Big Data and Data Mining

Web Information Retrieval

Flavio Bertini

flavio.bertini@unipr.it

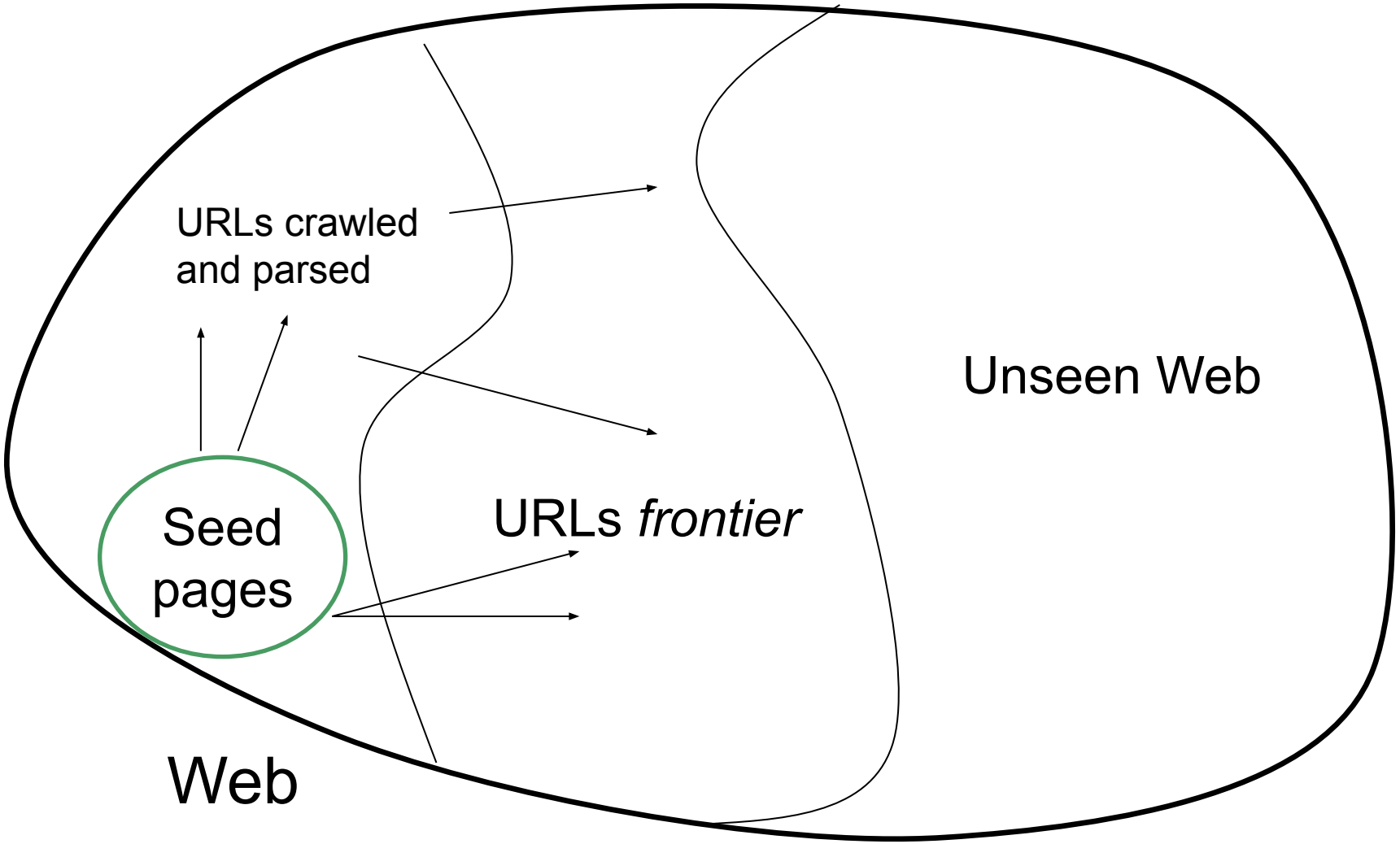
Web Crawling

- Web crawling is the process by which **we gather pages from the Web**
- Goal: **quickly** and efficiently gather as many useful Web pages as possible, together with the **link structure** that interconnects them

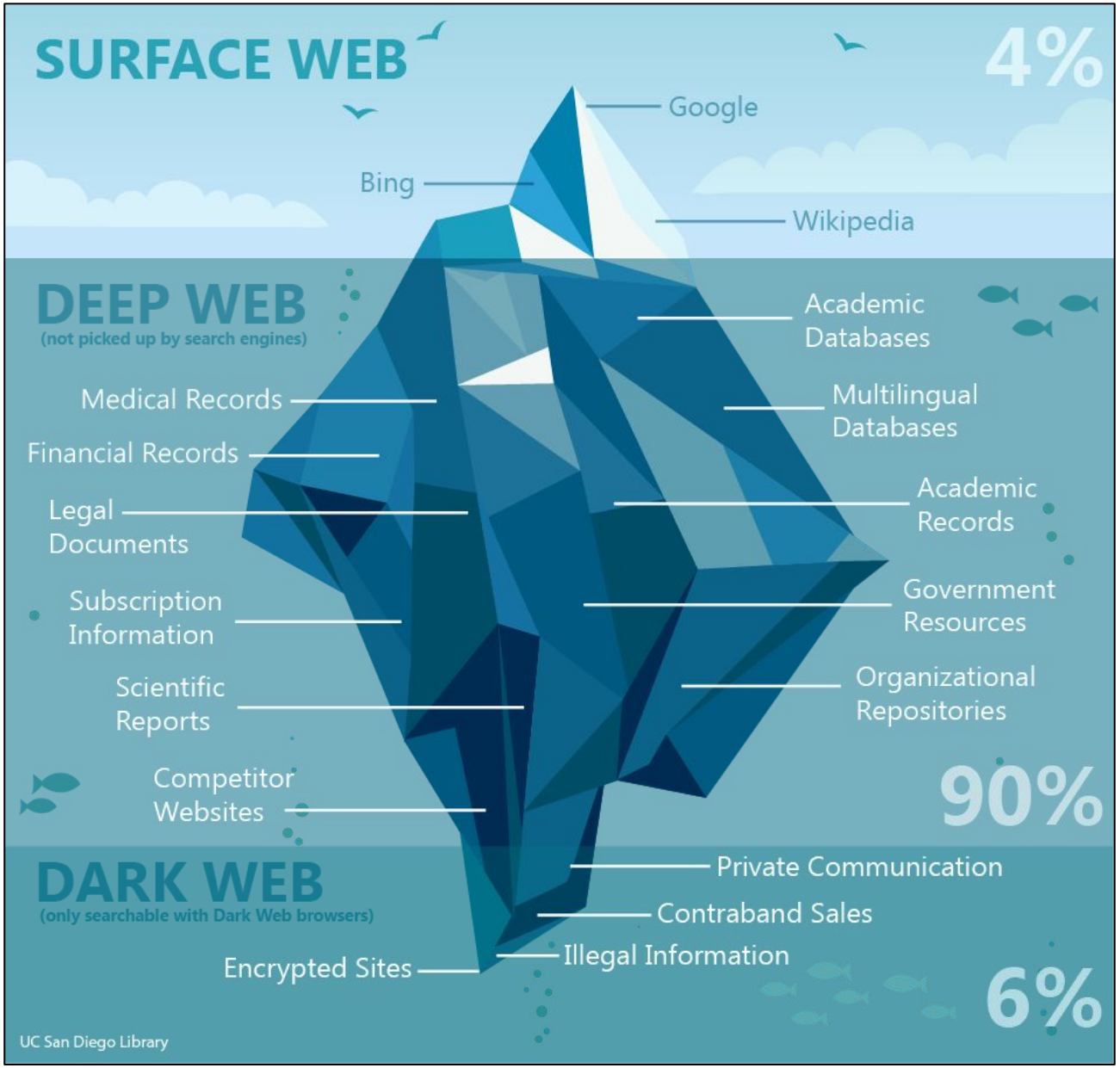
Basic Crawler Operation

- A crawler (a.k.a. spider)
  - Begin with known “seed” URLs
  - Fetch and parse them
    - Extract URLs they point to
    - Place the extracted URLs on a queue (the URLs *frontier*)
  - Fetch each URL on the frontier and repeat

Crawling Picture



Web, Deep Web & Dark Web



Crawler requirements

- A crawler must respect some requirements:
  - **Robustness**: MUST avoid spider traps (fetching an infinite number of pages in a particular domain)
  - **Politeness**: MUST respect Web servers policies, regulating the rate at which crawlers can visit them

Robustness

- Web crawling isn't feasible with one machine
  - All of the above steps are distributed
- Malicious pages
  - Spam pages
  - Spider traps – including dynamically generated
- Even non-malicious pages pose challenges
  - Latency/bandwidth to remote servers vary
  - Webmasters specific guidelines
    - How "deep" should you crawl a site's URL hierarchy?
  - Site mirrors and duplicate pages

Politeness

- **Explicit politeness**: specifications from webmasters on what portions of site can/cannot be crawled
  - `robots.txt`
- **Implicit politeness**: even with no specification, avoid hitting any site too often

Robots.txt

- Protocol for giving spiders (“robots”) limited access to a website, originally from 1994
  - www.robotstxt.org
- Website announces its request on what can (or cannot) be crawled
  - For a server, create a file named `robots.txt`
  - This file specifies access restrictions
- `Robots.txt` contains set of rules that **should** be followed by clients

Robots.txt: Example

- Example:
  - No robot should visit any URL starting with "/yoursite/temp/", except the robot called “searchengine":

```
User-agent: *
Disallow: /yoursite/temp/
```

For **all** user-agents (client names) forbid access to directory */yoursite/temp*

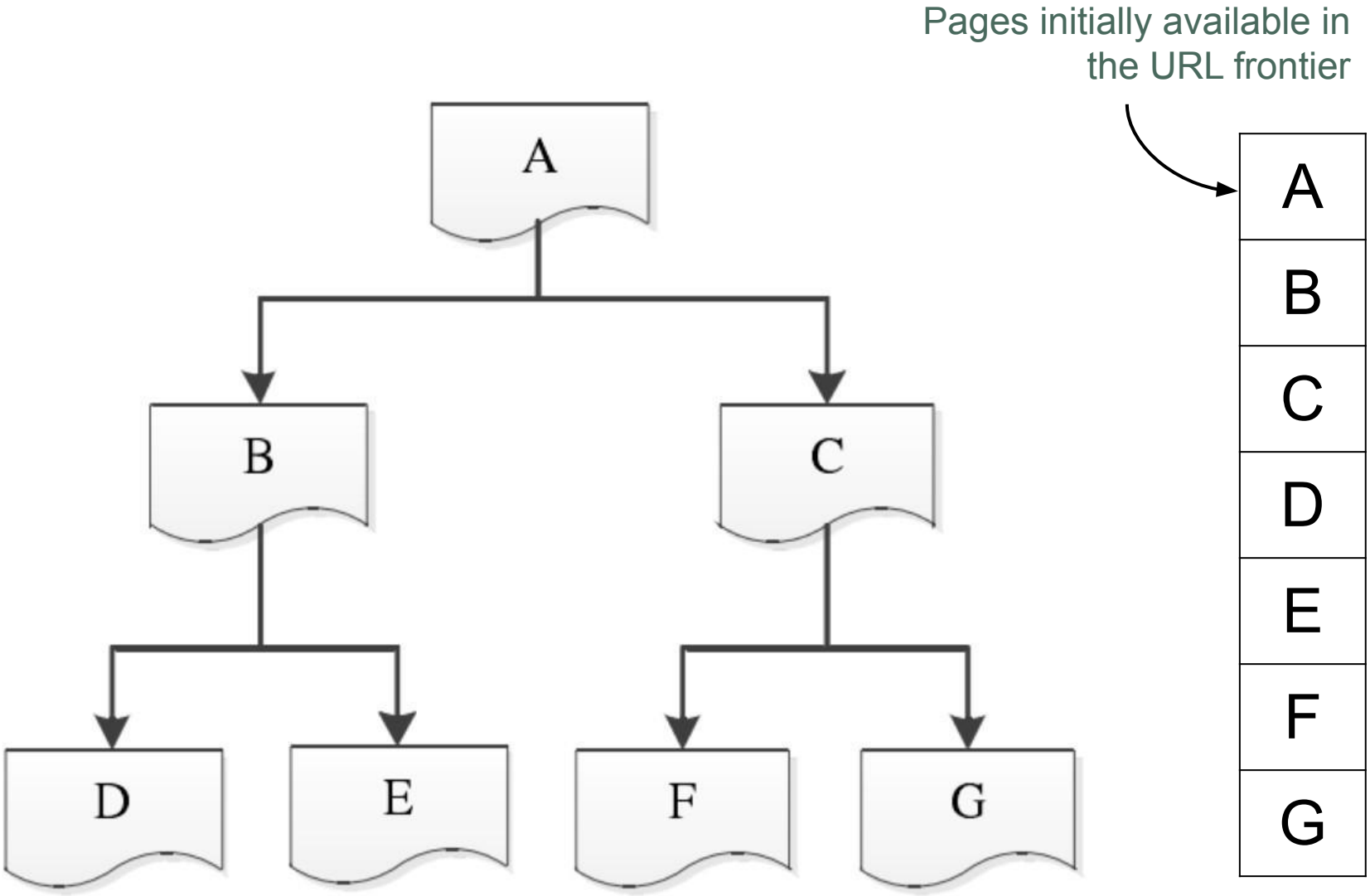
```
User-agent: searchengine
Disallow:
```

For user-agents named “searchengine” do not forbid nothing, everything is thus accessible

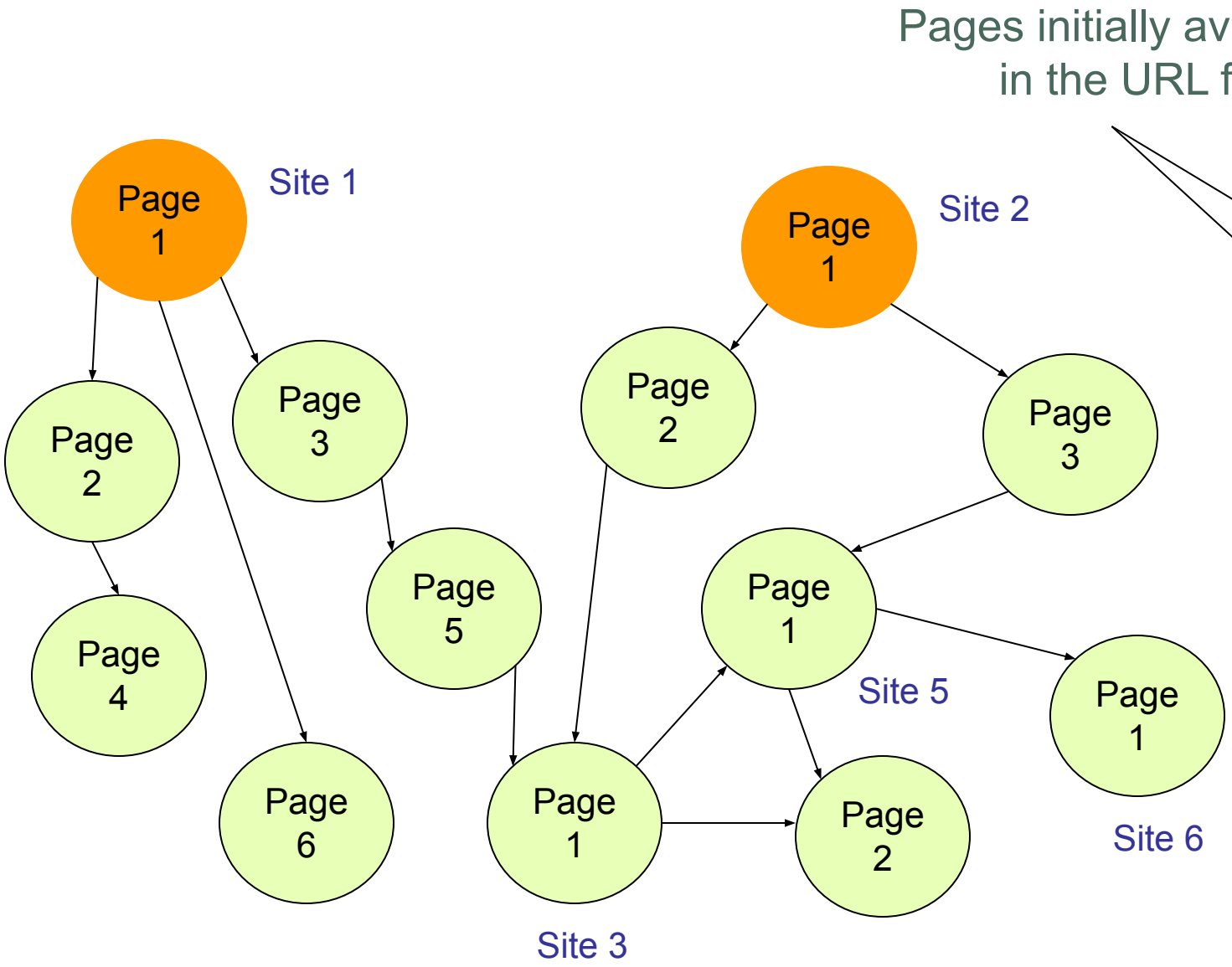
URL frontier

- Pages are **added** to the URL frontier according to the following strategies:
  - **Breadth first** strategy: given a Web page in the URL frontier, add **all pages linked by the current page**. Coverage is wide but superficial
  - **Depth first** strategy: given a Web page in the URL frontier, **follow the first link in the current page** until the first page without links

Breadth first strategy

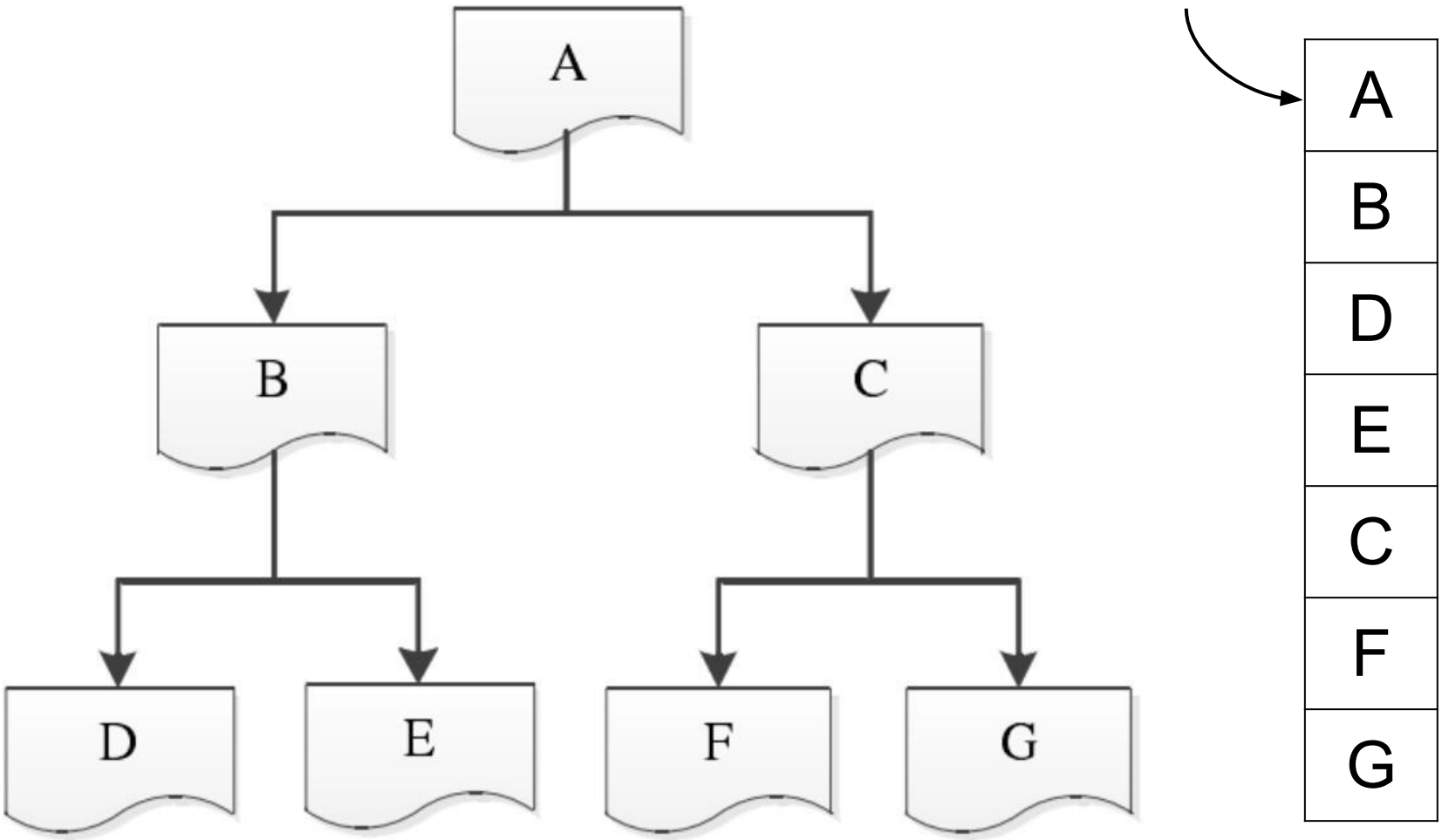


URL frontier with BFS

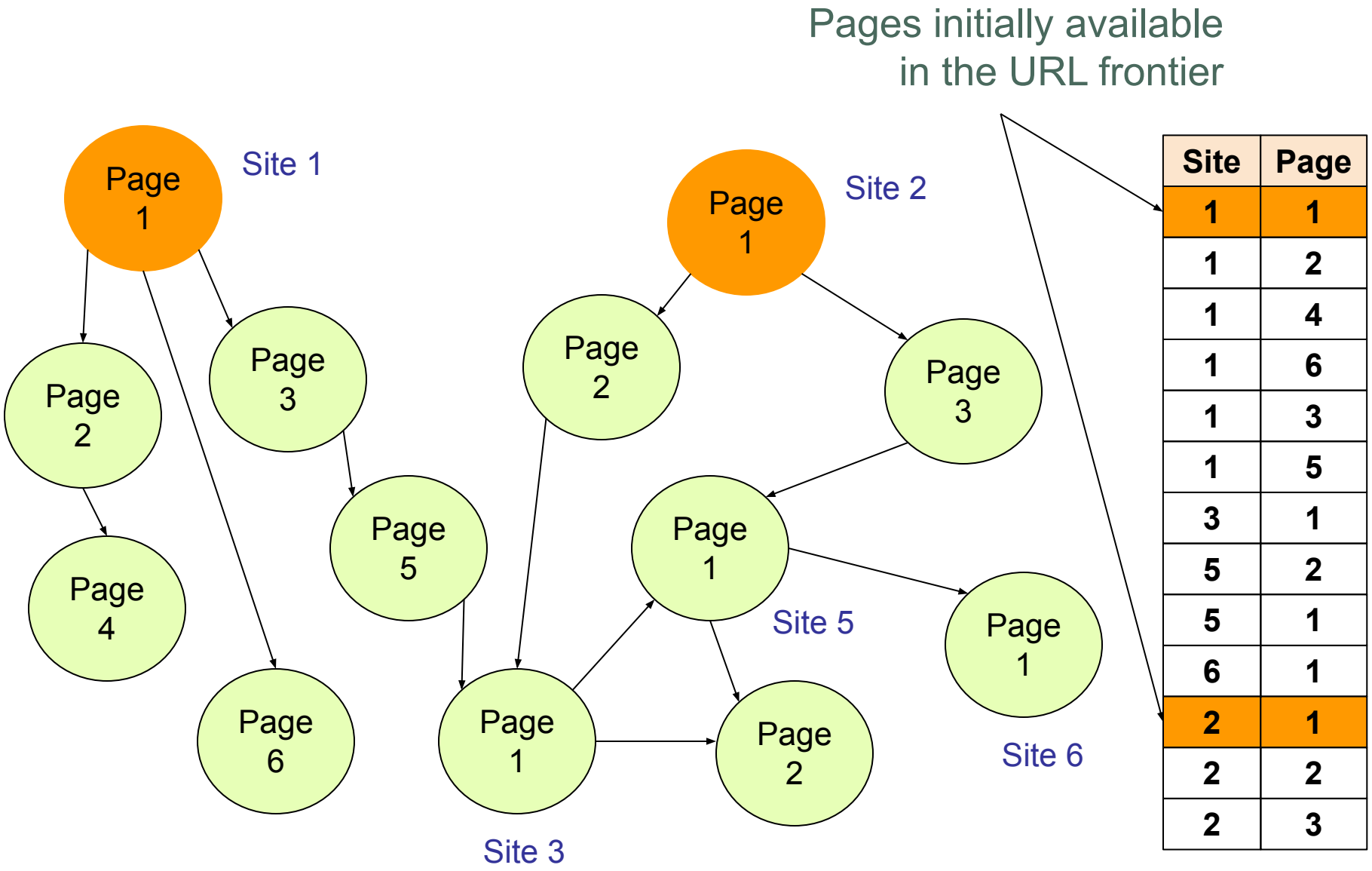


Site	Page
1	1
2	1
1	2
1	6
1	3
2	2
2	3
1	4
1	5
3	1
5	1
5	2
6	1

Depth first strategy



URL frontier with DFS



BFS vs DFS

BFS frontier

Site	Page
1	1
2	1
1	2
1	6
1	3
2	2
2	3
1	4
1	5
3	1
5	1
5	2
6	1

DFS frontier

Site	Page
1	1
1	2
1	4
1	6
1	3
1	5
3	1
5	2
5	1
6	1
2	1
2	2
2	3

Searching the web

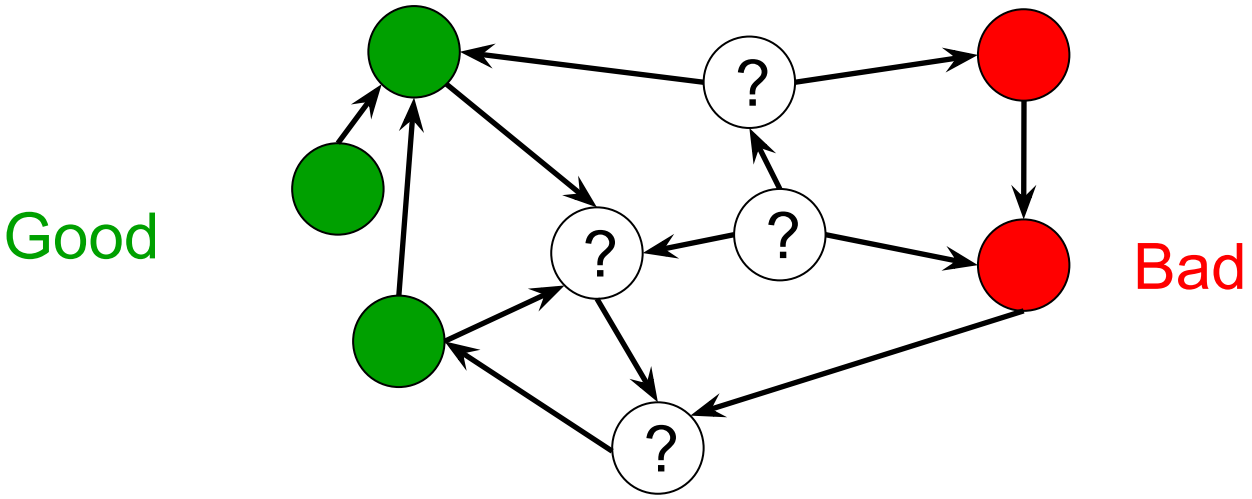
- There are thousands of billions of pages on the web, but most of them are not very interesting
- Suppose you have to visit the site for eBay and you don't know that www.ebay.com is the URL
  - There are millions of web pages that contain the term "eBay"
  - There can be websites with more frequency on the term "eBay" than eBay itself
- We need a notion of **popularity**, together with a notion of relevance

Web information retrieval

- With respect to traditional textual search engines, **Web information retrieval** systems build **ranking** by combining at least two evidences of relevance:
  - the degree of matching of a page: the **content score**
  - the degree of importance of a page: the **popularity score**
- While the **content score** can be calculated using one of the information retrieval models described so far
- The **popularity score** can be calculated from an analysis of the indexed pages' **hyperlink structure** using one or more ***link analysis*** models
  - Do the links represent a conferral of authority to some pages? Is this useful for ranking?

Simple link analysis

- Links are powerful sources of authenticity and authority
- The **Good**, The **Bad** and The **Unknown**, simple iterative logic
  - Good nodes won't point to Bad nodes
  - If you point to a Bad node, you're Bad
  - If a Good node points to you, you're Good



Citation Analysis

- Citation frequency is an estimation of a researcher popularity
- Bibliographic coupling frequency
  - Articles that co-cite the same articles are related
- Citation indexing: as a tool in journal evaluation
  - Who is this author cited by? (Garfield 1972)
- PageRank preview: Pinski and Narin ‘70s*
  - Asked: which journals are authoritative?

*Citation influence for journal aggregates of scientific publications: Theory, with application to the literature of physics

PageRank

- The PageRank technique for link analysis assigns a **numerical score between 0 and 1** to every node in the web graph
- The PageRank score of a node depends on the **link structure** of the web graph
- Given a query, a web search engine computes a **composite score** for each web page that combines hundreds of features such as cosine similarity, together with the PageRank score
- This composite score is used to provide a **ranked list of results** for the query

The random surfer (1/3)

- Consider a *random surfer* Alice who begins a random walk on the web, starting from a page
  - Alice is extremely bored, she wanders aimlessly between web pages
  - Her browser has a special "**surprise me**" button at the top that will jump to a random web page when clicked
  - Each time a web page loads she chooses whether to
    - Click on a **random** link on the page
    - Click the surprise me button
  - Alice is sufficiently bored that she intends to keep browsing the Web like this forever

The random surfer (2/3)

- Let provide a more formally definition: Alice browses the Web using this algorithm:
  1. Choose a random number *r* between 0 and 1
  2. If $r > \lambda$:

     ⇒ Click the “surprise me” button
  3. If $r \leq \lambda$:

     ⇒ Click a link at random on the current page
  4. Start again
- Because of Alice’s special “surprise me” button, we can be guaranteed that eventually she will reach every page on the Internet

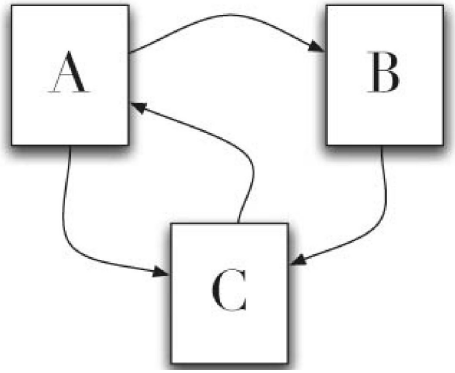
The random surfer (3/3)

- Now suppose that while Alice is browsing, you walk in and glance at the web page on her screen. **What is the probability** that she will be looking at the eBay website?

- That probability is eBay's **PageRank**

PageRank calculation

- The PageRank calculation corresponds to finding the stationary probability distribution of a *random walk* on the graph of the Web. A random walk is a special case of a *Markov chain* in which the next state depends solely on the current state



- If the web consists of the 3 pages in figure (A,B,C), the PageRank of C depends on the PageRank of A and B:

$$PR(C) = \frac{PR(A)}{2} + \frac{PR(B)}{1}$$

- The PageRank conferred by an outbound link is equal to the document's own PageRank score divided by the number of outbound links
- We start by assuming that the PageRank values for all pages are the same, then we iterate the calculation. After few iterations, the PageRank values converge to the final values of
  - PR(C) = 0.4
  - PR(A) = 0.4
  - PR(B) = 0.2

Use of PageRank in Google

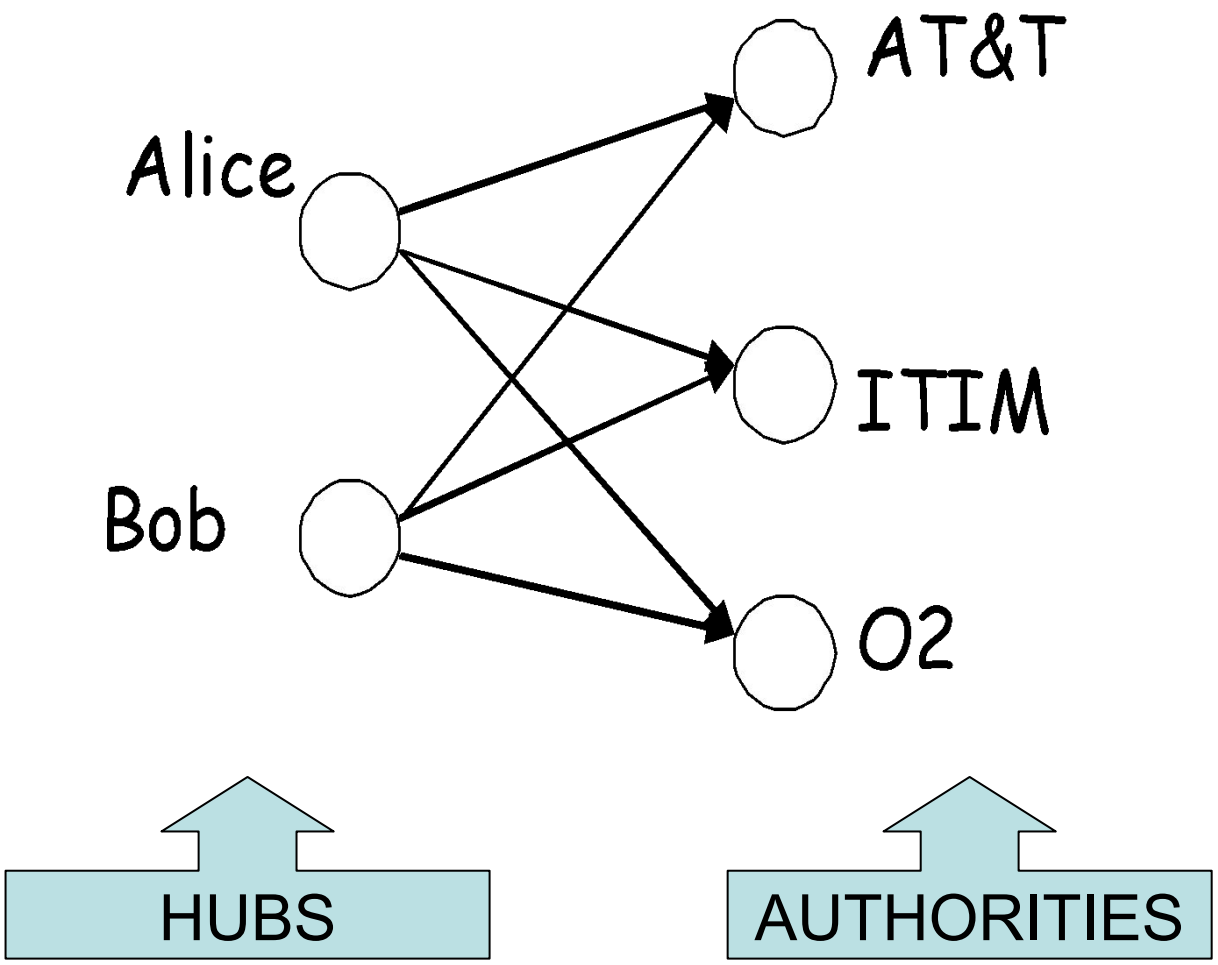
- PageRank is now **only one of the many** factors that determine the final score of a Web page in Google
- It is now a part of a much larger ranking system that it is believed to account for more than **200 different "signals"** (ranking variables):
  - **language features** (phrases, synonyms, spelling mistakes, etc.)
  - **query features** that relate to language features, trending terms/phrases
  - **time-related features** (e.g., "news" related queries might be best answered by recently indexed documents, while factual queries are better answered by more "resilient" pages)
  - **personalization features**, which relate to one's search history, behavior, and social surrounding

Hyperlink-Induced Topic Search (HITS)

- In response to a query, instead of an ordered list of pages each meeting the query, find **two sets of inter-related pages**:
  - ***Hub pages*** are good lists of links on a subject
    - e.g., “Bob’s list of cancer-related links.”
  - ***Authority pages*** occur recurrently on good hubs for the subject
- Best suited for “broad topic” queries rather than for page-finding queries
- Gets at a broader slice of common *opinion*

HITS Example

Query: "***Mobile telecom companies***"



Hubs and Authorities

- Thus, a **good hub page** for a topic *points* to many authoritative pages for that topic
- A **good authority page** for a topic is *pointed* to by many good hubs for that topic
- Circular definition - will turn this into an iterative computation

Semantic Search

- The name “information retrieval” is standard, but as traditionally practiced, it’s not really right
- All you get is **document retrieval**, and beyond that the job is up to you
- **Semantic Search**: doing graph search over structured knowledge rather than traditional text search:
  - Google Knowledge Graph
  - Facebook Graph Search
  - Bing’s Satori
  - Things like Wolfram Alpha

References

- Bruce Croft, Donald Metzler, Trevor Strohman **Search Engines: Information Retrieval in Practice** Pearson (2010)

- Christopher D. Manning, Prabhakar Raghavan and Hinrich Schütze **Introduction to Information Retrieval** Cambridge University Press. (2008)

- Stefano Ceri, Alessandro Bozzon **Web Information Retrieval** Springer. (2013)