

Extreme Classification

COV 878: Special Topics in
Machine Learning

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Binary Classification

- Answer yes/no questions involving uncertainty



Is this George Washington or not?

Multi-class Classification

- Answer multiple choice questions



Which US President is present in this image?

Multi-label Classification

- Pick multiple answers in a multiple choice question



Which US Presidents are present in this image?

Traditional Classification

- Classification with a small number of choices



Spam or not?



< 100 gestures



Windows Hello
User or not?

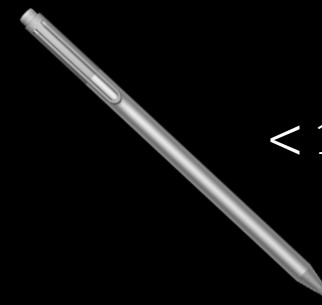


Microsoft Cognitive
Services

< 25K objects



< 1000 topics



Surface Pen
< 100 characters



Virus or not?



< 1000 tags



'Hey Cortana' or not?

Extreme Classification

- Classification with millions of labels

Ad



Do you know how much you could save on car insurance by switching to GEICO?

Get an online quote: [GO](#)

Get a quote by phone: [1-800-841-1588](tel:1-800-841-1588)

Find a local agent: [GO](#)

Need other insurance?

ATV	Homeowners	Overseas
Boat	ID Theft Protection	Renters
Commercial Auto	Life	RV
Condo/Ca-op	Mobile Home	Umbrella
Flood	Motorcycle	

Already a policyholder? [Log in.](#)

GEICO

© 1996-2012 GEICO

Predicted Bing Queries

geico auto insurance

geico car insurance

geico insurance

www geico com

care geicos

geico com

need cheap auto insurance

wisconsin cheap car insurance quotes

cheap auto insurance florida

all state car insurance coupon code

Extreme Classification in Academia



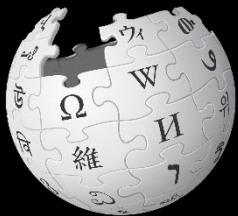
- Publications at AAAI, AISTATS, ECCV, IJCAI, ICLR, ICML, KDD, NIPS, SIGIR, WSDM, WWW, *etc.*



- 8 popular workshops organized in 5 years at Dagstuhl, ECML, ICML, NIPS, WWW, *etc.*



- Code, datasets & benchmarks released on The Extreme Classification Repository



- Wikipedia results have improved from 20% in 2013 to 65% in 2018

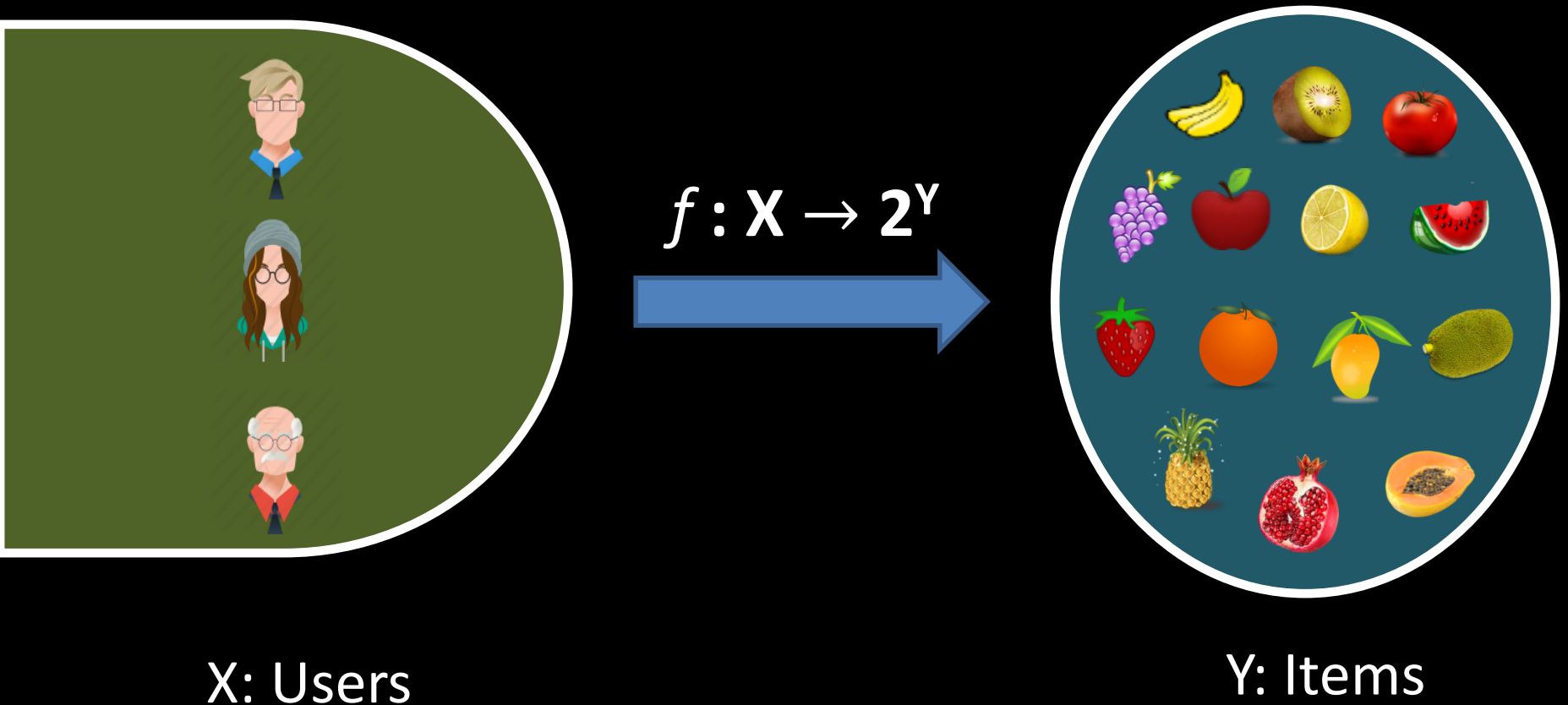
Applications

- Information Retrieval
 - Ranking for web search & advertising
- Recommender Systems
 - Item to item recommendation
- Natural Language Processing
 - Language modelling
 - Document tagging
- Computer Vision
 - Person recognition
 - Learning universal feature representations
- Bioinformatics
 - Gene function prediction



Extreme Multi-Label Classification

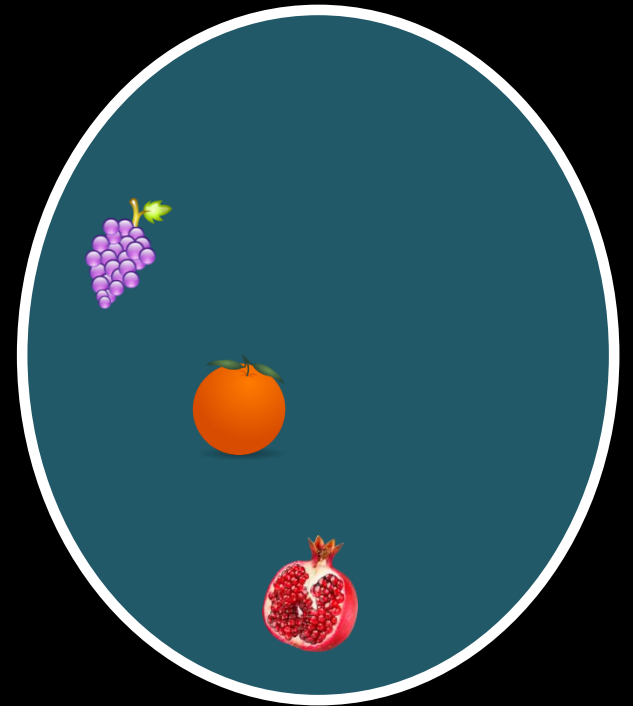
- Problem formulation




Extreme Multi-Label Learning

- Problem formulation

f ()



Bing Ads – Tesco's Distilled Water

amazon.co.uk Try Prime All ▾ distilled water 



Shop by **Department** ▾ Your Amazon.co.uk Today's Deals Christmas Store Hello. Sign in **Your Account** ▾ Try **Prime** ▾ Your **Lists** ▾ **0** **Basket**

[Amazon.co.uk](#) [Today's Deals](#) [Warehouse Deals](#) [Outlet](#) [Subscribe & Save](#) [Vouchers](#) [Amazon Family](#) [Amazon Prime](#) [Amazon Pantry](#) [Amazon Video](#)

1-16 of 3,179 results for "distilled water" Sort by **Relevance** ▾

Show results for

- Automotive**
 - Vehicle Oils & Fluids
 - Winter Goods for Cars
 - Car Lighting Assemblies & Components
- Health & Personal Care**
 - Wellness
 - Medication & Remedies
 - Vitamins, Minerals & Supplements
 - Alternative Medicine
 - Colloidal Silver
 - See more

	<p>Sponsored</p> <p>Distilled Water - 5 Litre (5L) - Pure Steam Distilled - 0ppm by Distilled Water UK</p> <p>£24.95 (£4.99/l) 30</p>
	<p>Adamol 1896 51635139 Distilled Water 5 L by ADAMOL 1896</p> <p>£7.20 16</p>

Bidded Query: distilled water 5 litres

Predictions: Bing Ads vs Extreme Classification

Bing Ads

water 5

Extreme Classification

distilled water tesco

where buy distilled water

distilled water

buy distilled water

distilled water amazon

distilled water vs purified water

distilled water uk

distilled water delivery

where can I buy distilled water

distilled water uk supermarket

Traditional Approach

- Reduction to binary classification

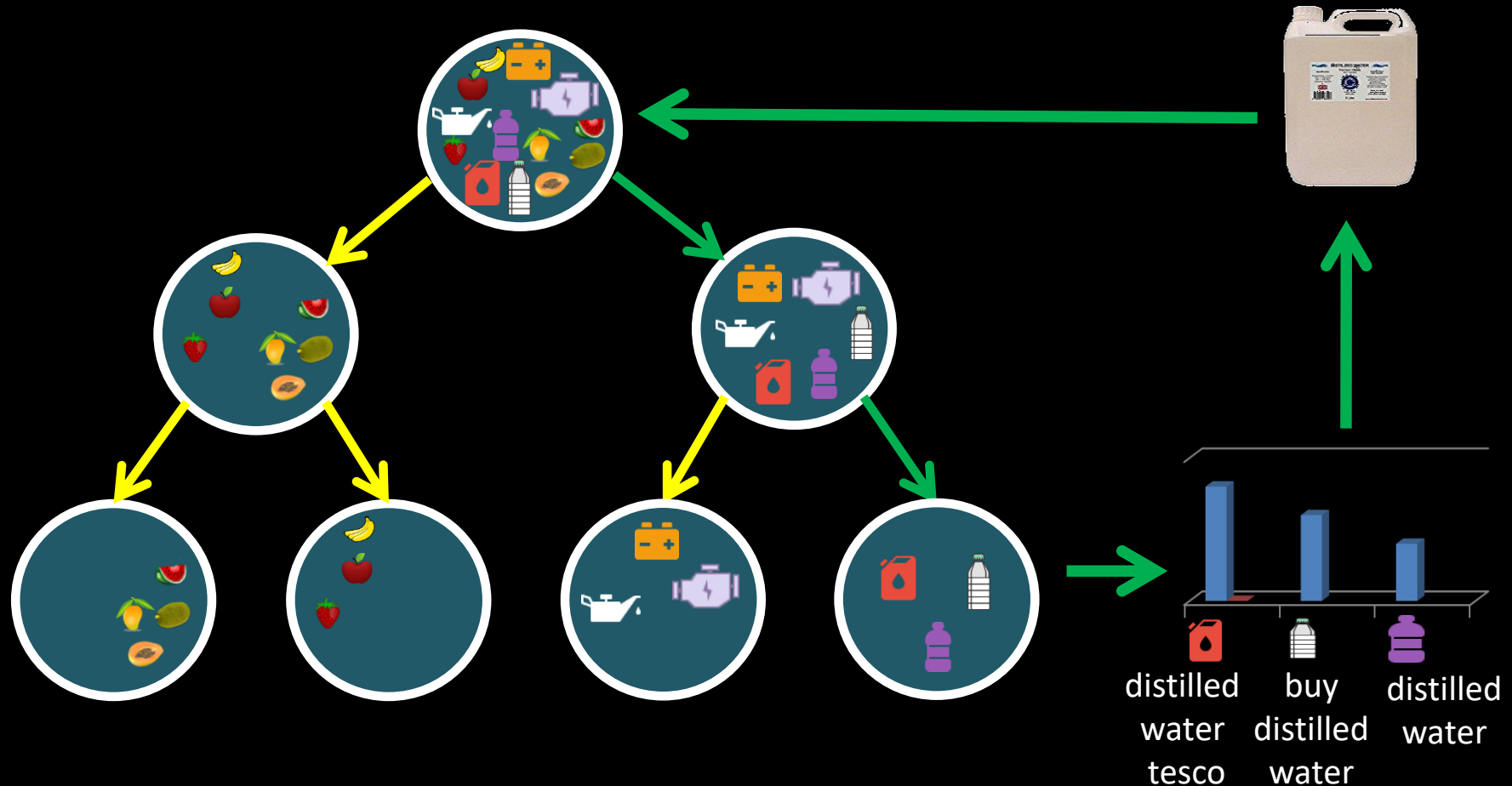
$h : (\text{Ad}, \text{Phrase}) \rightarrow \{\text{✗}, \text{✓}\}$

$h(\text{Image of water jug}, \text{buy distilled water}) \rightarrow \text{✗}$

$h(\text{Image of water jug}, \text{water 5}) \rightarrow \text{✓}$

Extreme Classification Approach

- Efficient & accurate prediction via a learnt hierarchy



Extreme Classification for Bing Ads

- Shipped in various products in international markets

UK Dynamic Search Ads

The screenshot shows a product page for 'Impey Coving Ext Profile Vinyl' on the Topps Tiles website. The product is priced at £54.65. The page includes a navigation menu, a search bar, and a 'Add to Basket' button. The product description mentions it is a single piece of anodized aluminum that accepts the cove finish on a vinyl floor.

French Text Ads

The screenshot shows a French insurance website with various categories like 'ASSURANCES', 'ASSURANCE AUTO', and 'ASSURANCE MOTO'. A yellow highlight box at the bottom contains the text: 'Bided Keywords: la vie assurance, assurance auto, assurance moto'.

German Product Ads

The screenshot shows a German advertisement for the Nikon Coolpix B500 Pflaume camera. The price is listed as 259,00 €. The ad includes the text 'Kostenloser Versand' and 'keine Versandinfo'.

Item-to-item Recommendation - Walmart



Sports Participation and Cultural Identity in the Experience of Young People

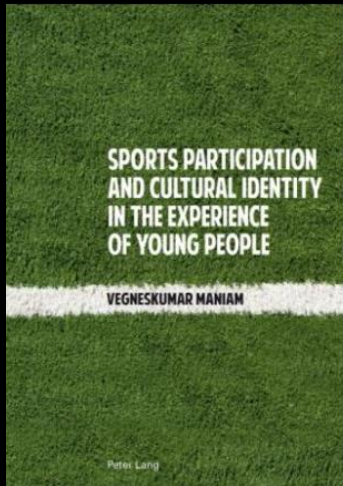
★★★★★ [Write a review](#)

\$48.97

Only 1 left!

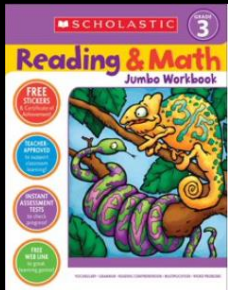
Free shipping

Arrives by Saturday, Aug 25 [Options](#)

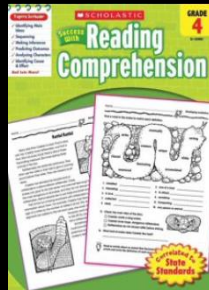


Qty:

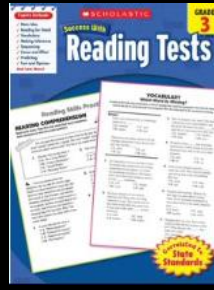
Consider these popular products



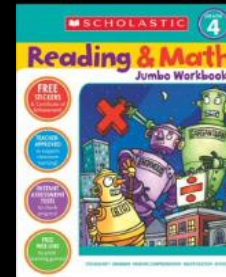
Reading & Math Jumbo Workbook: Grade 3



Scholastic Success with Reading Comprehension, Grade 4



Reading Tests, Grade 3



Reading & Math Jumbo Workbook: Grade 4

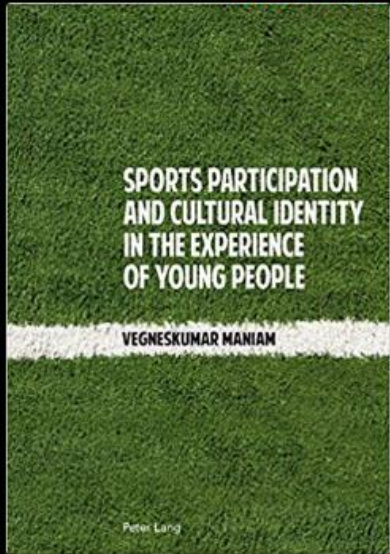
[return policy](#)

[stry](#)

Item-to-item Recommendation - Amazon



Look inside ↴



Sports Participation and Cultural Identity in the Experience of Young People

by Vegneskumar Maniam (Author)

Be the first to review this item

See all 2 formats and editions

Kindle
\$49.27

Paperback
\$59.49

Read with Our **Free App**

9 Used from \$25.58

13 New from \$47.63

This book focuses on inclusion and exclusion in sporting activities among young people in a multicultural society. Do young people who identify with cultural groups other than the majority experience exclusion from sporting teams, or do they find themselves readily included? Does this vary across identities, and sports? In the context of Australia, where sport is an integral part of national life and one in four of the population were born overseas, and over 270 different ancestries are acknowledged, young people were asked to write about their cultural identity and their experiences playing sport. Using a humanistic sociological approach, the inductive analysis juxtaposed their sense of cultural identity with their participation or non-participation in sport, and with the particular sports played. This book is important for

Sponsored products related to this item

Items related to this item



Amazon vs Walmart vs Extreme Classification

Amazon



Walmart

Reading & Math Jumbo Workbook: Grade 3

Scholastic Success with Reading
Comprehension, Grade 4

Reading Tests, Grade 3

Reading & Math Jumbo Workbook: Grade 4

Scholastic Success with
Multiplication Facts, Grades 3-4

Cursive Writing Practice: Inspiring Quotes

Modern Handwriting:
Beginning Cursive, Grades 1 - 3

Math, Grade 3

Cursive Writing Practice:
Jokes & Riddles, Grades 2-5

10 Week-By-Week Sight Word Packets

Extreme Classification

Sports in Society: Issues and Controversies

Beer and Circus: How Big-Time College
Sports Is Crippling Undergraduate Education

Sport in Contemporary Society :
An Anthology

Big-Time Sports in American Universities

Power at Play: Sports and the Problem of
Masculinity (Men and Masculinity)

Successful Coaching

Foundations of Sport and Exercise
Psychology With Web Study Guide-5th
Edition

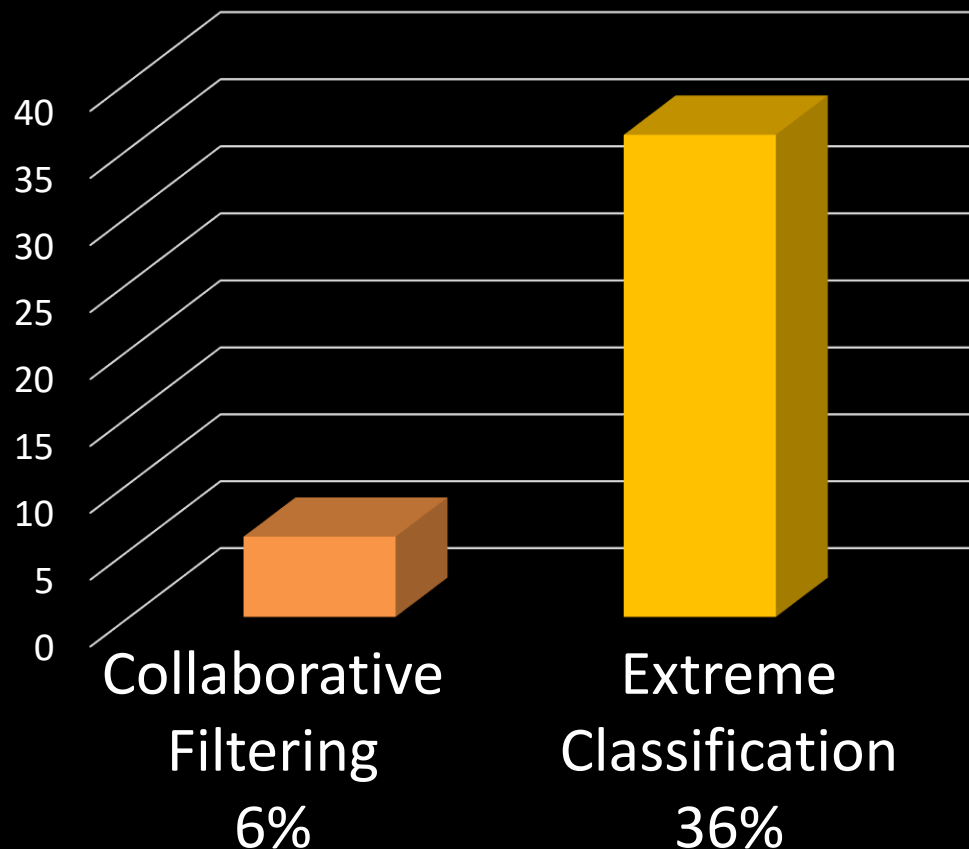
Friday Night Lights:
A Town, A Team, And A Dream

Out of Play: Critical Essays on
Gender and Sport



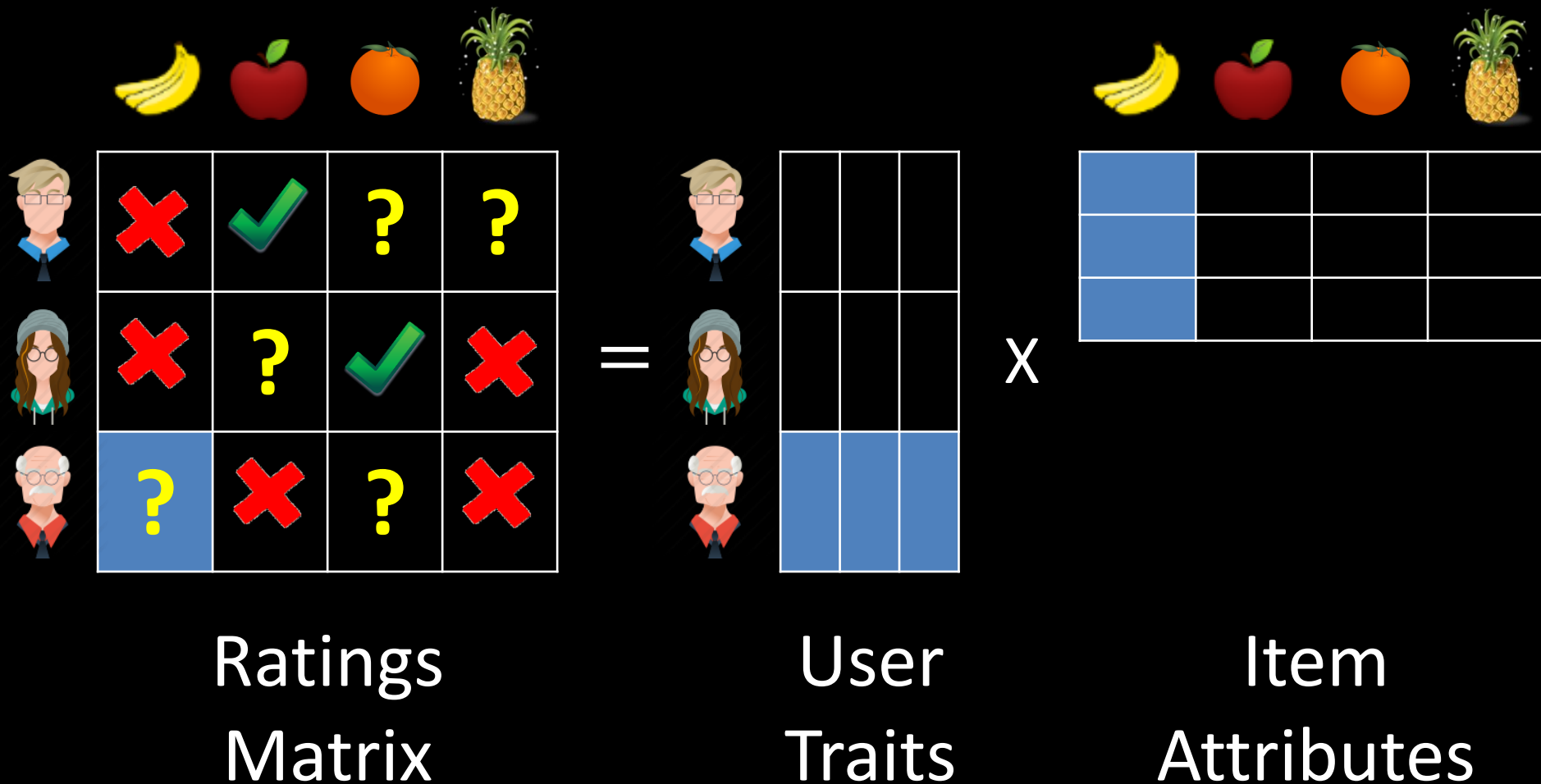
Collaborative Filtering

- Extreme classification can increase the recommendation accuracy from 6% to 36%



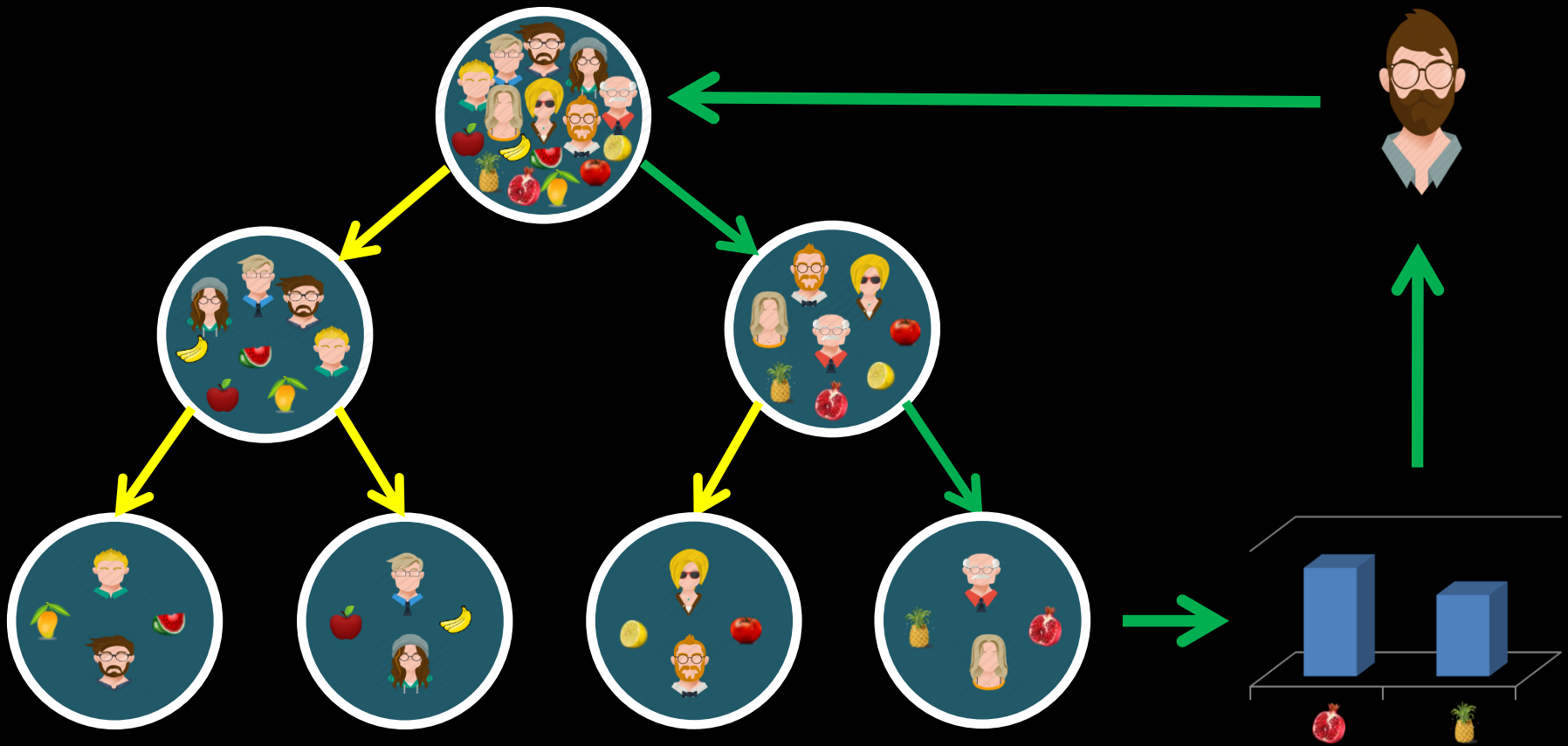
Traditional Approach

- Collaborative filtering & matrix factorization



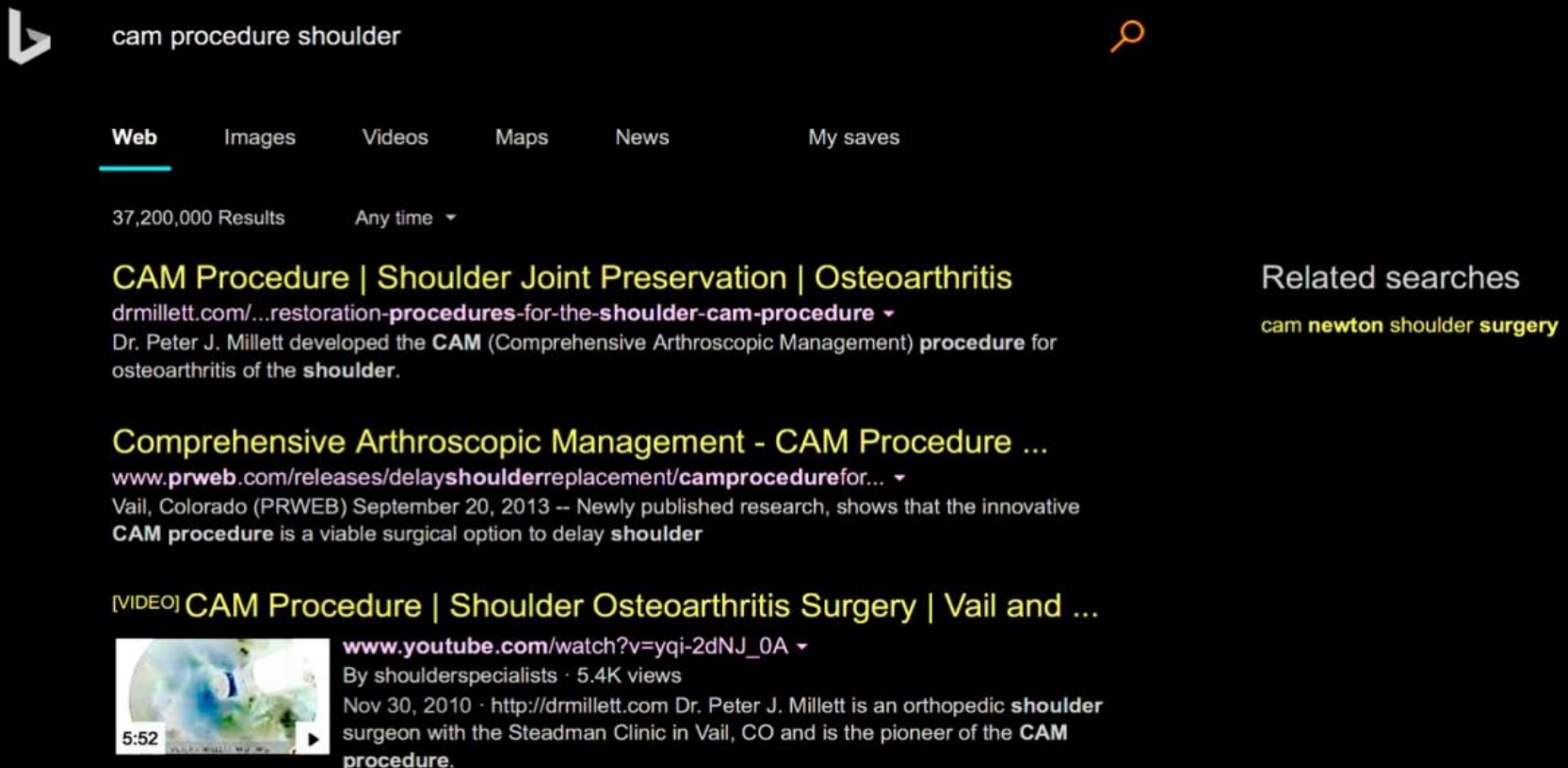
Extreme Classification Approach

- Recommendation based on user and item features



Bing RS – “cam procedure shoulder”

- Recommend related queries that might
 - Serve the user’s information requirements better
 - Provide more information on the topic



The screenshot shows a Bing search results page for the query "cam procedure shoulder". The search bar at the top contains the text "cam procedure shoulder" and a magnifying glass icon. Below the search bar, there are navigation tabs for "Web", "Images", "Videos", "Maps", "News", and "My saves", with "Web" selected. The search results are displayed in a list format. The first result is titled "CAM Procedure | Shoulder Joint Preservation | Osteoarthritis" and includes a snippet from drmillett.com. The second result is titled "Comprehensive Arthroscopic Management - CAM Procedure ..." and includes a snippet from www.prweb.com. The third result is a video titled "[VIDEO] CAM Procedure | Shoulder Osteoarthritis Surgery | Vail and ..." with a thumbnail image and a play button icon. To the right of the search results, there is a section for "Related searches" which includes the query "cam newton shoulder surgery".


cam procedure shoulder

Web Images Videos Maps News My saves

37,200,000 Results Any time ▾

CAM Procedure | Shoulder Joint Preservation | Osteoarthritis
drmillett.com/...restoration-procedures-for-the-shoulder-cam-procedure ▾
Dr. Peter J. Millett developed the **CAM** (Comprehensive Arthroscopic Management) **procedure** for osteoarthritis of the **shoulder**.

Comprehensive Arthroscopic Management - CAM Procedure ...
www.prweb.com/releases/delayshoulderreplacement/camprocedurefor... ▾
Vail, Colorado (PRWEB) September 20, 2013 – Newly published research, shows that the innovative **CAM procedure** is a viable surgical option to delay **shoulder**

[VIDEO] **CAM Procedure | Shoulder Osteoarthritis Surgery | Vail and ...**
 **www.youtube.com/watch?v=yqi-2dNJ_0A** ▾
By shoulderspecialists · 5.4K views
Nov 30, 2010 · http://drmillett.com Dr. Peter J. Millett is an orthopedic **shoulder** surgeon with the Steadman Clinic in Vail, CO and is the pioneer of the **CAM procedure**.

Related searches
cam newton shoulder surgery

Predictions: Bing vs Extreme Classification

Bing

cam newton
shoulder surgery

Extreme Classification

how long off work for shoulder
surgery

shoulder surgery procedures

recovery from arthroscopic shoulder
surgery

shoulder joint resurfacing surgery

shoulder clean up surgery

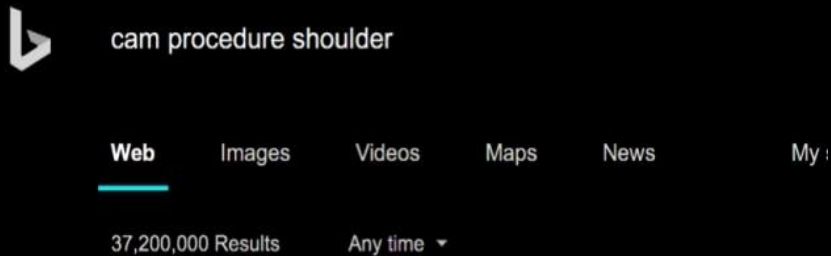
tenex procedure for rotator cuff

cost of arthroscopic shoulder surgery

shoulder replacement surgery
success rate

Sessions Based Approaches

- Might not work well for tail queries
- Intent changes might lead to poor suggestions



cam procedure shoulder

Web Images Videos Maps News My

37,200,000 Results Any time

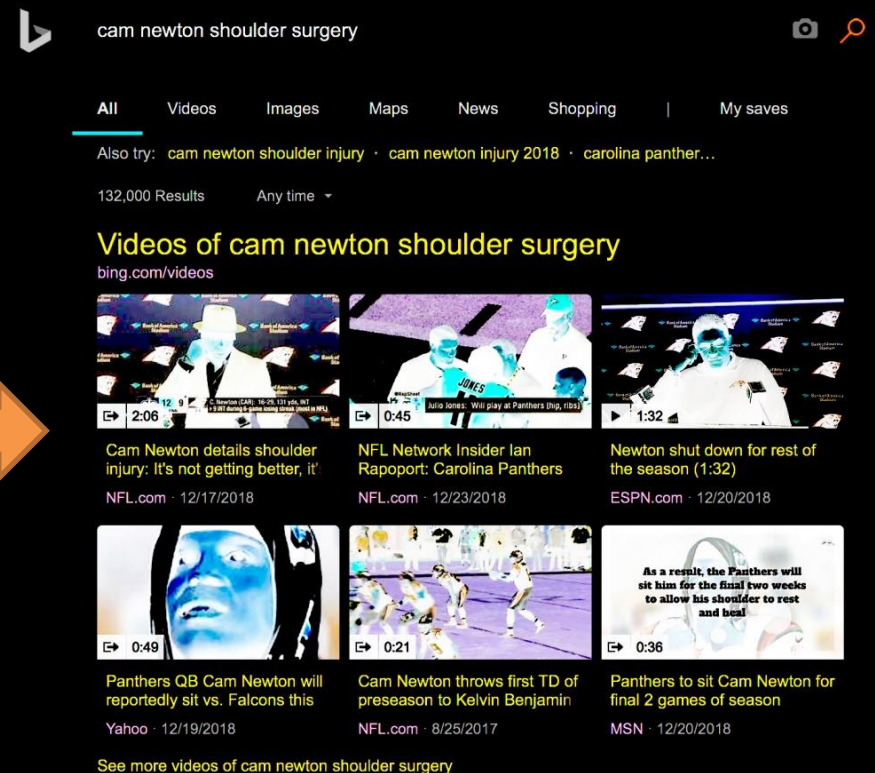
CAM Procedure | Shoulder Joint Preservation | Or
drmillett.com/...restoration-procedures-for-the-shoulder-cam-procedu
Dr. Peter J. Millett developed the CAM (Comprehensive Arthroscopic Manag osteoarthritis of the shoulder.

Comprehensive Arthroscopic Management - CAM
www.prweb.com/releases/delayshoulderreplacement/camproceduref
Vail, Colorado (PRWEB) September 20, 2013 – Newly published research, s CAM procedure is a viable surgical option to delay shoulder

[VIDEO] **CAM Procedure | Shoulder Osteoarthritis Sui**



www.youtube.com/watch?v=yqi-2dNJ_0A
By shoulderspecialists · 5.4K views
Nov 30, 2010 · <http://drmillett.com> Dr. Peter J. Millett surgeon with the Steadman Clinic in Vail, CO and is procedure.








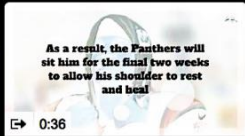
cam newton shoulder surgery

All Videos Images Maps News Shopping | My saves

Also try: cam newton shoulder injury · cam newton injury 2018 · carolina panther...

132,000 Results Any time

Videos of cam newton shoulder surgery
bing.com/videos

 <p>Cam Newton details shoulder injury: It's not getting better, it' NFL.com · 12/17/2018</p>	 <p>NFL Network Insider Ian Rapoport: Carolina Panthers NFL.com · 12/23/2018</p>	 <p>Newton shut down for rest of the season (1:32) ESPN.com · 12/20/2018</p>
 <p>Panthers QB Cam Newton will reportedly sit vs. Falcons this Yahoo · 12/19/2018</p>	 <p>Cam Newton throws first TD of preseason to Kelvin Benjamin NFL.com · 8/25/2017</p>	 <p>As a result, the Panthers will sit him for the final two weeks to allow his shoulder to rest and heal. Panthers to sit Cam Newton for final 2 games of season MSN · 12/20/2018</p>

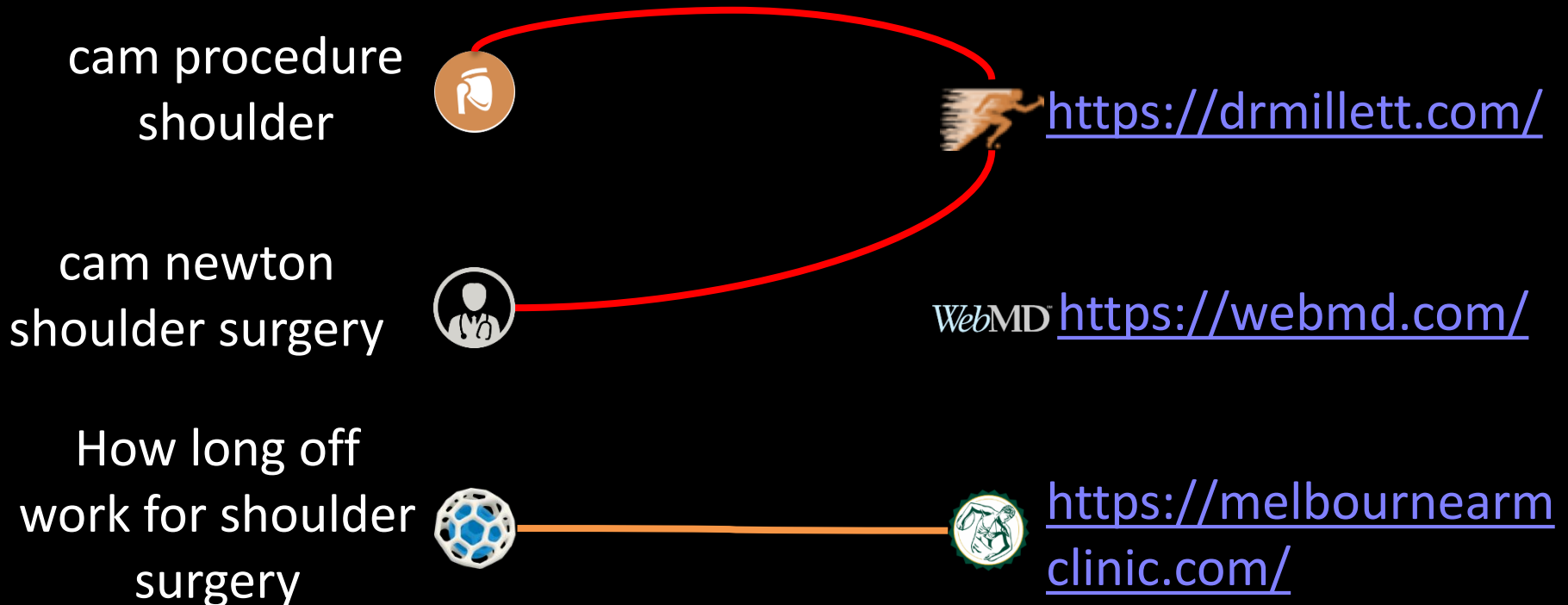
See more videos of cam newton shoulder surgery

Cam Newton recovering after shoulder surgery - NFL.com

www.nfl.com/.../article/cam-newton-recovering-after-shoulder-surgery
Mar 30, 2017 · The process of recovery begins now for Cam Newton. The Panthers announced that their star quarterback is on the mend after undergoing surgery on his throwing shoulder in Charlotte.

Query-URL Based Approaches

- Might not work well for tail queries
- Might lead to content drift



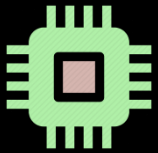
Slice [WSDM 2019]

- Specialized for low-dimensional dense unit-norm features

- Scales to 100 M labels and 240 M training points



- Leverages label sparsity



- Log time training based on negative sampling
- Log time prediction using approximate NN search

- Improvements in Bing Related Searches



Trigger Coverage	Suggestion Density	Success Rate	Tail Success Rate
52.01%	33.0%	2.62%	12.62%

Tagging Wikipedia Articles



Not logged in [Talk](#) [Contributions](#) [Create account](#) [Log in](#)

Article **Talk**

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WIKIPEDIA
The Free Encyclopedia

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Divine Comedy

From Wikipedia, the free encyclopedia

"The Divine Comedy" redirects here. For other uses, see [The Divine Comedy \(disambiguation\)](#).

"La commedia" redirects here. For other uses, see [Commedia \(disambiguation\)](#).

The ***Divine Comedy*** (Italian: *Divina Commedia* [diˈviːna komˈmɛːdja]) is a long narrative poem by Dante Alighieri, begun c. 1308 and completed in 1320, a year before his death in 1321. It is widely considered the preeminent work in Italian literature,^[1] and is seen as one of the greatest works of world literature.^[2] The poem's imaginative vision of the afterlife is representative of the medieval world-view as it had developed in the Western Church by the 14th century. It helped establish the Tuscan language, in which it is written, as the standardized Italian language.^[3] It is divided into three parts: *Inferno*, *Purgatorio*, and *Paradiso*.

The narrative describes Dante's travels through Hell, Purgatory, and Paradise or Heaven;^[4] while allegorically the poem represents the soul's journey towards God.^[5] Dante draws on medieval Christian theology and philosophy, especially Thomistic philosophy and the *Summa Theologica* of Thomas Aquinas.^[6] Consequently, the *Divine Comedy* has been called "the *Summa* in verse".^[7]



Dante shown holding a copy of the *Divine Comedy*, next to the entrance to Hell, the seven terraces of Mount Purgatory and the city of Florence, with the spheres of Heaven above, in Michelino's fresco

Predictions: Wiki vs Extreme Classification

Wikipedia

Works by Dante Alighieri
Divine Comedy
1321 books
1300 in Italy
Visionary poems
Epic poems in Italian
14th-century Christian texts
14th-century books
Virgil
Afterlife

Extreme Classification

Works by Dante Alighieri
Divine Comedy
1321 books
1300 in Italy
Visionary poems
Epic poems in Italian
14th-century Christian texts
14th-century books
Virgil
Dante Alighieri

Recognizing People on Facebook



Choices: Bradley Cooper, Ellen DeGeneres, Meryl Streep, Jennifer Lawrence, Channing Tatum, Julia Roberts, Kevin Spacey, Brad Pitt, Angelina Jolie, Lupita Nyong'o, Peter Nyong'o

Language Modelling

Brevity is the soul of ...



Wit



Twit



Lingerie



Conclusions

- Extreme classification
 - Tackle applications with millions of choices
 - A new paradigm for ranking & recommendation
- Algorithms & papers
 - MLRF [WWW 2013], FastXML [KDD 2014]
 - SLEEC [NIPS 2015], PfastreXML[KDD 2016]
 - SwiftXML [WSDM 2018], Parabel [WWW 2018]
 - Slice [WSDM 2019]
- The Extreme Classification Repository
 - Code & datasets
 - Benchmark results
 - Papers

Research Questions

- Applications
- Obtaining good quality training data
- Log time and space training and prediction
- Obtaining discriminative features at scale
- Extreme loss functions
- Performance evaluation
- Dealing with tail labels and label correlations
- Dealing with missing and noisy labels
- Explore/exploit for tail labels
- Statistical guarantees
- Fine-grained classification

