# Information Retrieval

## Web Search: Page Rank

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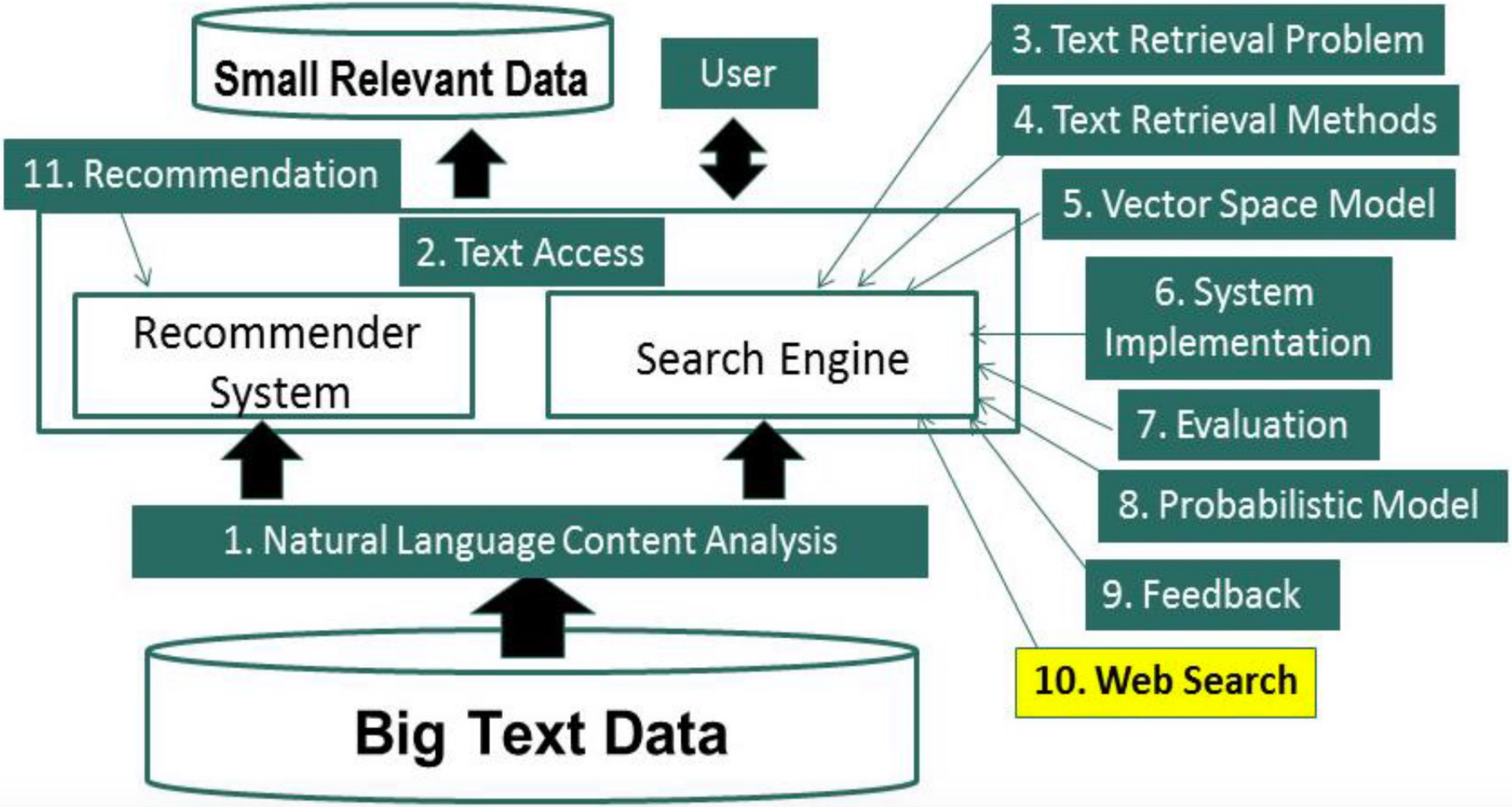
# Course Schedule



# Page Rank Algorithm

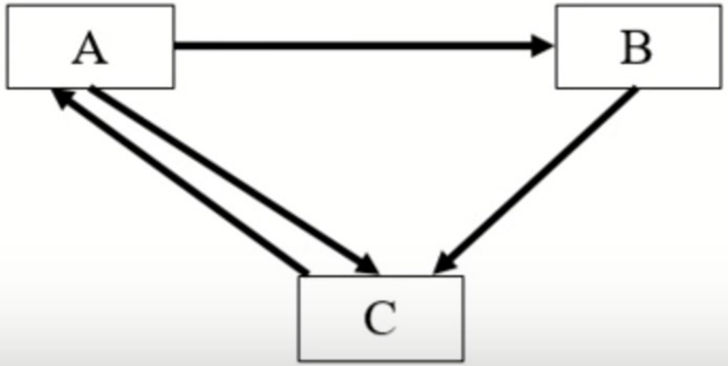
- PageRank is a "vote", by all the other pages on the Web, about how important a page is.
- A link to a page counts as a vote of support
- The original PageRank algorithm was designed by Lawrence Page and Sergey Brin.

# How Page Rank is Calculated

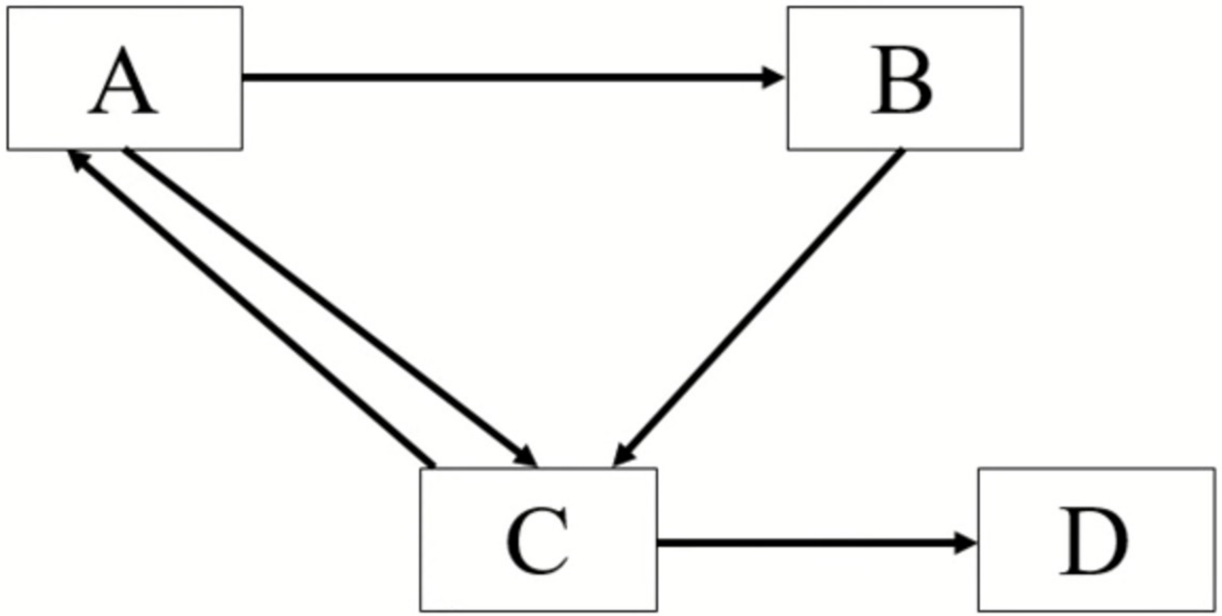
- The rank of a document is given by the rank of those documents which link to it.
- The PR of each page depends on the PR of the pages pointing to it.
- But we won't know what PR those pages have until the pages pointing to them have their PR calculated and so on.

# Inbound, Outbound and Dangling Links

- Inbound link for a web page always increases that page's PageRank.
- An important aspect of outbound links is the lack of them on web pages.
- When a web page has no outbound links, its PageRank cannot be distributed to other pages.
- Lawrence Page and Sergey Brin characterise links to those pages as dangling links.



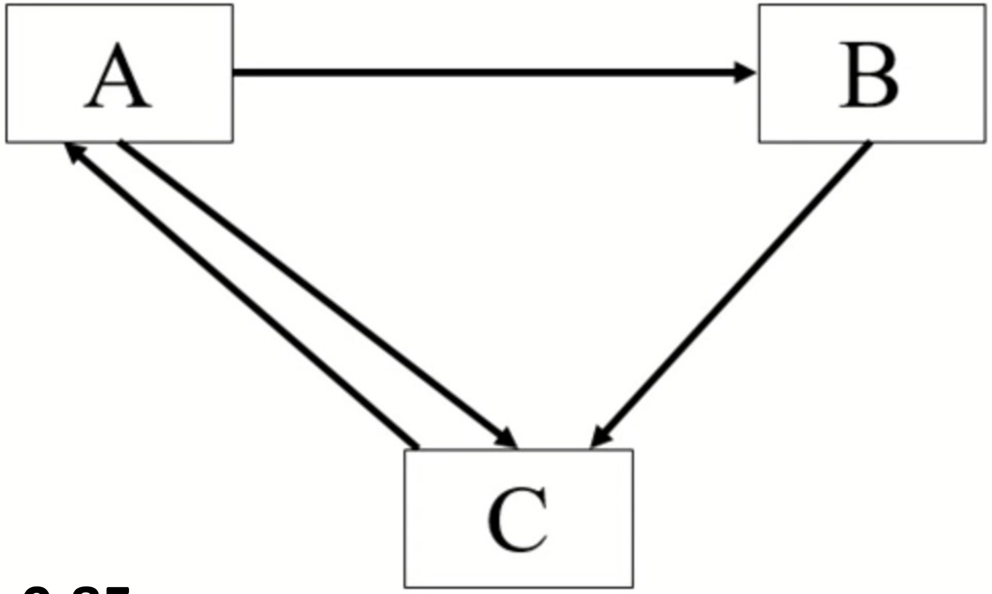
# Dangling Links



# Page Rank Initialization

- Initially Page Rank (PR) for all the web pages = 1

**The PageRank theory holds that an imaginary surfer who is randomly clicking on links will eventually stop clicking.** The probability, at any step, that the person will continue is a damping factor *d*. Various studies have tested different damping factors, but it is generally assumed that the damping factor will be set around 0.85




**Damping Factor = d= 0.85**

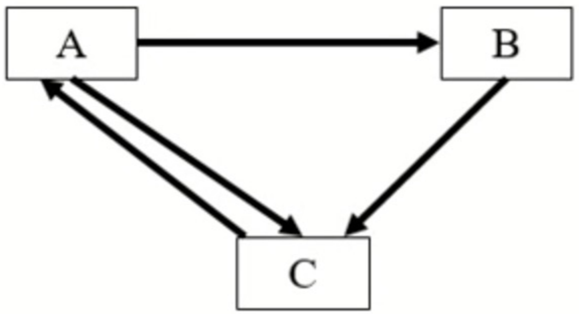
$$PR(A) = (1-d) + d(PR(Ti)/C(Ti) + \ldots + PR(Tn)/C(Tn))$$

# Page Rank of A & B

- Initially Page Rank (PR) for all the web pages = 1

$$PR(A) = (1\text{-}d) + d(PR(Ti)/C(Ti) + \ldots + PR(Tn)/C(Tn))$$

$$
\begin{aligned}
PR(A) &= (1\text{-}d) + d\,[\,PR(C) / C(C)\,] \\
&= (1-0.85) + 0.85\,[\,1/1] \\
&= 0.15 + 0.85[\,1] \\
&= 0.15 + 0.85 \\
&= 1
\end{aligned}
$$

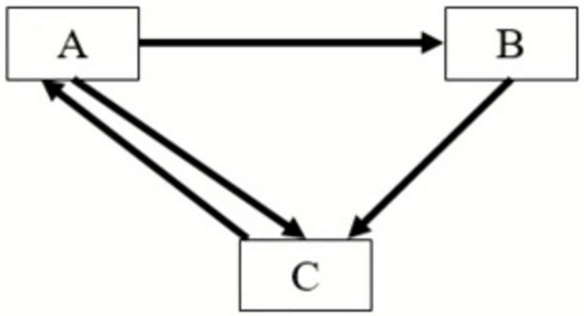



$$
\begin{aligned}
PR(B) &= (1\text{-}d) + d\,[\,PR(A) / C(A)] \\
&= (1-0.85) + 0.85\,[\,(1) / 2] \\
&= 0.15 + 0.85\,[0.5] \\
&= 0.15 + 0.425 \\
&= 0.575
\end{aligned}
$$

# Page Rank of C

- Initially Page Rank (PR) for all the web pages = 1

PR(A) = (1-d) + d(PR(Ti)/C(Ti) +…+PR(Tn)/C(Tn))

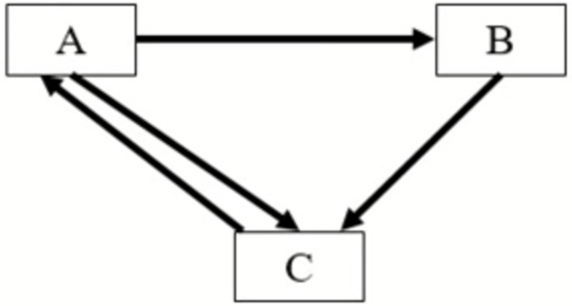



$$
\begin{aligned}
PR(C) &= (1-d) + d\,[\,PR(A) / C(A) + PR(B) / C(B)\,] \\
&=(1-0.85) + 0.85\,[\,(1/2) + (0.575 / 1)] \\
&= 0.15 + 0.85[\,0.5 + 0.575] \\
&= 0.15 + 0.85\,[\,1.075] \\
&= 0.15 + 0.91375 \\
&= 1.06375
\end{aligned}
$$

# Iterations

- Initially Page Rank (PR) for all the web pages = 1

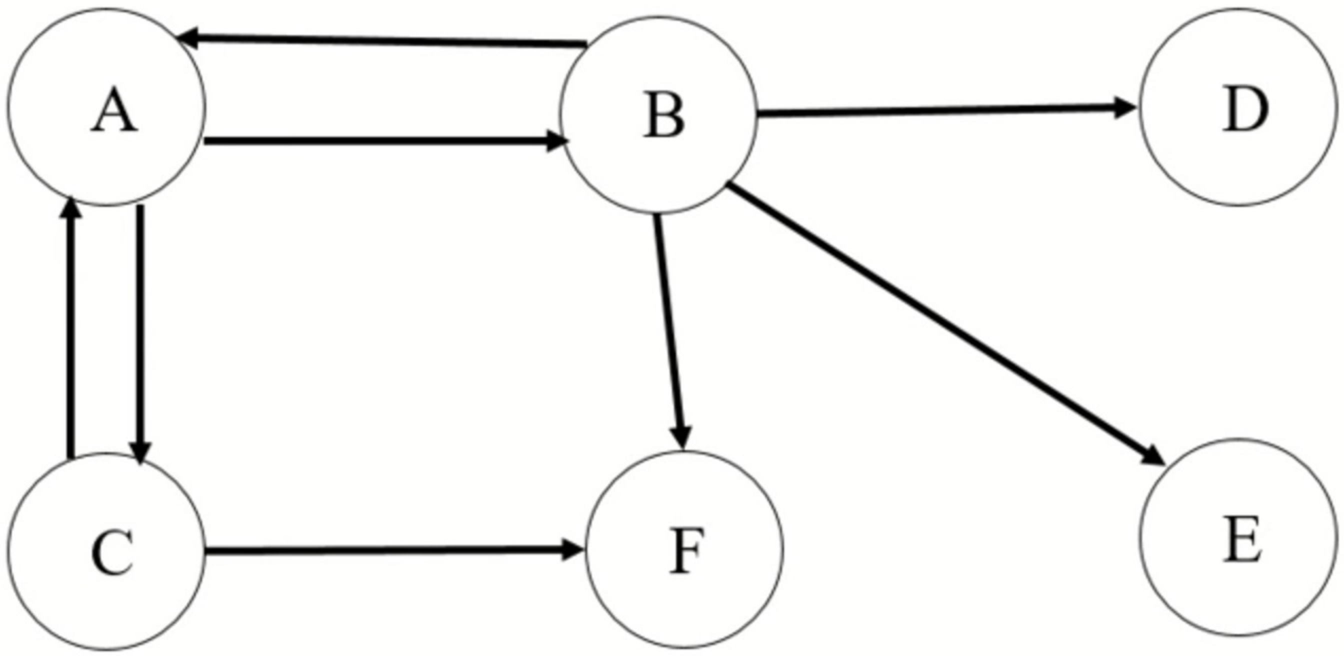
PR(A) = (1-d) + d(PR(Ti)/C(Ti) +…+PR(Tn)/C(Tn))




| Iteration | A | B | C |
|---|---|---|---|
| 0 | 1 | 1 | 1 |
| 1 | 1 | 0.575 | 1.06375 |
| 2 | 1.0541875 | 0.5980296875 | 1.06354922 |

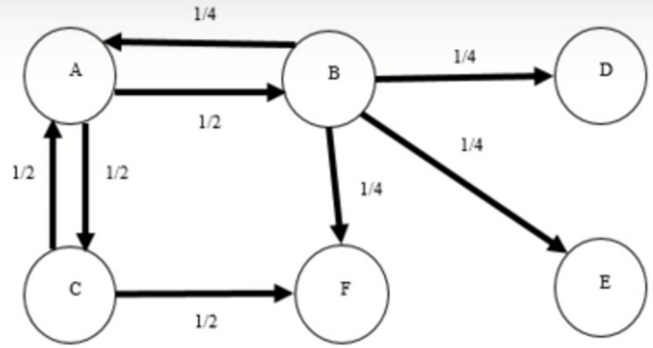
# Page Rank using Matrix

- Initially Page Rank (PR) for all the web pages = 1



# Matrix Representation

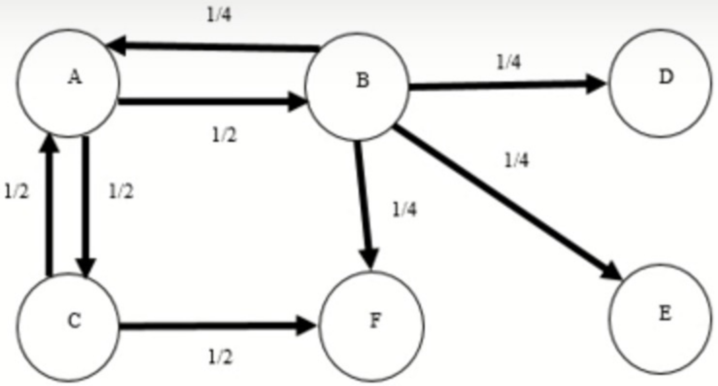
- Teleport Factor = 0.8




| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 0 | 1/2 | 1/2 | 0 | 0 | 0 |
| B | 1/4 | 0 | 0 | 1/4 | 1/4 | 1/4 |
| C | 1/2 | 0 | 0 | 0 | 0 | 1/2 |
| D | 0 | 0 | 0 | 0 | 0 | 0 |
| E | 0 | 0 | 0 | 0 | 0 | 0 |
| F | 0 | 0 | 0 | 0 | 0 | 0 |

# Matrix Transpose

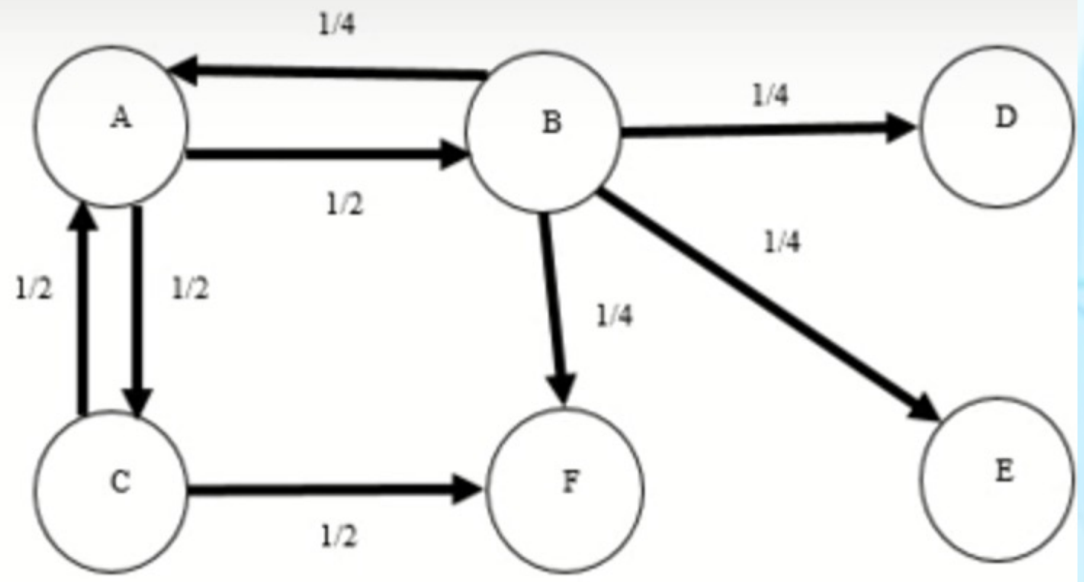
- Teleport Factor = 0.8




$M^T$

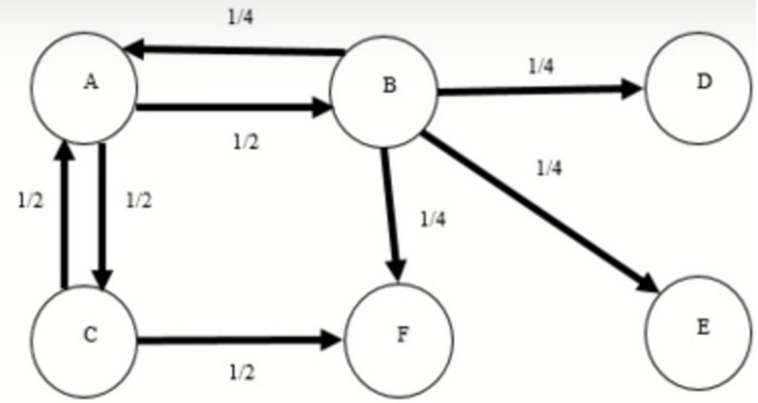
| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 0 | 1/4 | 1/2 | 0 | 0 | 0 |
| B | 1/2 | 0 | 0 | 0 | 0 | 0 |
| C | 1/2 | 0 | 0 | 0 | 0 | 0 |
| D | 0 | 1/4 | 0 | 0 | 0 | 0 |
| E | 0 | 1/4 | 0 | 0 | 0 | 0 |
| F | 0 | 1/4 | 1/2 | 0 | 0 | 0 |

- Teleport Factor = 0.8

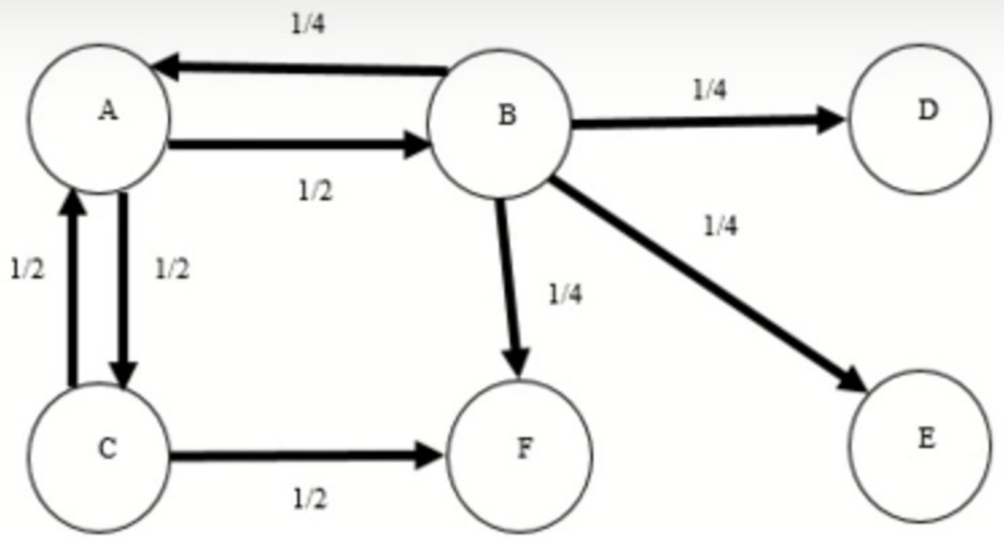



$$M^1 = \begin{pmatrix} 0 & 1/4 & 1/2 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 1/2 & 0 & 0 & 0 \end{pmatrix} * \begin{pmatrix} 0.8 \\ 0.8 \\ 0.8 \\ 0.8 \\ 0.8 \\ 0.8 \end{pmatrix} = \begin{pmatrix} 0.6 \\ 0.4 \\ 0.4 \\ 0.2 \\ 0.2 \\ 0.6 \end{pmatrix}$$

# Inbound, Outbound and Dangling Links




$$M^2 = \begin{pmatrix} 0 & 1/4 & 1/2 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 1/2 & 0 & 0 & 0 \end{pmatrix} * \begin{pmatrix} 0.6 \\ 0.4 \\ 0.4 \\ 0.2 \\ 0.2 \\ 0.6 \end{pmatrix} = \begin{pmatrix} 0.3 \\ 0.3 \\ 0.3 \\ 0.1 \\ 0.1 \\ 0.3 \end{pmatrix}$$




$$M^3 = \begin{pmatrix} 0 & 1/4 & 1/2 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 1/2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 0 & 0 & 0 & 0 \\ 0 & 1/4 & 1/2 & 0 & 0 & 0 \end{pmatrix} * \begin{pmatrix} 0.3 \\ 0.3 \\ 0.3 \\ 0.1 \\ 0.1 \\ 0.3 \end{pmatrix} = \begin{pmatrix} 0.225 \\ 0.15 \\ 0.15 \\ 0.075 \\ 0.075 \\ 0.225 \end{pmatrix}$$

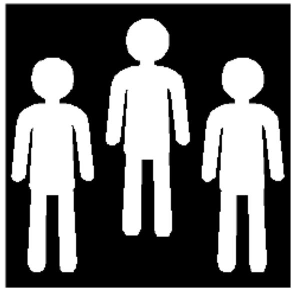
# Next Generation Search Engines

- More specialized/customized (vertical search engines)
  - Special group of users (community engines, e.g., Citeseer)
  - Personalized (better understanding of users)
  - Special genre/domain (better understanding of documents)
- Learning over time (evolving)
- Integration of search, navigation, and recommendation/filtering (full-fledged information management)
- Beyond search to support tasks (e.g., shopping)
- Many opportunities for innovations!

# The Data-User-Service (DUS) Triangle

Lawyers
Scientists
Online shoppers
…
…

Users



Data

Search
Browsing
Mining
Task support
…

Web pages
News articles
Blog articles
Literature
Email
…

Services

# Future Intelligent Information Systems