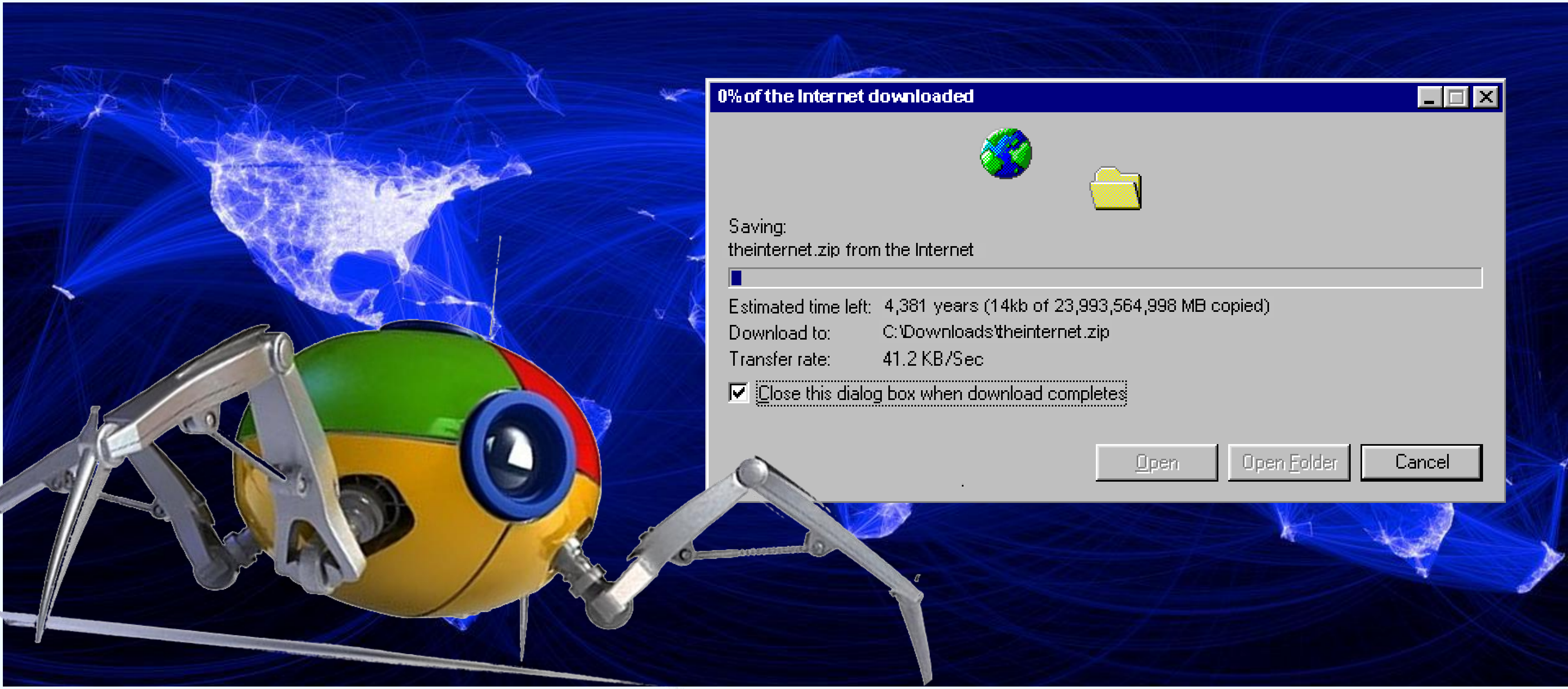
CC5212-1
Procesamiento Masivo de Datos
Otoño 2017

Lecture 7: Information Retrieval II

Aidan Hogan
aidhog@gmail.com

How does Google know about the Web?



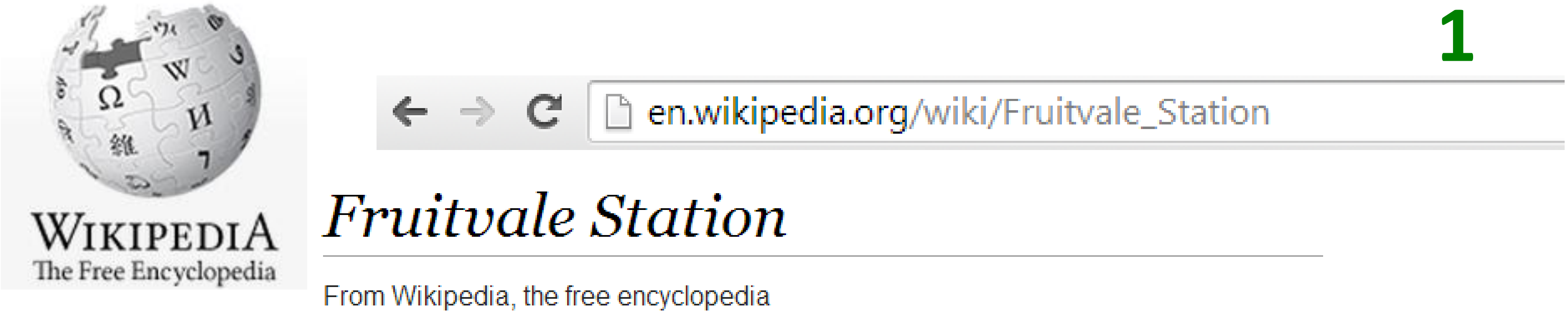
0% of the Internet downloaded

Saving:
theinternet.zip from the Internet

Estimated time left: 4,381 years (14kb of 23,993,564,998 MB copied)
Download to: C:\Downloads\theinternet.zip
Transfer rate: 41.2 KB/Sec

☑ Close this dialog box when download completes

Inverted Index: Example



1

Wikipedia
The Free Encyclopedia

en.wikipedia.org/wiki/Fruitvale_Station

Fruitvale Station

From Wikipedia, the free encyclopedia

Fruitvale Station is a 2013 American drama film written and directed by Ryan Coogler.

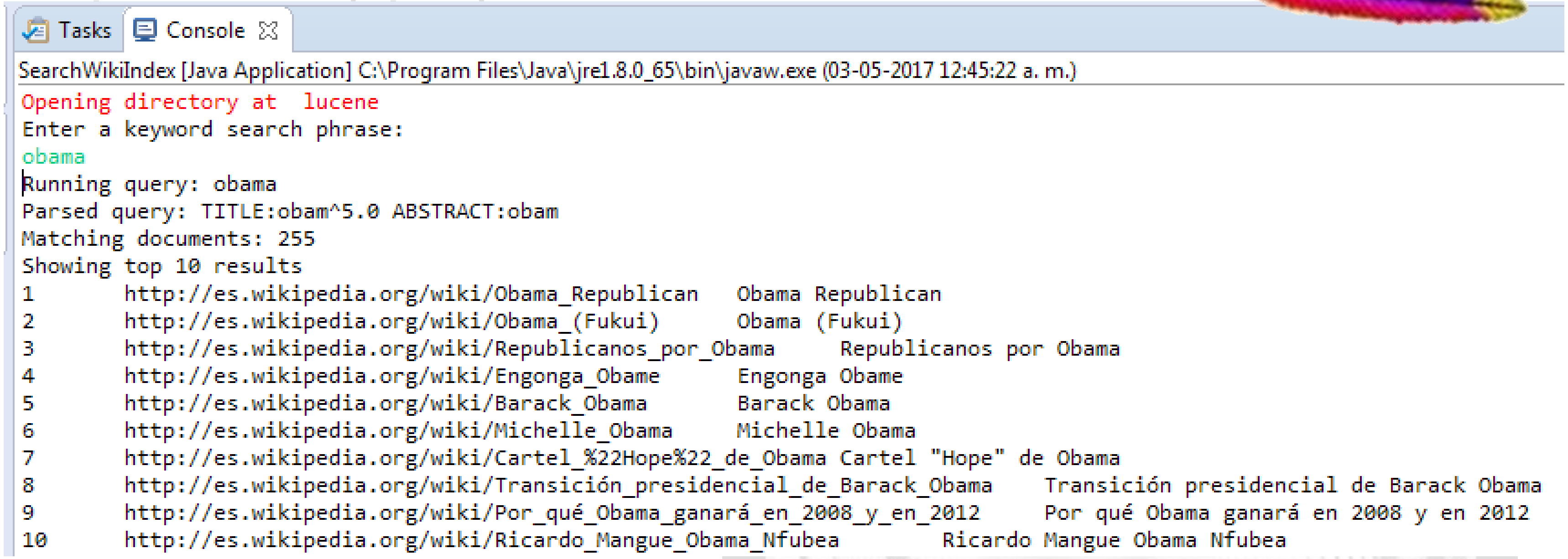
Inverted index:

Term List	Posting List
a	(1,2,…)
american	(1,5,…)
and	(1,2,…)
by	(1,2,…)
directed	(1,2,…)
drama	(1,16,…)
…	…

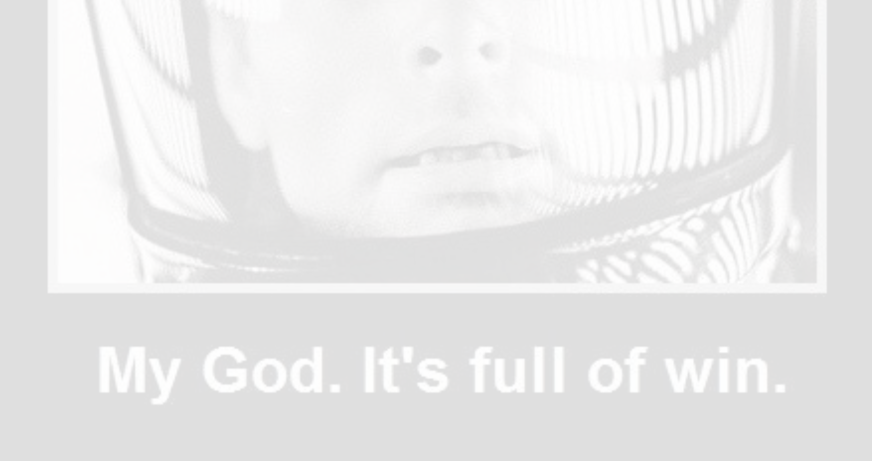
Apache Lucene

- Inverted Index
  - They built one so you don’t have to!
  - Open Source in Java

Apache Lucene

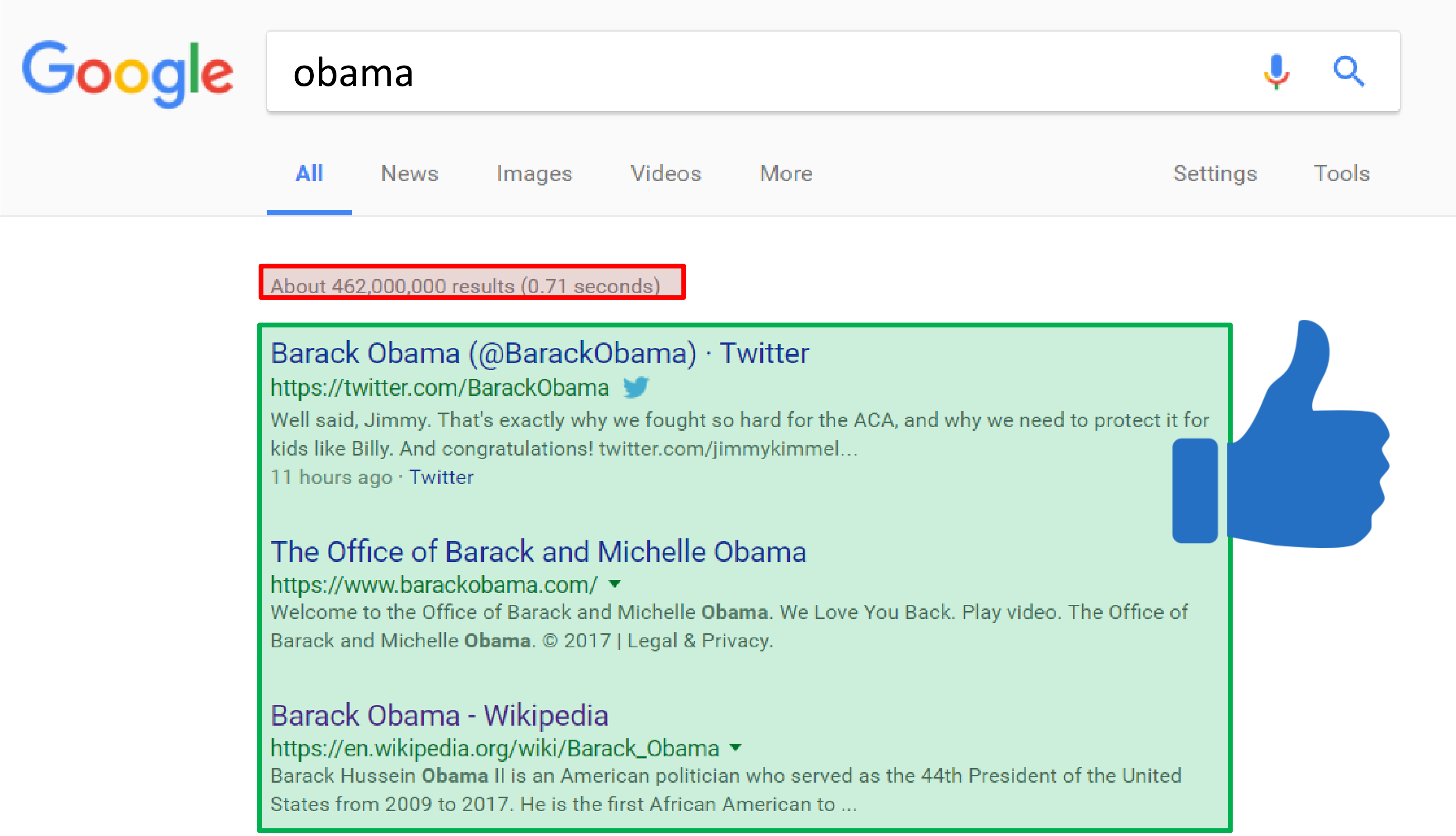


```
SearchWikiIndex [Java Application] C:\Program Files\Java\jre1.8.0_65\bin\javaw.exe (03-05-2017 12:45:22 a. m.)
Opening directory at  lucene
Enter a keyword search phrase:
obama
Running query: obama
Parsed query: TITLE:obam^5.0 ABSTRACT:obam
Matching documents: 255
Showing top 10 results
1       http://es.wikipedia.org/wiki/Obama_Republican   Obama Republican
2       http://es.wikipedia.org/wiki/Obama_(Fukui)      Obama (Fukui)
3       http://es.wikipedia.org/wiki/Republicanos_por_Obama     Republicanos por Obama
4       http://es.wikipedia.org/wiki/Engonga_Obame      Engonga Obame
5       http://es.wikipedia.org/wiki/Barack_Obama       Barack Obama
6       http://es.wikipedia.org/wiki/Michelle_Obama     Michelle Obama
7       http://es.wikipedia.org/wiki/Cartel_%22Hope%22_de_Obama Cartel "Hope" de Obama
8       http://es.wikipedia.org/wiki/Transición_presidencial_de_Barack_Obama    Transición presidencial de Barack Obama
9       http://es.wikipedia.org/wiki/Por_qué_Obama_ganará_en_2008_y_en_2012     Por qué Obama ganará en 2008 y en 2012
10      http://es.wikipedia.org/wiki/Ricardo_Mangue_Obama_Nfubea        Ricardo Mangue Obama Nfubea
```



INFORMATION RETRIEVAL: RANKING

How Does Google Get Such Good Results?



obama

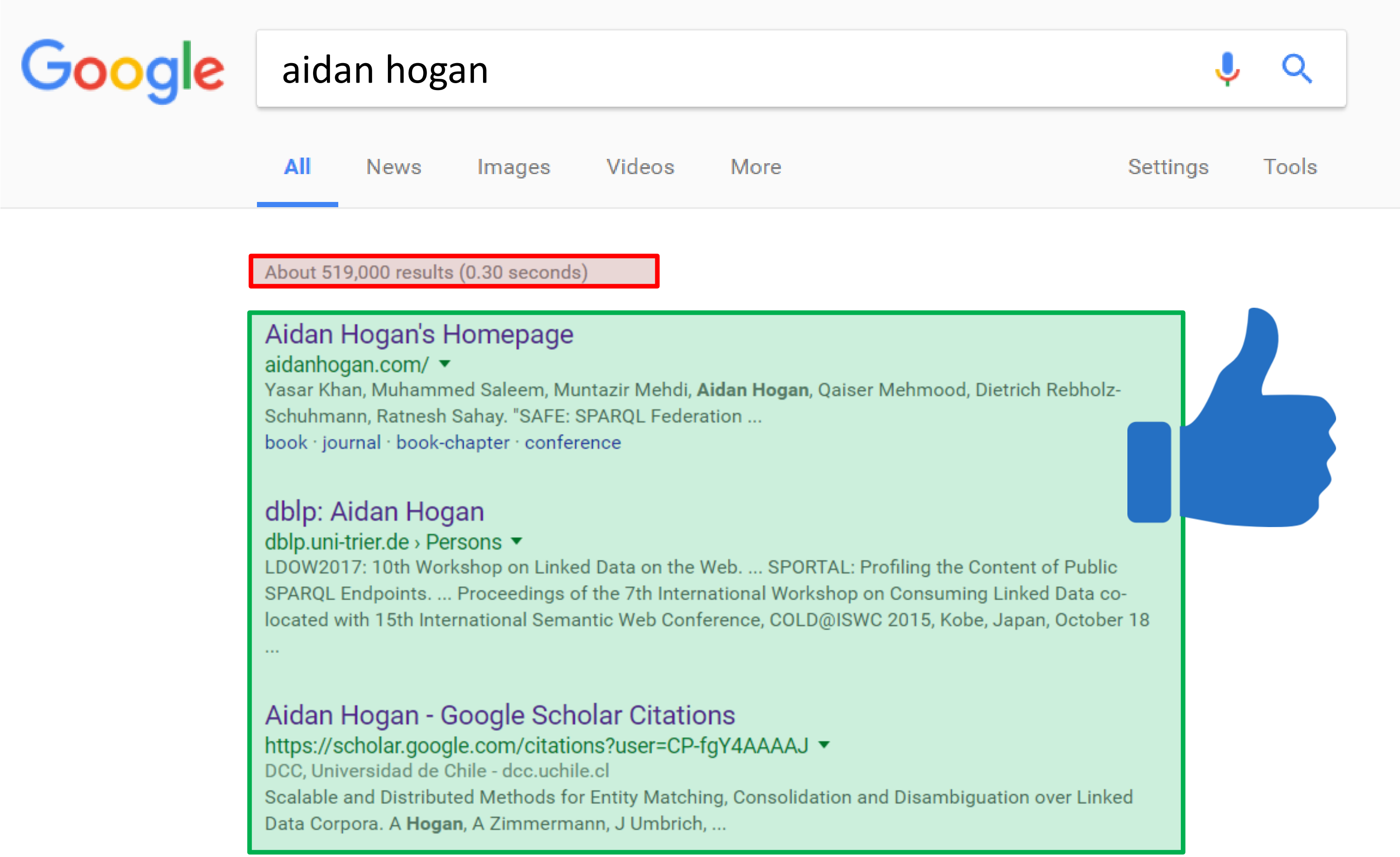
About 462,000,000 results (0.71 seconds)

Barack Obama (@BarackObama) · Twitter
https://twitter.com/BarackObama
Well said, Jimmy. That's exactly why we fought so hard for the ACA, and why we need to protect it for kids like Billy. And congratulations! twitter.com/jimmykimmel...
11 hours ago · Twitter

The Office of Barack and Michelle Obama
https://www.barackobama.com/
Welcome to the Office of Barack and Michelle **Obama**. We Love You Back. Play video. The Office of Barack and Michelle **Obama**. © 2017 | Legal & Privacy.

Barack Obama - Wikipedia
https://en.wikipedia.org/wiki/Barack_Obama
Barack Hussein **Obama** II is an American politician who served as the 44th President of the United States from 2009 to 2017. He is the first African American to ...

How Does Google Get Such Good Results?



aidan hogan

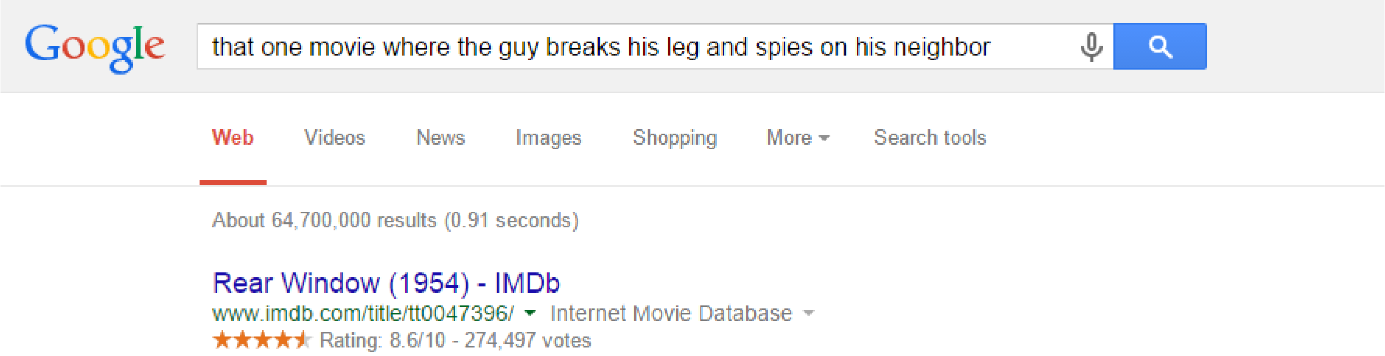
About 519,000 results (0.30 seconds)

Aidan Hogan's Homepage
aidanhogan.com/ ▾
Yasar Khan, Muhammed Saleem, Muntazir Mehdi, **Aidan Hogan**, Qaiser Mehmood, Dietrich Rebholz-Schuhmann, Ratnesh Sahay. "SAFE: SPARQL Federation ...
book · journal · book-chapter · conference

dblp: Aidan Hogan
dblp.uni-trier.de › Persons ▾
LDOW2017: 10th Workshop on Linked Data on the Web. ... SPORTAL: Profiling the Content of Public SPARQL Endpoints. ... Proceedings of the 7th International Workshop on Consuming Linked Data co-located with 15th International Semantic Web Conference, COLD@ISWC 2015, Kobe, Japan, October 18 ...

Aidan Hogan - Google Scholar Citations
https://scholar.google.com/citations?user=CP-fgY4AAAAJ ▾
DCC, Universidad de Chile - dcc.uchile.cl
Scalable and Distributed Methods for Entity Matching, Consolidation and Disambiguation over Linked Data Corpora. A **Hogan**, A Zimmermann, J Umbrich, ...

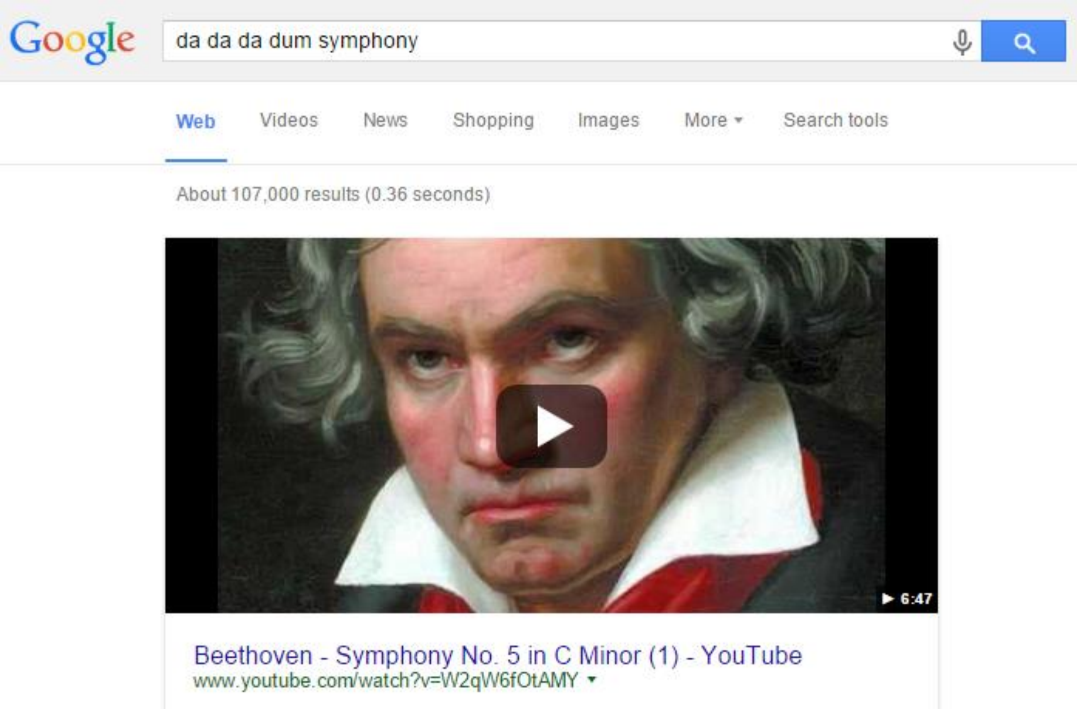
How does Google Get Such Good Results?



that one movie where the guy breaks his leg and spies on his neighbor

About 64,700,000 results (0.91 seconds)

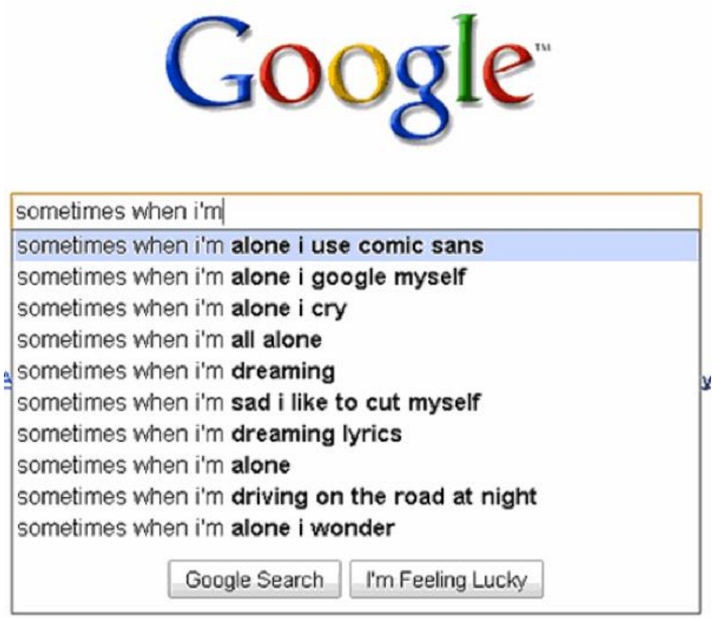
Rear Window (1954) - IMDb
www.imdb.com/title/tt0047396/ Internet Movie Database
★★★★★ Rating: 8.6/10 - 274,497 votes



da da da dum symphony

About 107,000 results (0.36 seconds)

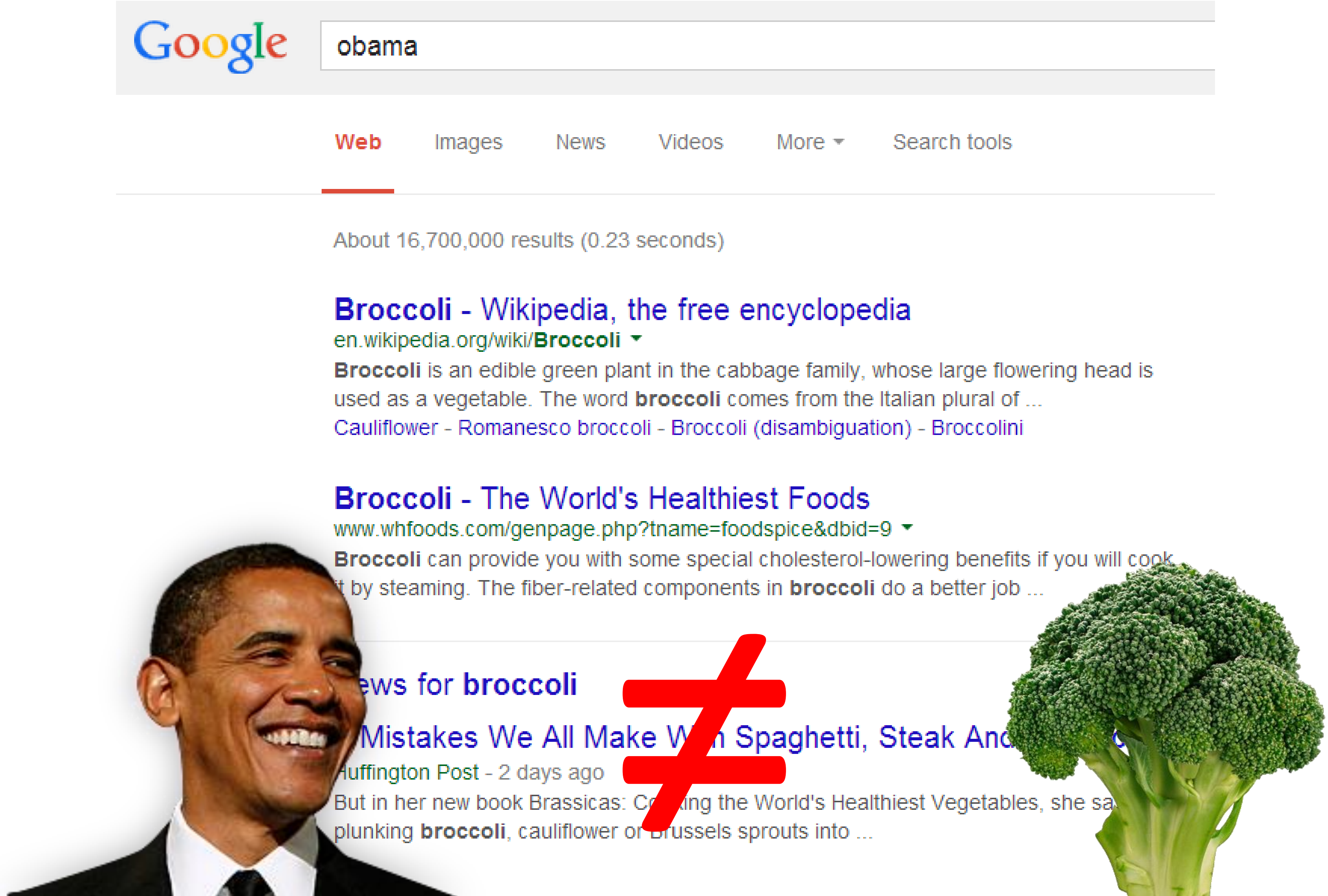
Beethoven - Symphony No. 5 in C Minor (1) - YouTube
www.youtube.com/watch?v=W2qW6fOtAMY



sometimes when i'm

- sometimes when i'm **alone i use comic sans**
- sometimes when i'm **alone i google myself**
- sometimes when i'm **alone i cry**
- sometimes when i'm **all alone**
- sometimes when i'm **dreaming**
- sometimes when i'm **sad i like to cut myself**
- sometimes when i'm **dreaming lyrics**
- sometimes when i'm **alone**
- sometimes when i'm **driving on the road at night**
- sometimes when i'm **alone i wonder**

Two Sides to Ranking: Relevance



About 16,700,000 results (0.23 seconds)

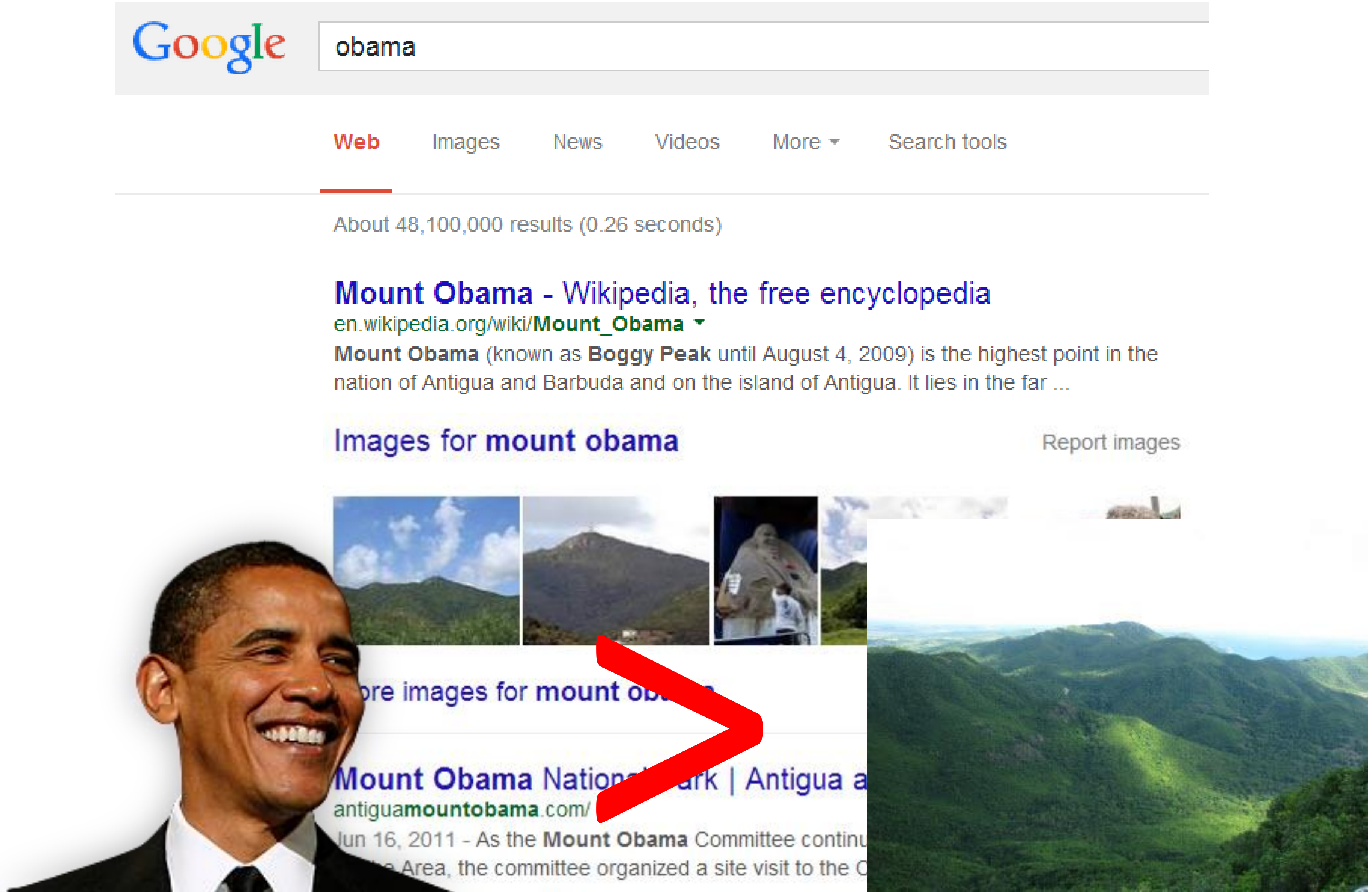
Broccoli - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/**Broccoli**
Broccoli is an edible green plant in the cabbage family, whose large flowering head is used as a vegetable. The word **broccoli** comes from the Italian plural of ...
Cauliflower - Romanesco broccoli - Broccoli (disambiguation) - Broccolini

Broccoli - The World's Healthiest Foods
www.whfoods.com/genpage.php?tname=foodspice&dbid=9
Broccoli can provide you with some special cholesterol-lowering benefits if you will cook t by steaming. The fiber-related components in **broccoli** do a better job ...

ews for broccoli

Mistakes We All Make W h Spaghetti, Steak And
Huffington Post - 2 days ago
But in her new book Brassicas: Co ing the World's Healthiest Vegetables, she sa
plunking **broccoli**, cauliflower or russels sprouts into ...

Two Sides to Ranking: Importance



obama

Web Images News Videos More Search tools

About 48,100,000 results (0.26 seconds)

Mount Obama - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/**Mount_Obama**
Mount Obama (known as **Boggy Peak** until August 4, 2009) is the highest point in the nation of Antigua and Barbuda and on the island of Antigua. It lies in the far ...

Images for **mount obama**

Report images

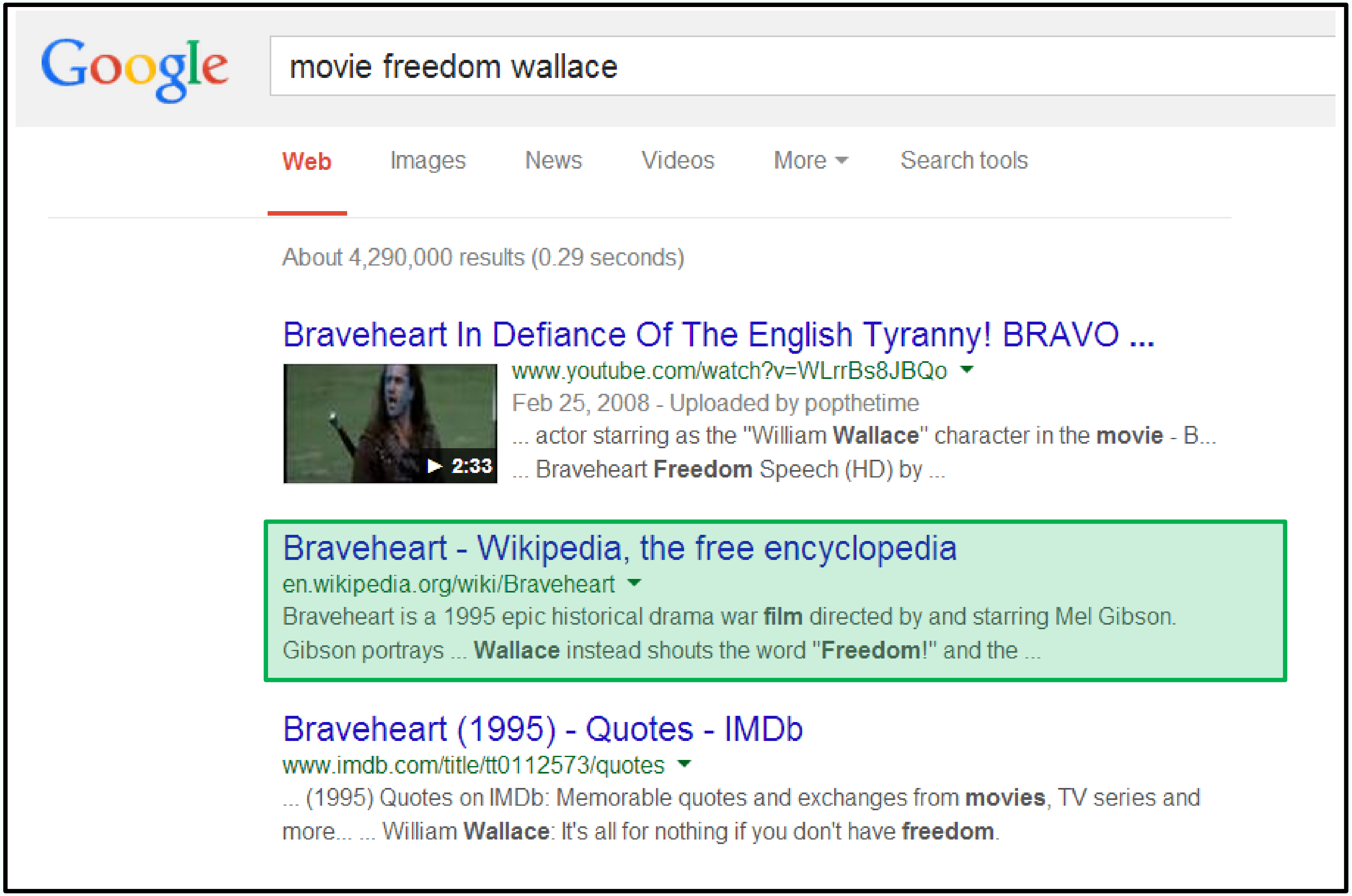
ore images for **mount ob**

Mount Obama Nation ark | Antigua a
antigua**mountobama**.com/
Jun 16, 2011 - As the **Mount Obama** Committee continu
Area, the committee organized a site visit to the C

RANKING:
RELEVANCE

Example Query

Which of these three keyword terms is most "important"? ?



movie freedom wallace

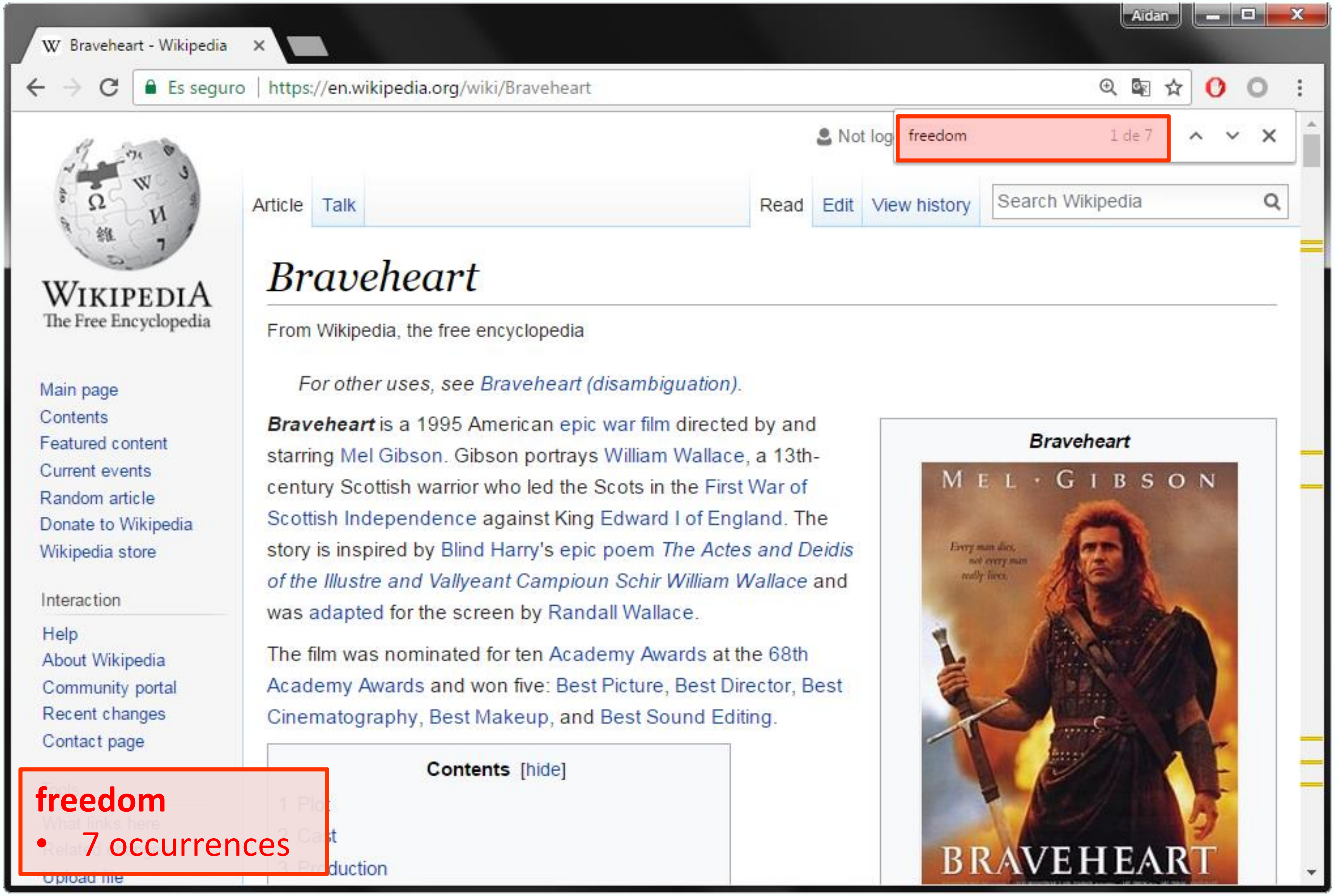
About 4,290,000 results (0.29 seconds)

Braveheart In Defiance Of The English Tyranny! BRAVO ...
www.youtube.com/watch?v=WLrrBs8JBQo
Feb 25, 2008 - Uploaded by popthetime
... actor starring as the "William **Wallace**" character in the **movie** - B...
... Braveheart **Freedom** Speech (HD) by ...

Braveheart - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Braveheart
Braveheart is a 1995 epic historical drama war **film** directed by and starring Mel Gibson. Gibson portrays ... **Wallace** instead shouts the word "**Freedom**!" and the ...

Braveheart (1995) - Quotes - IMDb
www.imdb.com/title/tt0112573/quotes
... (1995) Quotes on IMDb: Memorable quotes and exchanges from **movies**, TV series and more... ... William **Wallace**: It's all for nothing if you don't have **freedom**.

Matches in a Document



Braveheart

From Wikipedia, the free encyclopedia

For other uses, see Braveheart (disambiguation).

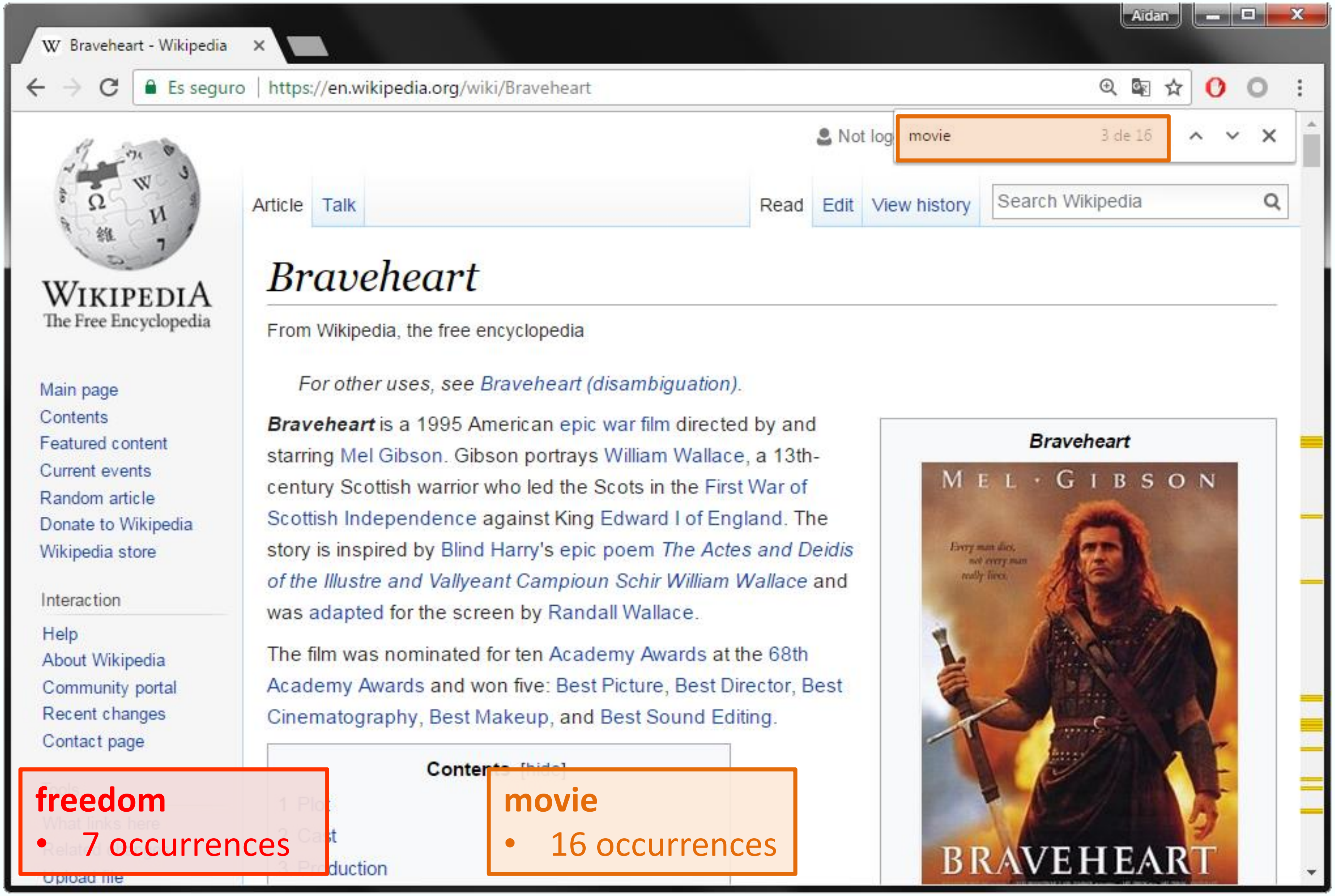
Braveheart is a 1995 American epic war film directed by and starring Mel Gibson. Gibson portrays William Wallace, a 13th-century Scottish warrior who led the Scots in the First War of Scottish Independence against King Edward I of England. The story is inspired by Blind Harry's epic poem *The Actes and Deidis of the Illustre and Vallyeant Campioun Schir William Wallace* and was adapted for the screen by Randall Wallace.

The film was nominated for ten Academy Awards at the 68th Academy Awards and won five: Best Picture, Best Director, Best Cinematography, Best Makeup, and Best Sound Editing.

freedom

- 7 occurrences

Matches in a Document



Braveheart

From Wikipedia, the free encyclopedia

For other uses, see Braveheart (disambiguation).

Braveheart is a 1995 American epic war film directed by and starring Mel Gibson. Gibson portrays William Wallace, a 13th-century Scottish warrior who led the Scots in the First War of Scottish Independence against King Edward I of England. The story is inspired by Blind Harry's epic poem *The Actes and Deidis of the Illustre and Vallyeant Campioun Schir William Wallace* and was adapted for the screen by Randall Wallace.

The film was nominated for ten Academy Awards at the 68th Academy Awards and won five: Best Picture, Best Director, Best Cinematography, Best Makeup, and Best Sound Editing.

Braveheart

Contents [hide]

1 Plot
2 Cast
3 Production

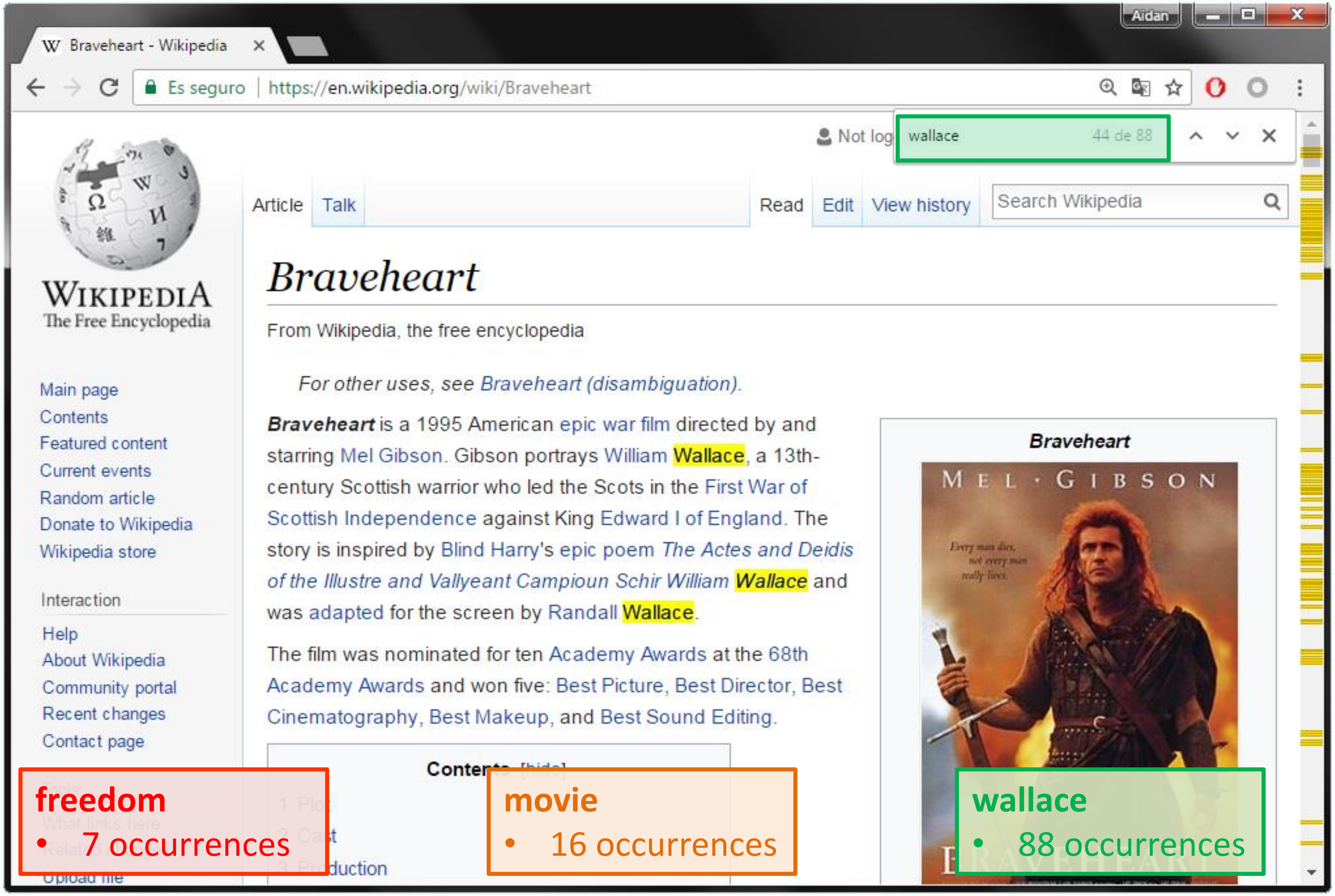
freedom

- 7 occurrences

movie

- 16 occurrences

Matches in a Document



Braveheart

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Braveheart is a 1995 American epic war film directed by and starring Mel Gibson. Gibson portrays William Wallace, a 13th-century Scottish warrior who led the Scots in the First War of Scottish Independence against King Edward I of England. The story is inspired by Blind Harry's epic poem *The Actes and Deidis of the Illustre and Vallyeant Campioun Schir William Wallace* and was adapted for the screen by Randall Wallace.

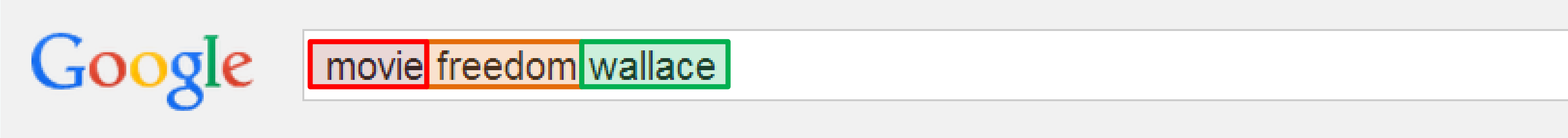
The film was nominated for ten Academy Awards at the 68th Academy Awards and won five: Best Picture, Best Director, Best Cinematography, Best Makeup, and Best Sound Editing.

freedom
- 7 occurrences

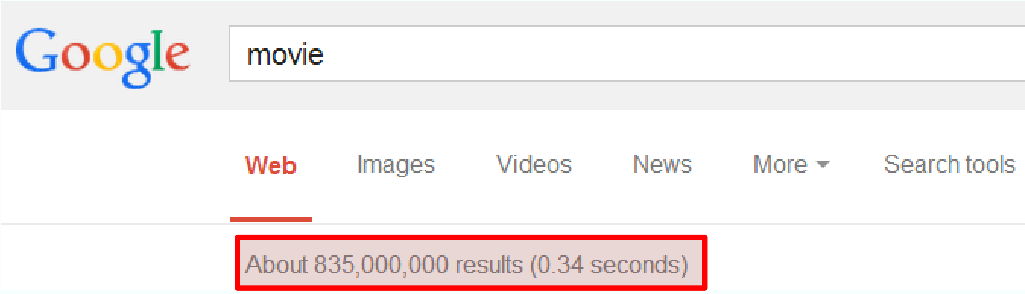
movie
- 16 occurrences

wallace
- 88 occurrences

Usefulness of Words



movie freedom wallace

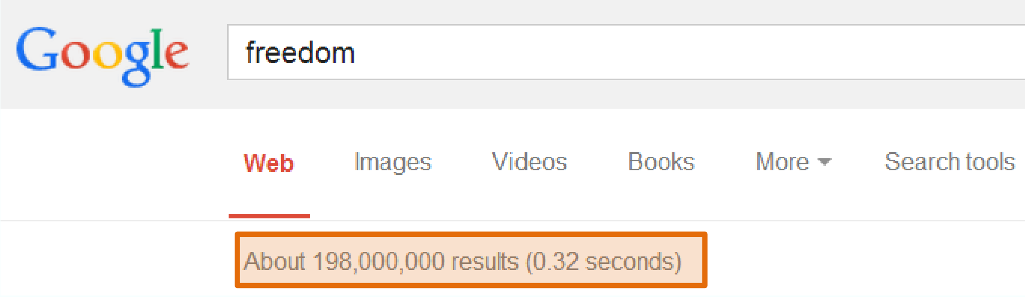


movie

About 835,000,000 results (0.34 seconds)

movie

- occurs very frequently

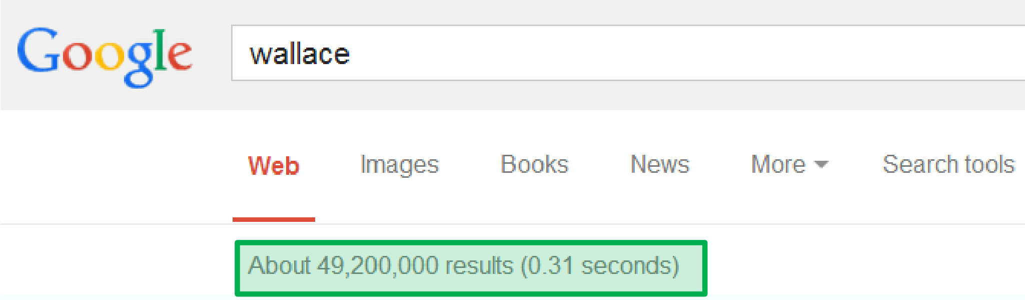


freedom

About 198,000,000 results (0.32 seconds)

freedom

- occurs frequently



wallace

About 49,200,000 results (0.31 seconds)

wallace

- occurs occassionally

Estimating Relevance

- Rare words more important than common words
  - wallace (49M) more important than freedom (198M) more important than movie (835M)

- Words occurring more frequently in a document indicate higher relevance
  - wallace (88) more matches than movie (16) more matches than freedom (7)

Relevance Measure: TF–IDF

- TF: Term Frequency
  - Measures occurrences of a term in a document
  - $\mathrm{tf}(t,d)$ … various options
    - Raw count of occurrences

$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

    - Logarithmically scaled

$$\boxed{\mathrm{tf}(t,d) = \log(\mathrm{count}(t,d) + 1)}$$

    - Normalised by document length

$$\boxed{\mathrm{tf}(t,d) = \frac{\mathrm{count}(t,d)}{\sum_{t' \in d} \mathrm{count}(t',d)}}$$

$$\boxed{\mathrm{tf}(t,d) = \frac{\mathrm{count}(t,d)}{\max_{t' \in d} \mathrm{count}(t',d)}}$$

    - A combination / something else ☺

Relevance Measure: TF–IDF

- IDF: Inverse Document Frequency
  - How common a term is across **all** documents
  - $\mathrm{idf}(t, D)$ …
    - Logarithmically scaled document occurrences

$$\boxed{\mathrm{idf}(t, D) = \log\left(\frac{|D|}{|\{d \in D : t \in d\}| + 1}\right)}$$

    - Note: The more rare, the larger the value

Relevance Measure: TF–IDF

- TF–IDF: Combine Term Frequency and Inverse Document Frequency:

$$\text{tf-idf}(t, d) = \text{tf}(t, d) \times \text{idf}(t, D)$$

- Score for a query
  - Let query $q = (t_1, \ldots, t_n)$
  - Score for a query: $score(q, d) = \sum_{t \in q} \text{tf-idf}(t, d)$

(There are other possibilities)

Relevance Measure: TF–IDF

movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

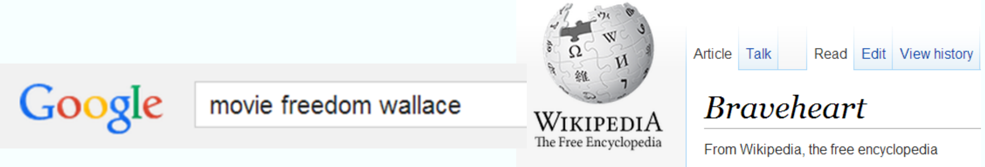
Inverse Document Frequency

$$\boxed{\mathrm{idf}(t,D) = \log_2\left(\frac{|D|}{|\{d \in D : t \in d\}| + 1}\right)}$$

$$\mathrm{tf\text{-}idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

t	$\mathrm{tf}(t,d)$
movie	16
freedom	7
wallace	43

Relevance Measure: TF–IDF



movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

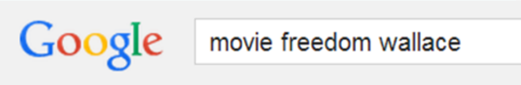
Inverse Document Frequency

$$\boxed{\mathrm{idf}(t,D) = \log_2\left(\frac{|D|}{|\{d\in D : t\in d\}|+1}\right)}$$

$$\text{tf-idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

t	$\mathrm{tf}(t,d)$	$\lvert\{d \in D \,:\, t \in d\}\rvert$
movie	16	835,000,000
freedom	7	198,000,000
wallace	43	49,200,000

Relevance Measure: TF–IDF



movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

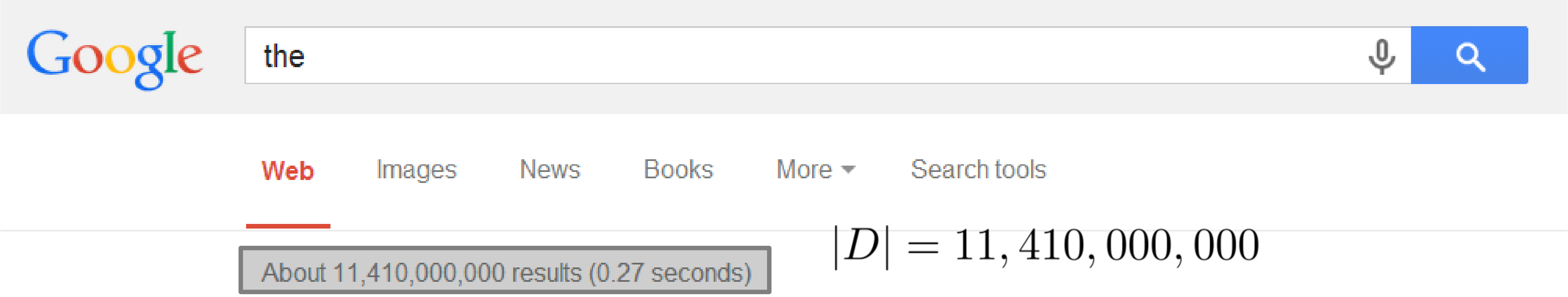
$$\mathrm{tf}(t, d) = \mathrm{count}(t, d)$$

Inverse Document Frequency

$$\mathrm{idf}(t, D) = \log_2\left(\frac{|D|}{|\{d \in D : t \in d\}| + 1}\right)$$

$$\text{tf-idf}(t, d) = \boxed{\mathrm{tf}(t, d)} \times \boxed{\mathrm{idf}(t, D)}$$

t	$\mathrm{tf}(t, d)$	$\lvert\{d \in D : t \in d\}\rvert$	$\frac{\lvert D\rvert}{\lvert\{d \in D : t \in d\}\rvert + 1}$
movie	16	835,000,000	
freedom	7	198,000,000	
wallace	43	49,200,000	

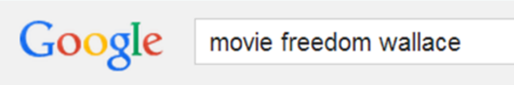


the

About 11,410,000,000 results (0.27 seconds)

$$|D| = 11,410,000,000$$

Relevance Measure: TF–IDF



movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

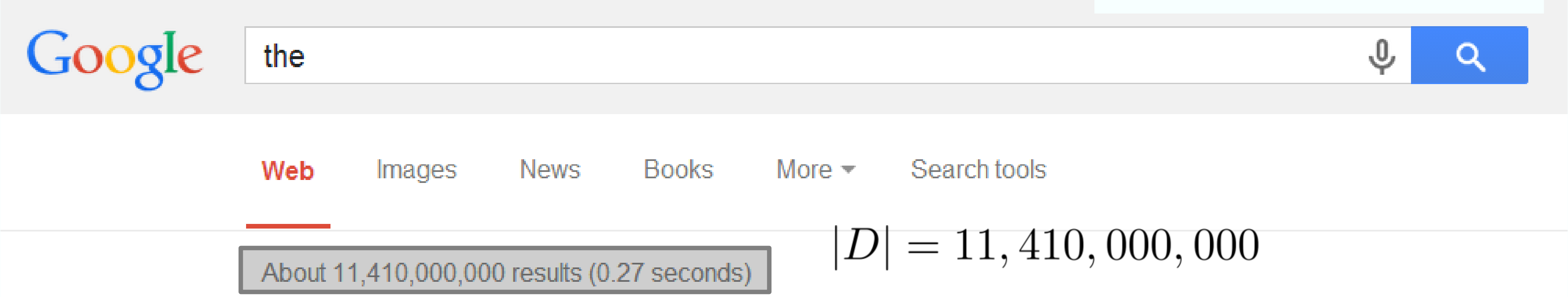
$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

Inverse Document Frequency

$$\boxed{\mathrm{idf}(t,D) = \log_2\left(\frac{|D|}{|\{d \in D : t \in d\}|+1}\right)}$$

$$\text{tf-idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

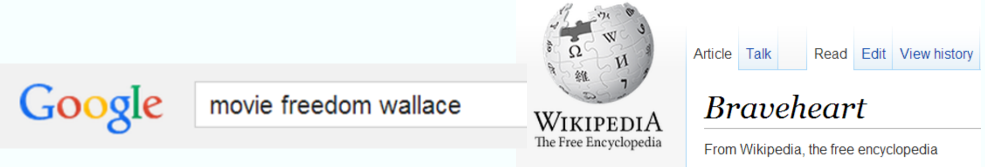
t	$\mathrm{tf}(t,d)$	$\lvert\{d \in D : t \in d\}\rvert$	$\frac{\lvert D\rvert}{\lvert\{d\in D : t\in d\}\rvert+1}$
movie	16	835,000,000	13.66
freedom	7	198,000,000	57.62
wallace	43	49,200,000	231.91



About 11,410,000,000 results (0.27 seconds)

$$|D| = 11,410,000,000$$

Relevance Measure: TF–IDF



movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

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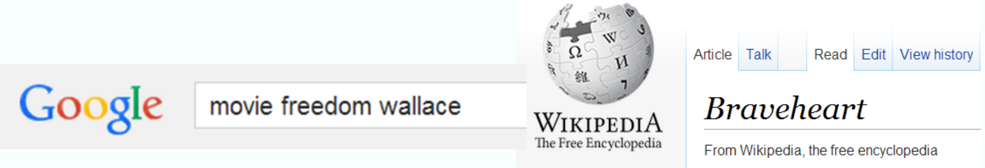
$$\mathrm{tf\text{-}idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

t	$\mathrm{tf}(t,d)$	$\lvert\{d \in D : t \in d\}\rvert$	$\frac{\lvert D\rvert}{\lvert\{d \in D : t \in d\}\rvert+1}$	$\mathrm{idf}(t,D)$
movie	16	835,000,000	13.66	3.77
freedom	7	198,000,000	57.62	5.84
wallace	43	49,200,000	231.91	7.85

Relevance Measure: TF–IDF



Google movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

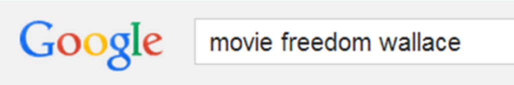
Inverse Document Frequency

$$\boxed{\mathrm{idf}(t,D) = \log_2\left(\frac{|D|}{|\{d \in D : t \in d\}|+1}\right)}$$

$$\text{tf-idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

t	$\mathrm{tf}(t,d)$	$\lvert\{d \in D : t \in d\}\rvert$	$\frac{\lvert D\rvert}{\lvert\{d \in D : t \in d\}\rvert+1}$	$\mathrm{idf}(t,D)$	$\text{tf-idf}(t,d)$
movie	16	835,000,000	13.66	3.77	60.36
freedom	7	198,000,000	57.62	5.84	40.94
wallace	43	49,200,000	231.91	7.85	337.87

Relevance Measure: TF–IDF



movie freedom wallace

Braveheart

From Wikipedia, the free encyclopedia

Term Frequency

$$\boxed{\mathrm{tf}(t,d) = \mathrm{count}(t,d)}$$

Inverse Document Frequency

$$\boxed{\mathrm{idf}(t,D) = \log_2\left(\frac{|D|}{|\{d \in D : t \in d\}|+1}\right)}$$

$$\text{tf-idf}(t,d) = \boxed{\mathrm{tf}(t,d)} \times \boxed{\mathrm{idf}(t,D)}$$

t	$\mathrm{tf}(t,d)$	$\lvert\{d \in D \,:\, t \in d\}\rvert$	$\frac{\lvert D\rvert}{\lvert\{d \in D : t \in d\}\rvert+1}$	$\mathrm{idf}(t,D)$	$\text{tf-idf}(t,d)$
movie	16	835,000,000	13.66	3.77	60.36
freedom	7	198,000,000	57.62	5.84	40.94
wallace	43	49,200,000	231.91	7.85	337.87

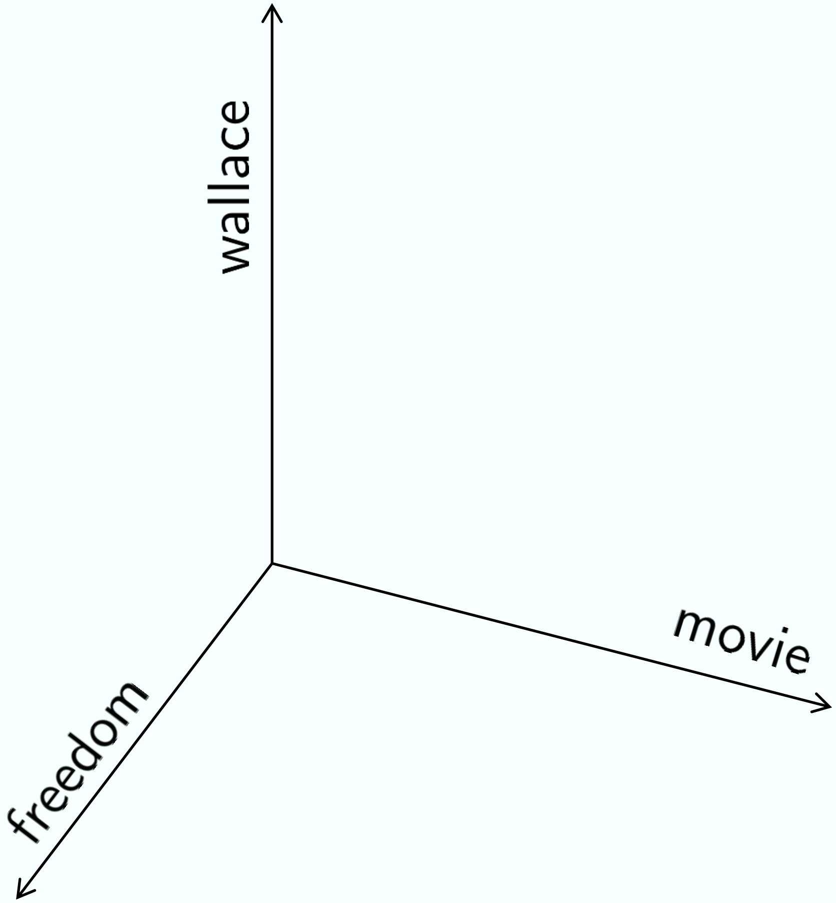
$$\mathrm{score}(q,d) = \sum_{t \in q} \text{tf-idf}(t,d)$$

$$\mathrm{score}\big((\text{movie}, \text{freedom}, \text{wallace}), \text{http://en.wikipedia.org/Braveheart}\big) \approx 439.17$$

Vector Space Model (a mention)

t	$\mathrm{tf}(t, d)$
movie	16
freedom	7
wallace	43

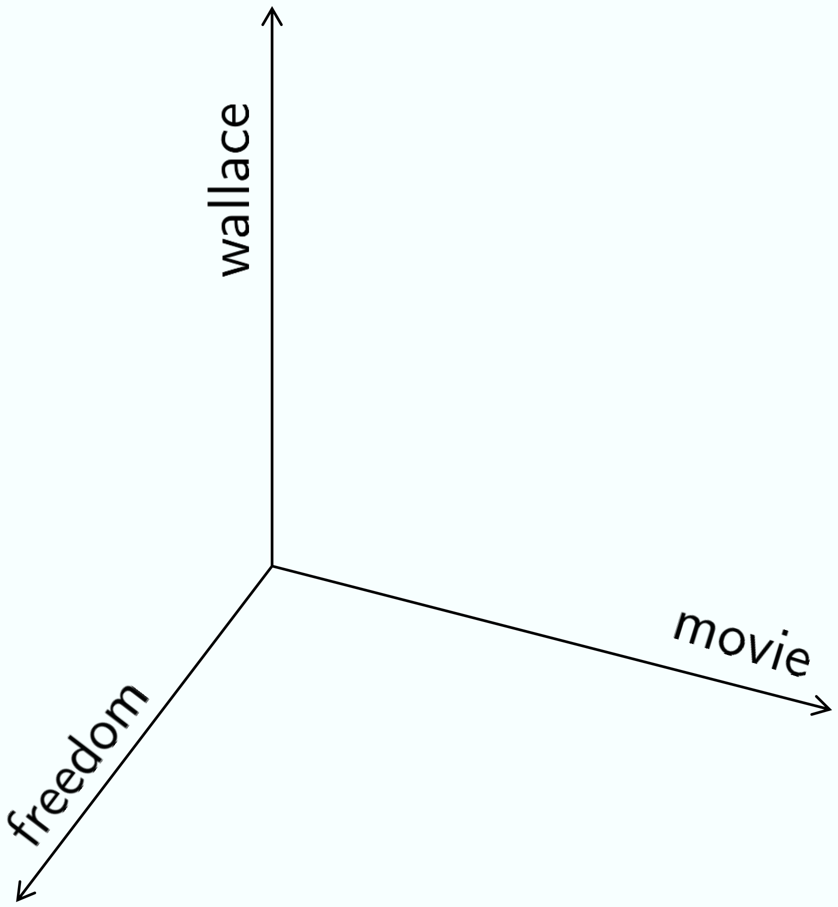
$$l = \sqrt{\sum_{t \in q} \mathrm{tf}(t, d)^2}$$



Vector Space Model (a mention)

t	$\mathrm{tf}(t,d)$	$\mathrm{tf}(t,d)^2$
movie	16	256
freedom	7	49
wallace	43	1,894

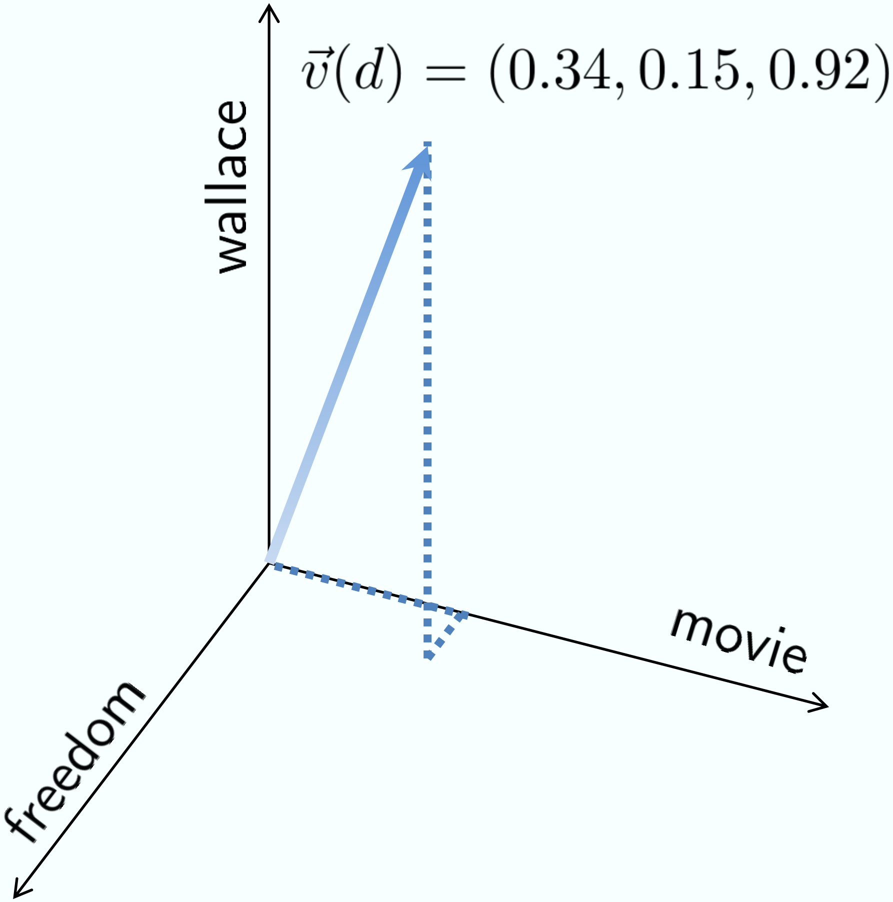
$$l = \sqrt{\sum_{t \in q} \mathrm{tf}(t,d)^2}$$



Vector Space Model (a mention)

t	$\mathrm{tf}(t,d)$	$\mathrm{tf}(t,d)^2$	$\frac{\mathrm{tf}(t,d)}{l}$
movie	16	256	0.34
freedom	7	49	0.15
wallace	43	1,894	0.92

$$l = \sqrt{\sum_{t \in q} \mathrm{tf}(t,d)^2}$$



Dividing by l normalises length of vector to 1

Vector Space Model (a mention)

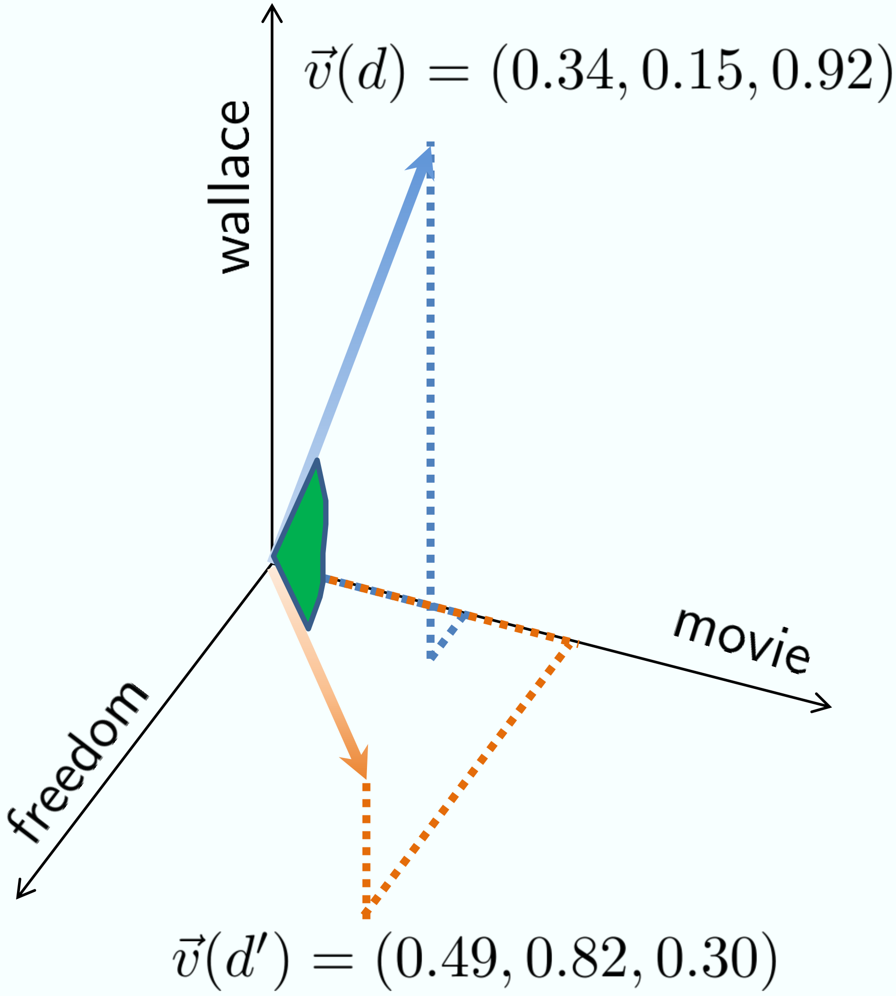
- Cosine Similarity

$$\mathrm{sim}(d, d') = \vec{v}(d) \cdot \vec{v}(d')$$

t	$\vec{v}(d)$	$\vec{v}(d')$	$\times$
movie	0.34	0.49	0.17
freedom	0.15	0.82	0.12
wallace	0.93	0.30	0.28

$\sum$

$$\mathrm{sim}(d, d') \approx \boxed{0.57}$$


$\vec{v}(d) = (0.34, 0.15, 0.92)$
wallace
movie
freedom
$\vec{v}(d') = (0.49, 0.82, 0.30)$

- Note:

$$\mathbf{a} \cdot \mathbf{b} = |\mathbf{a}|\,|\mathbf{b}| \cos(\angle(\mathbf{a}, \mathbf{b}))$$

$$|\vec{v}(d)| = |\vec{v}(d')| = 1$$

Hence the similarity is the cosine of the **angle** between the vectors

Relevance Measure: TF–IDF

- TF–IDF: Combine Term Frequency and Inverse Document Frequency:

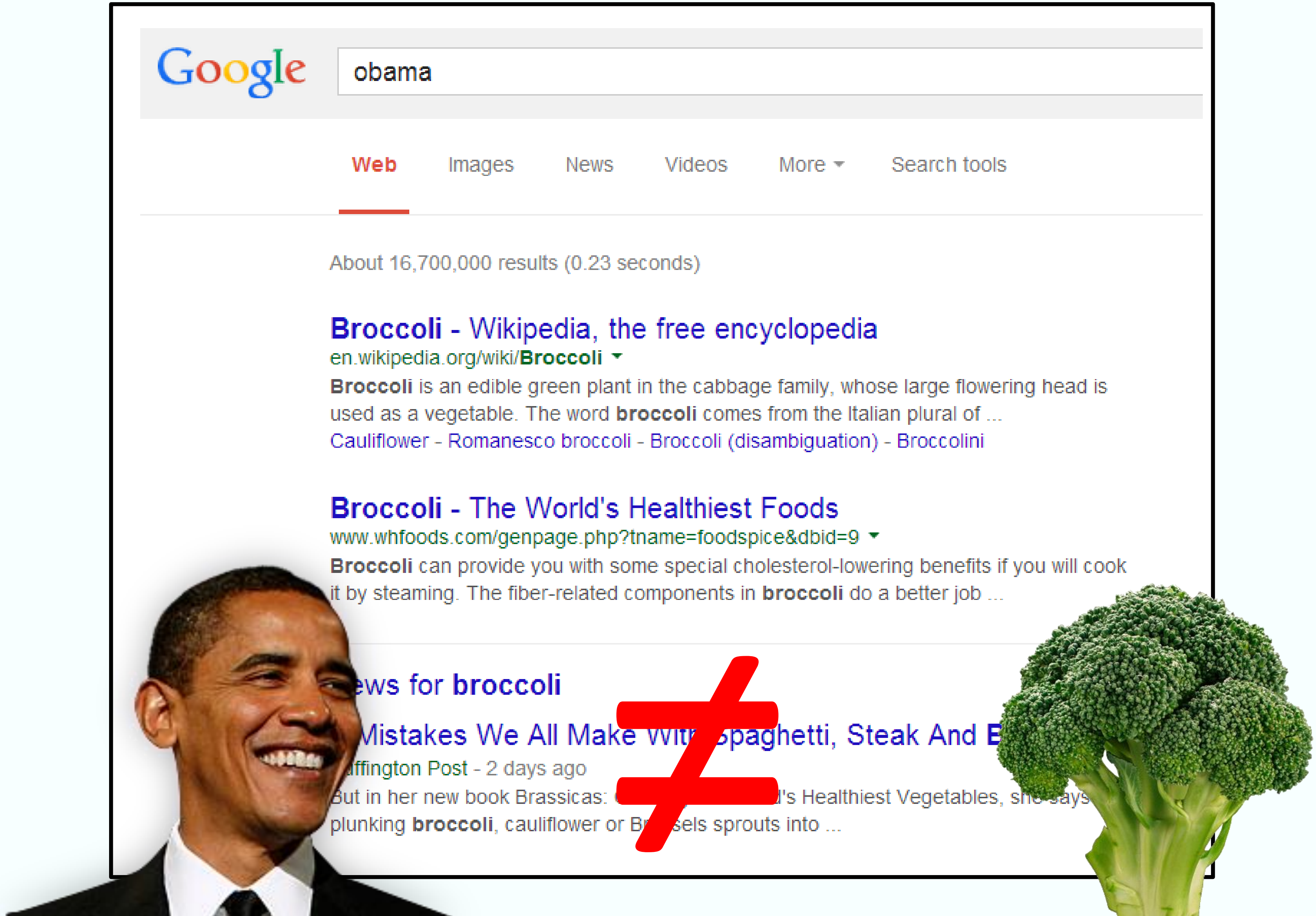
$$\text{tf-idf}(t, d) = \text{tf}(t, d) \times \text{idf}(t, D)$$

- Score for a query
  - Let query $q = (t_1, \ldots, t_n)$
  - Score for a query: $score(q, d) = \sum_{t \in q} \text{tf-idf}(t, d)$

(There are other possibilities)

... we could also use cosine similarity between query and document using TF–IDF weights

Two Sides to Ranking: Relevance



About 16,700,000 results (0.23 seconds)

Broccoli - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/**Broccoli**
Broccoli is an edible green plant in the cabbage family, whose large flowering head is used as a vegetable. The word **broccoli** comes from the Italian plural of ...
Cauliflower - Romanesco broccoli - Broccoli (disambiguation) - Broccolini

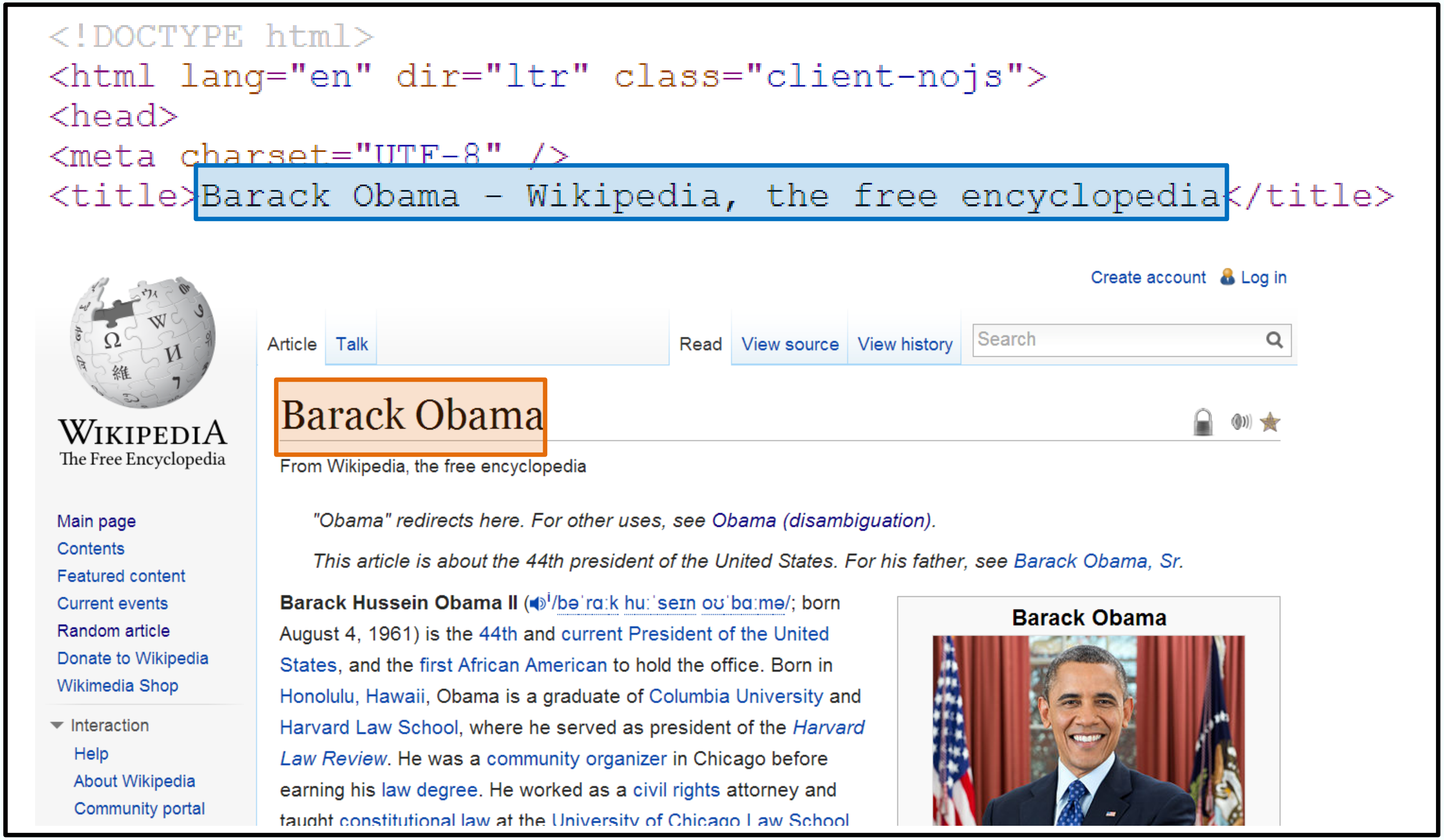
Broccoli - The World's Healthiest Foods
www.whfoods.com/genpage.php?tname=foodspice&dbid=9
Broccoli can provide you with some special cholesterol-lowering benefits if you will cook it by steaming. The fiber-related components in **broccoli** do a better job ...

ews for **broccoli**

Mistakes We All Make Wit Spaghetti, Steak And E
ffington Post - 2 days ago
But in her new book Brassicas: C 's Healthiest Vegetables, sh ays
plunking **broccoli**, cauliflower or B sels sprouts into ...

Field-Based Boosting

- Not all text is equal: titles, headers, etc.



```
<!DOCTYPE html>
<html lang="en" dir="ltr" class="client-nojs">
<head>
<meta charset="UTF-8" />
<title>Barack Obama - Wikipedia, the free encyclopedia</title>
```

Barack Obama

From Wikipedia, the free encyclopedia

"Obama" redirects here. For other uses, see Obama (disambiguation).

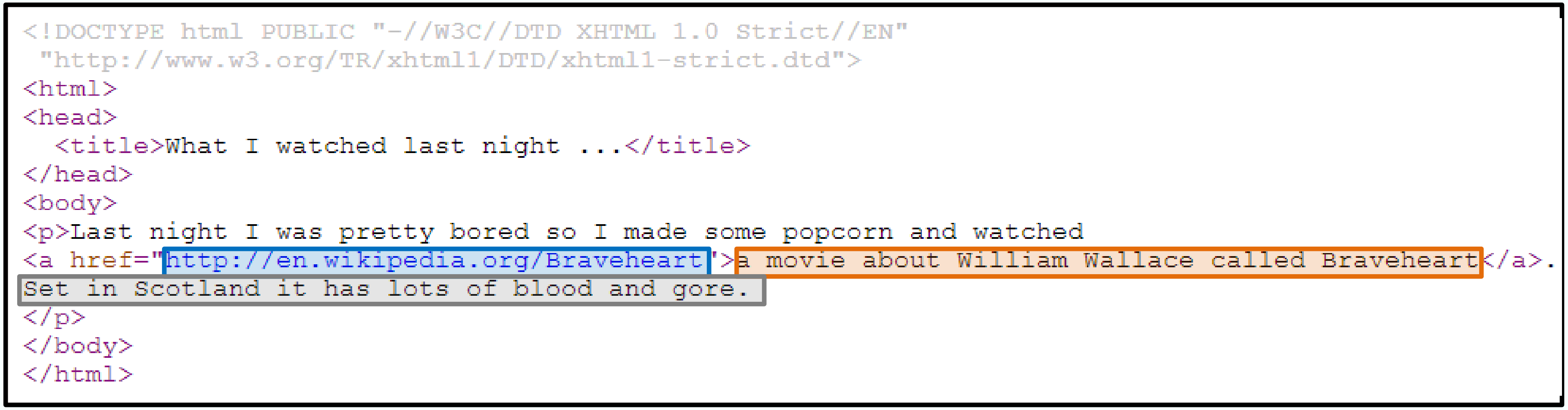
This article is about the 44th president of the United States. For his father, see Barack Obama, Sr.

Barack Hussein Obama II (/bəˈrɑːk huːˈseɪn oʊˈbɑːmə/; born August 4, 1961) is the 44th and current President of the United States, and the first African American to hold the office. Born in Honolulu, Hawaii, Obama is a graduate of Columbia University and Harvard Law School, where he served as president of the *Harvard Law Review*. He was a community organizer in Chicago before earning his law degree. He worked as a civil rights attorney and taught constitutional law at the University of Chicago Law School

Barack Obama

Anchor Text

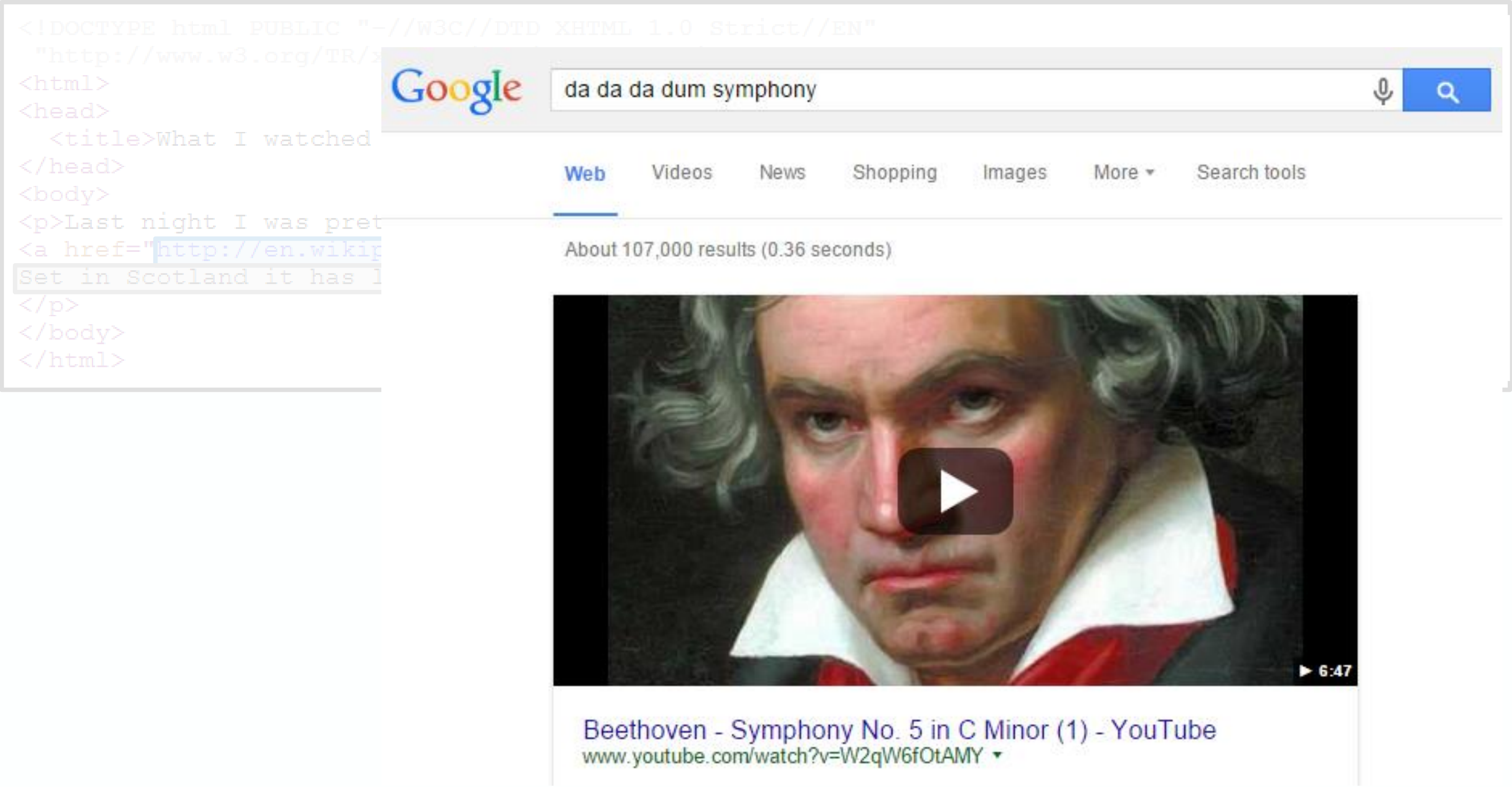
- See how the Web views/tags a page



```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
 "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html>
<head>
  <title>What I watched last night ...</title>
</head>
<body>
<p>Last night I was pretty bored so I made some popcorn and watched
<a href="http://en.wikipedia.org/Braveheart">a movie about William Wallace called Braveheart</a>.
Set in Scotland it has lots of blood and gore.
</p>
</body>
</html>
```

Anchor Text

- See how the Web views/tags a page



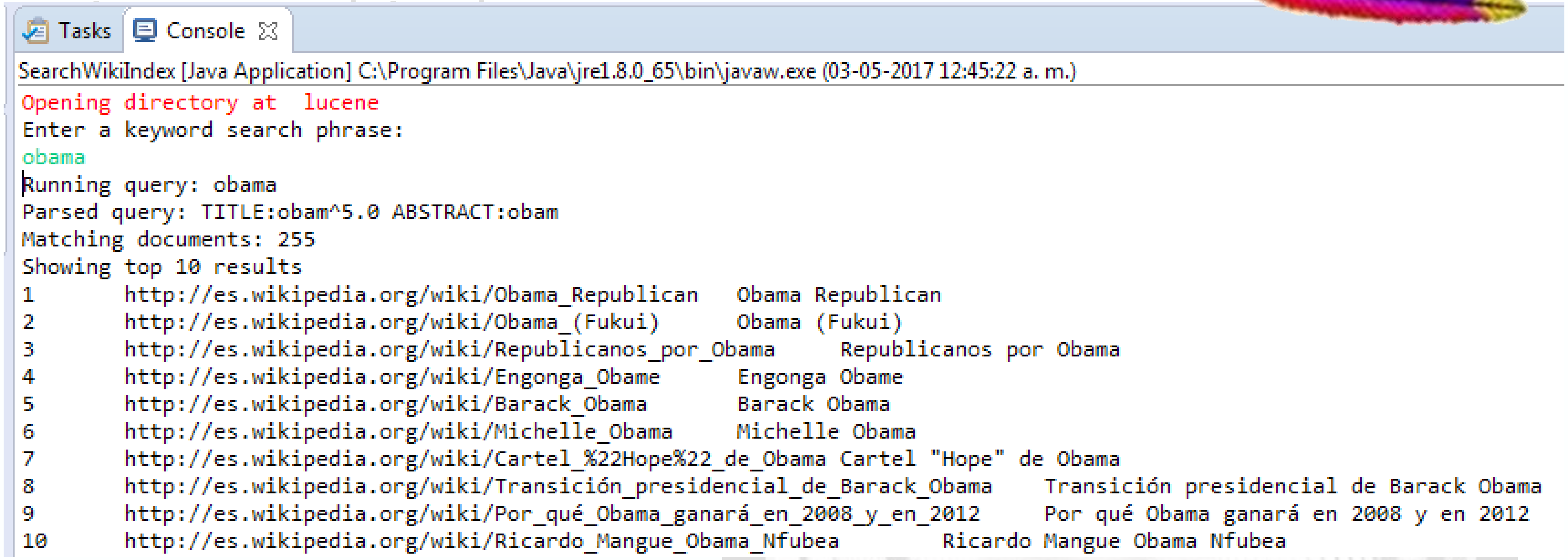
```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
 "http://www.w3.org/TR/x
<html>
<head>
  <title>What I watched
</head>
<body>
<p>Last night I was pret
<a href="http://en.wikip
Set in Scotland it has l
</p>
</body>
</html>
```

da da da dum symphony

About 107,000 results (0.36 seconds)

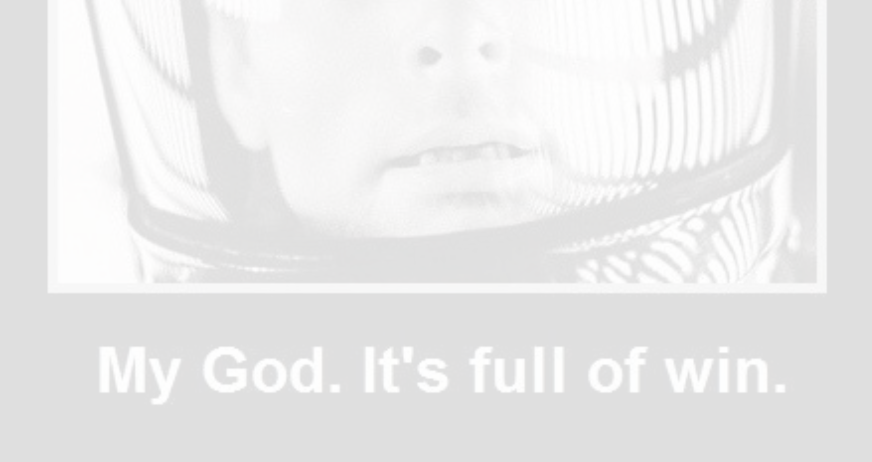
Beethoven - Symphony No. 5 in C Minor (1) - YouTube
www.youtube.com/watch?v=W2qW6fOtAMY

Lucene uses relevance scoring



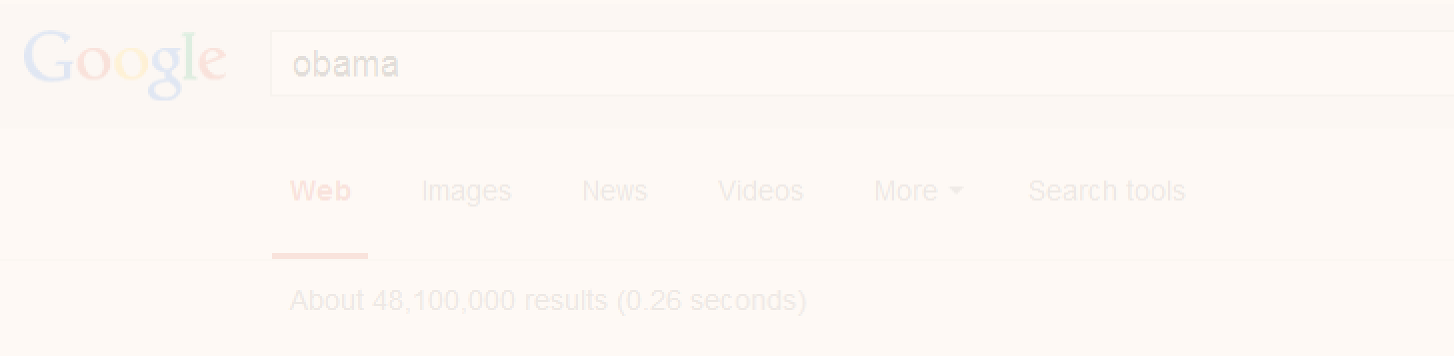
SearchWikiIndex [Java Application] C:\Program Files\Java\jre1.8.0_65\bin\javaw.exe (03-05-2017 12:45:22 a. m.)

```
Opening directory at  lucene
Enter a keyword search phrase:
obama
Running query: obama
Parsed query: TITLE:obam^5.0 ABSTRACT:obam
Matching documents: 255
Showing top 10 results
1       http://es.wikipedia.org/wiki/Obama_Republican   Obama Republican
2       http://es.wikipedia.org/wiki/Obama_(Fukui)      Obama (Fukui)
3       http://es.wikipedia.org/wiki/Republicanos_por_Obama     Republicanos por Obama
4       http://es.wikipedia.org/wiki/Engonga_Obame      Engonga Obame
5       http://es.wikipedia.org/wiki/Barack_Obama       Barack Obama
6       http://es.wikipedia.org/wiki/Michelle_Obama     Michelle Obama
7       http://es.wikipedia.org/wiki/Cartel_%22Hope%22_de_Obama Cartel "Hope" de Obama
8       http://es.wikipedia.org/wiki/Transición_presidencial_de_Barack_Obama    Transición presidencial de Barack Obama
9       http://es.wikipedia.org/wiki/Por_qué_Obama_ganará_en_2008_y_en_2012     Por qué Obama ganará en 2008 y en 2012
10      http://es.wikipedia.org/wiki/Ricardo_Mangue_Obama_Nfubea        Ricardo Mangue Obama Nfubea
```



RANKING: IMPORTANCE

Two Sides to Ranking: Importance



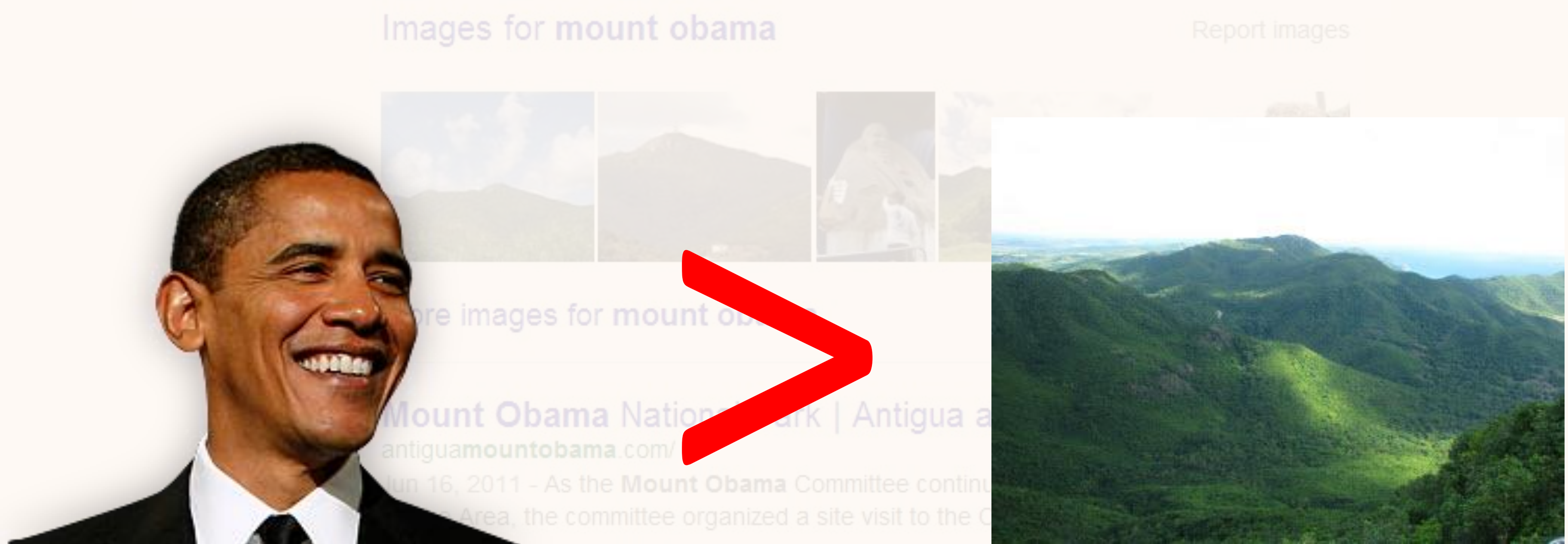
Google

obama

Web Images News Videos More Search tools

About 48,100,000 results (0.26 seconds)

How could we determine that Barack Obama is more important than Mount Obama as a search result on the Web?



Images for **mount obama**

Report images

ore images for **mount ob**

Mount Obama Nation ark | Antigua a

antigua**mountobama**.com/

Jun 16, 2011 - As the **Mount Obama** Committee continu

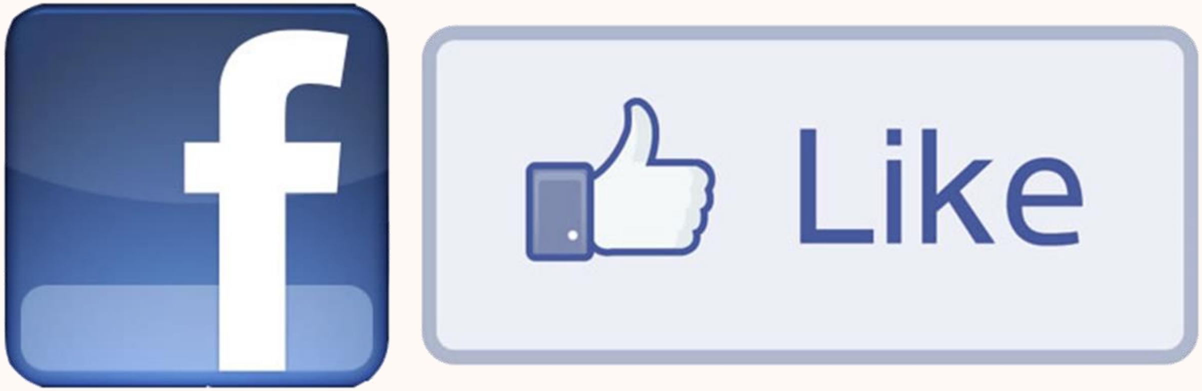
Area, the committee organized a site visit to the C

Link Analysis

Which will have more links from other pages?
The Wikipedia article for Mount Obama?
The Wikipedia article for Barack Obama?

Link Analysis

- Consider links as votes of confidence in a page
- A hyperlink is the open Web's version of …

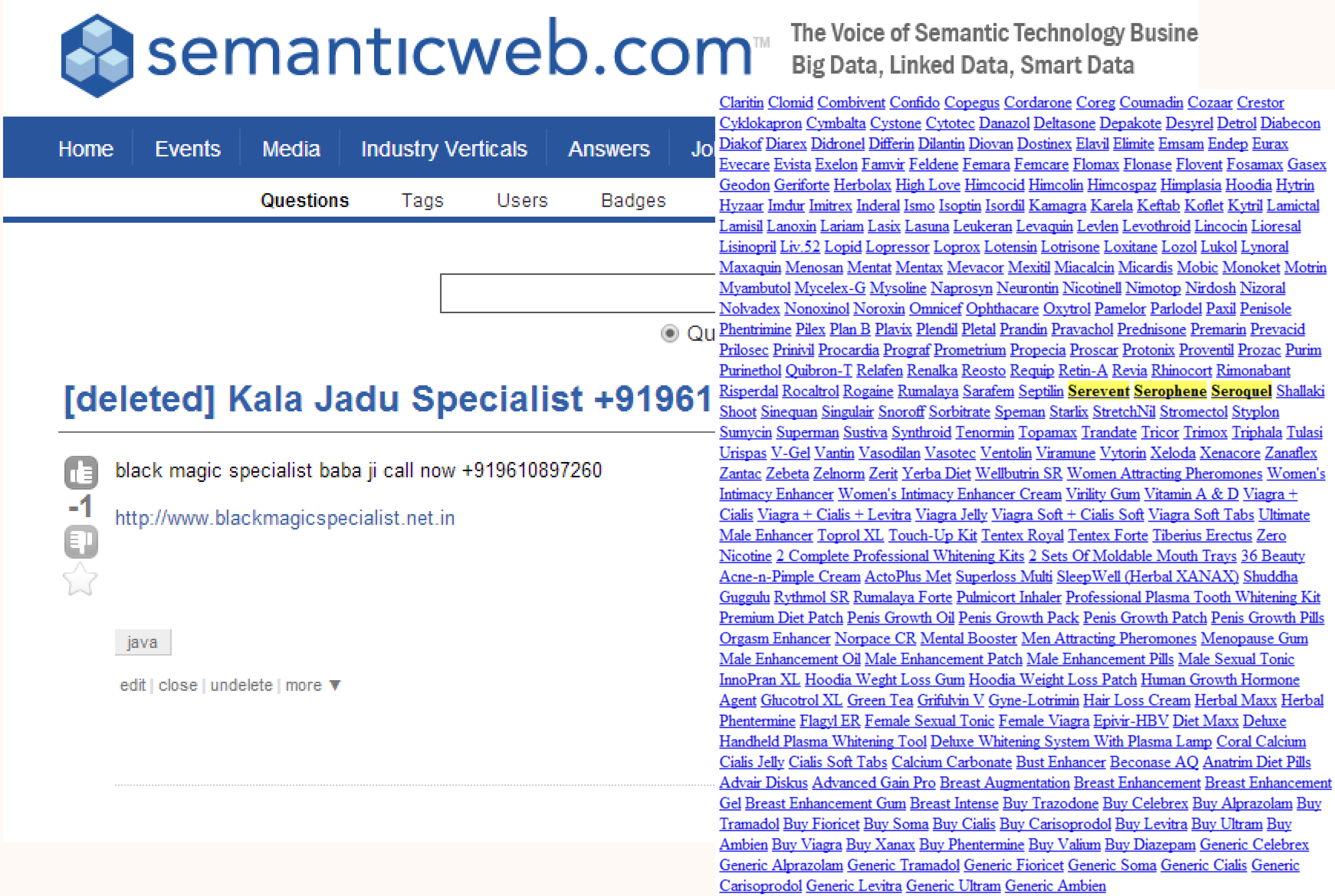


(… even if the page is linked in a negative way.)

Link Analysis

So if we just count links to a page we can determine its importance and we are done?

Link Spamming



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http://www.blackmagicspecialist.net.in

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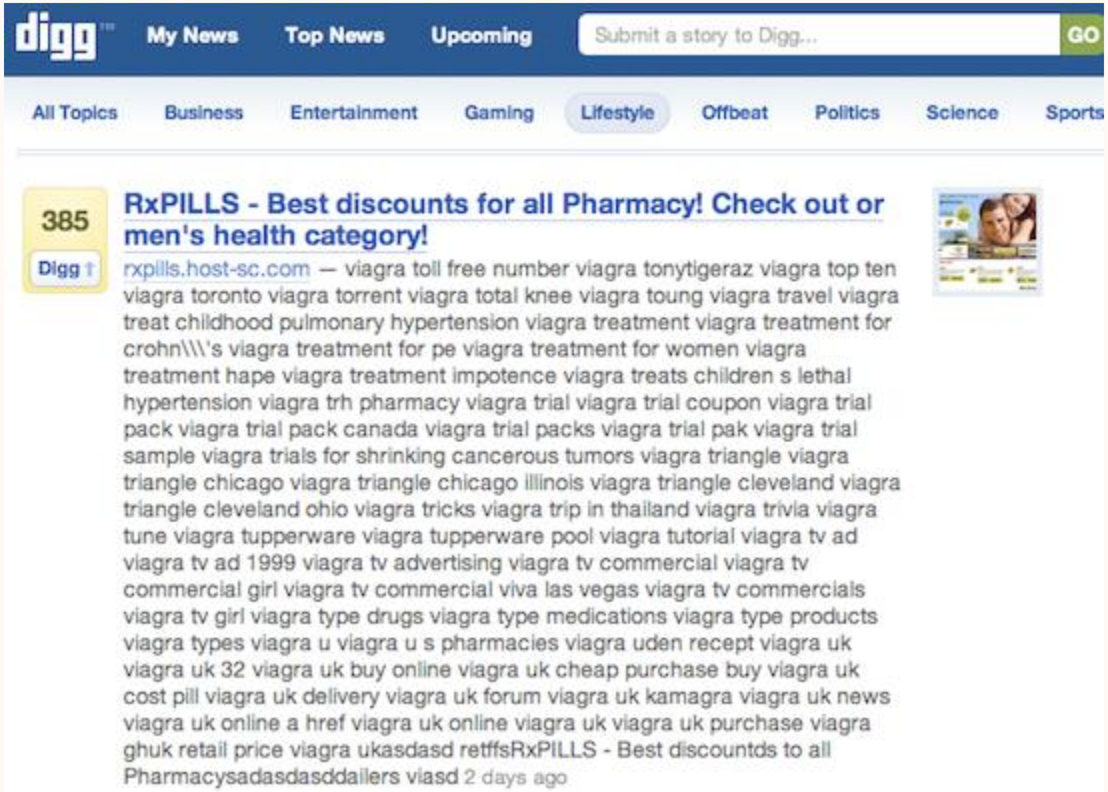
Link Importance

So which should count for more?
A link from http://en.wikipedia.org/wiki/Barack_Obama?
Or a link from http://freev1agra.com/shop.html?

Link Importance

Maybe we could consider links from some domains as having more “vote”?



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PageRank

PageRank

- Not just a count of inlinks
  - A link from a more important page is more important
  - A link from a page with fewer links is more important

  ∴ A page with lots of inlinks from important pages (which have few outlinks) is more important

PageRank is Recursive

- Not just a count of inlinks
  - A link from a more important page is more important
  - A link from a pag

∴ A page with lots

have few out

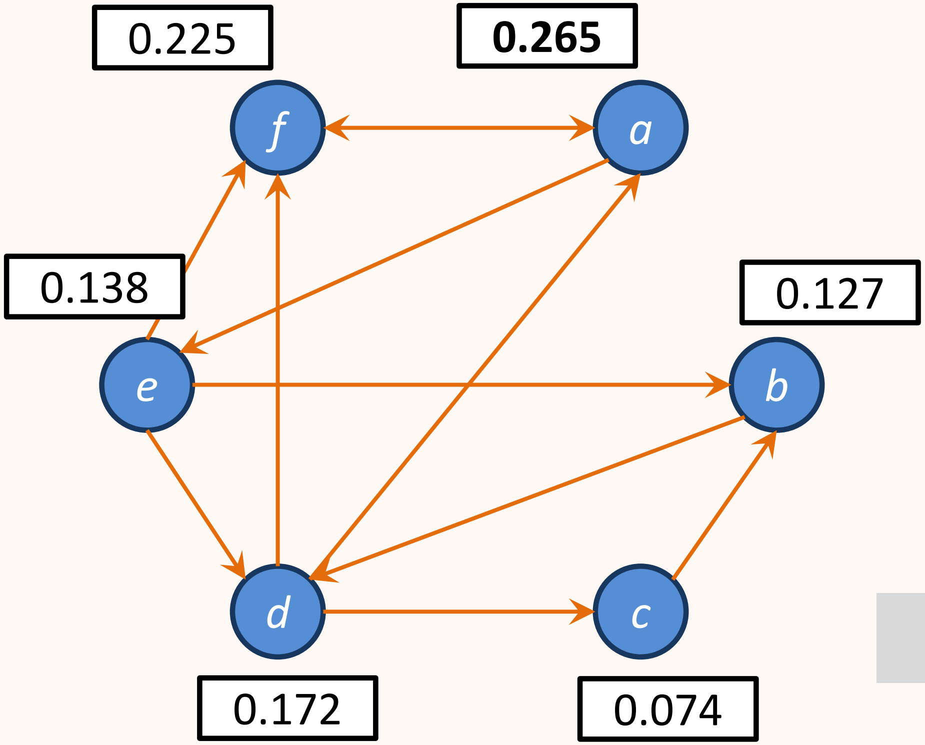
PageRank Model

- The Web: a directed graph

$G = \boxed{(V,}\boxed{E)}$

Vertices (*pages*)

Edges (*links*)



Which vertex is most important? ?

$V = \{a, b, c, d, e, f\}$

$E = \{(a,e), (a,f), (b,d), (c,b), (d,a), (d,c), (d,f), (e,b), (e,d), (e,f), (f,a)\}$

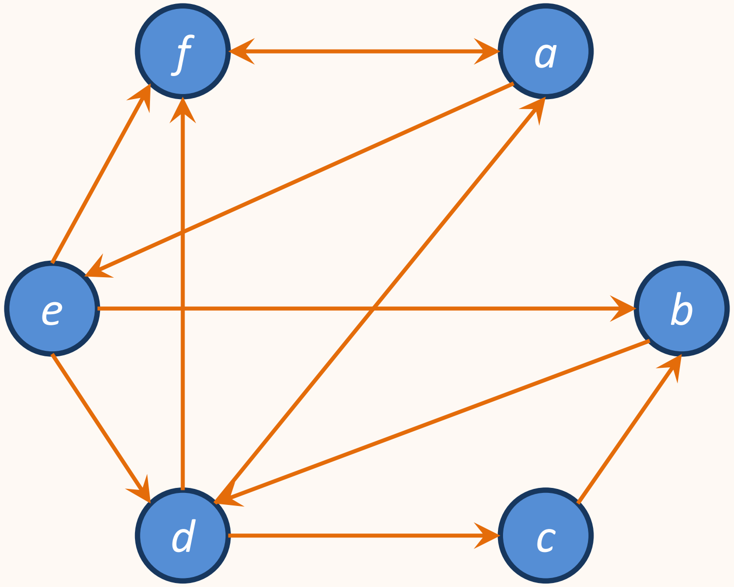
PageRank Model

- The Web: a directed graph

$$G = (\boxed{V}, \boxed{E})$$

Vertices (*pages*)

Edges (*links*)

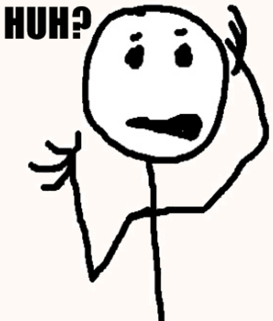


$$\mathrm{out}(v) \coloneqq \{v' \in V \mid (v, v') \in E\}$$

$$\mathrm{in}(v) \coloneqq \{v' \in V \mid (v', v) \in E\}$$

$$\mathrm{rank}_0(v) \coloneqq \frac{1}{|V|}$$

$$\mathrm{rank}_i(v) \coloneqq \sum_{v' \in \mathrm{in}(v)} \frac{\mathrm{rank}_{i-1}(v')}{|\mathrm{out}(v')|}$$



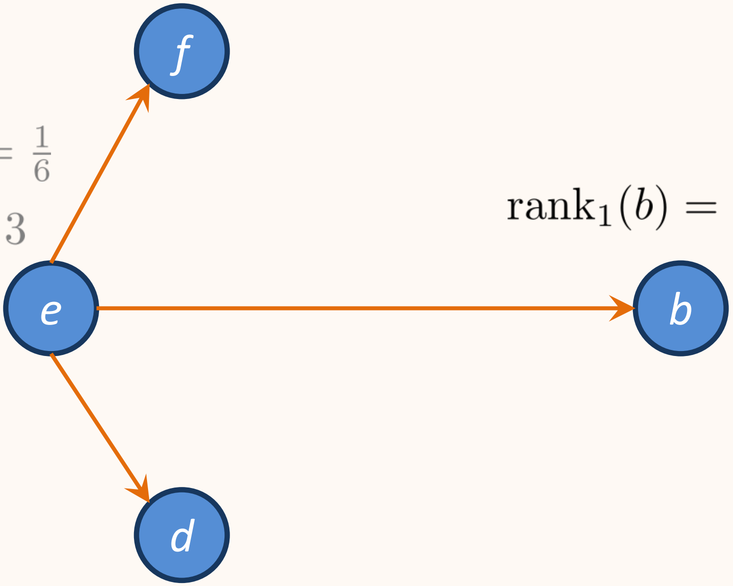
PageRank Model

$$G = (V, E)$$

Vertices (*pages*)

Edges (*links*)

$$\mathrm{rank}_1(f) = \tfrac{1}{6} \times \tfrac{1}{3}$$



$$\mathrm{rank}_0(e) = \tfrac{1}{6}$$

$$|\mathrm{out}(e)| = 3$$

$$\mathrm{rank}_1(b) = \tfrac{1}{6} \times \tfrac{1}{3}$$

$$\mathrm{rank}_1(d) = \tfrac{1}{6} \times \tfrac{1}{3}$$

$$\mathrm{out}(v) \coloneqq \{v' \in V \mid (v, v') \in E\}$$

$$\mathrm{in}(v) \coloneqq \{v' \in V \mid (v', v) \in E\}$$

$$\mathrm{rank}_0(v) \coloneqq \frac{1}{|V|}$$

$$\mathrm{rank}_i(v) \coloneqq \sum_{v' \in \mathrm{in}(v)} \frac{\mathrm{rank}_{i-1}(v')}{|\mathrm{out}(v')|}$$

PageRank Model

$\mathrm{rank}_2(a) = \frac{1}{6} \times \frac{1}{3} \times 1 + \frac{1}{6} \times \frac{1}{3} \times \frac{1}{3}$

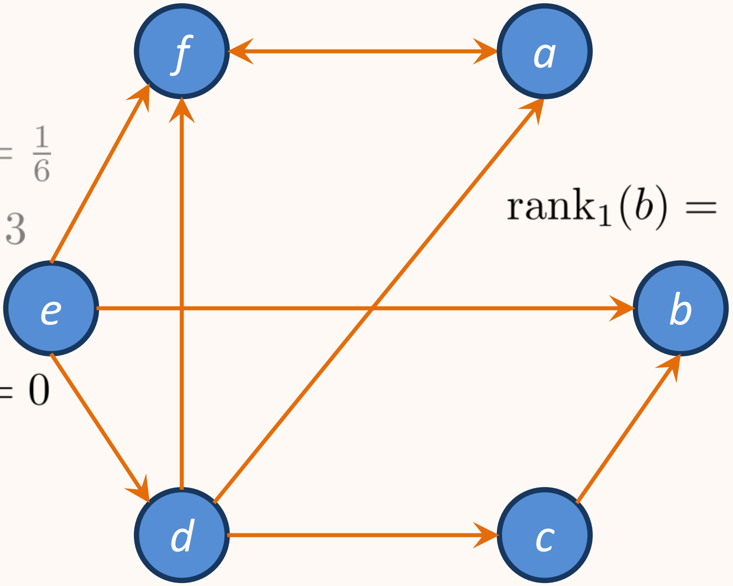
$\mathrm{rank}_1(f) = \frac{1}{6} \times \frac{1}{3}$

$\mathrm{rank}_1(a) = \frac{1}{6} \times 1 + \frac{1}{6} \times \frac{1}{3}$

$G = (V, E)$

Vertices (*pages*)

Edges (*links*)



$\mathrm{rank}_0(e) = \frac{1}{6}$

$|\mathrm{out}(e)| = 3$

$\mathrm{rank}_1(b) = \frac{1}{6} \times \frac{1}{3} + 1 \times \frac{1}{6}$

$\mathrm{rank}_1(e) = 0$

$$\mathrm{out}(v) \coloneqq \{v' \in V \mid (v, v') \in E\}$$

$$\mathrm{in}(v) \coloneqq \{v' \in V \mid (v', v) \in E\}$$

$$\mathrm{rank}_0(v) \coloneqq \frac{1}{|V|}$$

$$\mathrm{rank}_i(v) \coloneqq \sum_{v' \in \mathrm{in}(v)} \frac{\mathrm{rank}_{i-1}(v')}{|\mathrm{out}(v')|}$$

$\mathrm{rank}_1(d) = \frac{1}{6} \times \frac{1}{3}$

$\mathrm{rank}_0(c) = \frac{1}{6}$

$|\mathrm{out}(c)| = 1$

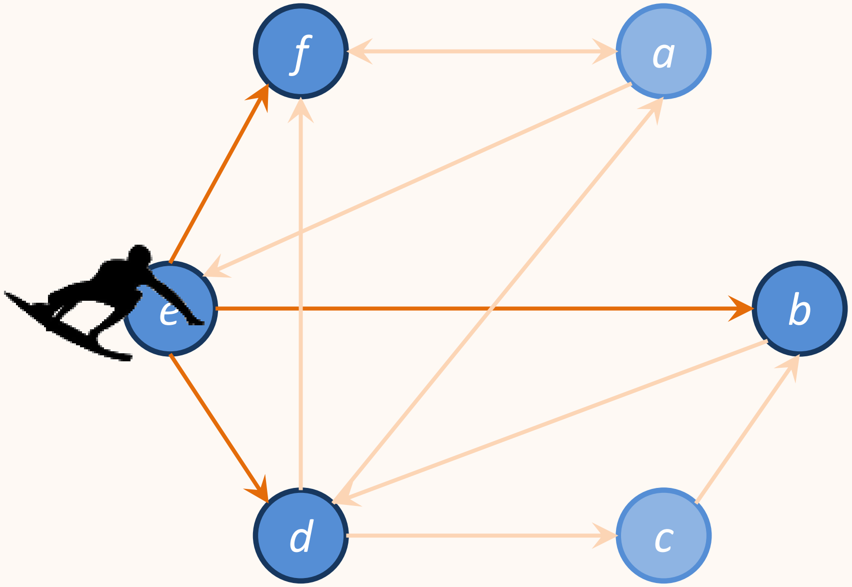
$\mathrm{rank}_1(c) = \frac{1}{6} \times \frac{1}{3}$

$\mathrm{rank}_2(c) = \frac{1}{6} \times \frac{1}{3} \times \frac{1}{3}$

PageRank: Random Surfer Model

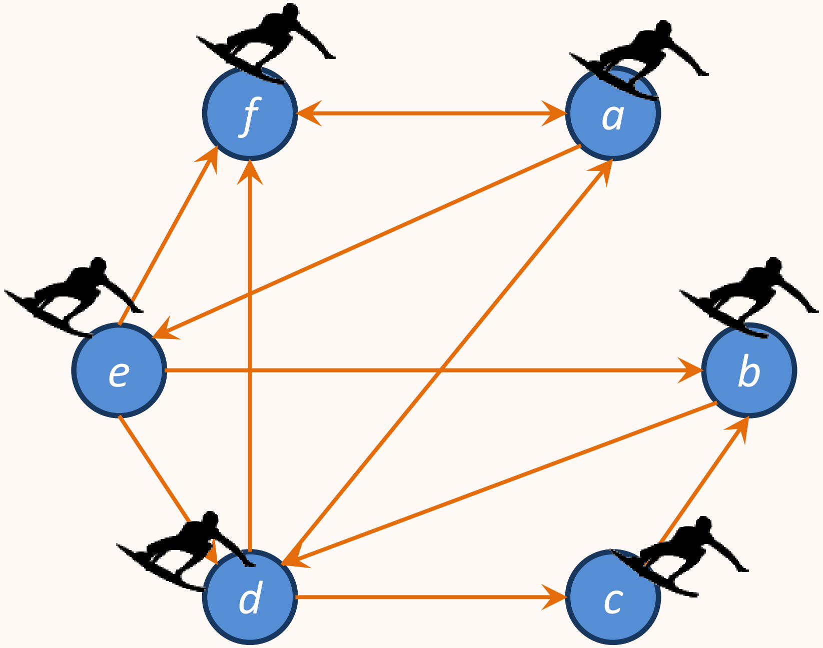
= someone surfing the web, clicking links randomly

- What is the probability of being at page *x* after *n* hops?



PageRank: Random Surfer Model

= someone surfing the web, clicking links randomly

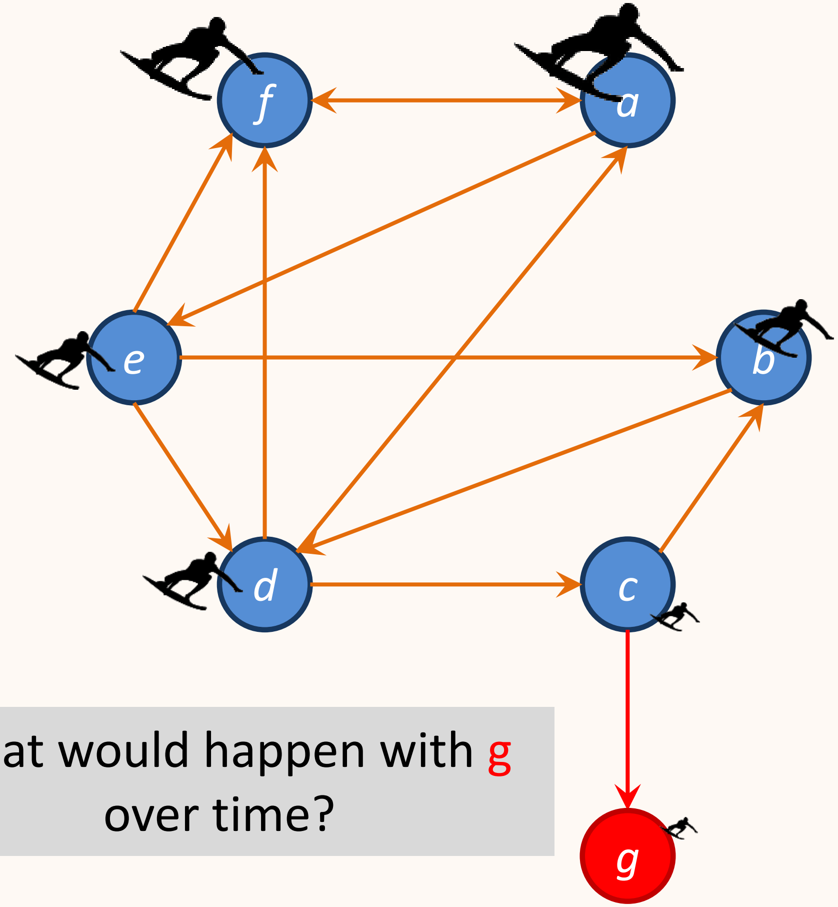


- What is the probability of being at page *x* after *n* hops?
- *Initial state:* surfer equally likely to start at any node

PageRank: Random Surfer Model

= someone surfing the web, clicking links randomly

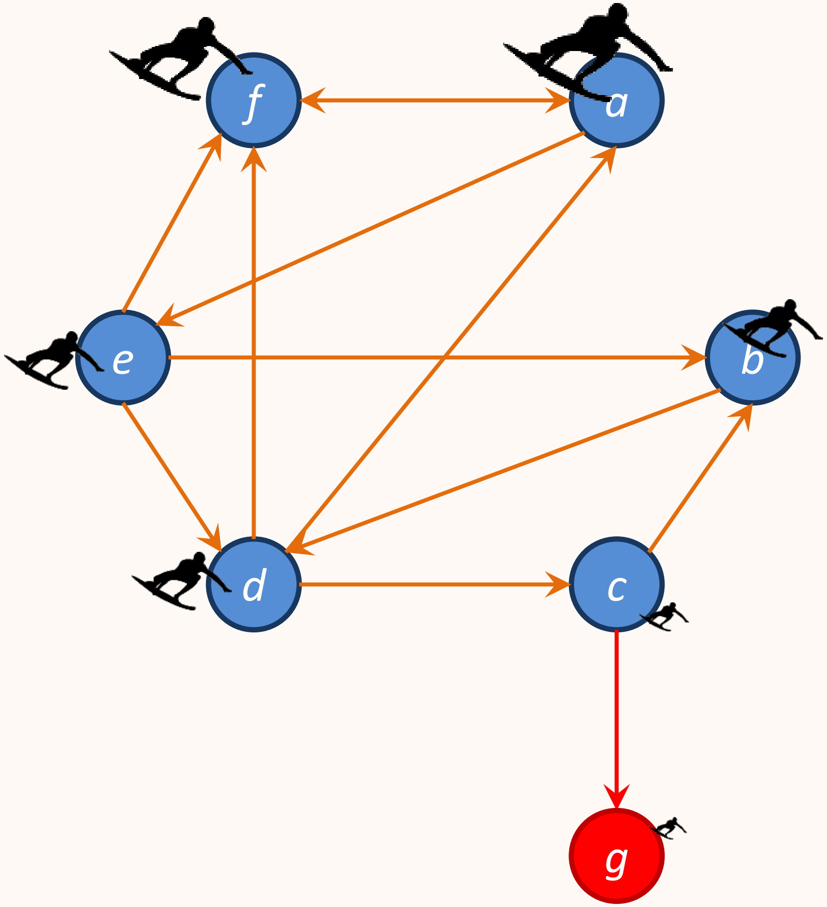
- What is the probability of being at page *x* after *n* hops?
- *Initial state:* surfer equally likely to start at any node
- PageRank applied iteratively for each hop: score indicates probability of being at that page after that many hops



What would happen with g over time?

PageRank: Random Surfer Model

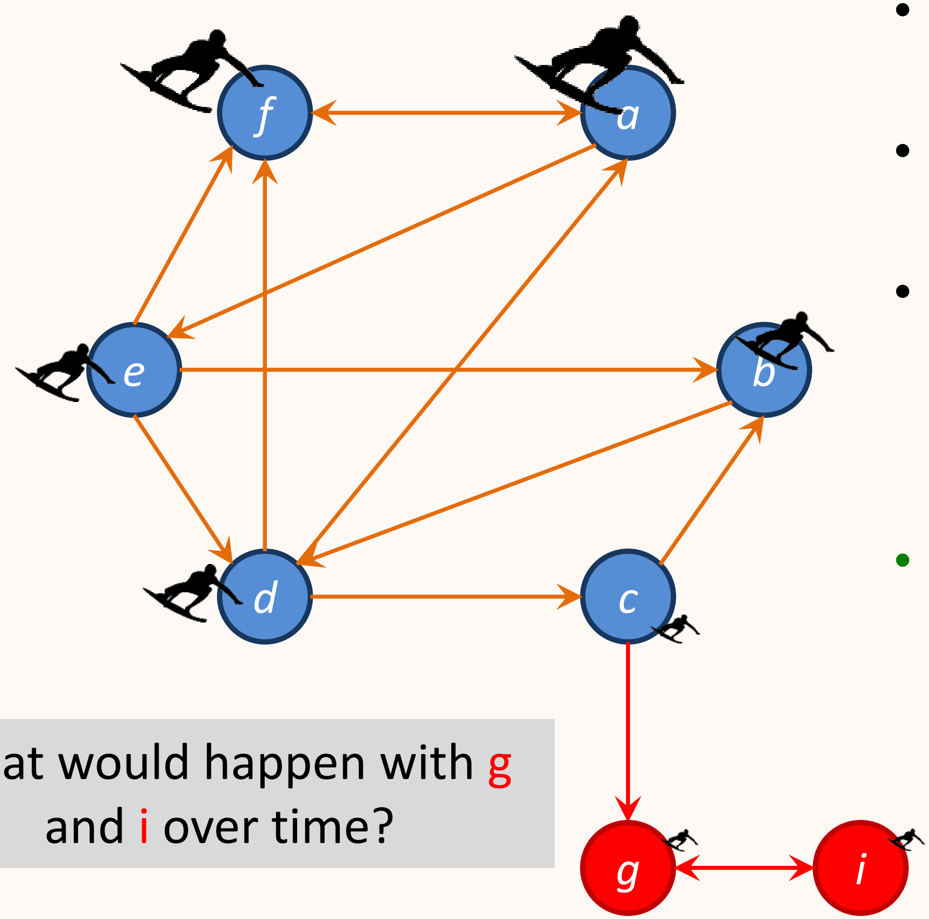
= someone surfing the web, clicking links randomly



- What is the probability of being at page *x* after *n* hops?
- *Initial state:* surfer equally likely to start at any node
- PageRank applied iteratively for each hop: score indicates probability of being at that page after than many hops
- If the surfer reaches a page without links, the surfer randomly jumps to another page

PageRank: Random Surfer Model

= someone surfing the web, clicking links randomly



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What would happen with g and i over time?

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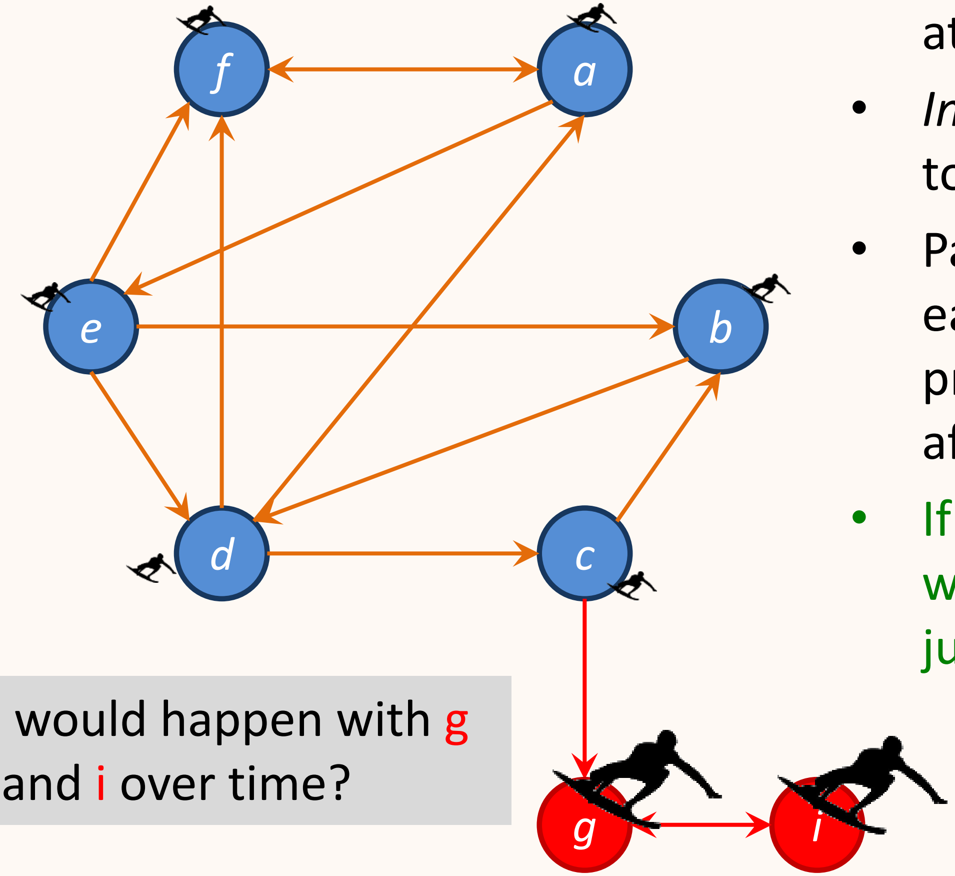

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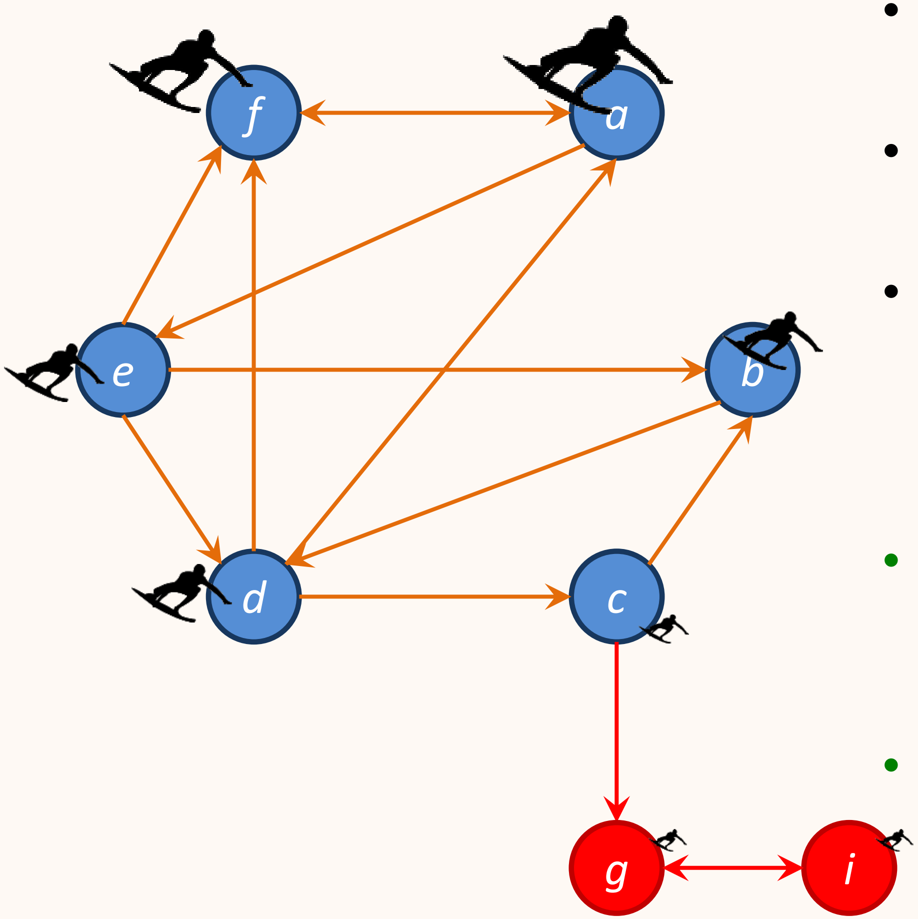

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- The surfer will jump to a random page at any time with a probability 1 – *d … this avoids traps and ensures convergence!*

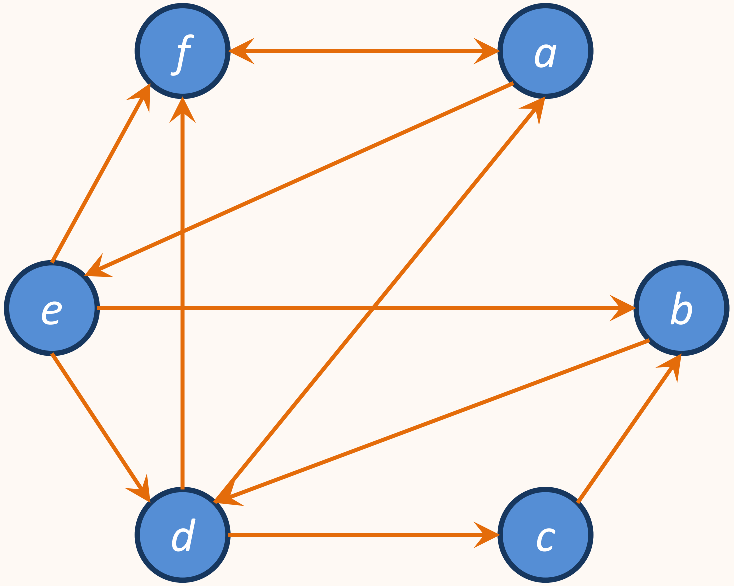
PageRank Model: Final Version

- The Web: a directed graph

$$G = (\boxed{V}, \boxed{E})$$

Vertices (*pages*)

Edges (*links*)



$$\mathrm{out}(v) \coloneqq \{v' \in V \mid (v, v') \in E\}$$

$$\mathrm{in}(v) \coloneqq \{v' \in V \mid (v', v) \in E\}$$

$$\mathrm{rank}_0(v) \coloneqq \frac{1}{|V|}$$

$$V' \coloneqq \{v \in V : |\mathrm{out}(v)| = 0\}$$

$$V'' \coloneqq \{v \in V : |\mathrm{out}(v)| \neq 0\}$$

d is the follow-a-link probability

typically $(d = 0.85)$

$$\mathrm{rank}_i(v) \coloneqq \boxed{d \times \sum_{u \in \mathrm{in}(v)} \frac{\mathrm{rank}_{i-1}(u)}{|\mathrm{out}(u)|}} + \boxed{\sum_{v' \in V'} \frac{\mathrm{rank}_{i-1}(v')}{|V|}} + \boxed{(1-d) \times \sum_{v'' \in V''} \frac{\mathrm{rank}_{i-1}(v'')}{|V|}}$$

PageRank: Benefits

- ✓ More robust than a simple link count
- ✓ Fewer ties than link counting
- ✓ Scalable to approximate (for sparse graphs)
- ✓ Convergence guaranteed

Two Sides to Ranking: Importance

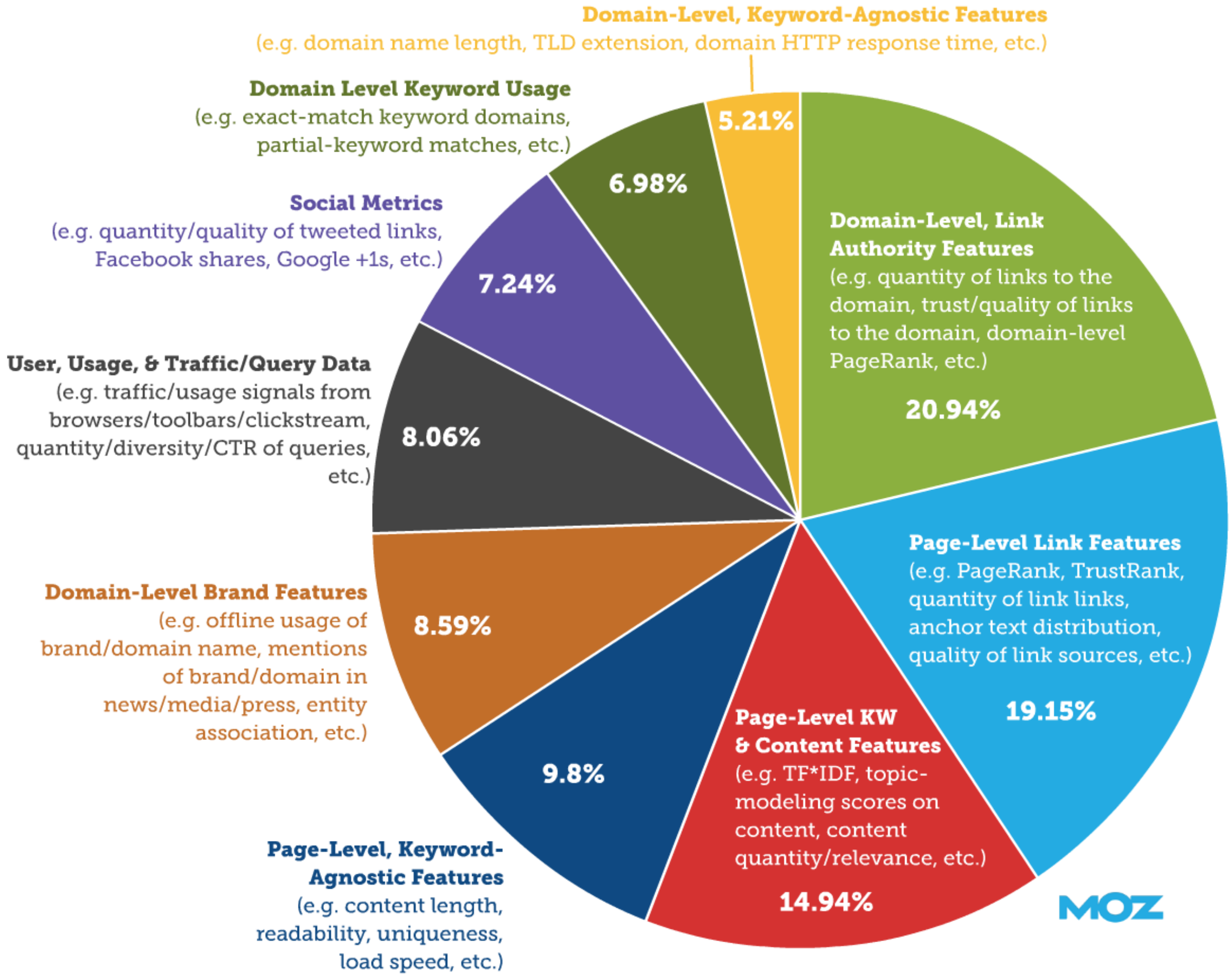
Google
PageRank
>
obama
Web
Mount Obama - Wikipedia, the free encyclopedia
Report images
Mount Obama National Park | Antigua a
antiguamountobama.com/
Jun 16, 2011 - As the Mount Obama Committee continu

GOOGLE: A GUESS

How Modern Google ranks results (maybe)

Weighting of Thematic Clusters of Ranking Factors in Google

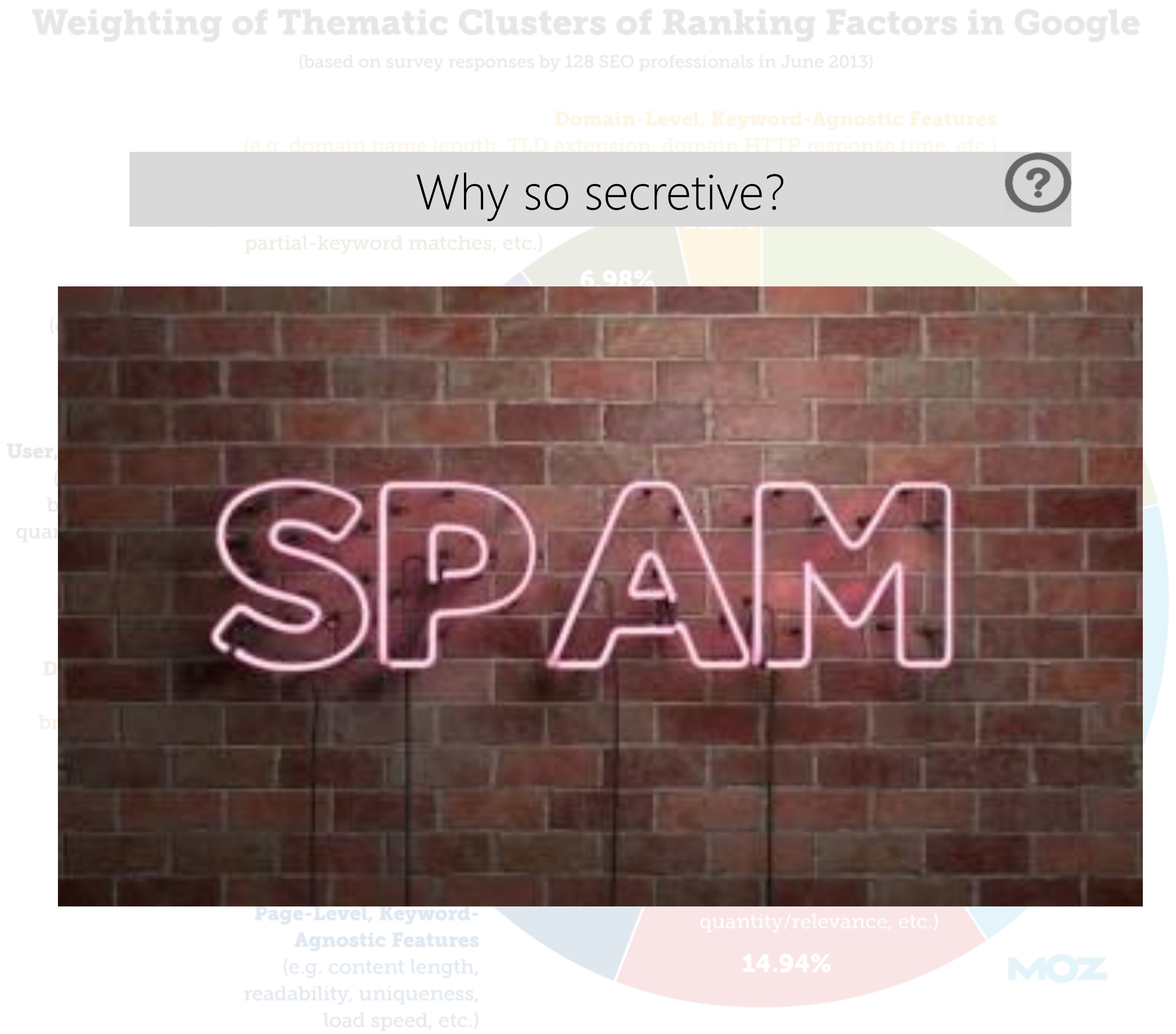
(based on survey responses by 128 SEO professionals in June 2013)



According to survey of SEO experts, not people in Google

How Modern Google ranks results (maybe)

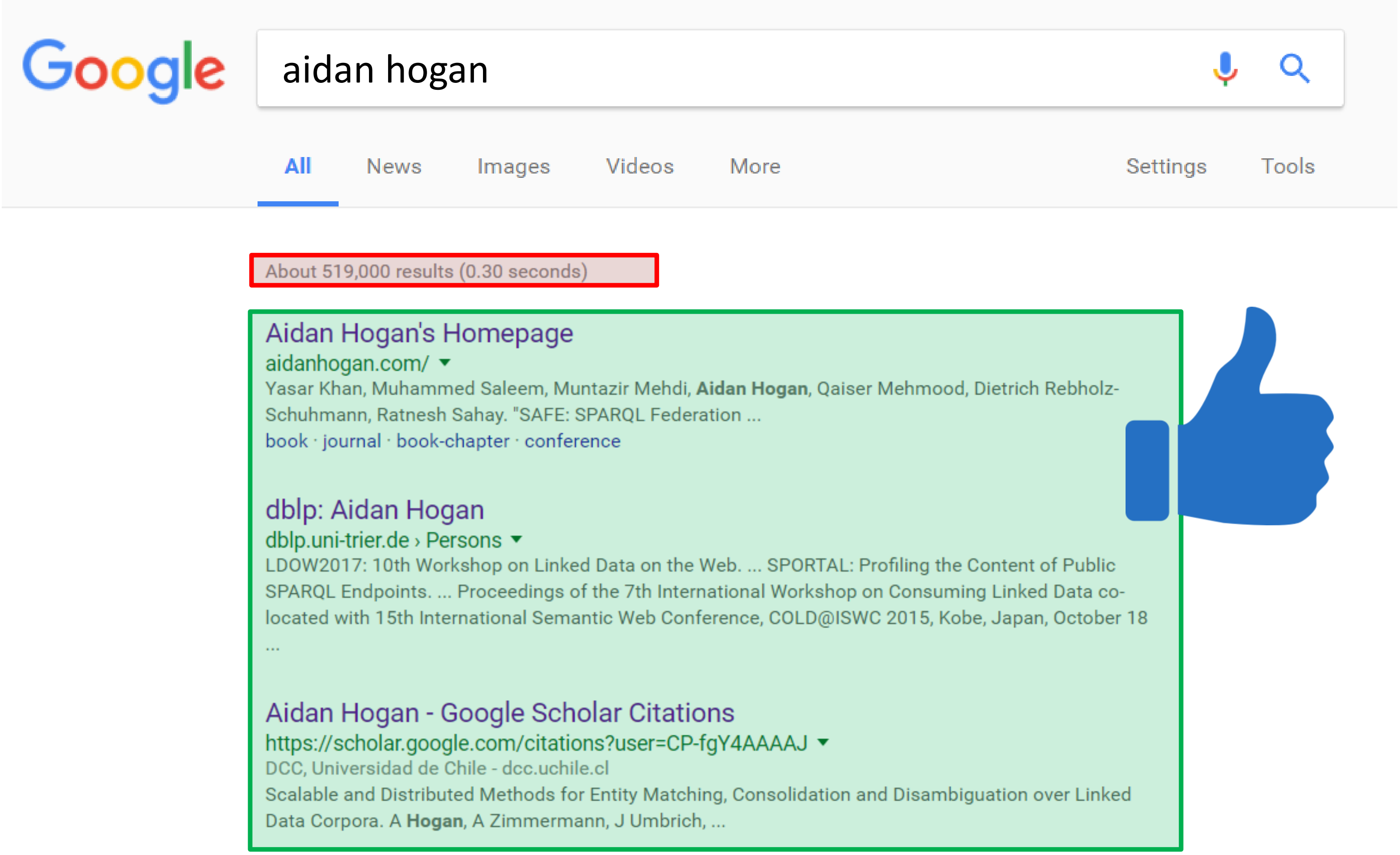
Why so secretive?


Weighting of Thematic Clusters of Ranking Factors in Google
(based on survey responses by 128 SEO professionals in June 2013)
Domain-Level, Keyword-Agnostic Features
(e.g. domain name length, TLD extension, domain HTTP response time, etc.)
partial-keyword matches, etc.)
6.98%
SPAM
Page-Level, Keyword-Agnostic Features
(e.g. content length, readability, uniqueness, load speed, etc.)
quantity/relevance, etc.)
14.94%
MOZ

According to survey of SEO experts, not people in Google

INFORMATION RETRIEVAL: RECAP

How Does Google Get Such Good Results?



aidan hogan

About 519,000 results (0.30 seconds)

Aidan Hogan's Homepage
aidanhogan.com/ ▾
Yasar Khan, Muhammed Saleem, Muntazir Mehdi, **Aidan Hogan**, Qaiser Mehmood, Dietrich Rebholz-Schuhmann, Ratnesh Sahay. "SAFE: SPARQL Federation ...
book · journal · book-chapter · conference

dblp: Aidan Hogan
dblp.uni-trier.de › Persons ▾
LDOW2017: 10th Workshop on Linked Data on the Web. ... SPORTAL: Profiling the Content of Public SPARQL Endpoints. ... Proceedings of the 7th International Workshop on Consuming Linked Data co-located with 15th International Semantic Web Conference, COLD@ISWC 2015, Kobe, Japan, October 18 ...

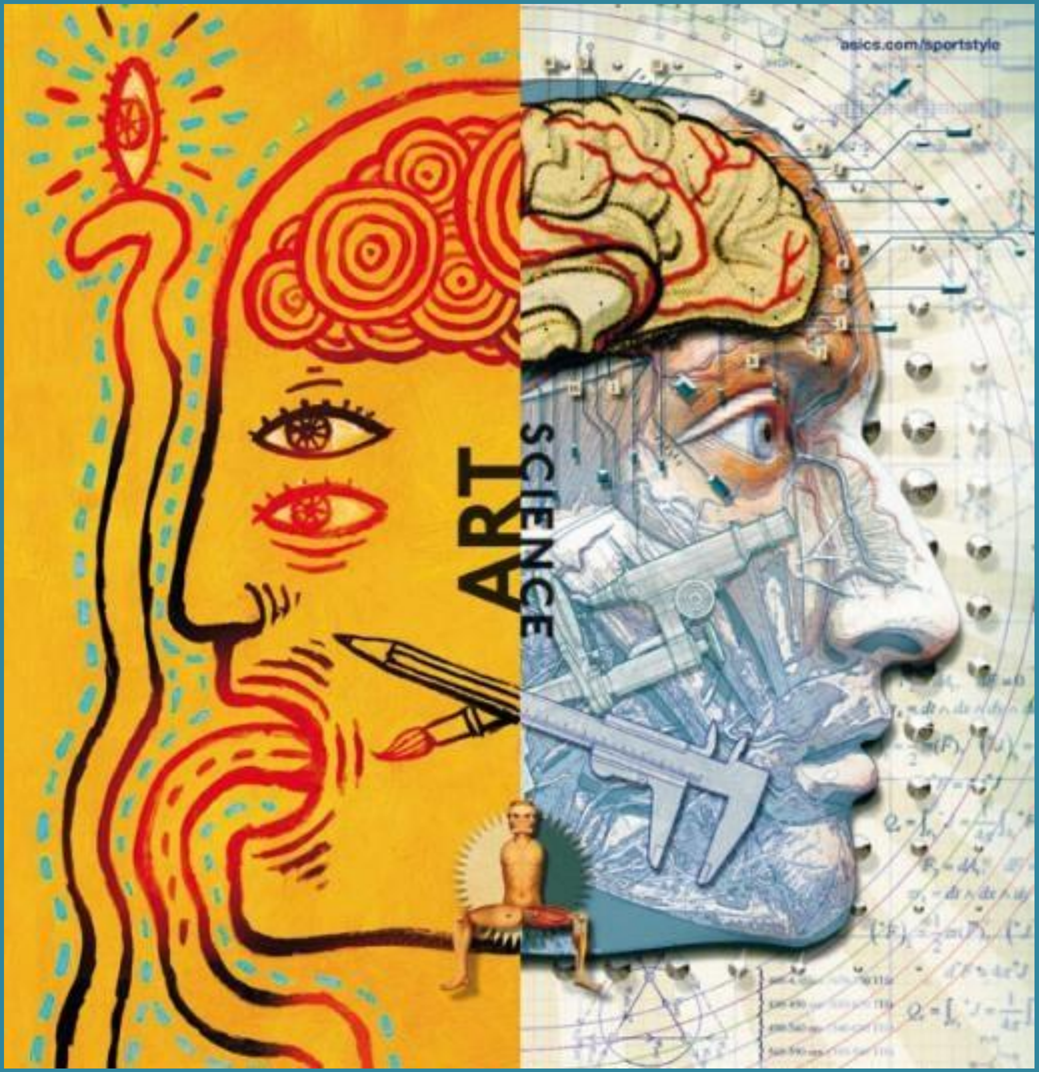
Aidan Hogan - Google Scholar Citations
https://scholar.google.com/citations?user=CP-fgY4AAAAJ ▾
DCC, Universidad de Chile - dcc.uchile.cl
Scalable and Distributed Methods for Entity Matching, Consolidation and Disambiguation over Linked Data Corpora. A **Hogan**, A Zimmermann, J Umbrich, ...

Ranking in Information Retrieval

- Relevance: Is the document relevant for the query?
  - Term Frequency * Inverse Document Frequency
  - Cosine similarity

- Importance: Is the document a popular one?
  - Links analysis
  - PageRank

Ranking: Science or Art?



Questions?