Link Analysis

Stony Brook University CSE545, Fall 2016

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Enter PageRank

The Anatomy of a Large-Scale Hypertextual Web Search Engine

Sergey Brin and Lawrence Page

Computer Science Department, Stanford University, Stanford, CA 94305, USA sergey@cs.stanford.edu and page@cs.stanford.edu

Abstract

In this paper, we presen use of the structure pres and produce much more text and hyperlink data

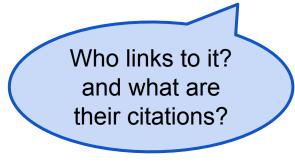
The PageRank Citation Ranking: Bringing Order to the Web

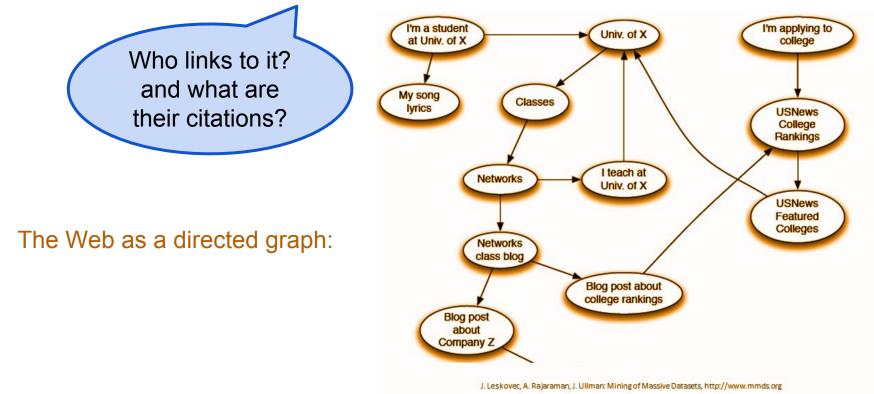
January 29, 1998

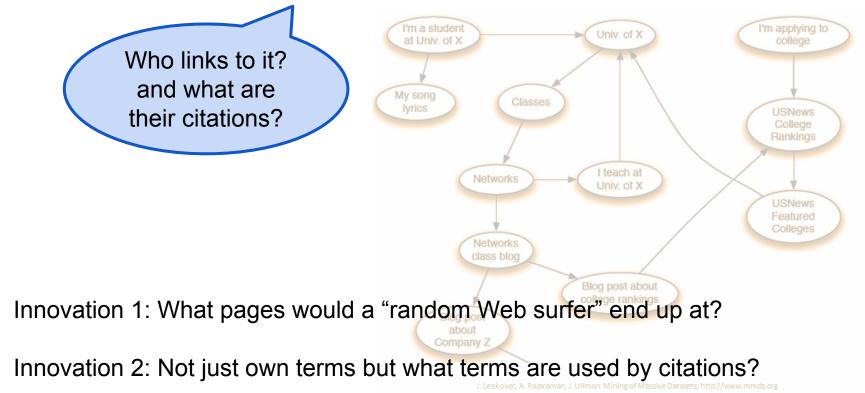
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Abstract

The importance of a Web page is an inherently subjective matter, which depends on the readers interests, knowledge and attitudes. But there is still much that can be said objectively

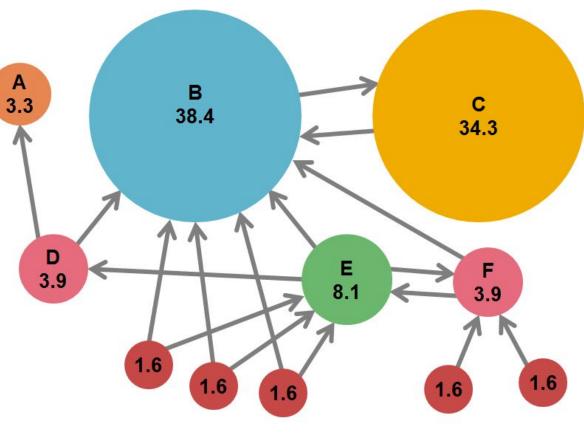






Key Idea: Consider the

Flow Model: in-links as votes



J. Leskovec, A. Rajaraman, J. Ullman: Mining of Massive Datasets, http://www.mmds.org

Innovation 1: What pages would a "random Web surfer" end up at?

Key Idea: Consider the citations of the website in addition to keywords.

Flow Model: in-links (citations) as votes

But citations from important pages should count more.

Use recursion to figure out if each page is important.

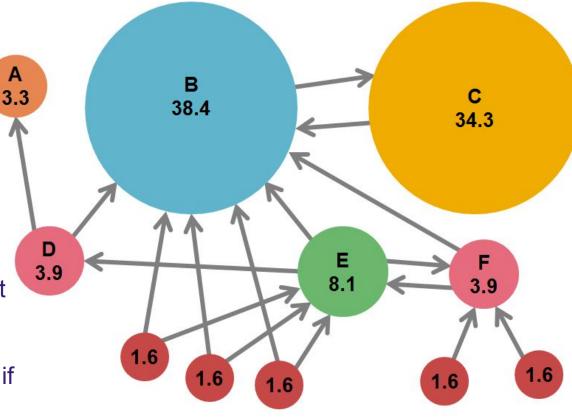
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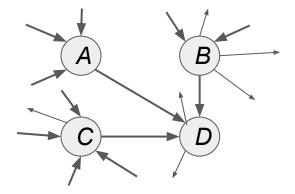
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Use recursion to figure out if each page is important.

How to compute? Each page (*j*) has an importance (i.e. rank, r_j) $vote_j = \frac{r_j}{n_j}$ (n_j is |out-links|) $r_j = \sum_{i \in inLinks(j)} vote_i$

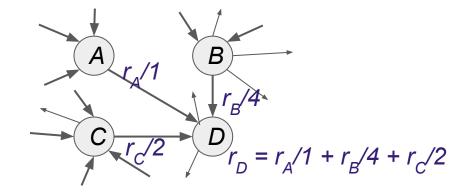
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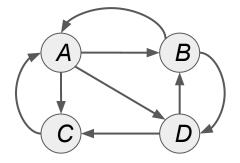
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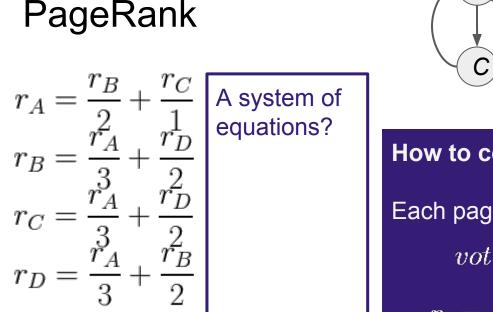
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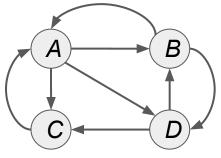
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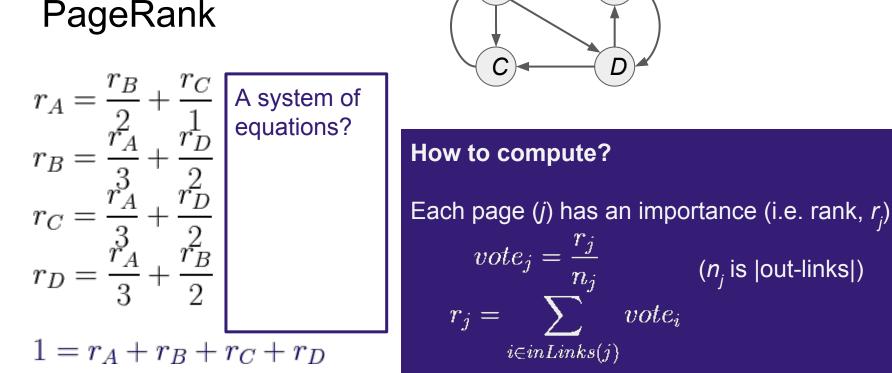
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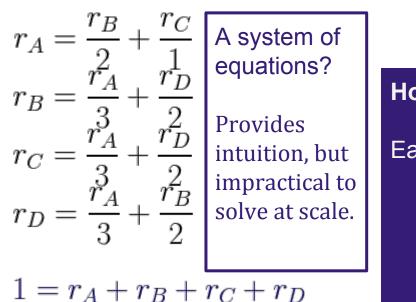
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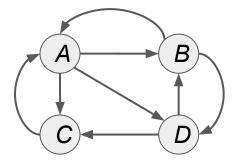
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B

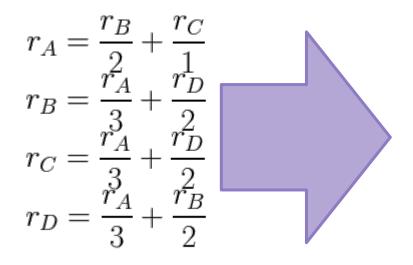
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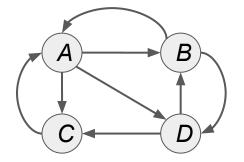




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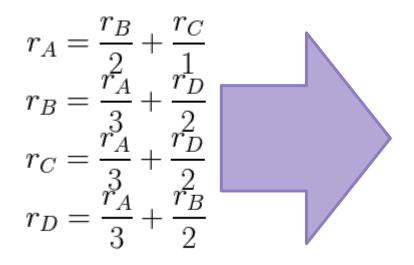


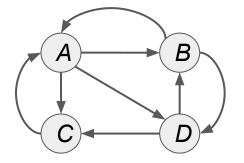


to \ from	A	В	С	D
А	0	1/2	1	0
В	1/3	0	0	1/2
С	1/3	0	0	1/2
D	1/3	1/2	0	0

 $1 = r_A + r_B + r_C + r_D$

"Transition Matrix", M



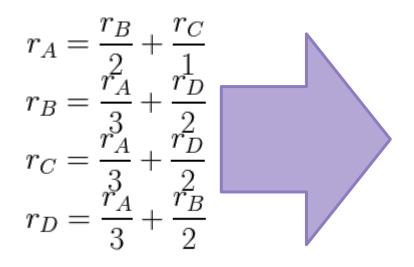


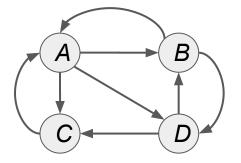
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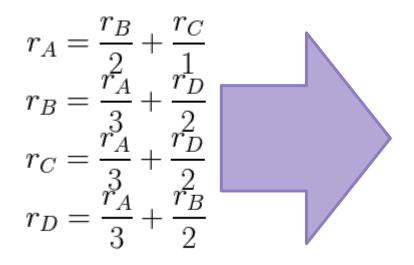


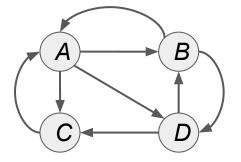
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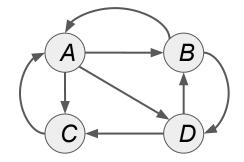
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Power iteration algorithm



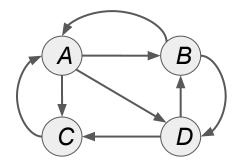


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Power iteration algorithm



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Power iteration algorithm

As err_norm gets smaller we are moving toward: $r = M \cdot r$

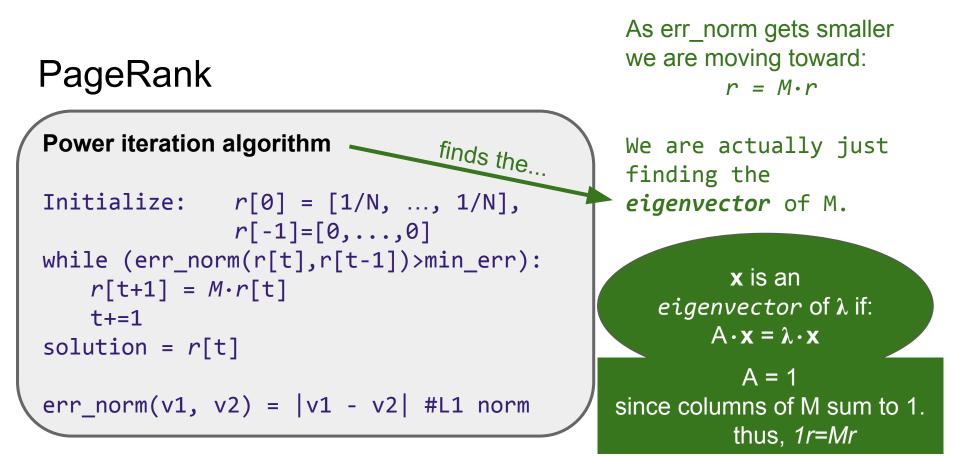
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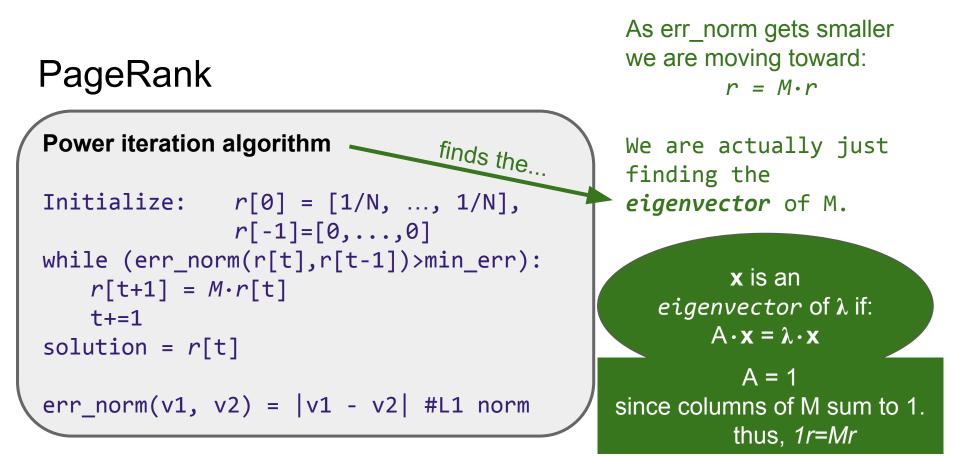
Power iteration algorithm

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> **x** is an eigenvector of λ if: $A \cdot \mathbf{x} = \lambda \cdot \mathbf{x}$





Power iteration algorithm

```
Where is surfer at time t+1?
p(t+1) = M \cdot p(t)
```

Suppose: p(t+1) = p(t), then p(t) is a *stationary distribution* of a random walk.

Thus, r is a stationary distribution. Probability of being at given node.

aka 1st order Markov Process

- Rich probabilistic theory. One finding:
 - Stationary distributions have a unique distribution if:

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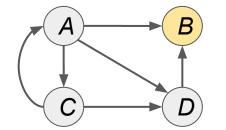
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to \ from	Α	В	ເັ	D
А	0	0	1	0
В	1/3	0	0	1
С	1/3	0	0	0

r would eventually converge to [0, 0, ...]

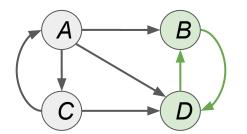
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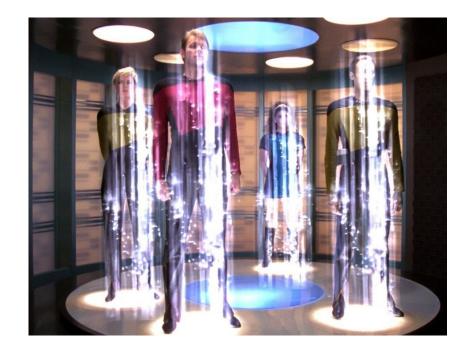
columns sum to 1 same node doesn't repeat at a regular interval non-zero chance of going to any another node

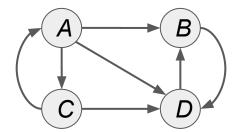
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The "Google" PageRank Formulation

Add teleportation: At each step, two choices

- 1. Follow a random link (probability, $\beta = \sim .85$)
- 2. Teleport to a random node (probability, $1-\beta$)





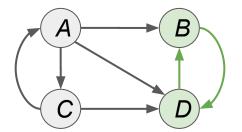
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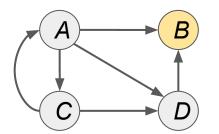
Add teleportation chance at all nodes.

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Add teleportation from dead end with probability 1

to \ from	Α	В	С	D
А	0	0	1	0
В	1/3	0	0	1
С	1/3	0	0	0
D	1/3	0	0	0



No "dead-ends" No "spider traps"

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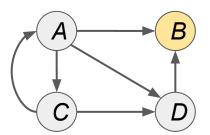
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to \	from	Α	В	С	D
	Α	0	1⁄4	1	0
	В	1/3	1⁄4	0	1
	С	1/3	1⁄4	0	0
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$$r_{j} = \sum_{i \to j} \beta \frac{r_{i}}{d_{i}} + (1 - \beta) \frac{1}{N}$$
(Brin and Page, 1998)

$$A = 0 = 0 = 1 = 0$$

$$B = 1/3 = 0 = 0 = 0$$

$$D = 1/3 = 0 = 0 = 0$$

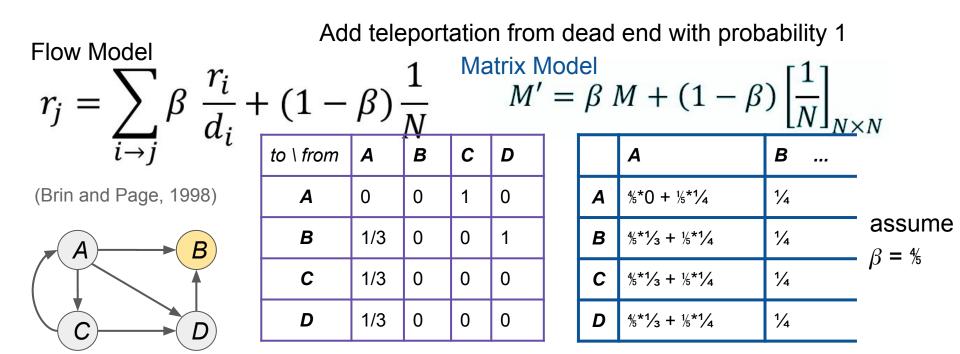
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Matrix Model

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Add teleportation from dead end with probability 1

 $M' = \beta M + (1 - \beta) \left[\frac{1}{N}\right]$

To apply:

run power iterations over M' instead of M.

		$\lfloor N \rfloor_N$	<n< th=""></n<>
	Α	В	
Α	⁴ ∕5*0 + ½*1∕4	1⁄4	
В	⁴ / ₅ * ¹ / ₃ + ¹ / ₅ * ¹ / ₄	1⁄4	assume $\beta = \frac{4}{3}$
С	⁴ / ₅ * ¹ / ₃ + ¹ / ₅ * ¹ / ₄	1⁄4	p - 75
D	⁴ / ₅ * ¹ / ₃ + ¹ / ₅ * ¹ / ₄	1⁄4	