The PageRank Citation Ranking: Bringing Order to the Web

Marlon Dias
msdias@dcc.ufmg.br

Information Retrieval
DCC/UFMG - 2017

Introduction

Paper: **The PageRank Citation Ranking: Bringing Order to the Web**, 1999

Authors: **Lawrence Page**, **Sergey Brin**, Rajeev Motwani, Terry Winograd

Page and Brin were MS students at Stanford

They founded Google in September, 98.

Most of this presentation is based on the original paper (link)

> “ *The Initiative's focus is to dramatically advance the means to collect, store, and organize information in digital forms, and make it available for searching, retrieval, and processing via communication networks -- all in user-friendly ways.*

Stanford WebBase project

Pagerank
Motivation

- Web is vastly large and heterogeneous
    - Original paper's estimation were over 150 M pages and 1.7 billion of links
- Pages are extremely diverse
    - Ranging from "*What does the fox say?*" to journals about IR
- Web Page present some "structure"
    - Pagerank takes advantage of links structure

Pagerank
Motivation

- Inspiration: Academic citation
- Papers
  - are well defined units of work
  - are roughly similar in quality
  - are used to extend the body of knowledge
  - can have their "*quality*" measured in number of citations

Pagerank
Motivation

- Web pages, on the other hand
  - proliferate free of quality control or publishing costs
  - huge numbers of pages can be created easily
    - artificially inflating citation counts
  - They vary on much wider scale than academic papers in quality, usage, citations and length

Pagerank
Motivation

A random archived message posting asking an obscure question about an IBM computer is very different from the IBM home page

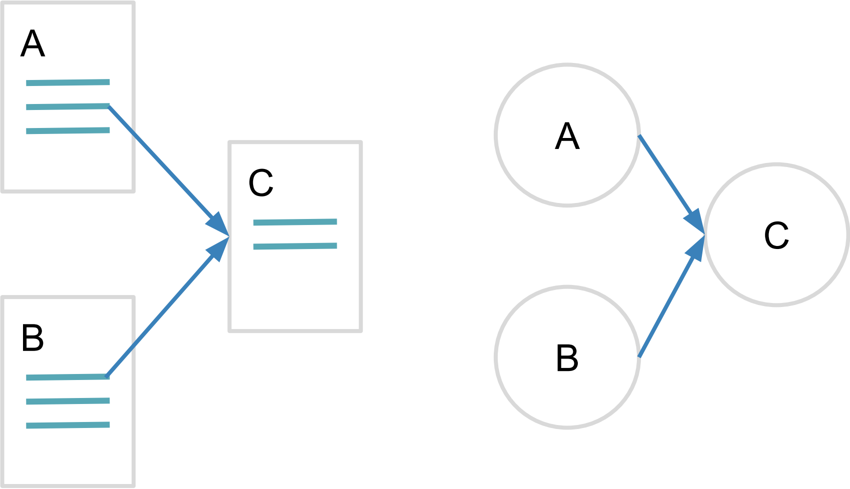
A research article about the effects of cellphone use on driver attention is very different from an advertisement for a particular cellular provider

“ *The average web page quality experienced by a user is higher than the quality of the average web page. This is because the simplicity of creating and publishing web pages results in a large fraction of low quality web pages that users are unlikely to read.*

Pagerank

Idea

- Creates a graph based on link structure
  - Pages are nodes
  - Links are edges
  - Forward links are outedges
  - Backlinks are inedges
- A and B are backlinks of C

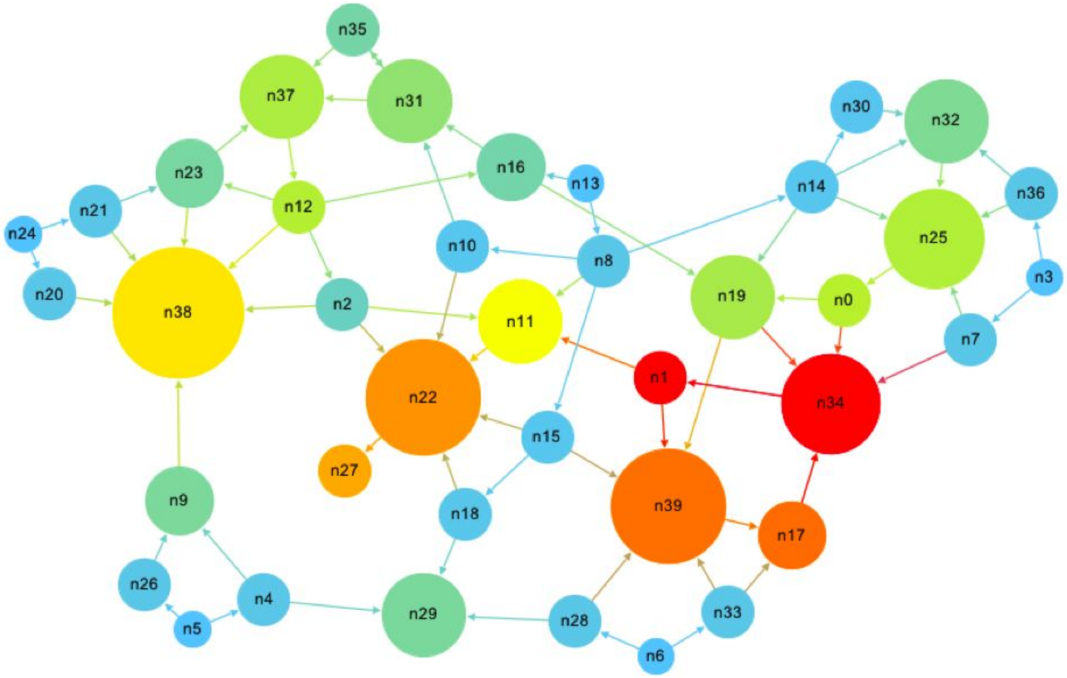


Pagerank

Assumptions

- Link from page A to page B is a vote from A to B
- Highly linked pages are more “important” than pages with few links
- Backlinks from high PR-pages count more than links from low PR-pages
- combination of PR and text-matching techniques result in highly relevant search results

Pagerank


n35
n37
n31
n30
n32
n23
n16
n13
n14
n36
n21
n12
n24
n10
n8
n25
n3
n20
n38
n2
n11
n19
n0
n7
n1
n22
n34
n15
n27
n39
n9
n18
n17
n26
n4
n29
n28
n33
n5
n6

Pagerank
Definition

Simplification of Pagerank

A simple ranking function

- u is a web page
- $\mathcal{F}_u$ is a set of pages that u points
- B_u is the set of pages pointing to u
- c is a normalization factor
- $N_u = |\mathcal{F}_u|$

$$R(u) = c \sum_{v \in B_u} \frac{R(v)}{N_v}$$

Pagerank
Definition

- Rank of a page is divided among its forward links
- Equation is recursive
- May be computed by starting with any set of ranks
    - it iterates until it converges.

Pagerank
Definition

Problem with previous equation:

- Consider two web pages that point to each other
  - but to no other page.
- Suppose there is some web page which points to one of them.
- During iteration, this loop will accumulate rank but never distribute any rank
  - Since there are no outedges.

Pagerank
Definition

To overcome the problem:

$$R'(u) = c \sum_{v \in B_u} \frac{R'(v)}{N_v} + cE(u)$$

where $E(u)$ is come vector over the web pages.

Based on a random surfer model.

Pagerank
Definition

- Finally, Pagerank is usually defined as:

$$PR(u) = 1 - d + d \sum_{v \in B_v} \frac{PR(v)}{N(v)}$$

Pagerank
Definition

- Finally, Pagerank is usually defined as:

$$PR(u) = \boxed{1 - d} + d \sum_{v \in B_v} \frac{PR(v)}{N(v)}$$

represents the change to get
to page u from any other page
(random walk)

Pagerank
Definition

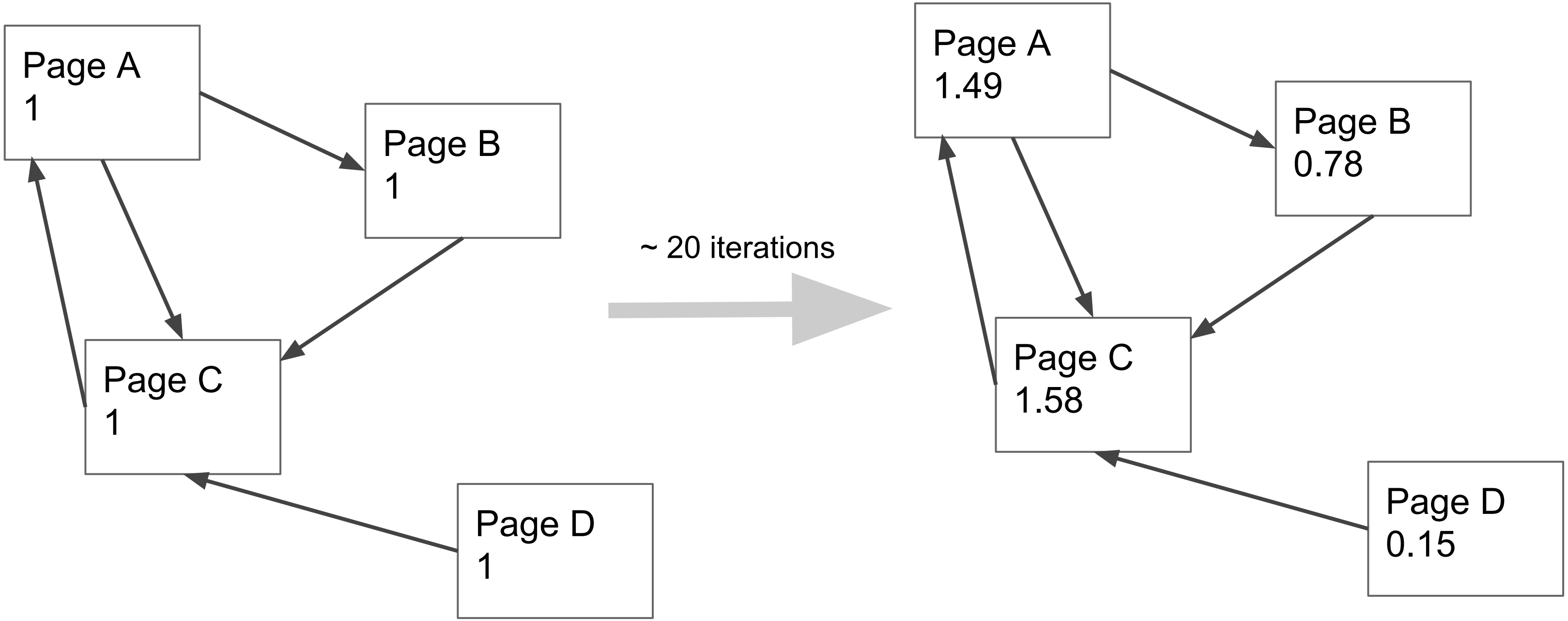
- Finally, Pagerank is usually defined as:

$$PR(u) = 1 - d + d \sum_{v \in B_v} \frac{PR(v)}{N(v)}$$

represents the change to get to u from pages that points to u, B_u.

Pagerank

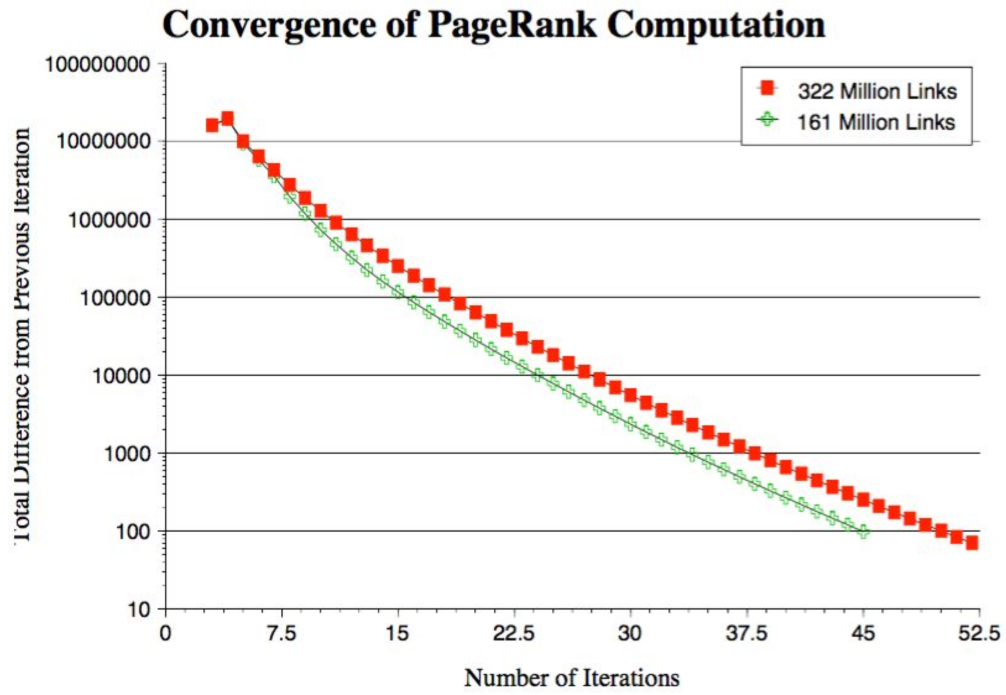
Example



Complete iteration process can be found here (made by Alberto Ueda).

Pagerank

Convergence



Pretty quick and robust!

Pagerank

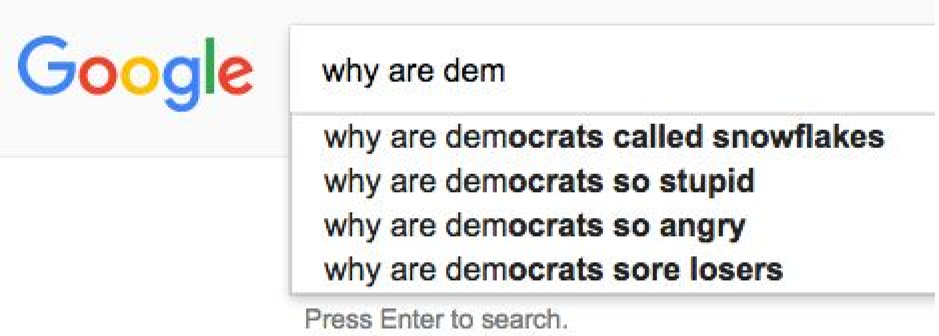
Paper Implementation

- Repository size: 24M web pages (over 75M unique URLs)
- computing PR of entire repository takes ~5h
- Issues:
  - Volume
  - incorrect HTML
  - dynamics of the web, page exclusion (robots.txt)

Pagerank
Usage

- Search
  - combination of retrieve models and pagerank for ranking
- Commercial Interests
  - It is not easily manipulated
- Estimation of Web Traffic
  - Corresponds to a random web surfer
- Backlink predictor for crawling

Pagerank
Unwanted usage

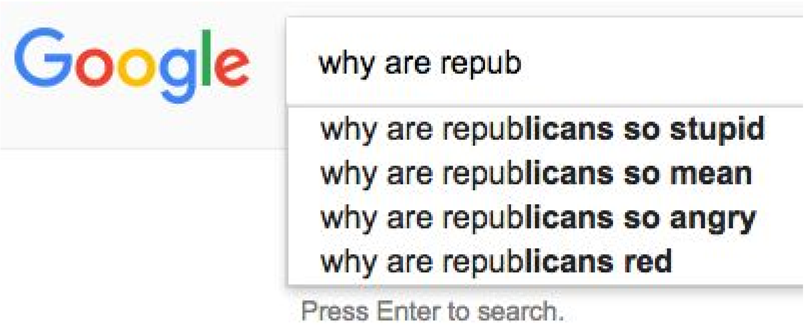


why are dem

why are democrats called snowflakes
why are democrats so stupid
why are democrats so angry
why are democrats sore losers

Press Enter to search.

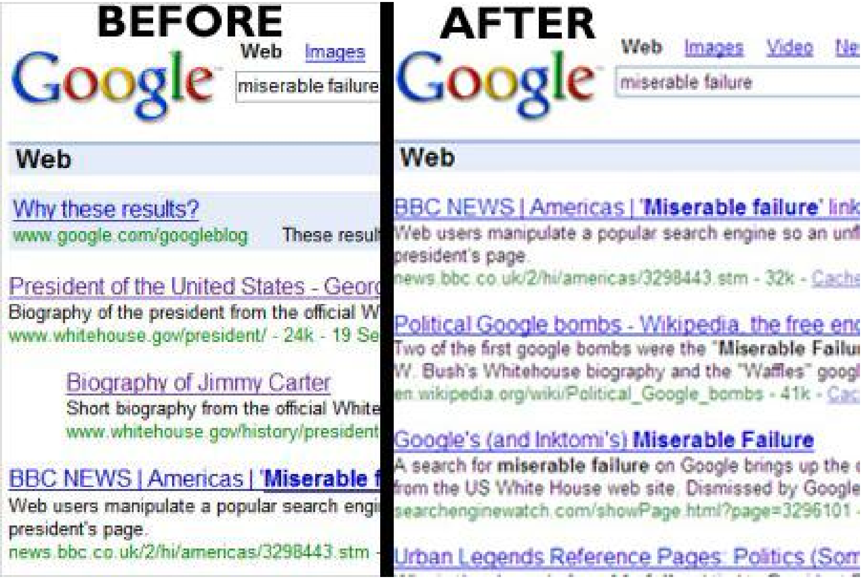
- Bmw.de banned from Google in early 2016
  - due to doorway page (link)
- Google bomb
  - President article (2007)
  - Repub & Dem article (2017)



why are repub

why are republicans so stupid
why are republicans so mean
why are republicans so angry
why are republicans red

Press Enter to search.



BEFORE

Web

Why these results?
www.google.com/googleblog These result

President of the United States - Georg
Biography of the president from the official W
www.whitehouse.gov/president/ - 24k - 19 Se

Biography of Jimmy Carter
Short biography from the official White
www.whitehouse.gov/history/president

BBC NEWS | Americas | 'Miserable f
Web users manipulate a popular search engi
president's page.
news.bbc.co.uk/2/hi/americas/3298443.stm -

AFTER

Web

BBC NEWS | Americas | 'Miserable failure' link
Web users manipulate a popular search engine so an unf
president's page.
news.bbc.co.uk/2/hi/americas/3298443.stm - 32k - Cache

Political Google bombs - Wikipedia, the free enc
Two of the first google bombs were the "Miserable Failu
W. Bush's Whitehouse biography and the "Waffles" googl
en.wikipedia.org/wiki/Political_Google_bombs - 41k - Cac

Google's (and Inktomi's) Miserable Failure
A search for miserable failure on Google brings up the
from the US White House web site. Dismissed by Google
searchenginewatch.com/showPage.html?page=3296101 -

Urban Legends Reference Pages: Politics (Som