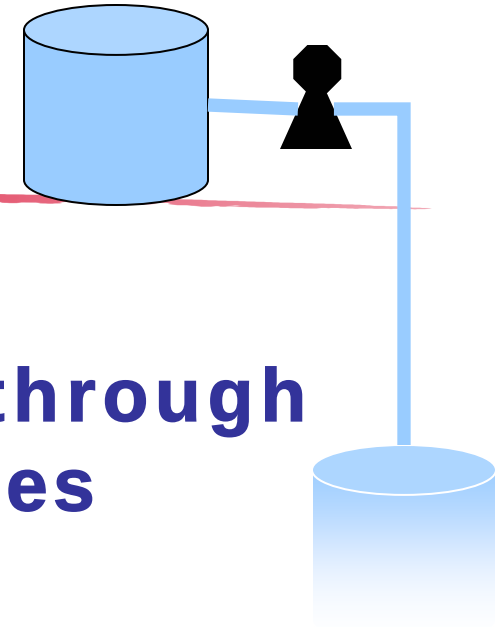

Siphoning Hidden-Web Data through Keyword-Based Interfaces

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Hidden/Deep/Invisible Web

- Databases and document collections on the Web *accessible through form interfaces*
  - Data is published as the result of a user request
- Lots of data – much bigger than the *visible* Web [BrightPlanet, 2001; Lawrence and Gyles,1998]
- High-quality content
- Several applications leverage (and are enabled by!) hidden data:
  - Web information integration, portals, data mining

Reconstructing Hidden Collections

- Form interfaces can be restrictive, and disallow *interesting* queries
- Some applications need *all data* hidden behind a form
  - Hidden-Web search engine
  - Data exploration and mining
  - Tracking changes to a gene database or your competitor's Web site
- *Can we automatically reconstruct a collection/database hidden behind a restrictive form interface?*

Hidden Web: Issues

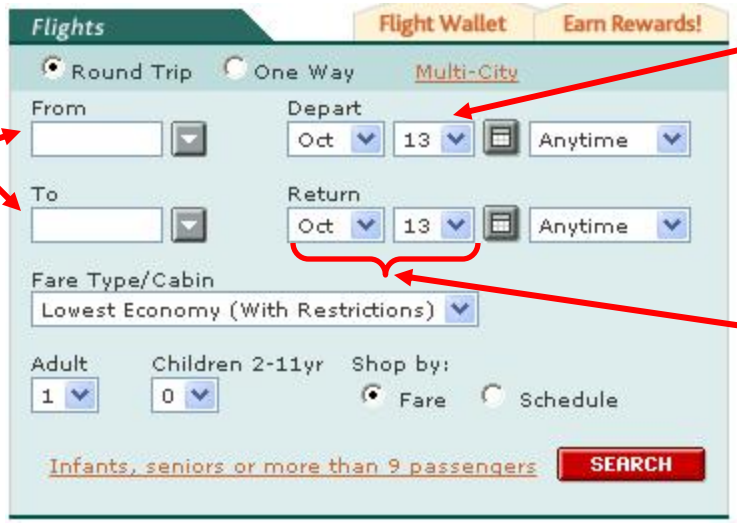
- Designed for human access
  - Fill out a form, get results
- Hard to find: Not accessible from search engines
- Hard to get:
  - Automation is hard – need to deal with form interface mechanics and restrictions
  - Expensive to retrieve data, e.g., a data mining application may require *too many* queries

Accessing Hidden Data: Challenges

- Automatically filling out forms

Constraints on individual values: days of month

Text fields: open-ended attributes



aircanada.ca

Constraints on set of values: Month = Sep, day = 31

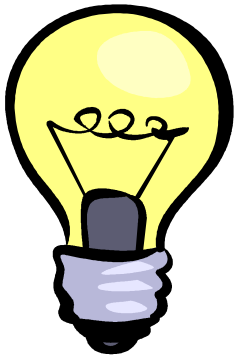
Accessing Hidden Data: State of the Art

- Wrappers can be very effective
  - Programs designed specifically to access data through a given form interface
  - Used in portals – small to medium scale
  - ☹ Require significant human input: write the program, specify input values
- Hidden-Web crawlers (HWC)
  - Attempt to automatically fill out *any form* encountered
  - ☺ More scalable than wrappers
  - ☹ Problems:
    - ☹ Not guaranteed to work – best effort…
    - ☹ Automatically filling out *unknown* forms is very hard, still need substantial human input
    - ☹ Can be very inefficient

Reconstructing Hidden Collections

- For reconstruction, need to generate a set of *valid inputs* that *retrieve all items* in the collection
- Wrappers are not a scalable solution
- HWCs focus on
  - Generating *valid inputs* – provide no guarantees all data will be retrieved
  - Structured (multi-attribute) forms – require deep understanding the semantics of forms and data

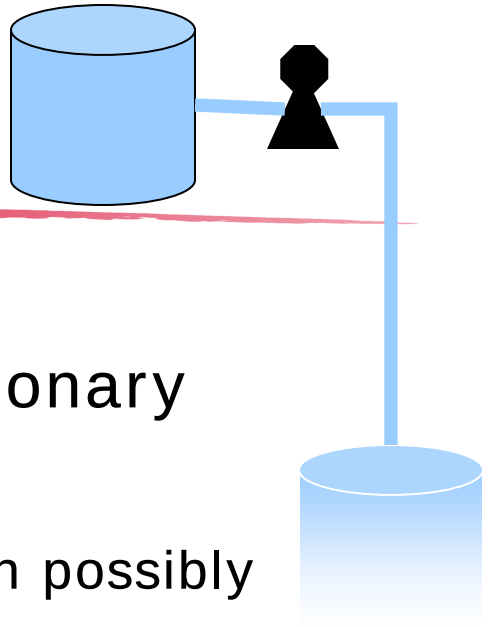
- Idea: Can we use keyword-based interfaces to automatically reconstruct hidden collections?



Keyword-based interfaces

- Intuitively, easier to fill out than structured forms
  - They have no structure
  - Domain = strings
- Widely used
  - Document collections
- ...even for structured data [BANKS – Bhalotia et al.,2002]
  - Web sites often support simple and advanced searches
  - Back-door access to structured databases!

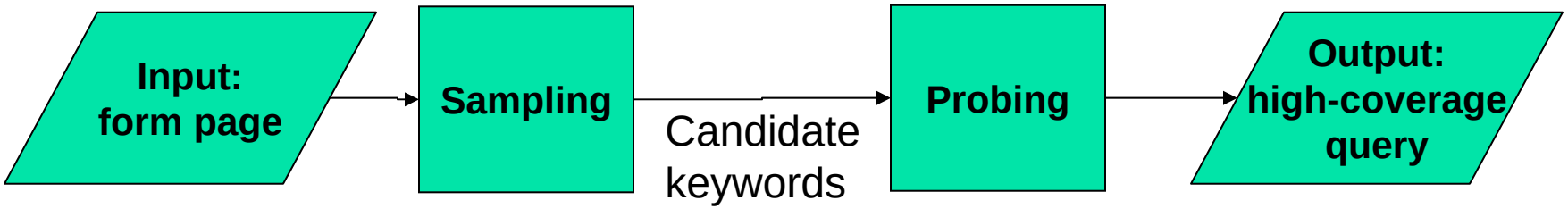
Using Keywords to Siphon Data



- Naïve solution
  - Issue query for each word in the dictionary
  - Problem:
    - Large number of unnecessary queries with possibly overlapping results
- Our solution
  - Identify high-frequency words in the database
    - Intuition: High-frequency words result in high coverage
  - Goal: high coverage with a small number of queries

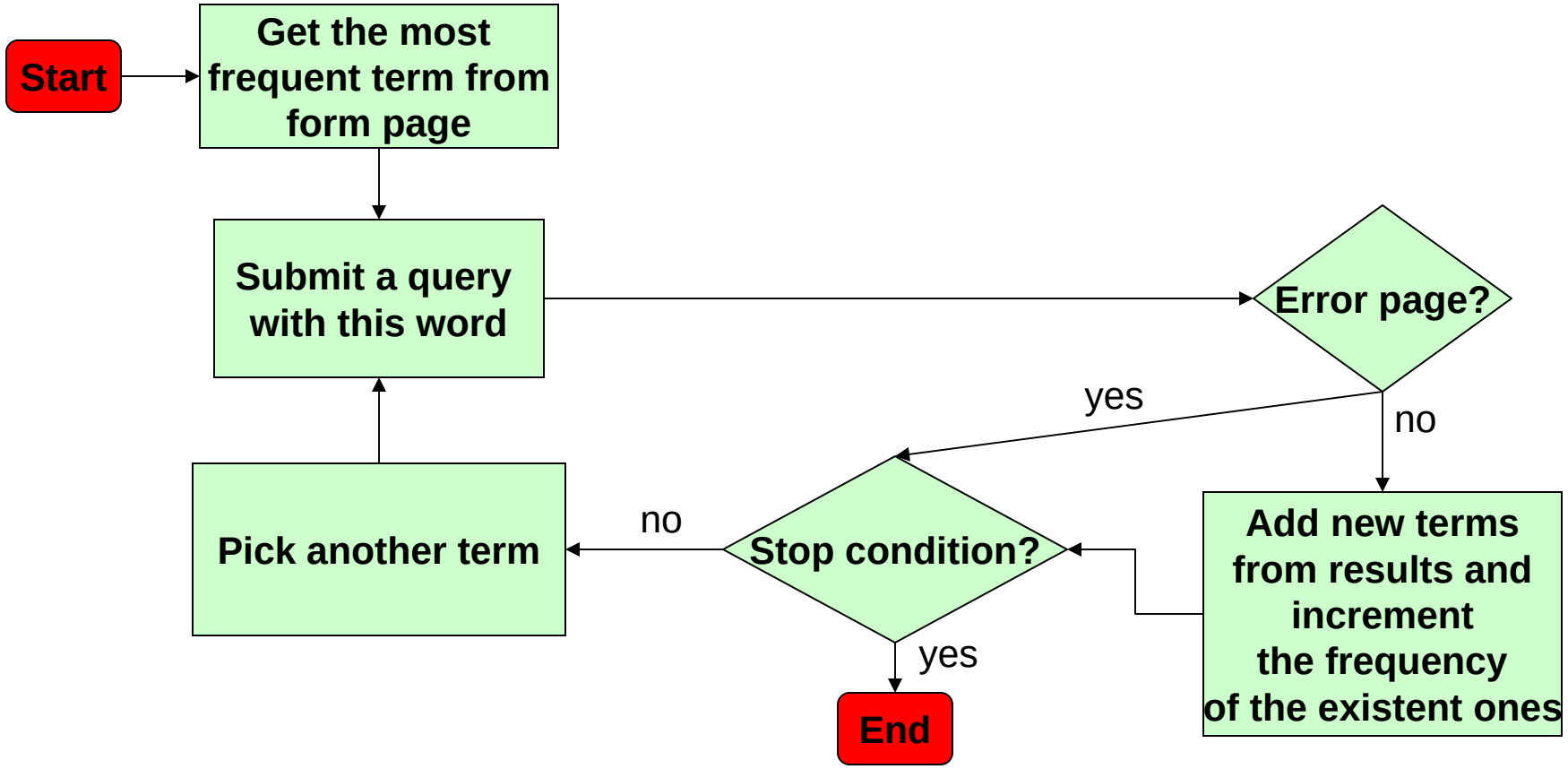
Reconstruction through Sampling and Probing

- The algorithm has two steps:
  1. Sampling: issue sampling queries to find high-frequency keywords – the *candidate keywords*
  2. Probing:
     - Combine the candidate keywords into a query, and probe the site to determine the query cardinality
     - Greedly select the query with largest cardinality



Sampling

- Building the keyword sample of the collection
  - Input: the form page
  - Output: candidate (high-frequency) keywords



Sampling: Issues and Solutions

- Choice of initial keyword submitted
  - Little effect on the final result as long as the query returns some answers [Callan and Connel, 2001]
  - Our approach: select terms in the form page
    - Probably related to the database content – likely to return some results
    - *Easy to obtain*
- Choice of stopping condition
  - Number of iterations: depends on the collection
    - Large/heterogeneous collections need a higher number of iterations
    - Larger number of iterations → higher cost
  - Our approach: try different values – if final coverage is low, iterate some more!

Sampling: Issues and Solutions

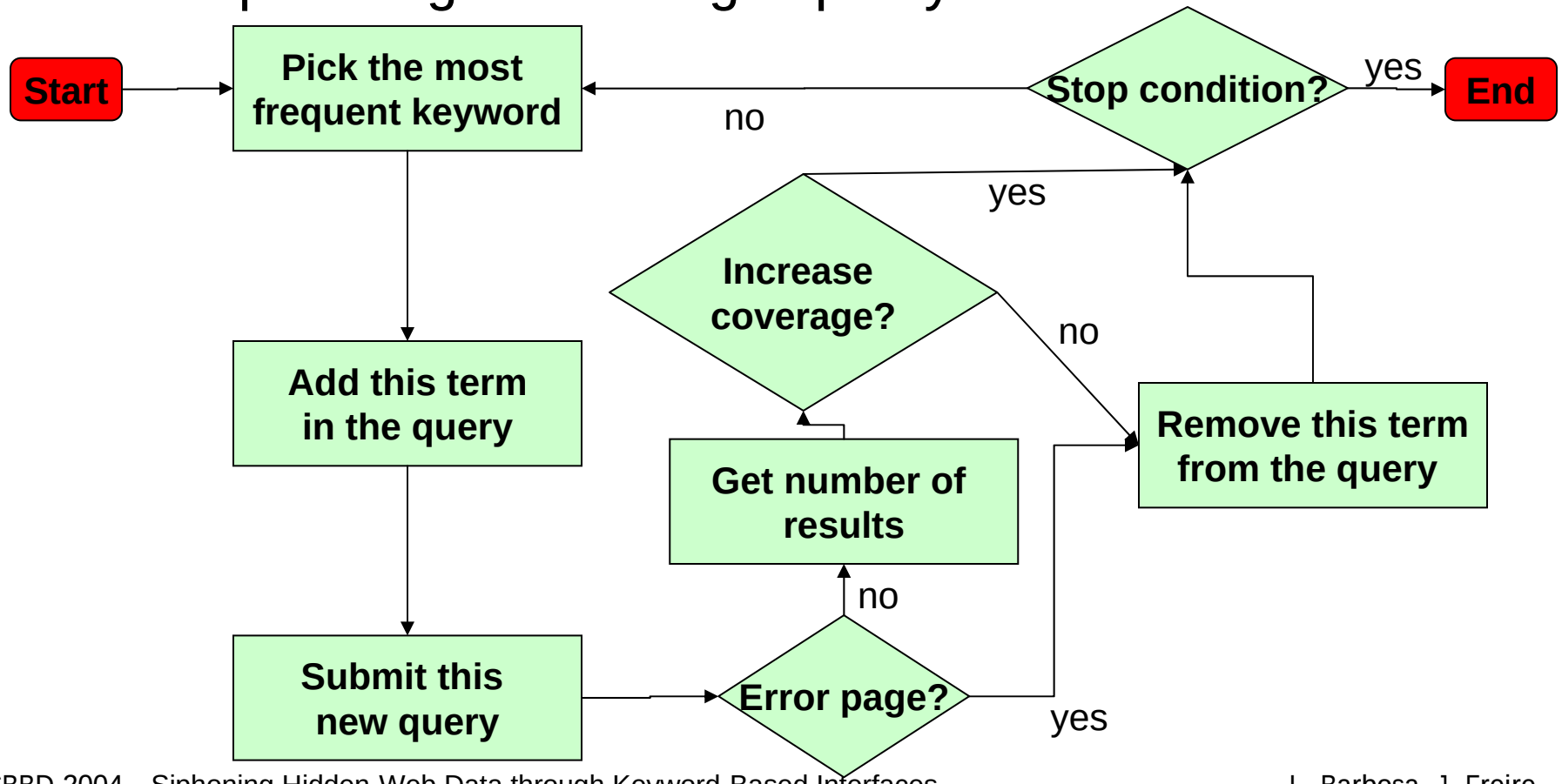
- Response page may contain content not related to the collection
  - May negatively impact the quality of the sample
  - E.g., ads and navigation bars
  - Error pages
  - Our solution: detect error pages – issue queries using *dummy* words [Doorebos et al]
  - *Future*: investigate *smart* techniques, such as automatic wrapper generation [Roadrunner, Crescenzi et al]

Sampling: Issues and Solutions

- Stopwords can lead to very high or very low coverage
  - Stopwords have the highest frequencies in collections
  - But they are not always indexed!
  - Our solution: detect whether stopwords are indexed – issue queries with stopwords before sampling

Probing

- Greedily building the high-coverage query
  - Input: candidate (high-frequency) keywords
  - Output: high-coverage query



Probing: Issues and Solutions

- Determining the number of results
  - Locate and extract the number of results from result page
  - Our approach: use heuristics to locate number of results
  - ☹ Some search sites do not make this information available or only provide an approximation
- Stopping condition
  - Max number of requests
    - Avoid overloading the Web server and search engine
  - Max number of words in the query
    - Avoid overloading the search engine, and some interfaces limit this anyway!
  - Values used: fixed in the experiments
    - Maximum number of requests: 15
    - Maximum query size: 10

Experiments

- Goals:
  - Measure coverage
  - Discover “good” parameters for algorithms
  - Study the effectiveness of our choices
    - Stopwords
  - Understand the limitations of the approach
    - Impact of query results: title only versus description; information-rich vs clutter-rich pages
- Issue: collection sizes aren’t always available

Experiments: Sites Used

Site	Size (number of results)	Description
nwfusion.com – Network World Fusion	60,000	News information about information technology
apsa.org – American Psychoanalytic Association	34,000	Bibliographies of psychoanalytic literature
cdc.gov – Centers for Disease Control and Prevention	461,194	Health-related documents
epa.gov – Environment Protection Agency	550,134	Environment-related documents
georgetown.edu – Georgetown University	61,265	Search interface to the site
chid.nih.gov – Combined Health Information Database	127,211	Health-related documents
www.gsfc.nasa.gov – NASA Goddard Space Flight Center	24,668	Astronomy-related documents
www.ncbi.nlm.nih.gov/pubmed – NCBI PubMed	14,000,000	Citations for biomedical articles

Experiments: Coverage

- High coverage and quick convergence in sampling

Site	5 iterations	10 iterations	15 iterations	Use stopwords
nwfusion.com	94.8	94.4	94.4	true
apsa.org	86.6	88.5	91.6	true
cdc.gov	90.4	90.4	90.4	true
epa.gov	94.2	94.2	94.2	true
georgetown.edu	98.3	97.9	97.9	true
chid	35.9	22.8	22.8	true
gsfc.nasa.gov	99.9	99.9	99.9	false
pubmed	33.8	34.6	48.9	false

- Pubmed: after 50 iterations, 79.8% coverage
  - Collection is very large and heterogeneous
  - Does not index stopwords

Collection Idiosyncrasies

- The algorithm assumes that all items in the collection are uniformly indexed
- CHID: different fields are indexed differently
- The lowest coverage:35.9%

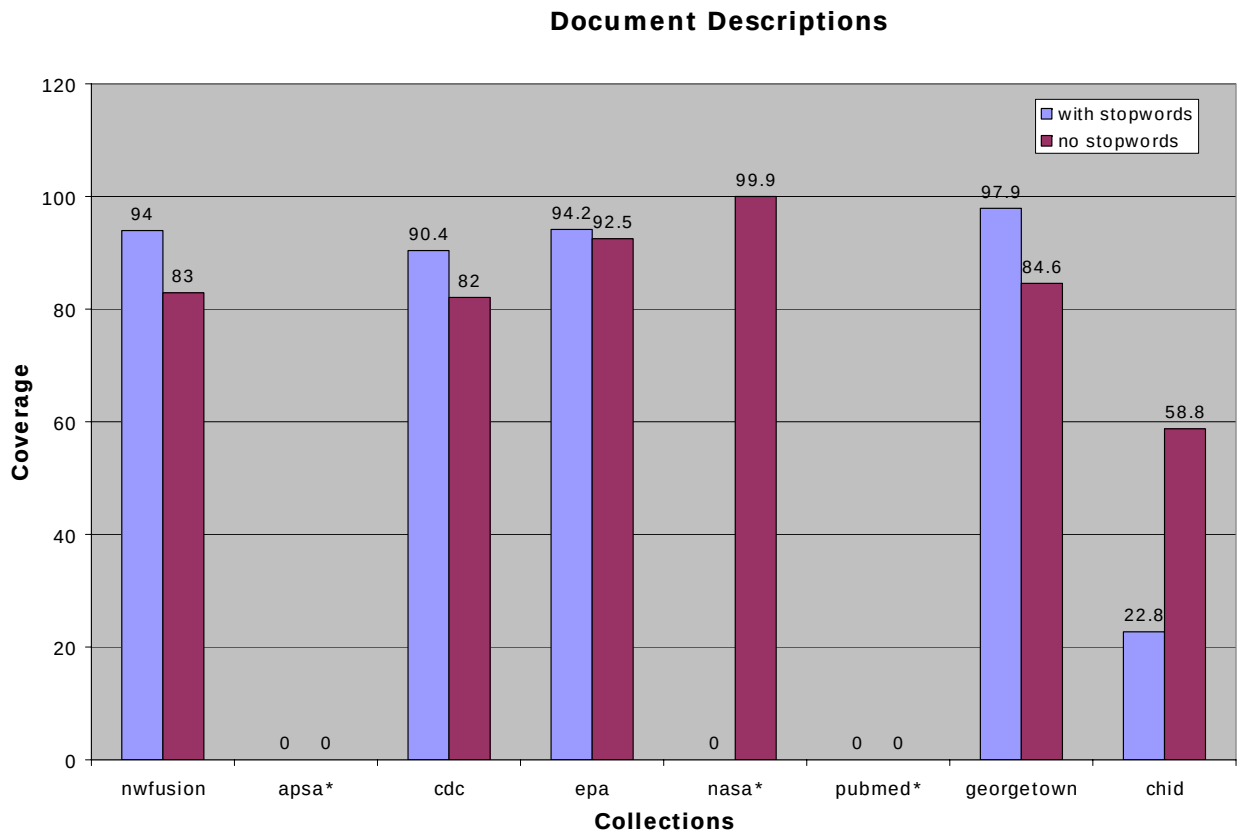
1. Preventing Crytposporidiosis.

Subfile: AIDS Education
Format (FM): 08 - Brochure.
Language(s) (LG): English.
Year Published (YR): 2003.
Audience code (AC): 084 - HIV Positive Persons. 157 - Persons with HIV/AIDS.
Corporate Author (CN): Project Inform, National HIV/AIDS Treatment Hotline.
Physical description (PD): 4 p.: b&w.
Availability (AV): Project Inform, National HIV/AIDS Treatment Hotline, 205 13th St Ste 2001, San Francisco, CA, 94103, (415) 558-8669, http://www.projectinform.org.
Abstract (AB): This information sheet discusses cryptosporidiosis (Crypto), a diarrheal disease caused by a parasite that can live in the intestines of humans and animals. This disease can be very serious, even fatal, in people with weakened immune systems. The information sheet describes, the symptoms, transmission, diagnosis, treatment, and prevention of Crypto, and gives examples of people who might be immuno-compromised or have a weakened immune system, such as people with AIDS or cancer, and transplant patients on immunosuppressive drugs. The information sheet also explains how crypto affects such people.
Major Descriptors (MJ): Disease Prevention. Disease Transmission. Guidelines. Hygiene. Opportunistic Infections. Sanitation.
Verification/Update Date (VE): 200304.
Notes (NT): This material is available in the following languages: AD0031721 Spanish.
Accession Number (AN): AD0031720.

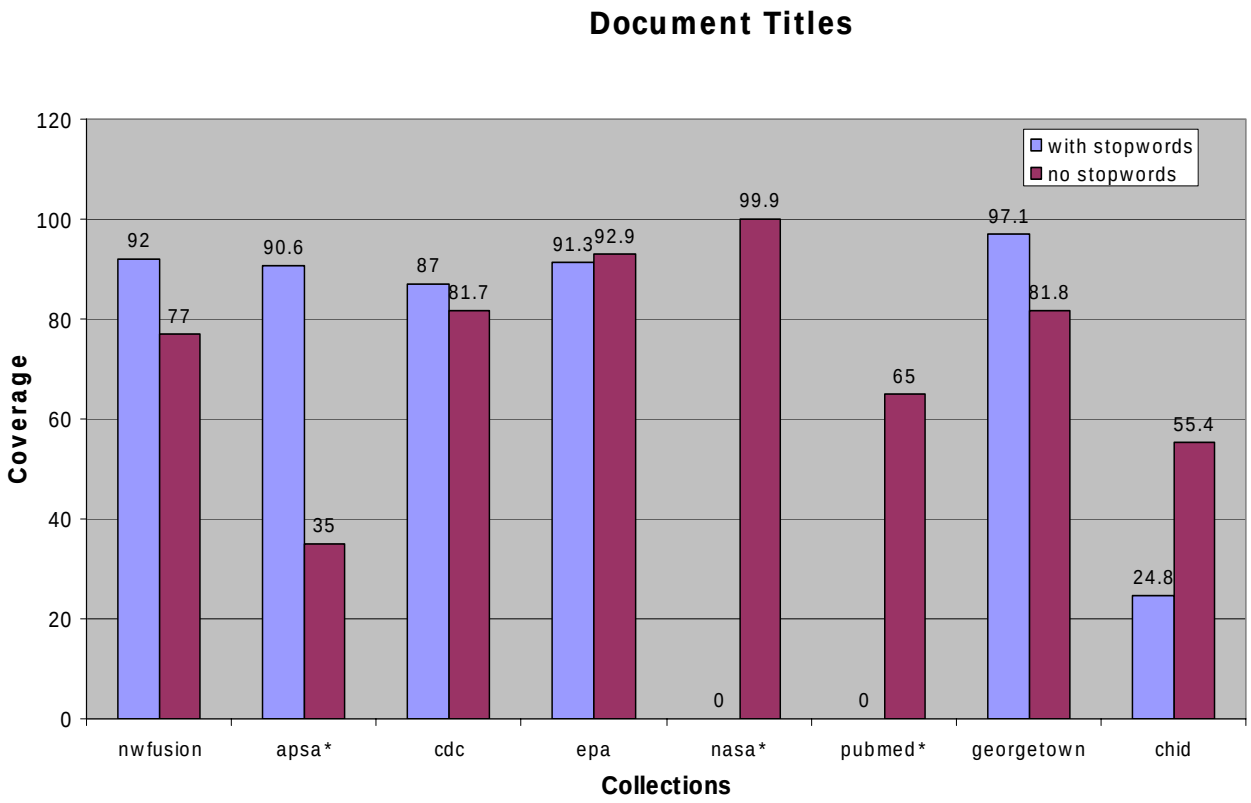
stopwords not indexed

stopwords indexed in an optional field

Experiments: Effectiveness of stopwords



Experiments: Effectiveness of stopwords

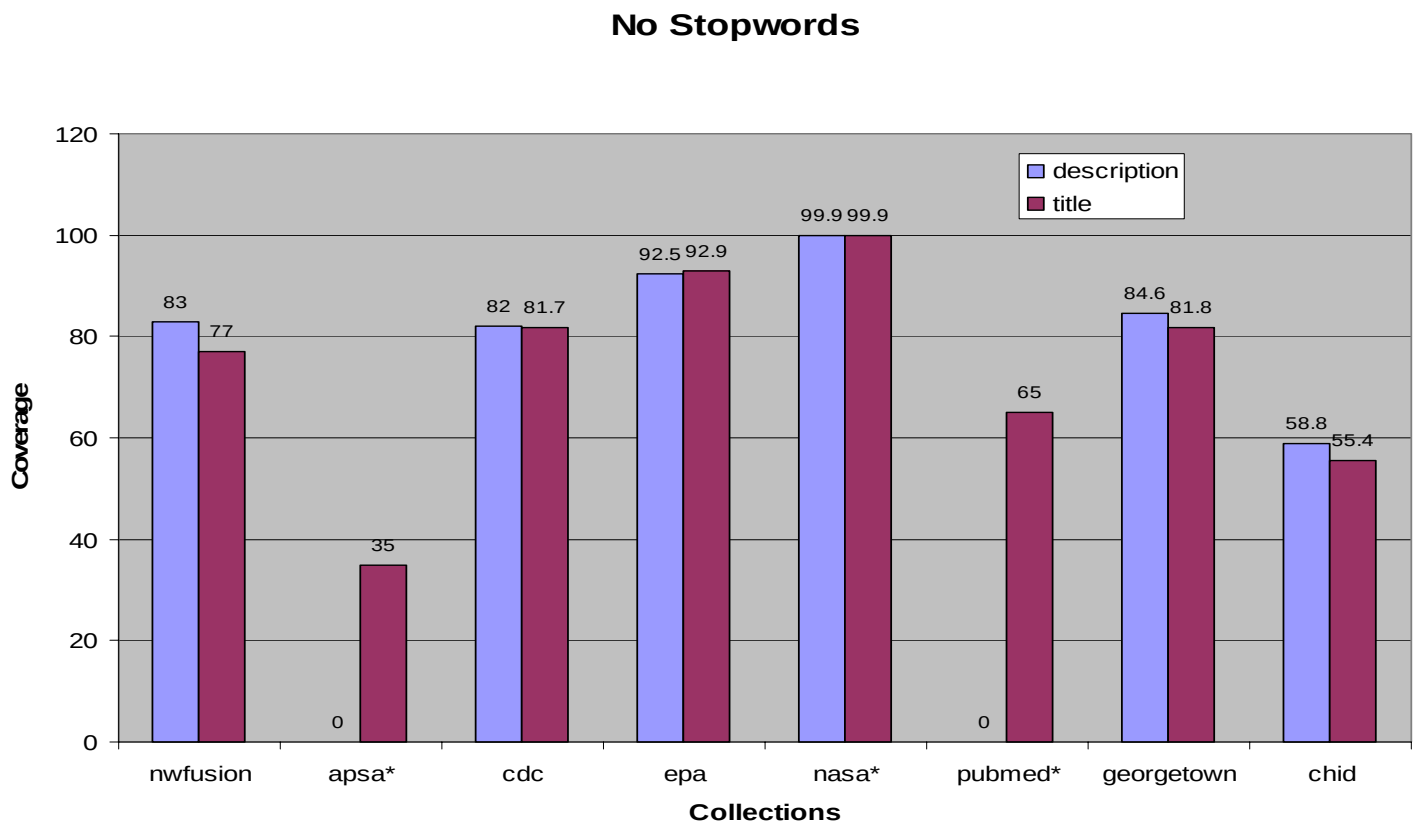


Using 15 iterations in sampling phase

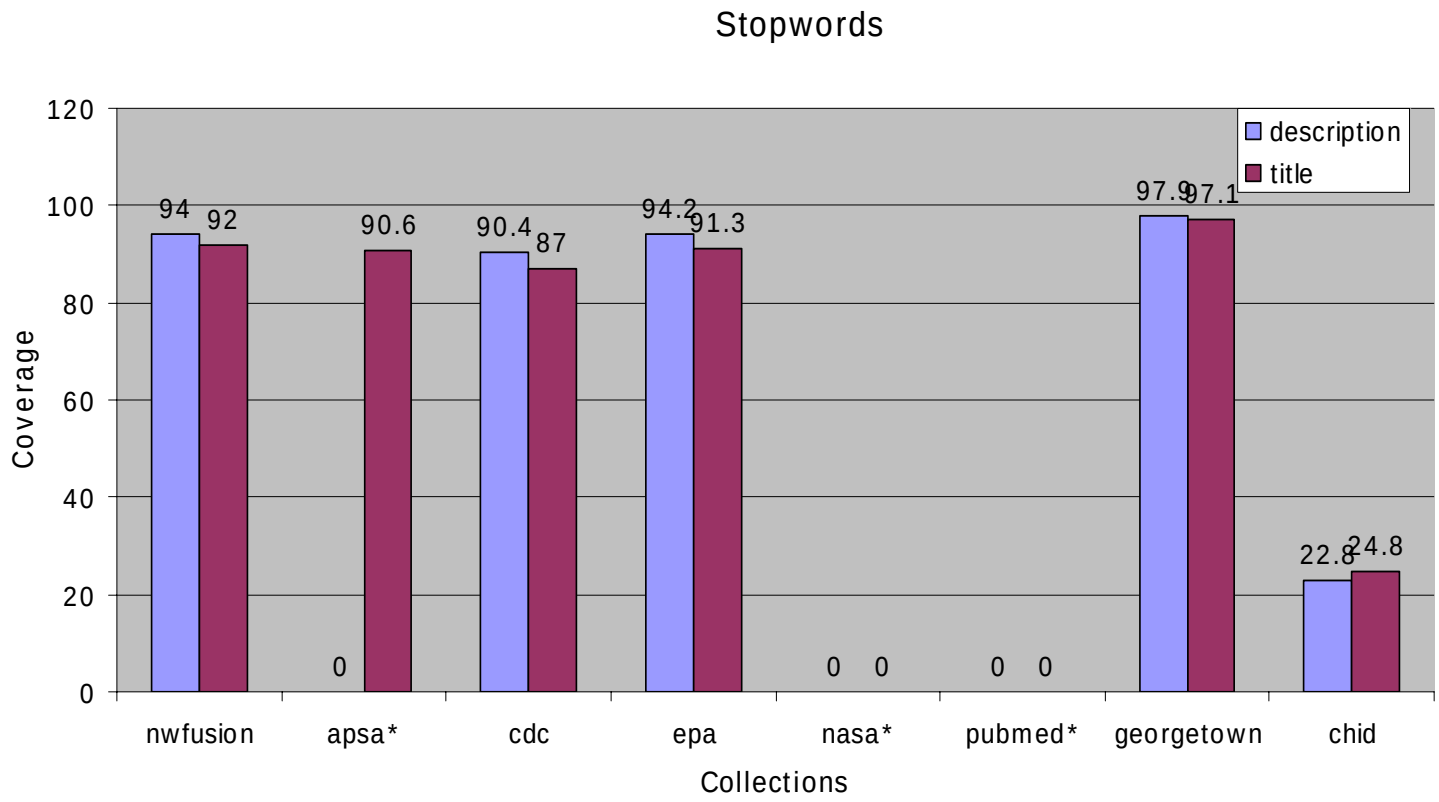
Stopwords *often* give higher coverage

Regardless of the presence or absence descriptions

Experiments: Result Contents



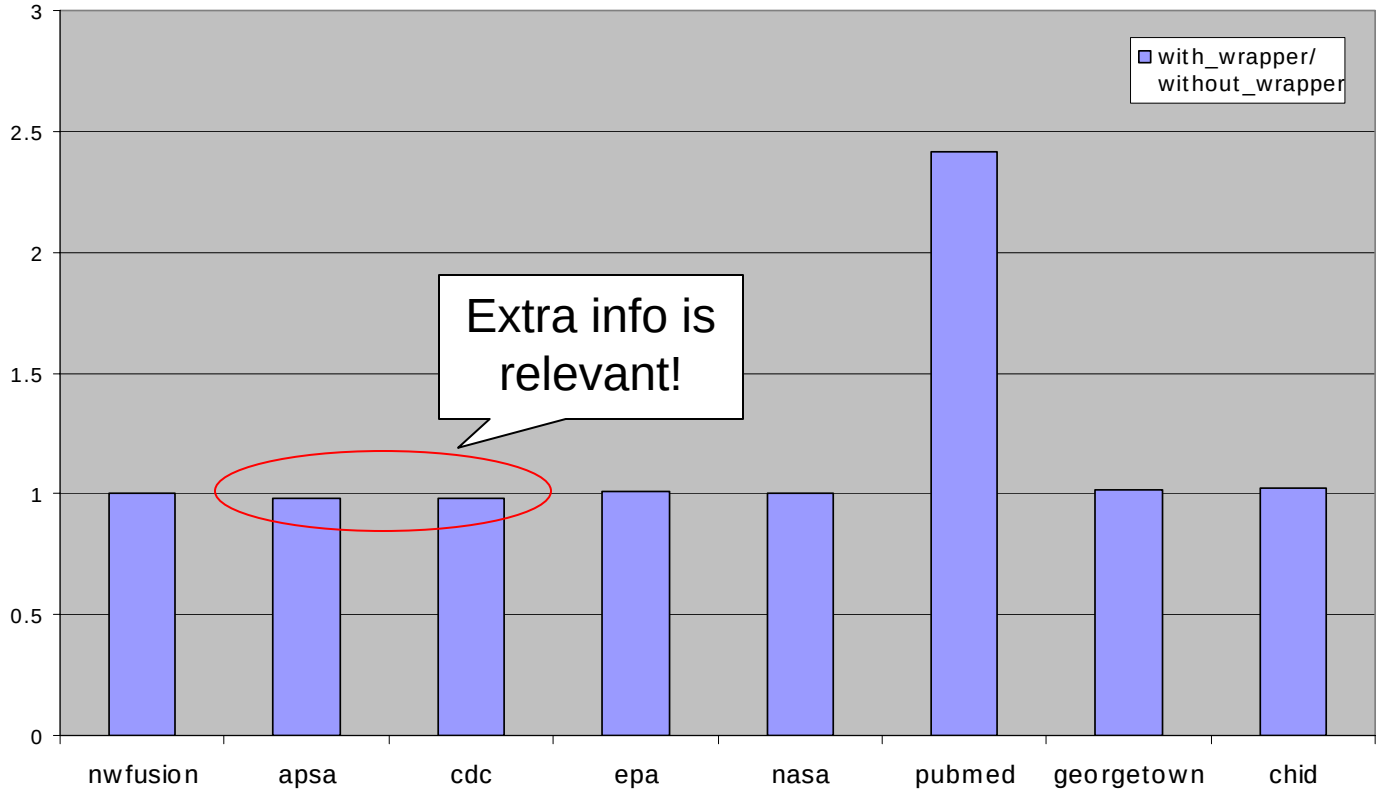
Experiments: Result Contents



The presence of descriptions lead to *slightly* larger coverage

Regardless of the presence or absence of indexing of stopwords

Experiments: Selecting Keywords



- Wrappers lead to marginal increases in coverage
  - Collections have content-rich pages
  - Exception: pubmed - result pages follow a template that contains a large percentage of extraneous information.

Coverage Queries: Examples

Site	With stopword	Without stopword
nwfusion	the,03,and	definition, data, latest, news, featuring
apsa	of,the,and,in,a,s,j	psychoanal, amer, review, psychoanalytic, int, new, study, family
cdc	cdc,search,health,of,the,to	health, department, texas, training, public, file, us, services
epa	epa,search,region,for,to,8	epa, environmental, site, data
georgetown	georgetown,the,and,of,to	university, georgetown, description, information
chid	chid,nih,hiv,for,aids,the,prevention,of,to,health	aids, health, disease, author, number, education, english
nasa	n/a	nasa
pubmed	n/a	nlm, nih, cells, cell, effects, expression, virus, after, proteins, human

- Words that are relevant for the site, e.g., “nasa” → 99.9% coverage!
- Reveal indexing strategies

Related: Web Wrappers

- Automate navigation: WebVCR
- Information dissemination: WebViews
- Data extraction: Roadrunner, LiXto, DEByE
- Data integration: Web Integrator
- How:
  - Manual
  - Semi-automatic generation
- Benefits
  - Flexibility, efficiency
- Drawbacks
  - Site-specific, not scalable

Related Work: Hidden-Web Crawlers

- Crawling: HiWe
  - Match labels to values
- Schema matching: Metaquerier
  - Statistical approach to form matching
- Benefits
  - More scalable than wrappers
- Drawbacks
  - Require substantial human input
  - Ignore forms with few fields
  - Not guaranteed to work...

Conclusions and Future Work

- A simple, yet effective, solution to siphon data hidden behind keyword-based search interfaces
  - Completely automatic
  - High-coverage
- Also works for Web services!
- Protect your data:
  - You may be *unknowingly* providing more access than intended
- Future work
  - Deal with limited number of returned results
  - Automatically derive page-cleaning wrappers
  - Automatically set parameters, e.g., stopping condition, …
  - Experiment with more sites, esp. structured sites
  - Structured forms (Vinit Kalra)
  - Characterize search interfaces wrt data protection guarantees

Tatu: Sifting through the Hidden Web

- Goal: Mine, query, integrate data
- Provide infrastructure for:
  - Automatically filling out forms
  - Searching and crawling through hidden data
- Applications
  - Hidden-Web search engine
  - Integrating hidden content
  - *Reconstructing hidden databases*