

FATREC 2018

# Using Image Fairness Representations in Diversity-Based Reranking for Recommendations

**CHEN KARAKO & PUTRA MANGGALA**

Discovery Algorithms @ Shopify

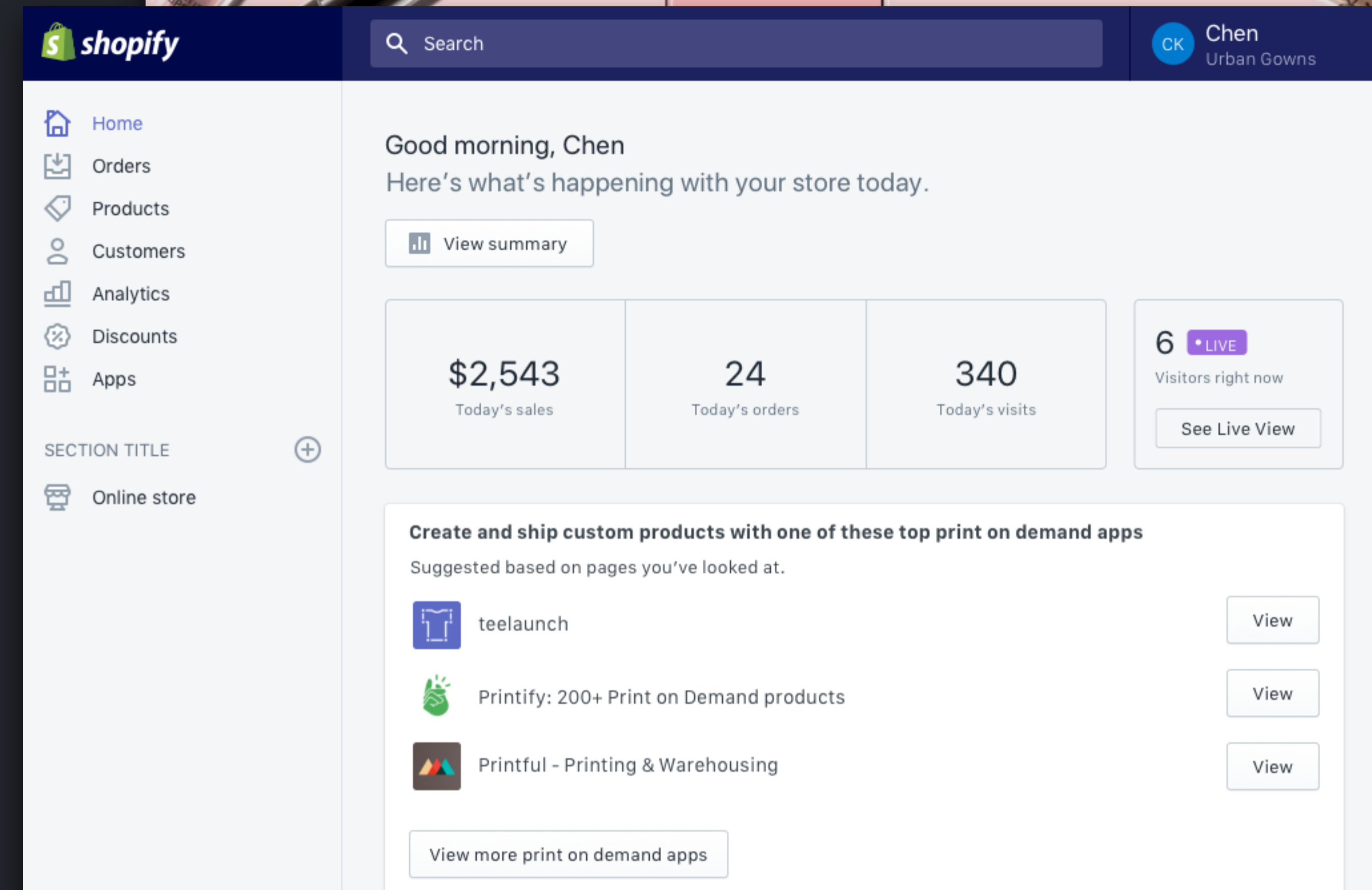
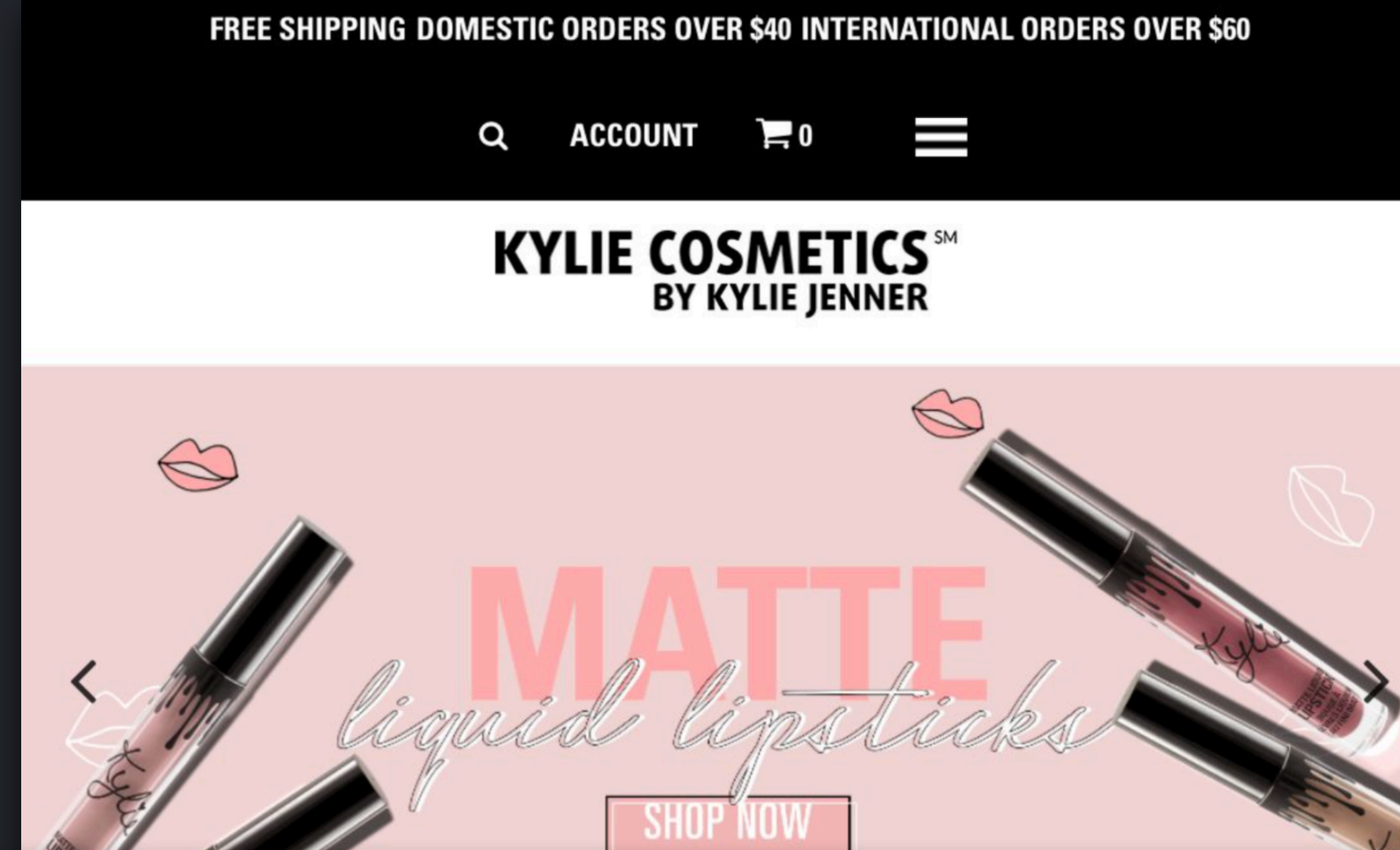


# Discovery Algorithms @ shopify

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

## Recommendations & Personalization

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



shopify Search

Chen  
Urban Gowns

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

[View summary](#)

\$2,543 Today's sales	24 Today's orders	340 Today's visits	6 <b>LIVE</b> Visitors right now <a href="#">See Live View</a>
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Create and ship custom products with one of these top print on demand apps  
Suggested based on pages you've looked at.

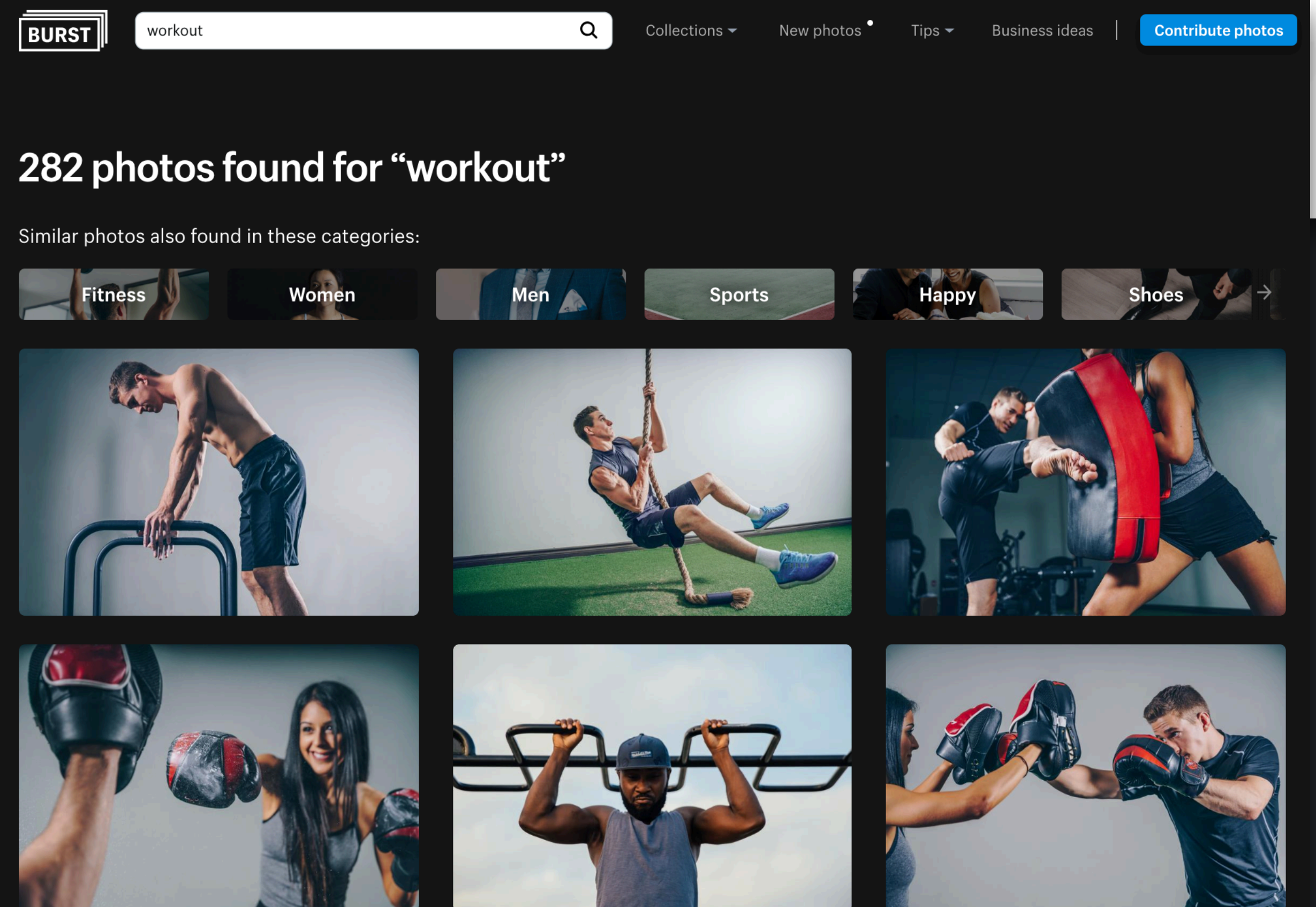
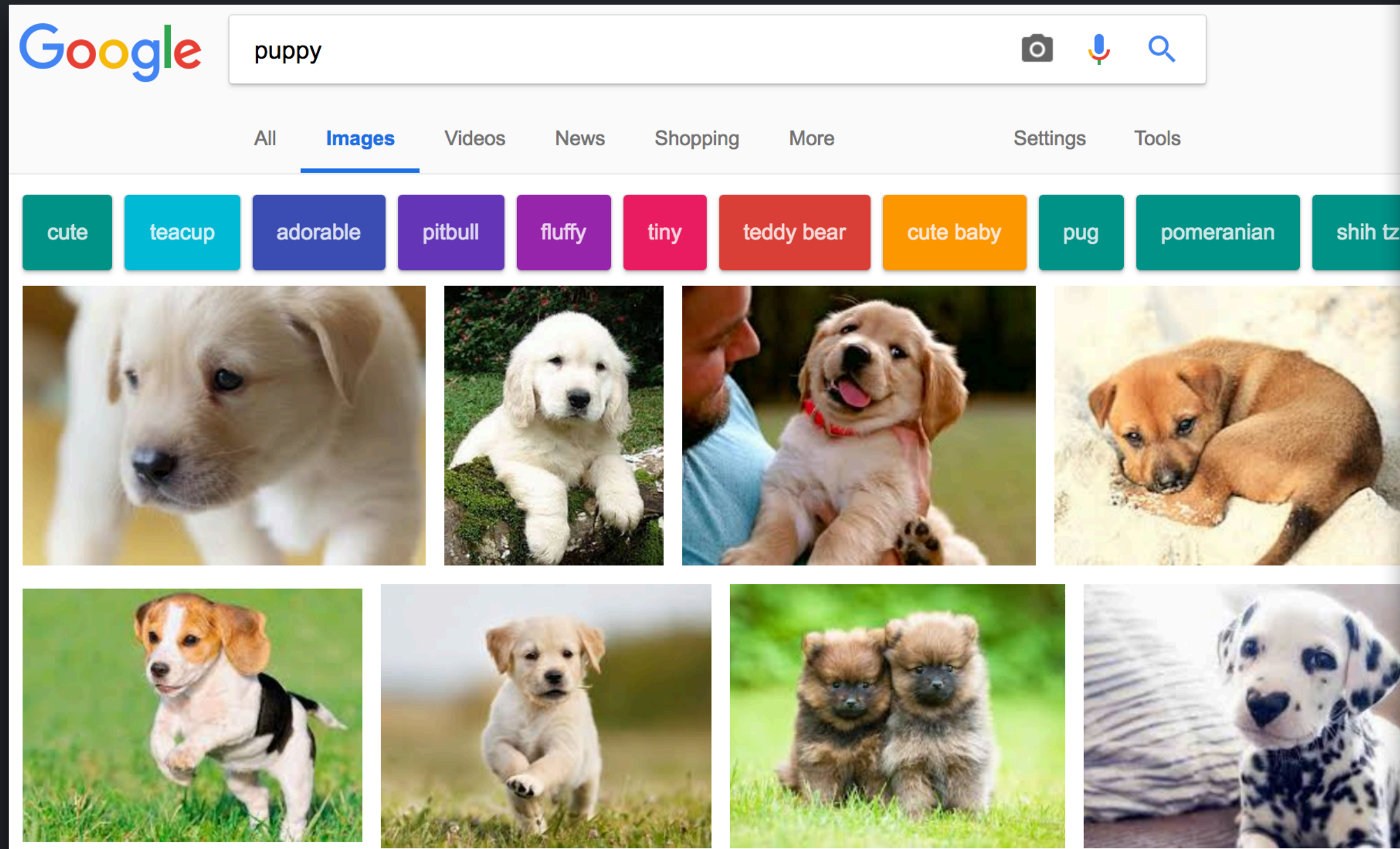
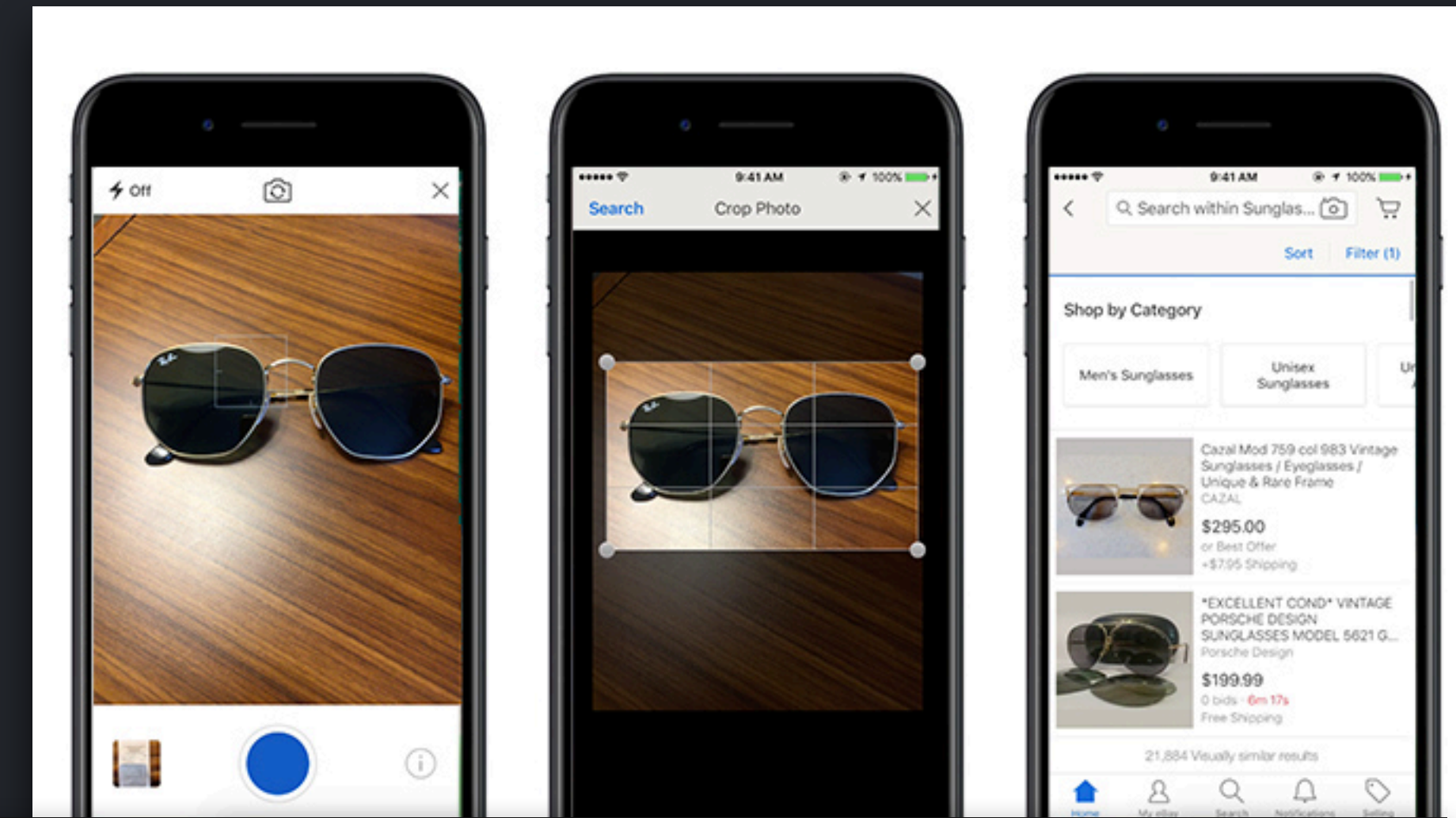
- [teelaunch](#) [View](#)
- [Printify: 200+ Print on Demand products](#) [View](#)
- [Printful - Printing & Warehousing](#) [View](#)

[View more print on demand apps](#)

Can we incorporate  
fairness into search  
results and  
recommendations?



# Image search



snapchat

instagram

twitter

netflix

youtube

linkedin

tide

male

lamborghini

ferrari

rolls royce

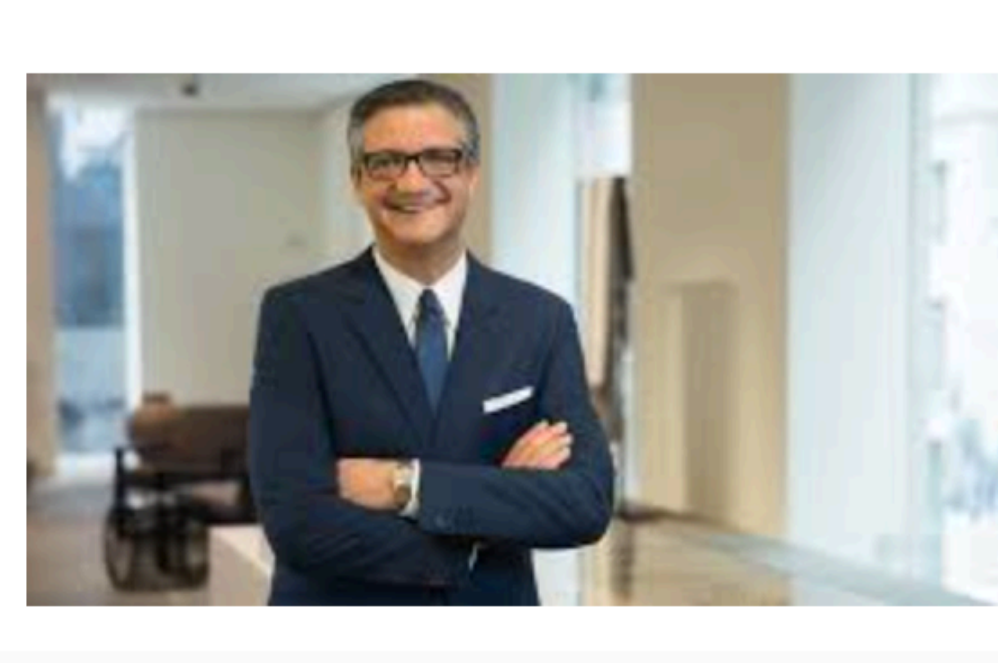
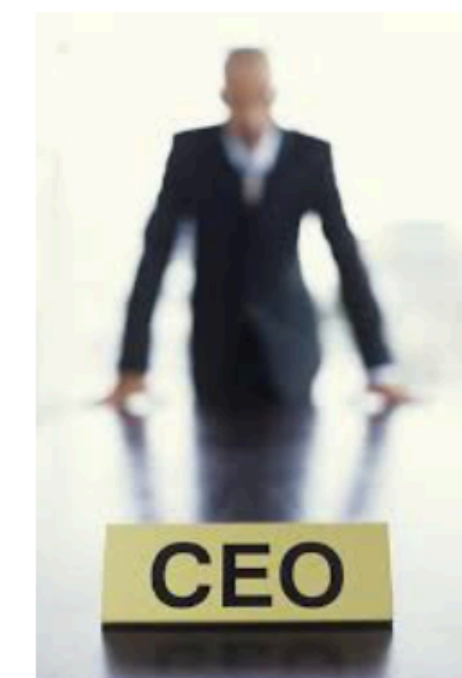
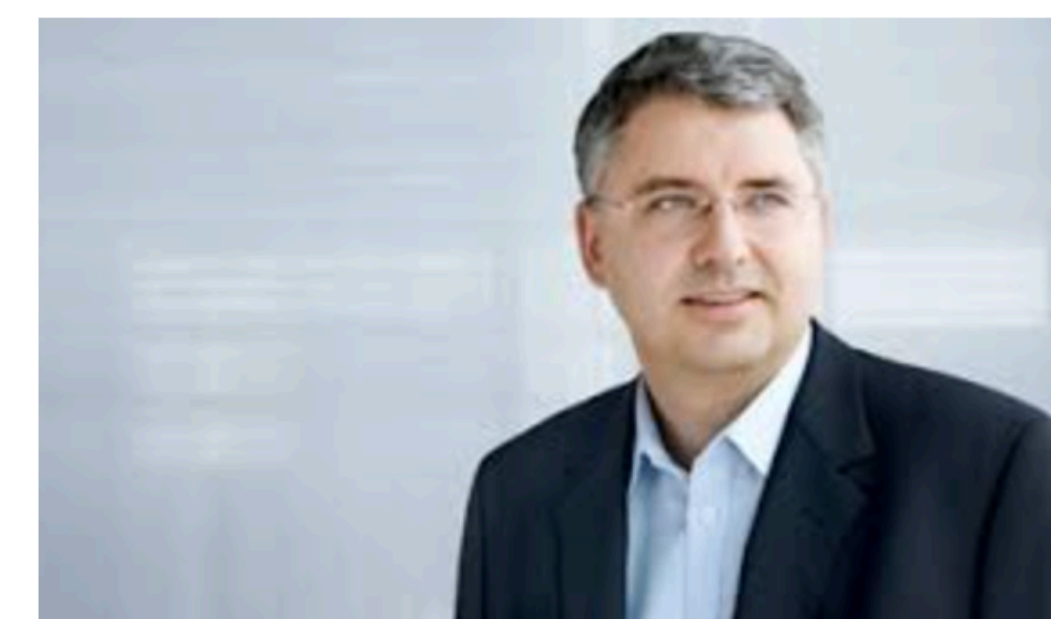
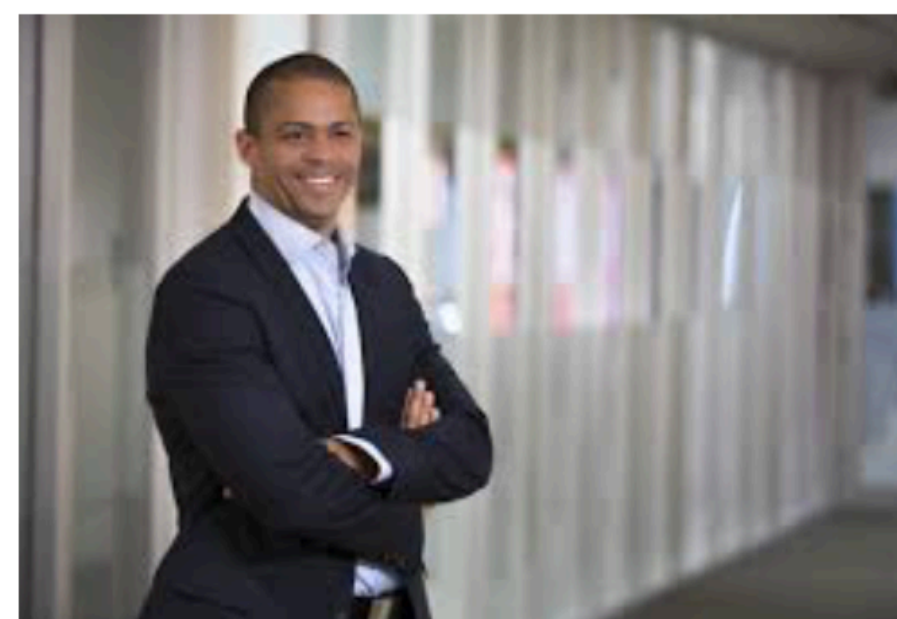
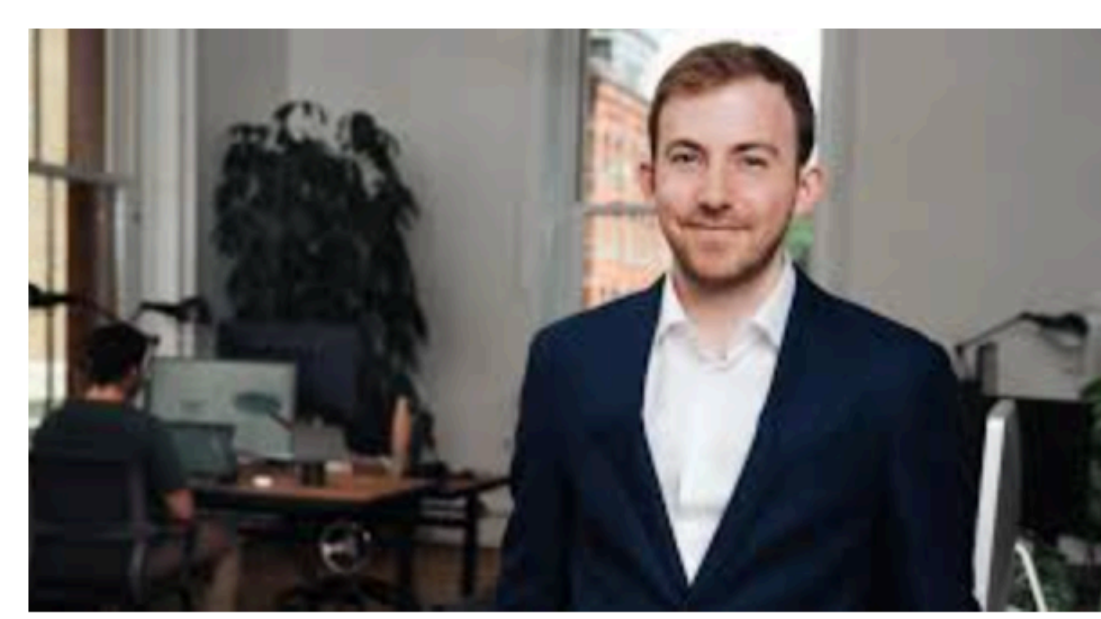
bugatti

rich

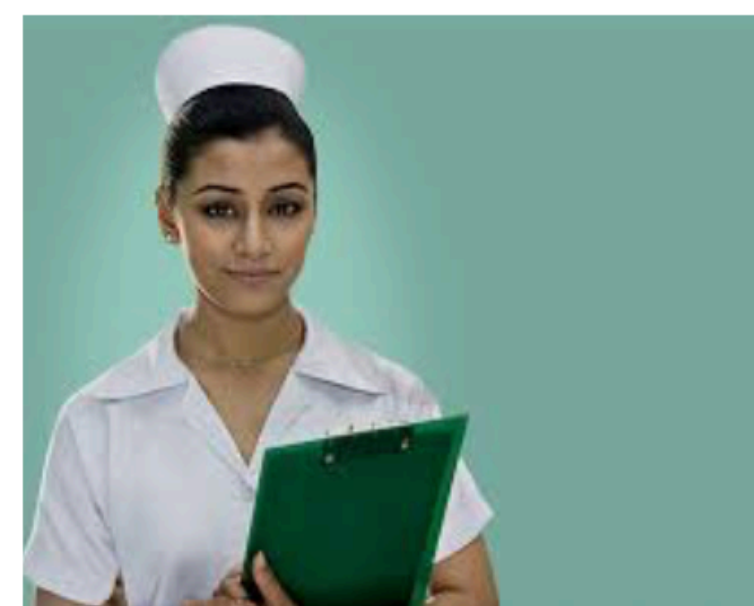
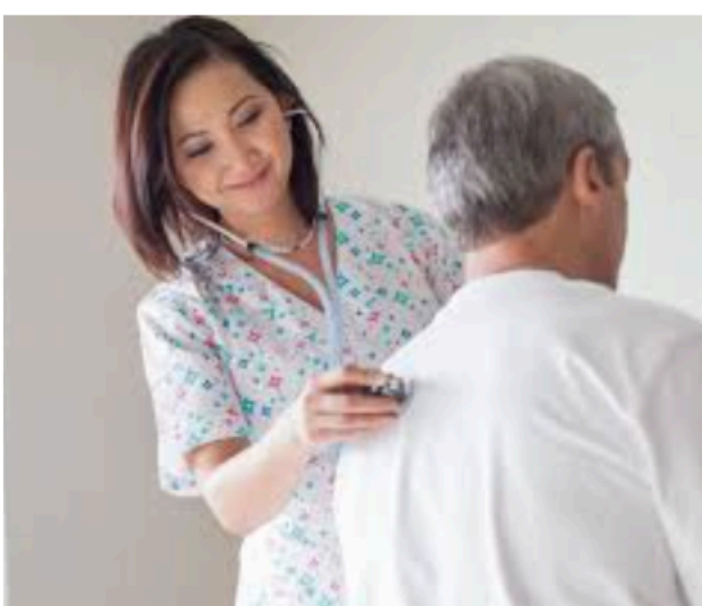
vidcon

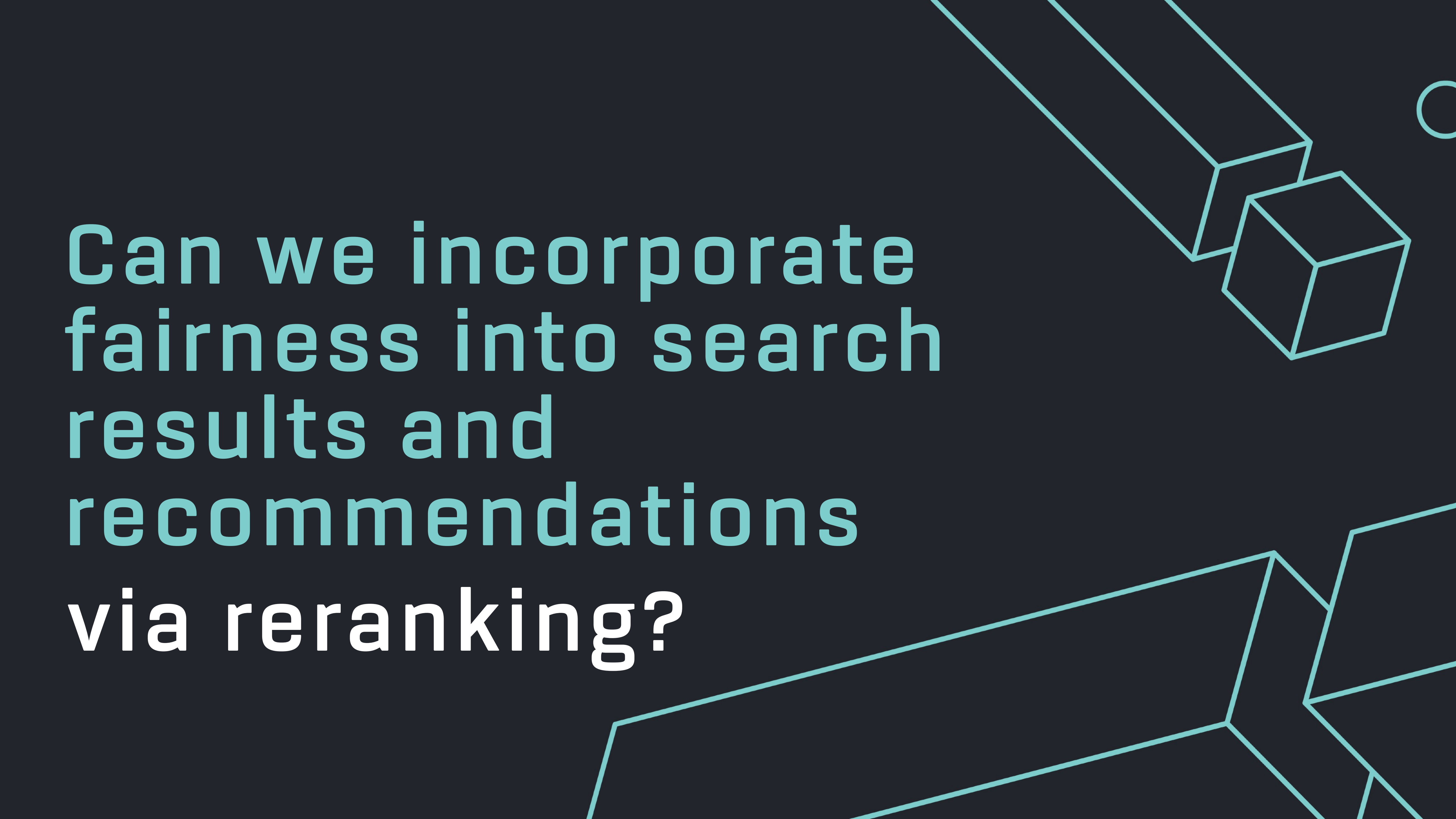
top 10

matthew harrigan



emergency room cartoon clip art logo infographic icon hospital office student british school day old fashioned stethoscope registered african american work background



The background features several abstract geometric shapes in teal and white. In the top right, there is a teal cube-like structure with a white circle nearby. In the bottom right, there are several white and teal lines forming a complex, angular shape. The text is positioned on the left side of the image.

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

# 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 ...  
Government: Unitary presidential Islamic repu... Calling code: +93  
Currency: Afghani (Afs) (AFN) Religion: Islam  
History · Demographics · Governance · Economy

**Top stories**

[Rare Eid al-Fitr ceasefire in Afghanistan offers a chance to reconnect](#)  
CBC.ca · 8 hours ago

[Afghan holiday catches up with crumpled Boris in Commons](#)  
The Guardian · 2 days ago

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Arab News · 14 hours ago

→ More for afghan

**Afghanistan | World | The Guardian**  
<https://www.theguardian.com/world/afghanistan>  
2 days ago - It's far easier to criticise events on the US-Mexico border than to admit the UK government's shameful behaviour, writes Guardian columnist ...

**Afghanistan Online**  
<https://www.afghan-web.com/>  
"Afghanistan: The Friendliest Country in the World, Possibly the Universe."

**Afghanistan News - Today's latest from Al Jazeera**  
<https://www.aljazeera.com/topics/country/afghanistan.html>  
Stay on top of Afghanistan's latest developments on the ground with Al Jazeera's fact-based news, exclusive video footage, photos and updated maps.

**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

**Destinations** View 2+ more

[Kabul](#) [Herat](#) [Kandahar](#) [Band-e Amir Nati...](#) [Zorkul](#)

**People also search for** View 10+ more

[Iran](#) [Pakistan](#) [United States of...](#) [Iraq](#) [Syria](#)

Feedback



# Limitations

The screenshot shows a Google search for 'afghan'. The search results include a Wikipedia entry for Afghanistan, a map of the country, and a list of destinations. The Wikipedia entry provides details about the country's location, government, currency, and religion. The map shows Afghanistan's location in South Asia, bordered by Tajikistan and Pakistan. The destinations list includes Kabul, Herat, Kandahar, Band-e Amir National Park, and Zorkul. The 'People also search for' section lists Iran, Pakistan, United States of America, Iraq, and Syria.

**Afghanistan - Wikipedia**  
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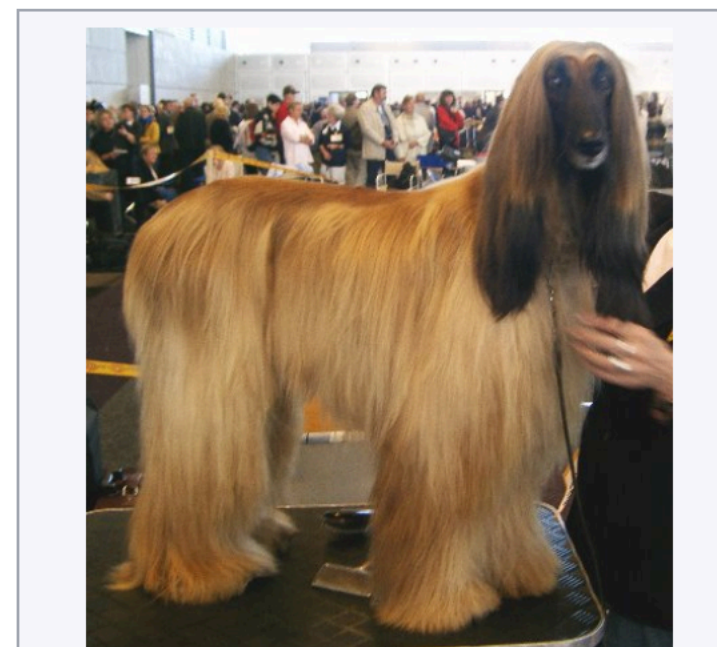
**People also search for** View 10+ more  
Iran Pakistan United States of America Iraq Syria

## Afghan Hound

From Wikipedia, the free encyclopedia

The **Afghan Hound** is a **hound** that is distinguished by its thick, fine, silky coat and its tail with a ring curl at the end. The breed is selectively bred for its unique features in the cold mountains of **Afghanistan**. Its local name is **Tāzī Spay** (Pashto: **تاږي سپی**) or **Sag-e Tāzī** (Dari Persian: **سگ تازی**). Other names for this breed are *Kuchi Hound*, *Tāzī*, *Balkh Hound*, *Baluchi Hound*, *Barakzai Hound*, *Shalgar Hound*, *Kabul Hound*, *Galanday Hound* or sometimes incorrectly *African Hound*.

Afghan Hound

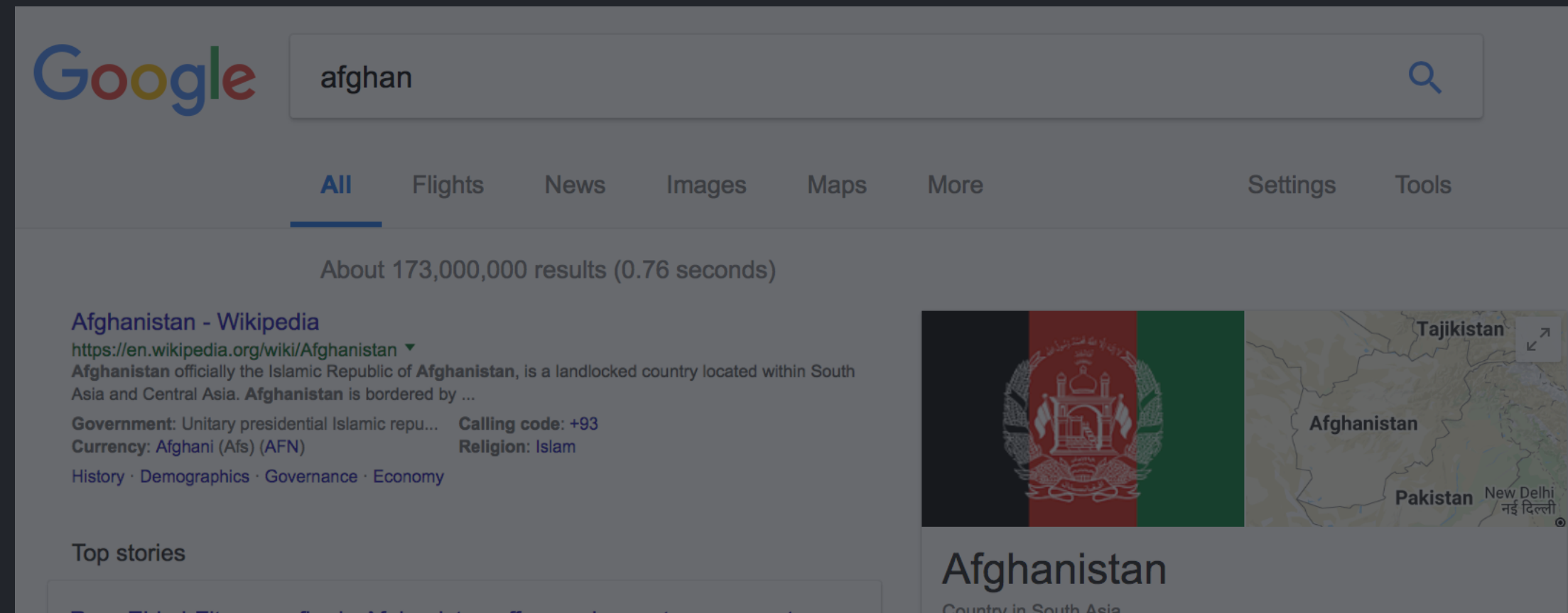


Afghan Hound, fully coated

### Contents [hide]

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

# Limitations



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Afghan Hound



Afghan Hound, fully coated

## Afghan (blanket)

From Wikipedia, the free encyclopedia



Some of this article's **listed sources may not be reliable**. Please help this article by looking for better, more reliable sources. Unreliable citations may be challenged or deleted. *(April 2018)* (*Learn how and when to remove this template message*)

An **afghan** is a woollen blanket or shawl, usually knitted or crocheted.<sup>[1]</sup> 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.<sup>[2]</sup>

### 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*.<sup>[3]</sup> The first mention of the word referring to the woven rug was in 1877.<sup>[4]</sup>



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:
  - $\lambda$  relevance  $+(1 - \lambda)$  gain in diversity

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

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

# MMR re-ranking

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

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

# 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



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

1. Afghanistan

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1. Afghanistan
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1. Afghanistan

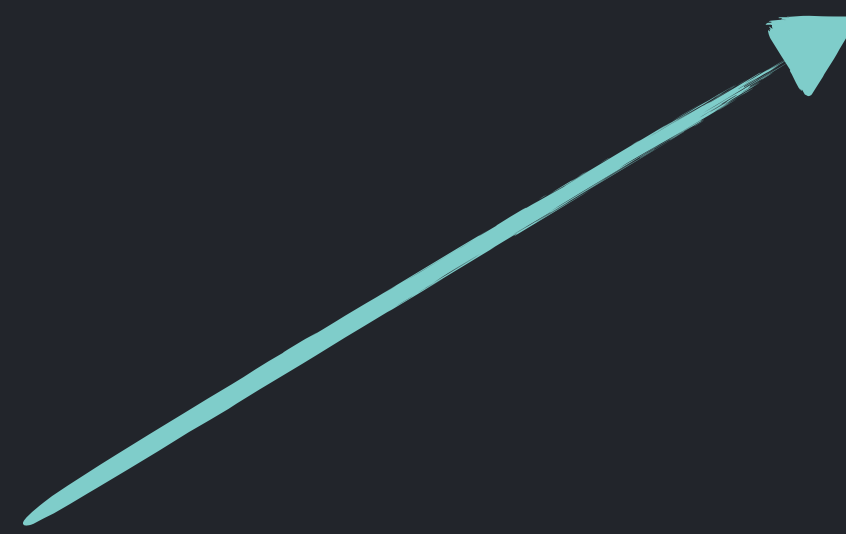
# MMR re-ranking

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

1. Afghanistan

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



1. Afghanistan
2. Dog

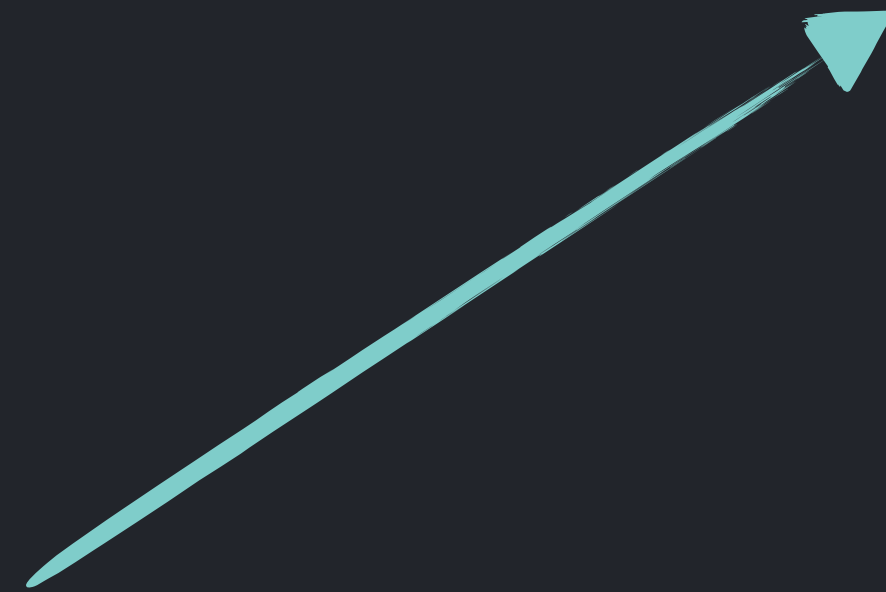
# MMR re-ranking

1. Afghanistan
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1. Afghanistan
2. Dog

# MMR re-ranking

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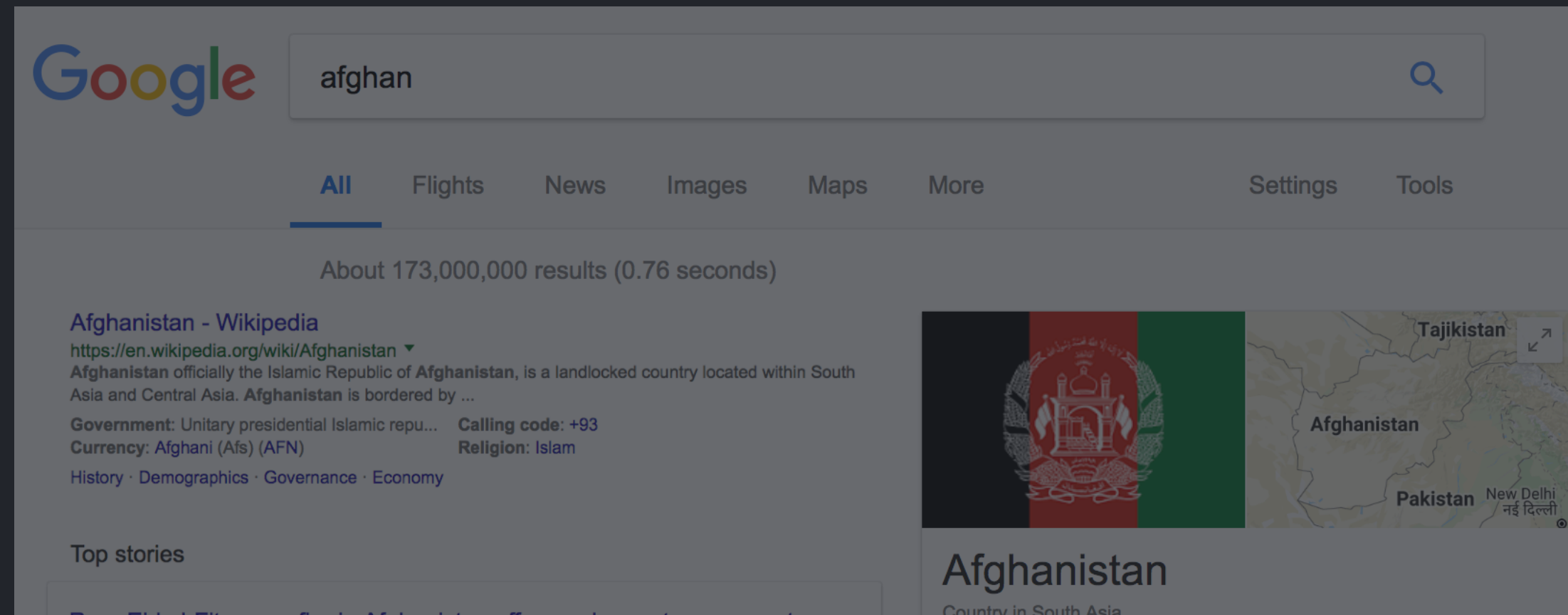
1. Afghanistan
2. Dog
3. Blanket

# MMR re-ranking

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

1. Afghanistan
2. Dog
3. Blanket
- 
- 
-

# MMR re-ranking



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

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Afghan Hound, fully coated

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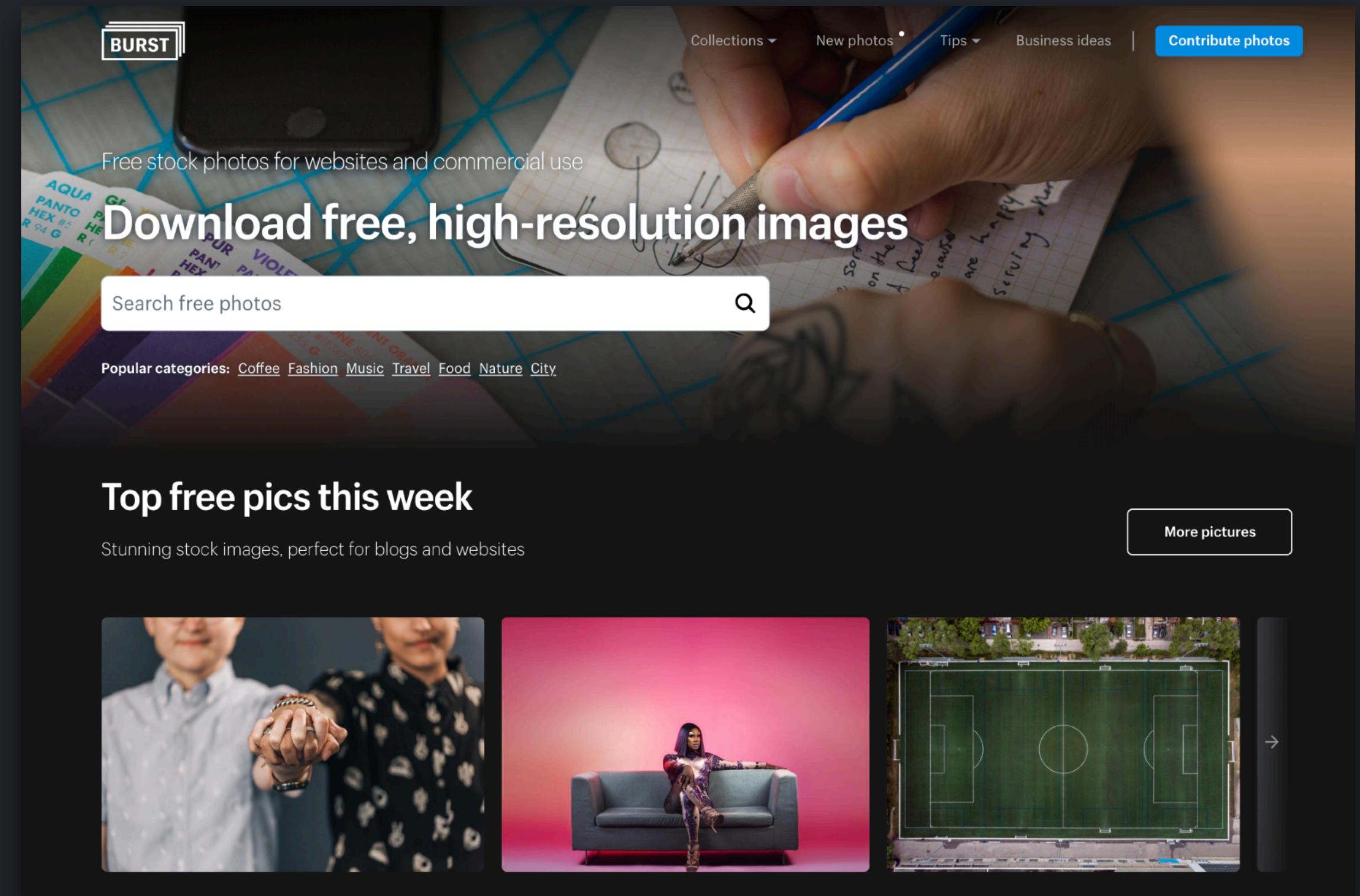
An afghan blanket



# 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

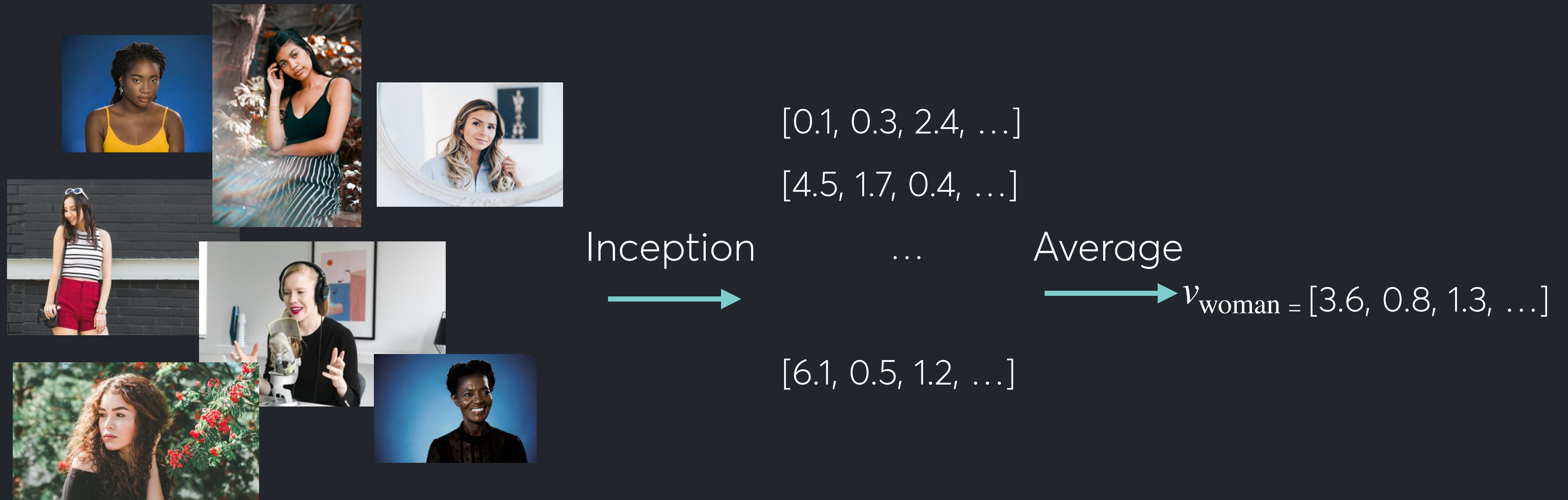
Can we use this instead for fairness?

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

# Image representations

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

# Image fairness representations



# Image fairness representations



tag: 'man'

Inception  
→

[6.1, 2.3, 7.3, ...]

[1.5, 1.7, 0.5, ...]

...

[2.0, 1.5, 4.2, ...]

Average  
→

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

# Fairness-aware MMR reranking (FMMR)

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

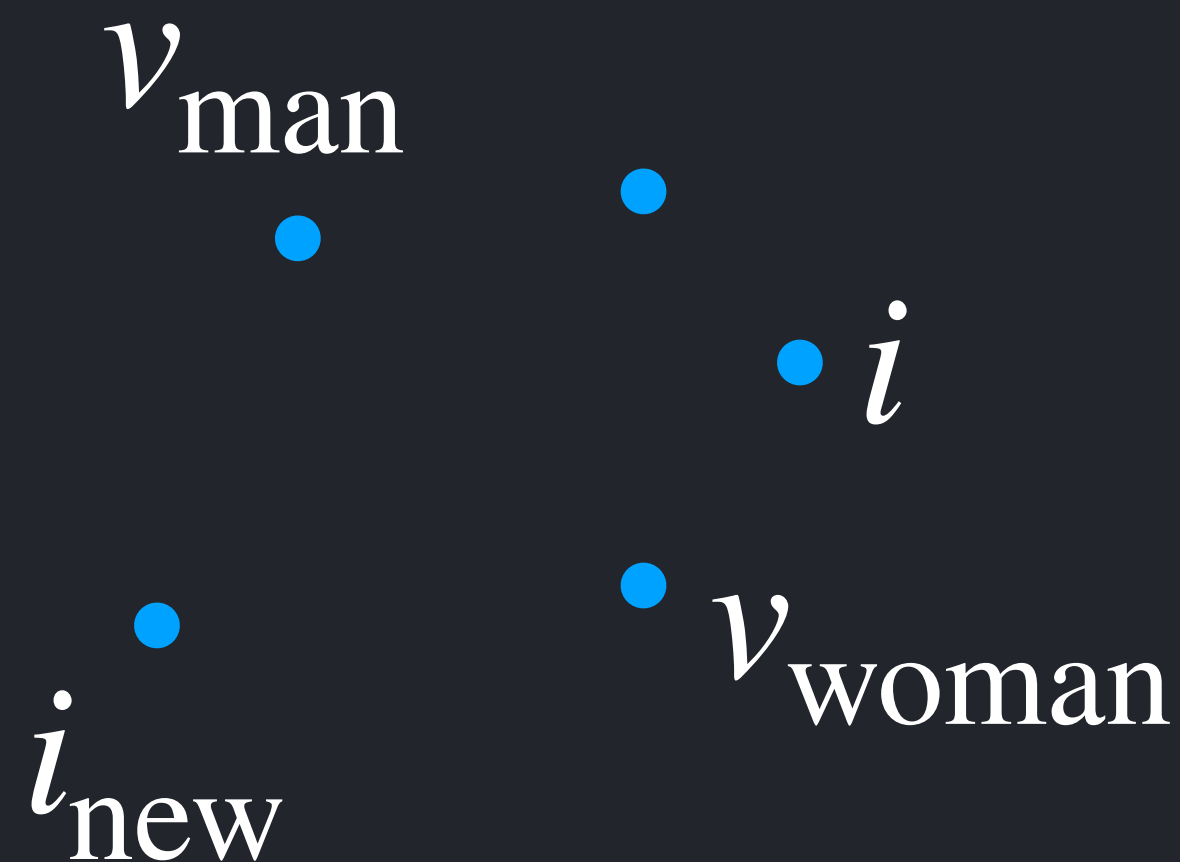
$$- \max_{i \in S_{\text{chosen items}}} \text{Sim}(i_{\text{new}}, i)$$



# Fairness-aware MMR reranking

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

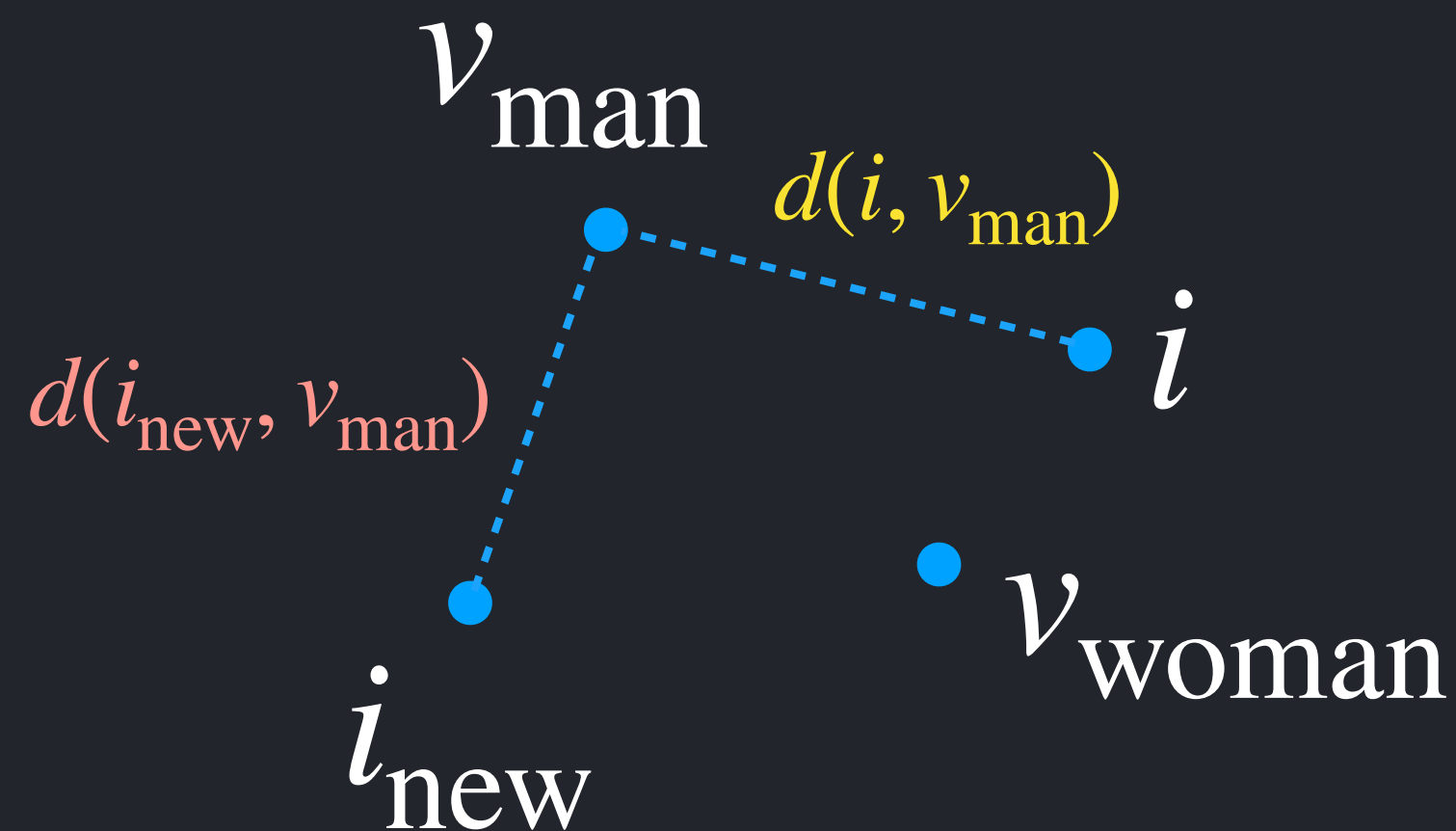
$\text{Sim}(i_{\text{new}}, i)$  ?



# Fairness-aware MMR reranking

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

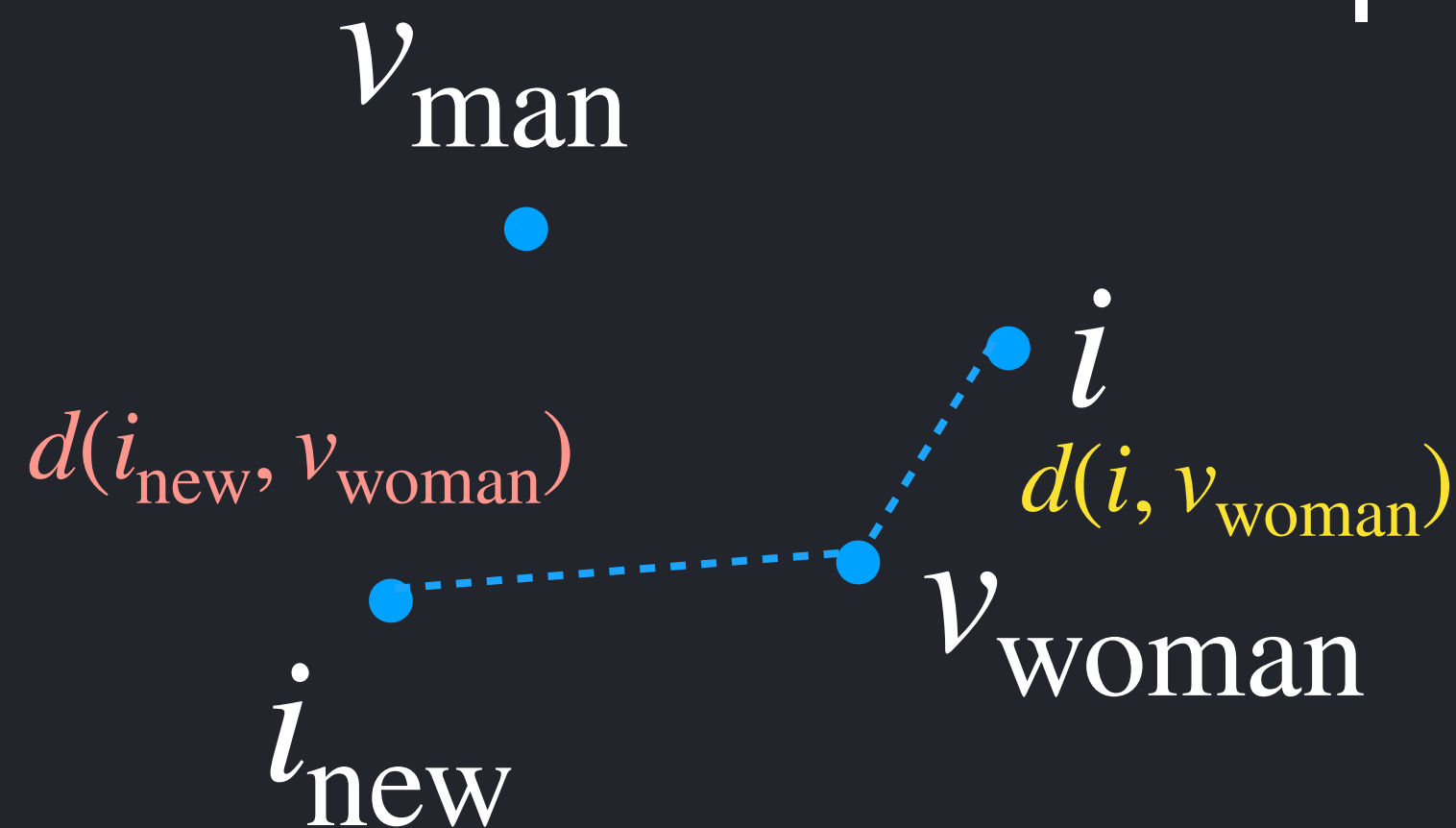
$$\text{Sim}(i_{\text{new}}, i) ? \quad - |d(i, v_{\text{man}}) - d(i_{\text{new}}, v_{\text{man}})|$$



# Fairness-aware MMR reranking

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

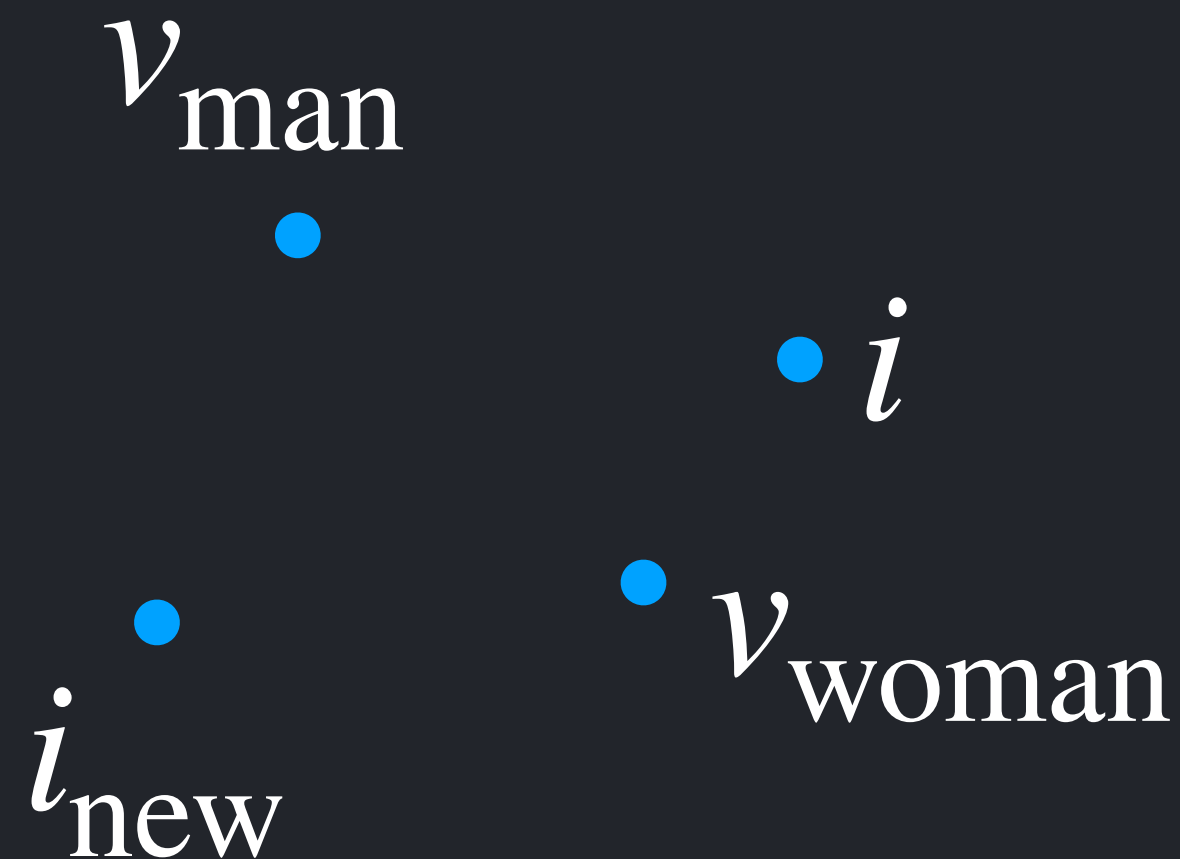
$$\text{Sim}(i_{\text{new}}, i) = -|d(i, v_{\text{man}}) - d(i_{\text{new}}, v_{\text{man}})| + |d(i, v_{\text{woman}}) - d(i_{\text{new}}, v_{\text{woman}})|$$



# Fairness-aware MMR reranking

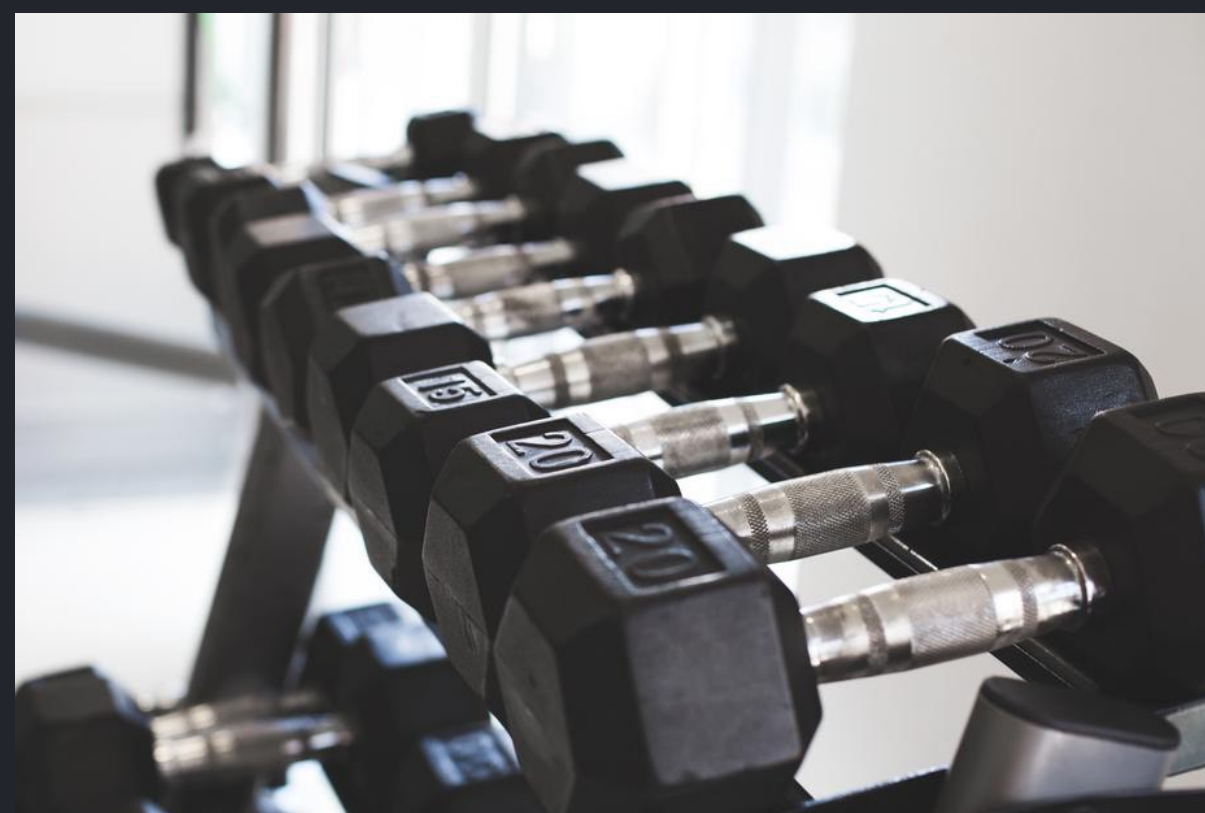
$\lambda$  relevance  $+(1 - \lambda)$  gain in fairness

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



# 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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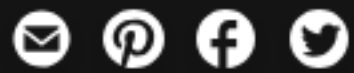
### Fitness Balancing

A man balancing on a bar.

#### Photo size

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

Download free photo



**Featured in:**  
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[Crossfit](#)





# 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,  $\lambda$  tuned using 100 query images to heuristically optimize the fairness-relevance tradeoff
- Evaluation done on remaining 638 images: use tuned  $\lambda$  to get top-10 results per query, compute  $p@10$ ,  $fr@10$ .

p@10

$0.59 \pm 0.02$

FMMR

$0.53 \pm 0.02$

MMR

fr@10

$0.65 \pm 0.02$

FMMR

$0.64 \pm 0.02$

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)
- x ✓ 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](mailto:chen.karako@shopify.com)  
[@chennerzz](#)



# Appendix 1: hyperparameter tuning heuristics

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

Guarantee of precision for  $\lambda$  by this constraint:

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