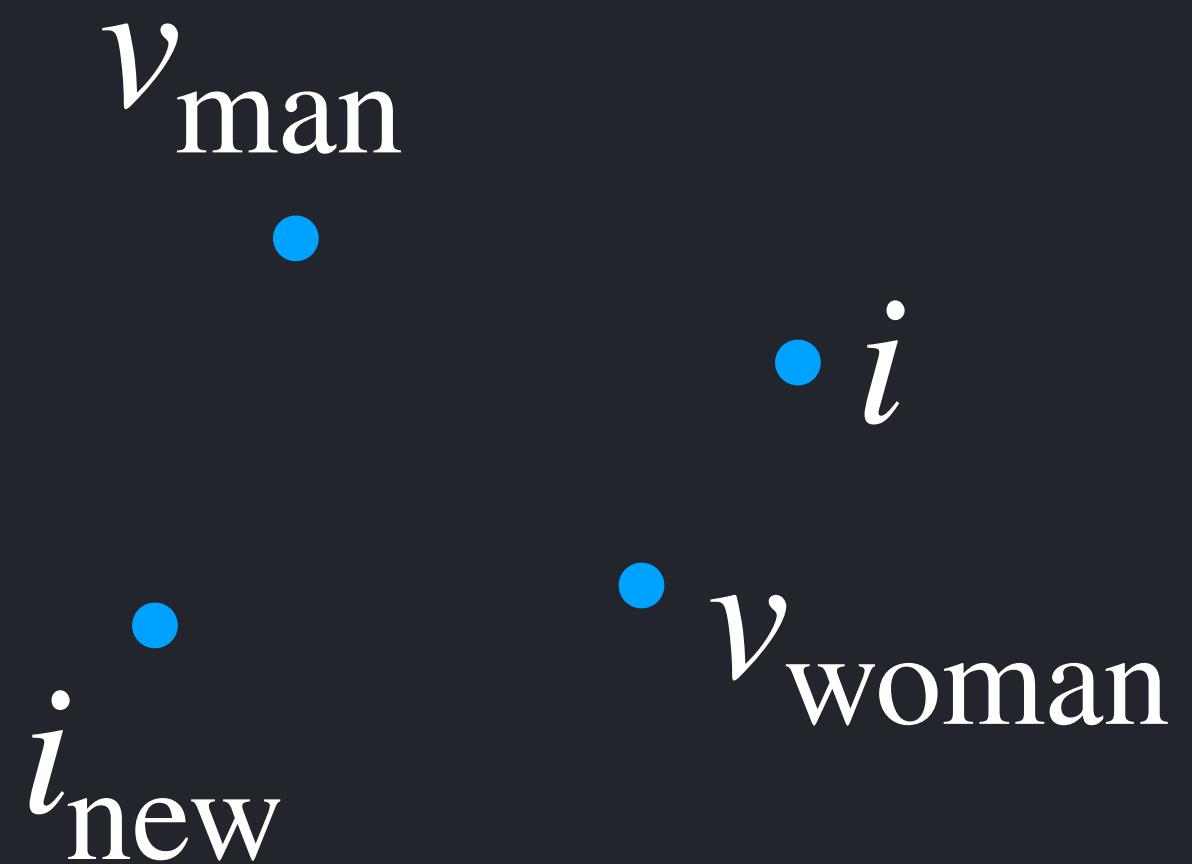
$$\text{Sim}(i_{\text{new}}, i) = - | d(i, v_{\text{man}}) - d(i_{\text{new}}, v_{\text{man}}) | + - | d(i, v_{\text{woman}}) - d(i_{\text{new}}, v_{\text{woman}}) |$$



Fairness-aware MMR reranking

λ relevance + $(1 - \lambda)$ gain in fairness

$$\text{Sim}(i_{\text{new}}, i) = - \sum_{v \in \{v_{\text{man}}, v_{\text{woman}}\}} |d(i, v) - d(i_{\text{new}}, v)|$$



Related images: FMMR

Query image



Experiment: Image search in Burst



Woman Applying Lip Balm

Woman applying lip balm from tube container.

Photo size

- High resolution
High quality for web and print
- Low resolution
Best for small web graphics

[Download free photo](#)

Featured in:

[Women](#), [Makeup](#), [Lifestyle](#),
[Craft/DIY](#), [Nails](#), [Relax](#), [Beauty](#)

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Fitness Balancing

A man balancing on a bar.

Photo size

- High resolution
High quality for web and print
- Low resolution
Best for small web graphics

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Task: similar image search

Dataset

3249 images used in search (objects, places, people).

291 men images, 458 women images used to create fairness representations.

738 sample human images used as query images for evaluation.

Metrics: relevance

Relevance: precision at k ($p@k$).

Based on tags: require at least 1/4 of query image tags to be matched by search result

Metrics: fairness

Tradeoff between relevance and fairness.

Fairness: fairness ratio at k ($fr@k$), defined as:

$$\frac{\# \text{ woman images}}{\# \text{ man images} + \# \text{ woman images}}$$

in top-k results.

Experiment: FMMR vs MMR

- Euclidean distance for all distance calculations
- For each algorithm, λ tuned using 100 query images to heuristically optimize the fairness-relevance tradeoff
- Evaluation done on remaining 638 images: use tuned λ to get top-10 results per query, compute p@10, fr@10.

p@10

0.59 ± 0.02

FMMR

0.53 ± 0.02

MMR

fr@10

0.65 ± 0.02

FMMR

0.64 ± 0.02

MMR

Results

When producing **gender-balanced results**, FMMR had **higher precision** than MMR (using same relevance model and hyperparameter tuning).

Conclusion & Applications

- ✓ Developed algorithm to incorporate fairness in image results
- ✓ Can be extended to other demographics (race, age)
- ✗ ✓ Small number of tagged images required
- ✓ Trade-off can be controlled by choice of hyperparameters
- ✓ Apply in post-processing for search + recommendations in many domains; not limited to images!

THANK YOU

chen.karako@shopify.com
@chennerzz

Appendix 1: hyperparameter tuning heuristics

Grid search on λ by optimizing for fairness while satisfying a pre-defined guarantee of precision.

Guarantee of precision for λ by this constraint:

$$\frac{p_{\lambda=1} @ 10 - p_{\lambda} @ 10}{p_{\lambda=1} @ 10} \geq d \text{ (allowable degradation ratio)}$$