Link analysis: HITS

Web search results: desired

- List of webpages / websites ranked according to
  - Relevance to query – we have already studied in detail
  - Importance / trustworthiness of websites - centrality
  - Location / time of query
  - Recency of page
  - … and many other factors

Node centrality

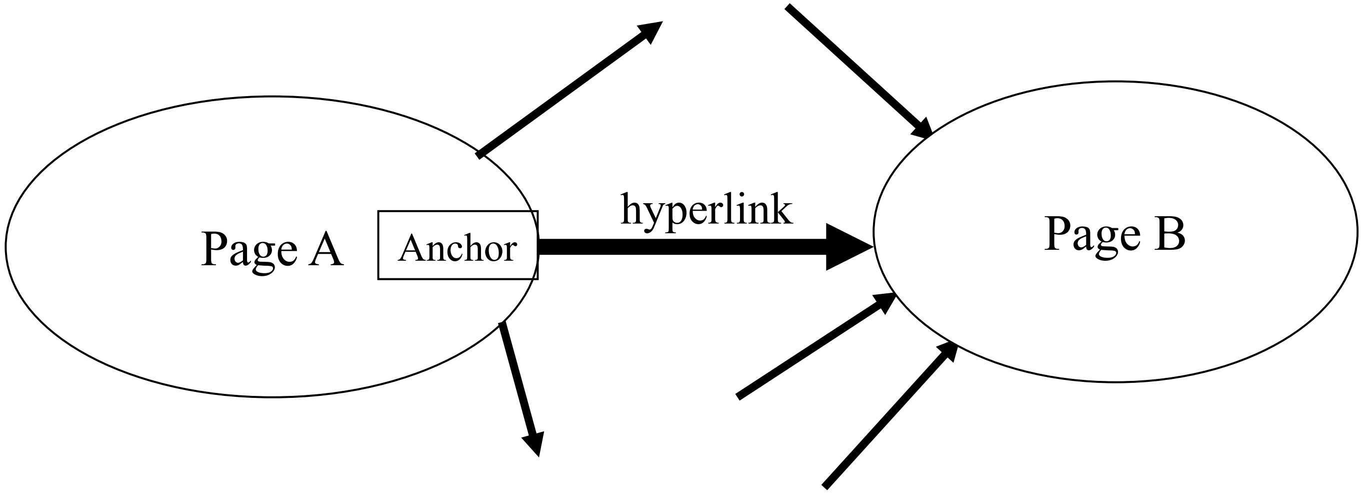
- Relative importance of a node in a network

- How influential a person is within a social network
- How important a webpage is in the Web

Node centrality in Web

- Web graph:
  - Nodes are webpages
  - Edges are hyperlinks (directed)

The Web as a Directed Graph



Hypothesis 1: A hyperlink between pages denotes a conferral of authority (quality signal)

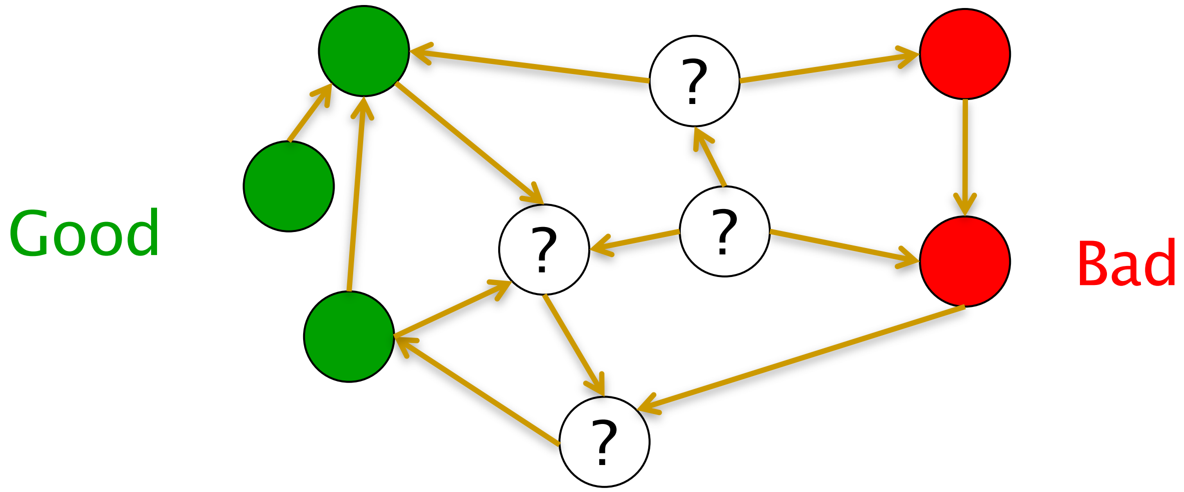
Hypothesis 2: The text in the anchor of a hyperlink on page A describes the target page B

Importance of node centrality in Web

- If only relevance used to rank webpages, ranking algorithm can be easily spammed
- Previously, indegree of webpages used to rank pages according to importance
- Easily gamed by spammers creating their own webpages

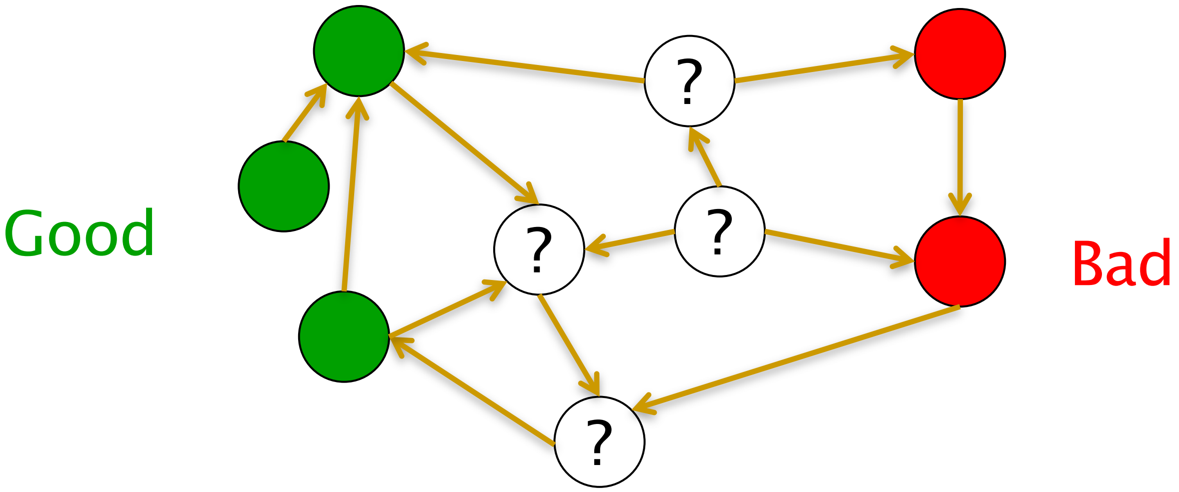
A better idea

- Nodes of three types: The Good, The Bad and The Unknown
  - Assumption: Good nodes won't point to Bad nodes
  - All other combinations plausible



Simple iterative logic

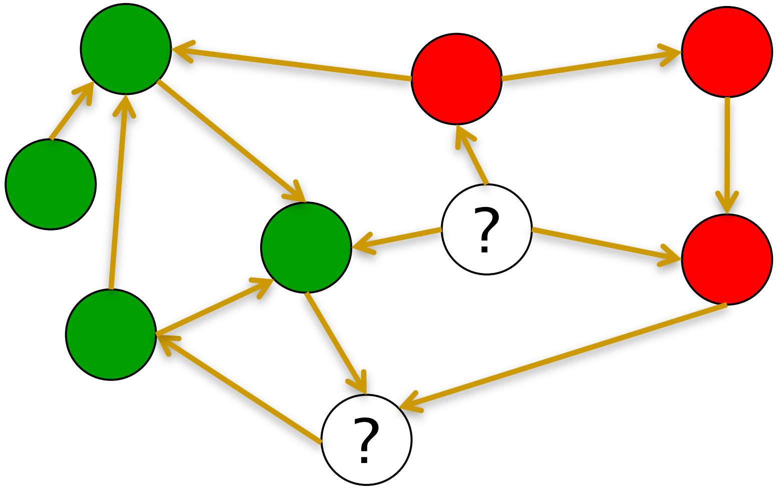
- Good nodes won't point to Bad nodes
  - If you point to a Bad node, you're Bad
  - If a Good node points to you, you're Good



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

Good



Bad

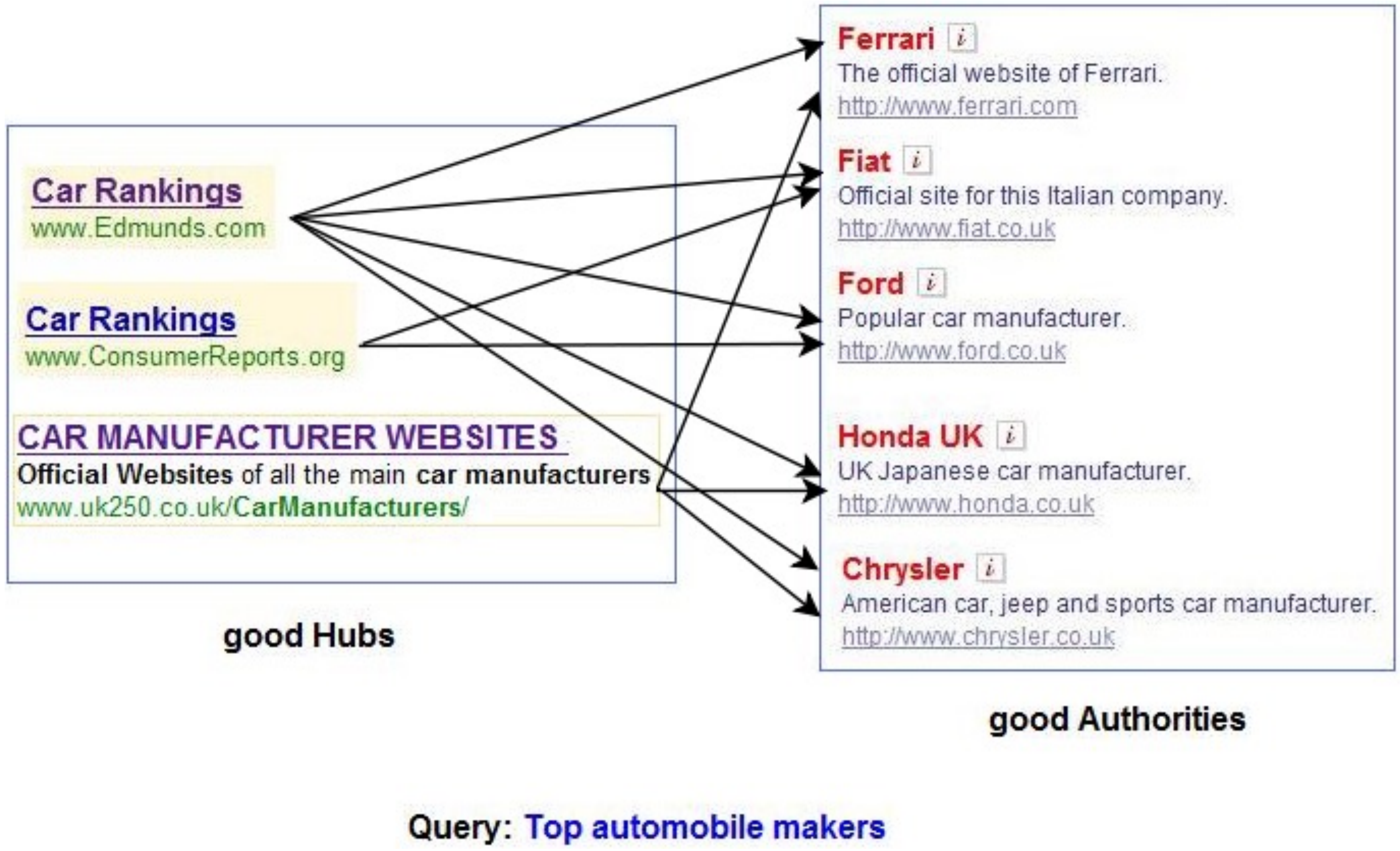
HITS ALGORITHM

HITS algorithm

- Hyperlink-Induced Topic Search, by Kleinberg

- Two types of important pages on the Web
  - Authority: has authoritative content on a topic
  - Hub: pages which link to many authoritative pages, e.g., a directory or catalog
  - A good hub is one which links to many good authorities
  - A good authority is one which is linked to by many good hubs

The hope



Car Rankings
www.Edmunds.com

Car Rankings
www.ConsumerReports.org

CAR MANUFACTURER WEBSITES
Official Websites of all the main car manufacturers
www.uk250.co.uk/CarManufacturers/

good Hubs

Ferrari i
The official website of Ferrari.
http://www.ferrari.com

Fiat i
Official site for this Italian company.
http://www.fiat.co.uk

Ford i
Popular car manufacturer.
http://www.ford.co.uk

Honda UK i
UK Japanese car manufacturer.
http://www.honda.co.uk

Chrysler i
American car, jeep and sports car manufacturer.
http://www.chrysler.co.uk

good Authorities

Query: Top automobile makers

HITS

- HITS computes two scores for each page *p*
  - Authority score: sum of hub scores of all pages which point to *p*
  - Hub score: sum of authority scores of all pages which *p* points to

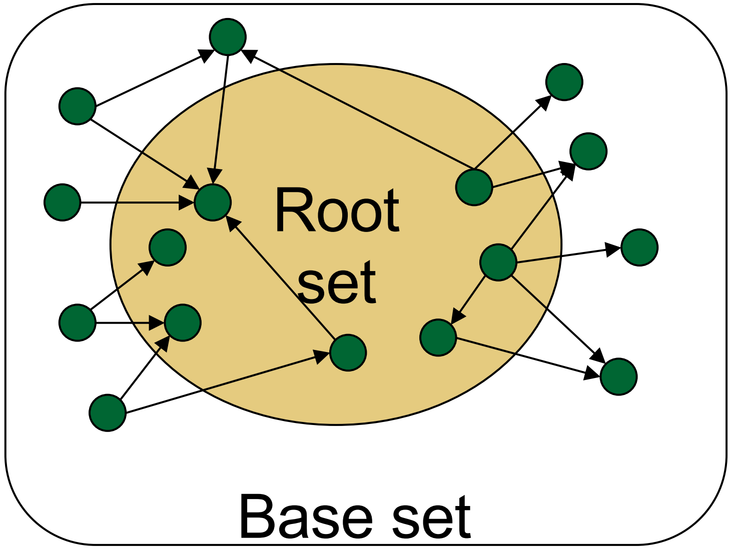
- Iterative algorithm
  - A series of iterations run, until the scores of all pages converge

HITS run on a query-dependent sub-graph

- Meant to run on a (sub)set of pages that are relevant to a given query
  - Top N pages relevant to query retrieved based on content → called the root set
  - Add to the root set all pages that are linked from it or that links to it → base set
  - Sub-graph of all nodes in base set → focused sub-graph

- Motivation of building base set
  - A good authority page may not contain the query term
  - Hubs describe authorities through the anchor text / text surrounding hyperlinks

Visualization



HITS Algorithm

```
Find focused sub-graph G of pages relevant to given query
for each page p in G:
    p.auth ← 1,  p.hub ← 1
do until convergence
    for each page p in G
        p.auth ← $\Sigma$ q.hub  for all pages q which link to p
        p.hub ← $\Sigma$ r.auth  for all pages r which p links to

    Normalize hub and auth scores for all pages
    Check convergence of scores
```

Normalization of scores

- Scores need to be normalized after each iteration
  - To prevent the *hub* and *auth* values from getting too big
  - Scaling factor does not really matter; we are only concerned with the relative values of the scores
- Different normalization schemes proposed
  - Normalize so that score vectors sum to 1
  - Normalization factor F: square root of sum of squares of current scores of all pages; divide score of each page by F at the end of each iteration

Checking for convergence

- Various convergence criteria used
  - Fixed number of iterations

  - Iterate until scores do not change appreciably from one iteration to the next (compute difference of score vectors from previous and current iterations)

  - Iterate until rankings of pages do not change

Matrix version of HITS

- Matrices / vectors
  - A: adjacency matrix of web graph. (u, v)-th element is 1 if page u links to page v
  - h: vector of hub scores of all pages
  - a: vector of authority scores of all pages

- $h \leftarrow A.a$
- $a \leftarrow A^T .h$

HITS not used commonly

- Topic Drift: Off-topic pages can cause off-topic "authorities" to be returned
- Hubs often transit to authorities
- Search engines themselves become hubs