

Machine Learning and Information Retrieval

The Combination of Expert Advice Problem

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Combination of Expert Advice

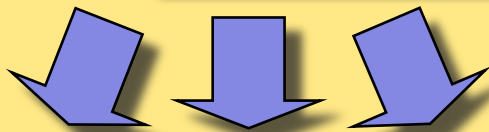
- Machine Learning
 - *Problems:*
 - medical diagnostics, stock market prediction, etc.
 - *Solutions:*
 - boosting, bagging, weighted majority, etc.

Combination of Expert Advice

- Information Retrieval
 - *Problems:*
 - filtering (news/spam), recommendation systems, *metasearch*, etc.
 - *Solutions:*
 - Linear classifiers, collaborative filtering, *on-line learning*, etc.

The Metasearch Problem

Search for: chili peppers



The image shows three overlapping browser windows. The top window is AltaVista, the middle is Excite, and the bottom is Google. All three have searched for 'chili peppers'. The Google window shows a list of search results with titles like 'Red Hot Chili Peppers Online - Official Website', 'Chili Peppers', and 'Red Hot Chili Peppers - Artist Search through AudioFind'.



The image shows a search results page for 'chili peppers'. The results are numbered 1 through 39. The first few results are:
1 Red Hot Chili Peppers
2 Hot Chili Peppers Homepage
3 Red Hot Chili Peppers Forum
4 Red Hot Chili Peppers Official Store
5 Chili Peppers
6 redhotchilipeppersonline
7 Red Hot Chili Peppers Online - Official Website
8 Red Hot Chili Peppers MP3 Pictures Articles Tour Dates Web
9 Wherehouse Music powered by CheckOut: The Red Hot Chili
10 Red Hot Chili Peppers
11 Red Hot Chili Peppers - Artist Search through AudioFind
12 Red Hot Chili Peppers
13 Rock On The Net: Red Hot Chili Peppers
14 Red Hot Chili Peppers Online
15 Red Hot Chili Peppers
16 Abbey Road: Red Hot Chili Peppers Fansite
17 dotmusic - Single Review - Red Hot Chili Peppers - 'Otherside' (WEA)
18 Chili peppers, gourmet foods and olives
19 Red Hot Chili Peppers Discography
20 Quiet, Exc Red Hot Chili Peppers
21 The Red Hot Chili Peppers mailing list
22 Red Hot Chili Peppers Online - Official Website
23 Ultimate Band Site - Red Hot Chili Peppers, Cypress Hill, KoRa and more!!!!!!
24 Chili peppers, gourmet foods and olives
25 Abbey Road: Red Hot Chili Peppers Fansite
26 Gilroy Foods - Industrial Supplier of Dehydrated Garlic, Onion & Chili Peppers
27 Brigay's Red Hot Chili Peppers & John Frustrante Tapes
28 Red Hot Chili Peppers free guitar tabs, bass tabs and ...
29 MTV News Gallery: Red Hot Chili Peppers
30 dotmusic - Single Review - Red Hot Chili Peppers - 'Otherside' (WEA)
31 Red Hot Chili Peppers: The Ultimate List of Essential Music
32 ...
33 A - Bandera chile peppers, Dried chili peppers all year, Chile pepper flakes, Chili pepper pow
34 Red Hot Chili Peppers mp3s lyrics photos on the web
35 Red Hot Chili Peppers Tickets
36 Music Modern Rock Showcase - Red Hot Chili Peppers
37 ICO Inc. - ICO Community - Red Hot Chili Peppers
38 Red Hot Chili Peppers on BandHut.com
39 RollinsStone.com - Artists - Red Hot Chili Peppers

Search and Metasearch

- Search engines:
 - Provide a ranked list of documents.
 - May provide relevance scores.
- Metasearch engines:
 - Query multiple search engines.
 - May or may not combine results.


Metasearch: Dogpile

The screenshot shows a web browser window displaying the Dogpile search results for the query "chili +peppers". The browser's address bar shows the URL: <http://search.dogpile.com/textis/search?q=chili+peppers&geo=no&fs=web&sv=custom&engines=goto&engines=Looksmart&engines=ti>. The Dogpile logo is prominently displayed, along with navigation links like Home, Custom Search, and Dogpile Remote. A SmarterKids.com banner is visible, along with a "Visit the Ask Our Teachers column at SmarterKids.com" link. Below the banner, there are several search suggestions: "Buy books about 'chili peppers' at Amazon.com", "Search for 'chili peppers' on Electric Library", and "Spend web time wisely. Shop smarter." A table of search results is shown, with columns for "Are you looking for:" and various search terms like "Red Hot Chili Peppers", "Peppers", "Chili", and "Hot Peppers". A "Dogpile Suggests" section follows, with a link to ClassMates.com. The main search results are listed under the heading "Search engine: Looksmart found 117 results." and include five numbered items: 1. The Red Hot Chili Peppers, 2. Red Hot Chili Peppers Audio and Video, 3. Chili and Hot Sauces, 4. Chili and Hot Sauces, and 5. Red Hot Chili Peppers - Screens and Themes. A "Next set of results from Looksmart" link is provided. At the bottom, another search engine result is shown: "Search engine: GoTo.com found 10 or more results."

File Edit View Go Communicator Help

Bookmarks Location: <http://search.dogpile.com/textis/search?q=chili+peppers&geo=no&fs=web&sv=custom&engines=goto&engines=Looksmart&engines=ti> What's Related

Home
Custom Search
Dogpile Remote
Search at Home
Help with Syntax
Tell a Friend
Go Shopping

 **DOGPILE**
Web Metasearch Results


SmarterKids.com Visit the Ask Our Teachers column at SmarterKids.com.
Education Center

[Spend web time wisely. Shop smarter.](#) [Hear My Mail from Weblev!](#) [Find old classmates here! ClassMates.com](#)

• Buy books about "chili peppers" at [Amazon.com](#) • Search for "chili peppers" on [Electric Library](#)

Are you looking for:

Red Hot Chili Peppers	Peppers	Chili	Hot Peppers
Red Hot Chili Peppers Tabs	Canning Recipes Peppers	Red Hot Chili Peppers Lyrics	Salsa Recipes Free

 [ClassMates.com](#): Remember your promise to "keep in touch" at graduation? With over 8.5 million registered high school alumni, chances are you'll find your old friends.

Search engine: [Looksmart](#) found 117 results.
The query string sent was [+chili +peppers](#)

- [1. The Red Hot Chili Peppers](#)
Find photos, lyrics, updates, tour info, and news on alternative-funk-rock band the Red Hot Chili Peppers.
[Looksmart category - Red Hot Chili Pepper](#)
- [2. Red Hot Chili Peppers Audio and Video](#)
Watch videos and listen to music by this rock/funk band.
[Looksmart category - Red Hot Chili Peppers](#)
- [3. Chili and Hot Sauces](#)
Shop for mouth-burning chili sauces, Tabasco, hot salsas and other pepper-inspired sauces.
[Looksmart category - Chili & Hot Sauces](#)
- [4. Chili and Hot Sauces](#)
Find chili and other hot sauce recipes, including salsas, dips, spices, and rubs, and visit the Pepper Fool.
[Looksmart category - Chili & Hot Sauces](#)
- [5. Red Hot Chili Peppers - Screens and Themes](#)
Promotional screensaver for the funk-rock band features falling chili peppers.
[LookSmart category - Red Hot Chili Peppers Multimedia](#)

[Next set of results from Looksmart](#)

Search engine: [GoTo.com](#) found 10 or more results.

Metasearch: Metacrawler

The screenshot shows the Metacrawler search engine interface. The search bar contains the text "chili peppers" and a "Search" button. Below the search bar, there are navigation options: "any", "all", and "phrase". A "The Web" button is also visible. The search results are displayed in a list format, with the first result being "Red Hot Chili Peppers". The interface includes a navigation menu with options like "Web Pages", "Directory Listings", "Audio/MP3", "Images", "News Groups", and "Auctions". The search results are for "chili peppers" and show 1 to 20 of 122 results. The results list includes links to "Red Hot Chili Peppers", "AltaVista", "Infoseek", "LookSmart", "Lycos", "GoTo", "Thunderstone", "DirectHit", "Google", "Internet Keywords", "FindWhat", and "Sprinks by About". The results also include a "MetaCrawler Suggests" section and a "You just searched these search engines" section. The interface is designed with a yellow and blue color scheme.

File Edit View Go Communicator Help

Bookmarks Location: <http://search.metacrawler.com/crawler?general=chili+peppers&method=0&redirect=web&pp=20&hp=10®ion=0&timeout=0&sort=> What's Related

metacrawler® chili peppers Search

any all phrase

The Web

Are you looking for:

[Red Hot Chili Peppers](#) [Peppers](#) [Chili](#) [Hot Peppers](#)

[Red Hot Chili Peppers Tabs](#) [Canning Recipes Peppers](#) [Red Hot Chili Peppers Lyrics](#) [Salsa Recipes Free](#)

Searching for

Discovery Health [Find!](#) Get Auto Insurance answers

View Related: [Web Pages](#) [Directory Listings](#) [Audio/MP3](#) [Images](#) [News Groups](#) [Auctions](#)

Results for "chili peppers" 1 to 20 of 122 results page: 1 - 2 - 3 - 4 - 5 - 6 - 7 - next

View by: Relevance | Site | Source [Email results to a friend](#)

MetaCrawler Suggests [ClassMates.com](#), where you can find your High School Friends!

You just searched these search engines: AltaVista, Infoseek, LookSmart, Lycos, GoTo, Thunderstone, DirectHit, Google, Internet Keywords, FindWhat, Sprinks by About

Red Hot Chili Peppers
AltaVista: Buy Californication Now. Enter your email address to receive information about The Red Hot Chili Peppers. Email: Go to the RED HOT CHILI PEPPERS...
Infoseek: Video clips and photos of the band, plus lyrics and interview.
Google: Buy Californication Now. Enter your email address to receive
1000, <http://www.wbr.com/chilipeppers/index.html> ([AltaVista](#), [Infoseek](#), [Google](#)) | [More Like This](#)

Red Hot Chili Peppers
This web site was created for FREE at www.homestead.com. Visit www.homestead.com to get your free web site - no programming required.
424, <http://www.homestead.com/mexicocomerhokhillpeppers.html> ([AltaVista](#)) | [More Like This](#)

redhotchilipeppers online
click here to skip intro...
424, <http://redhotchilipeppers.com/> ([Google](#)) | [More Like This](#)

The Red Hot Chili Peppers
Find photos, lyrics, updates, tour info, and news on alternative-funk-rock band the Red Hot Chili Peppers.
424, http://www.looksmart.com/ees12..._ees315010ees312562?reqid=6966 ([LookSmart](#)) | [More Like This](#)

Lycos Music: Red Hot Chili Peppers - Biography
Biography - Tolling in L.A.'s club circuit for years, the Red Hot Chili Peppers finally pounded their Funk/rap/rock into the mainstream with the 1989 LP Mother's Milk. Making bedfellows of their native L.A. Punk
424, <http://click.hotbot.com/direct...&2&peppers&source=LCOSMCW1> ([Lycos](#)) | [More Like This](#)

GlassShop.com - Handmade Blown Glass Chili Peppers
Our standard offering includes four gorgeous 4-6 inch long blown glass chili peppers. Check 'em out! They make a great gift item.
424, <http://www.glassshop.com/home.html> ([FindWhat](#)) | [More Like This](#)

Chili Pepper smoked Trout
Chili Pepper smoked Trout recipe.
424, http://bbq.about.com/bragp..._nmlh&ms=752&chili+62&peppers ([Sprinks by About](#)) | [More Like This](#)

0% Visa Cards Now! @ YourNextCreditCard
The best credit cards:
NextCard, CapitalOne, Aria...
0% intro, 9.9% fixed. Pick your card and get instant approval at YourNextCreditCard.com
[Hot Concert Tickets on sale now!](#)
Who do you want to see for the holidays? 'N Sync? Tina Turner? The Dixie Chicks? Get sold-out concert tickets NOW at eBay!
[Apply Now for an Aria Visa!](#)
Get a 30-second Online Credit Decision (subject to verification) with an Aria Visa credit card!
[Find old High School Friends Here!](#)
[ClassMates.com](#)
[Promote Your Site](#)

Metasearch: Profusion

The screenshot shows a web browser window with the Profusion metasearch engine interface. The search term "chili peppers" is entered in the search box. The results page displays a list of search results, each with a score, a title, a summary, and a URL. The results are as follows:

Score	Title	Summary	URL
1.0000	Red Hot Chili Peppers	Summary: This web site was created for FREE at www.homestead.com. Visit www.homestead.com to get your free web site - no programming required.	http://www.homestead.com/musiccorner/hotchilipeppers.html (AltaVista)
0.9667	Abbey Road: Red Hot Chili Peppers Fansite	Summary: For fans of pre-1992 Red Hot Chili Peppers Funk Style...	http://members.scoom.com/old_rhcp/index.html (AltaVista)
0.9333	dotmusic - Single Review - Red Hot Chili ...	Summary: Typically groovy bassist Flea fuels the momentum	http://www2.dotmusic.com/reviews/Singles/January2000/reviews12638... (AltaVista)
0.9000	Red Hot Chili Peppers	Summary: Buy Californication Now. Enter your email address to receive information about The Red Hot Chili Peppers. Email: Go to the RED HOT CHILI PEPPERS...	http://www.wbr.com/chilipeppers/index.html (AltaVista)
0.8781	Chili Pepper Rub for Brisket Recipe	Summary: Chili Pepper Rub for Brisket recipe.	http://bbq.about.com/library/recipe/070823a.htm (About)
0.8667	Red Hot Chili Peppers - Screens and Themes	Summary: Promotional screensaver for the funk-rock band features falling chili peppers. More like this: Red Hot Chili Peppers Multimedia	http://www.screensandthemes.com/Previews-Download/Screen-Savers/... (LookSmart)
0.8667	Briqey's Red Hot Chili Peppers & Jeha ...	Summary: Bootlegs of great classic rock, the Red Hot Chili Peppers, and John Fusciante. I've got stuff from both the Californication era and the pre-heroin...	http://members.aol.com/allformiandr/bootlegs.html (AltaVista)
0.8342	Chili Pepper smoked Trout	Summary: Chili Pepper smoked Trout recipe.	http://bbq.about.com/library/recipe/070816a.htm (About)
0.8333	Chili Peppers	Summary: Did You Know...? Home The Legend Legend Form A few items for those interested in chili peppers: Scoville Test For Capsaicin--A Thermal...	http://www.cbersaack.com/knowldge.htm (AltaVista)
0.8000	Hot Chili Peppers Homepage	Summary: Hot Chili Peppers Homepage (German)...	

Metasearch Algorithms

- Heuristics and hacks:
 - Interleave, average rank, sum scores, etc.
- Principled models:
 - Bayesian inference, election theory, etc.
 - *On-line combination of expert advice.*

On-line Metasearch [Aslam, Pavlu, Savell]

The screenshot shows a metasearch engine interface with three search engines: Google, altavista, and alltheweb. The search term is 'cikm 2003'. The results are displayed in a list format, with each search engine's results appearing side-by-side. The Google results include links to 'CIKM 2003 Homepage', 'ACM CIKM 2003 Call For Papers', and 'CIKM-2003 Registration'. The altavista results show 'Did you mean: ci km 2003' and 'AltaVista found 5,186 results'. The alltheweb results show '1 - 10 of 6,293 Results for cikm 2003' and include links to 'CIKM 2003 Homepage', 'IVML Call For Papers Archive', and 'ACM WIDM'2003'.

metasearch

[CIKM 2003 Homepage](#)
 ACM CIKM 2003 Call For Paper
 CIKM-2003 Registration
 ACM CIKM 2003 Call For Paper
 CIKM 2002 Homepage
 Conference on Information and
 [Asis-I] CIKM 2003
 (DBWORLD) CIKM 2003 (Padm
 bridge-cikm-2003
 Collaborative Filtering Mailing
 CIKM Home Page ACM DL: CIK
 Yahoo! Groups : webir Messag
 dBforums - Cfp: Cikm 03
 Mailing List ARL-ERESERVE@a
 Received: from cni.org by b.c
 ACM WIDM 2003
 ACM - MMDB 2003
 ACM CIKM 2003 PRELIMINARY
 Selected Publications
 Web Caching Publications/Ver
 cikm '03
 Call for papers
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 (DBWORLD) Final Call for ACM
 Collaborative Filtering Mailing

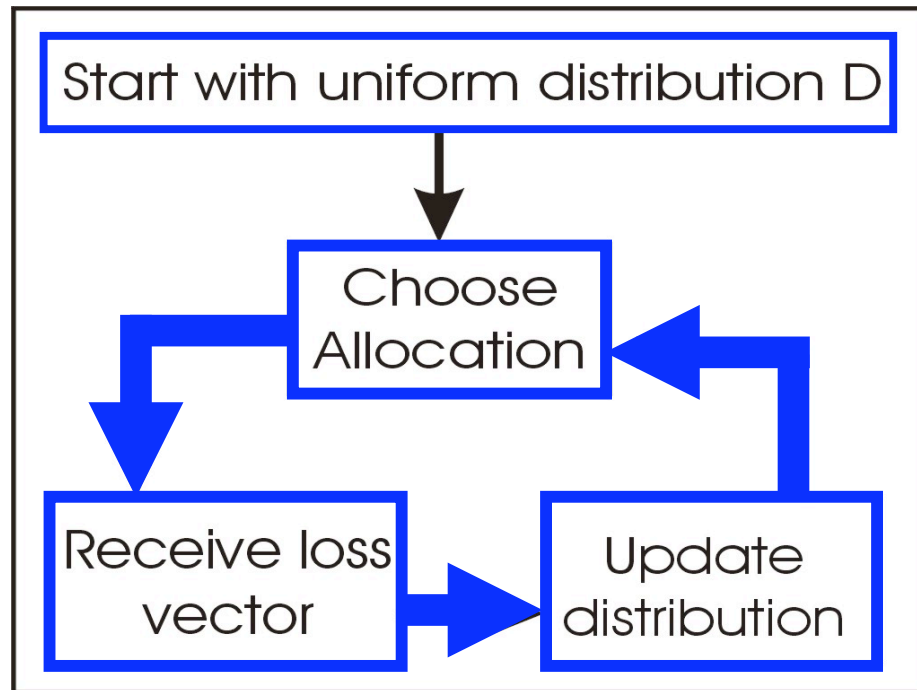
metasearch

[CIKM 2003 Homepage](#)
[CIKM-2003 Registration](#)
 CIKM 2002 Homepage
 ACM CIKM 2003 Call For Paper
 ACM CIKM 2003 Call For Paper
 CIKM Home Page ACM DL: CIK
 Conference on Information and
 ACM CIKM 2003 PRELIMINARY
 CIKM Home Page ACM DL: CIK
 ACM CIKM 2003 PRELIMINARY
 [Asis-I] CIKM 2003
 (DBWORLD) CIKM 2003 (Padm
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 Collaborative Filtering Mailing
 Yahoo! Groups : webir Messag
 dBforums - Cfp: Cikm 03
 Mailing List ARL-ERESERVE@a
 Received: from cni.org by b.c
 ACM WIDM 2003
 ACM - MMDB 2003
 Selected Publications
 Web Caching Publications/Ver
 cikm '03
 Call for papers
 Mario A. Nascimento - Person
 Iceived
 Conferences and Journals on T
 Conferences On Information V
 Calendrier des manifestations

On-line Allocation Problem

- Investment problem:
 - Monthly paycheck...
 - Many stock brokers & mutual funds...
 - *How to invest?*
 - *How to incorporate feedback?*

On-line Allocation: The Hedge Algorithm



$\beta \in [0,1]; N$ strategies (systems)

initial weights $w^1 \in [0,1]^N; \sum_{i=1}^N w_i^1 = 1$

$$p_i^t = \frac{w_i^t}{\sum_{i=1}^N w_i^t}$$

$$l^t \in [0,1]^N \quad L_H^t = p^t \cdot l^t$$

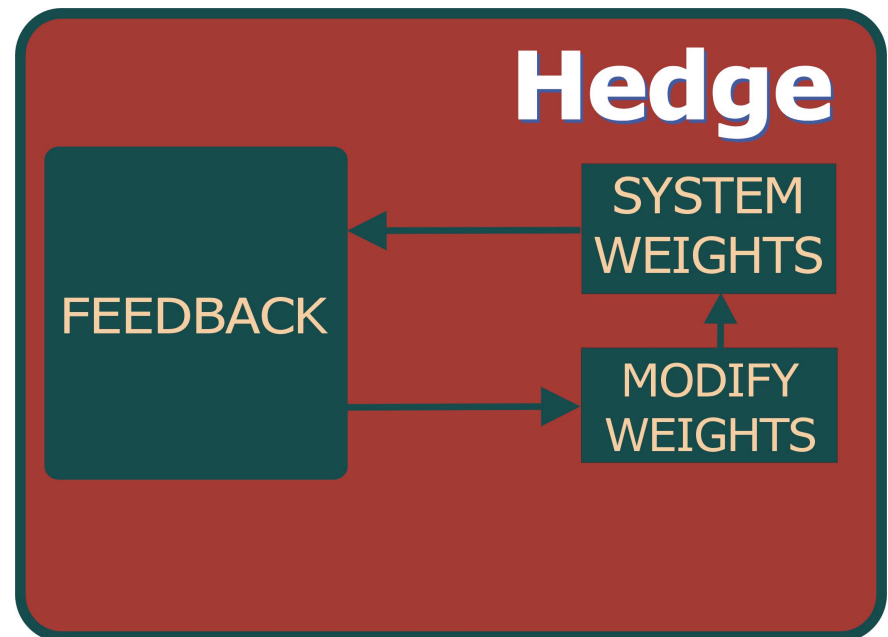
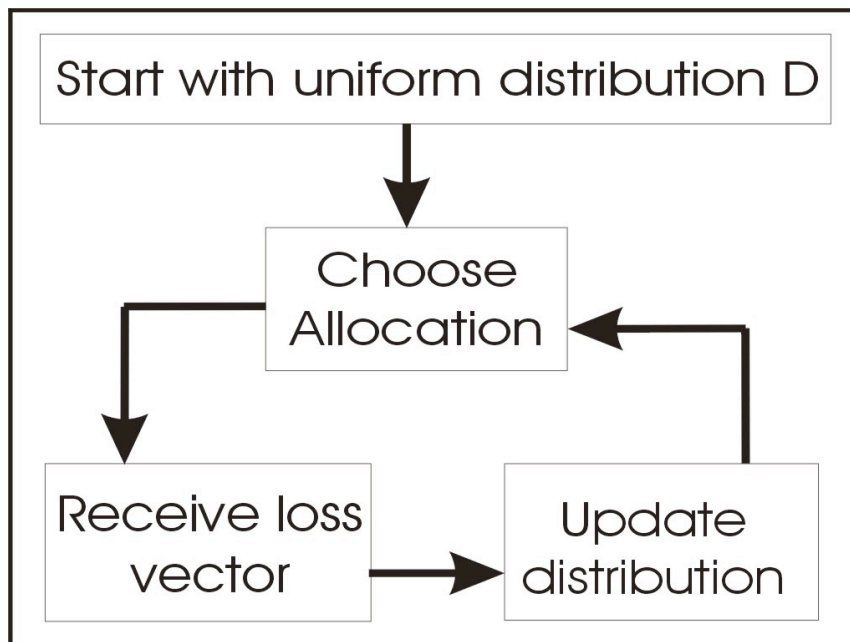
$$w_i^{t+1} = w_i^t \cdot \beta^{l_i^t}$$

$$L_{HEDGE} = \sum_{t=1}^T p^t \cdot l^t$$

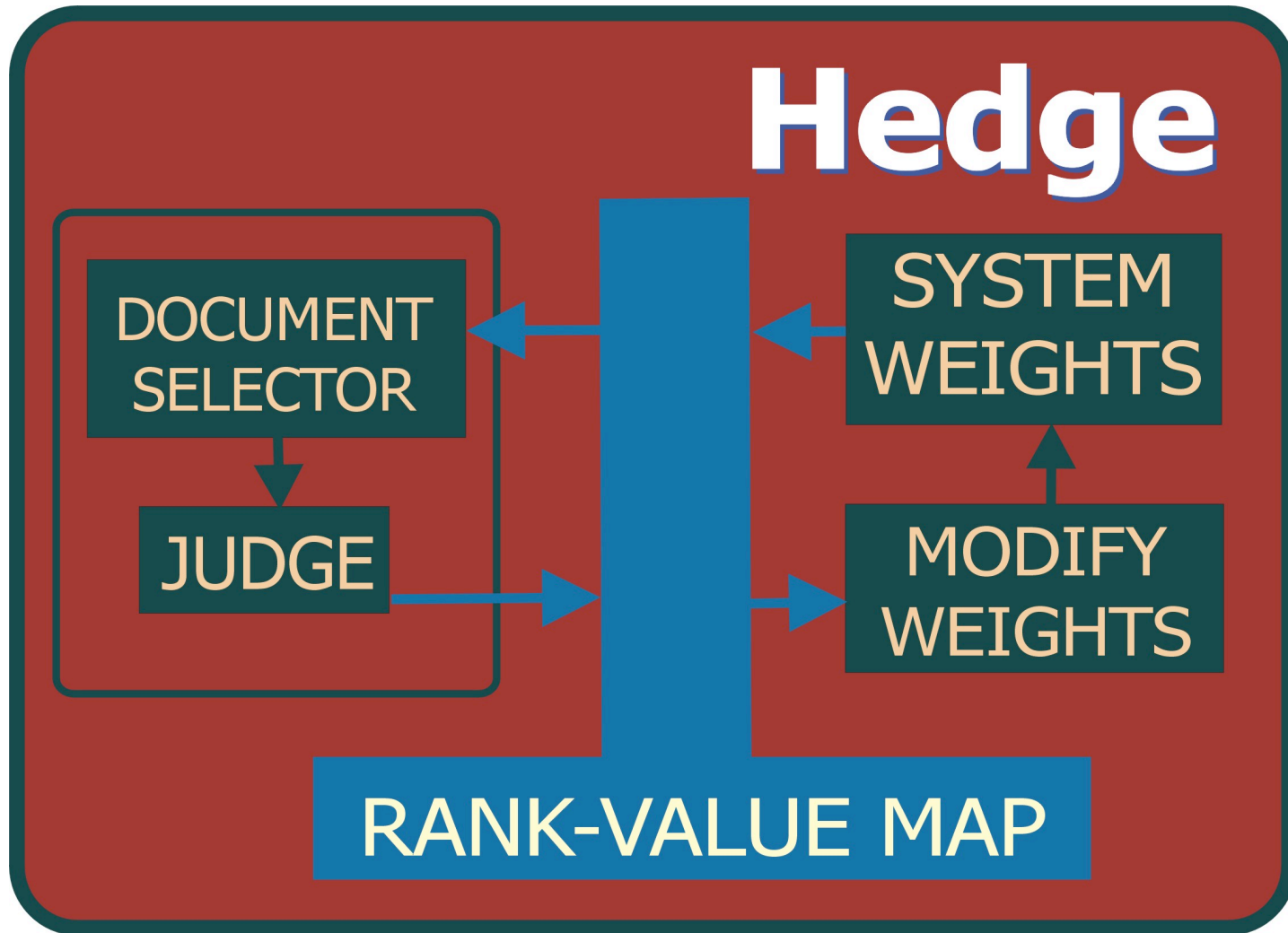
Why Hedge? [Schapire, Freund]

$$L_{HEDGE} \leq \frac{\ln\left(\frac{1}{\beta}\right) L_{BEST\ SYSTEM} + \ln N}{1 - \beta}$$

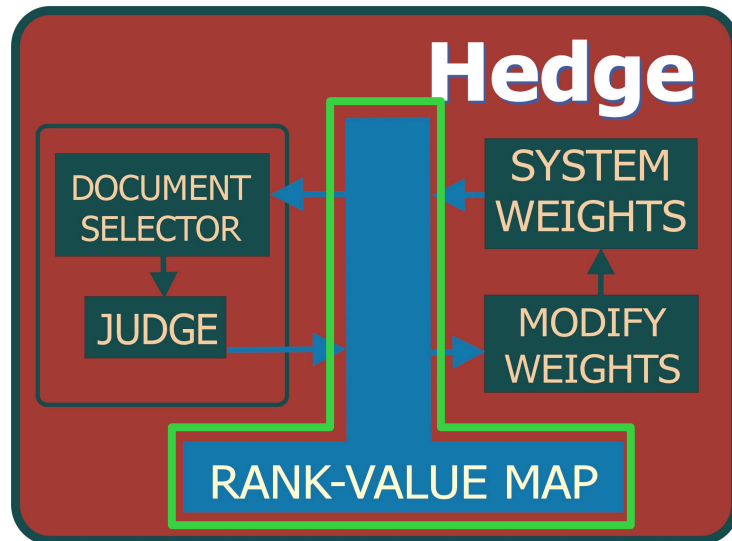
On-line Setup



A Unified Model



Implementation



- map ranks to values

$$value(r) = \frac{1}{r} + \frac{1}{r+1} + \dots + \frac{1}{Z} \approx \ln \frac{Z}{r}$$

RELEVANT = -1

NONRELEVANT = +1

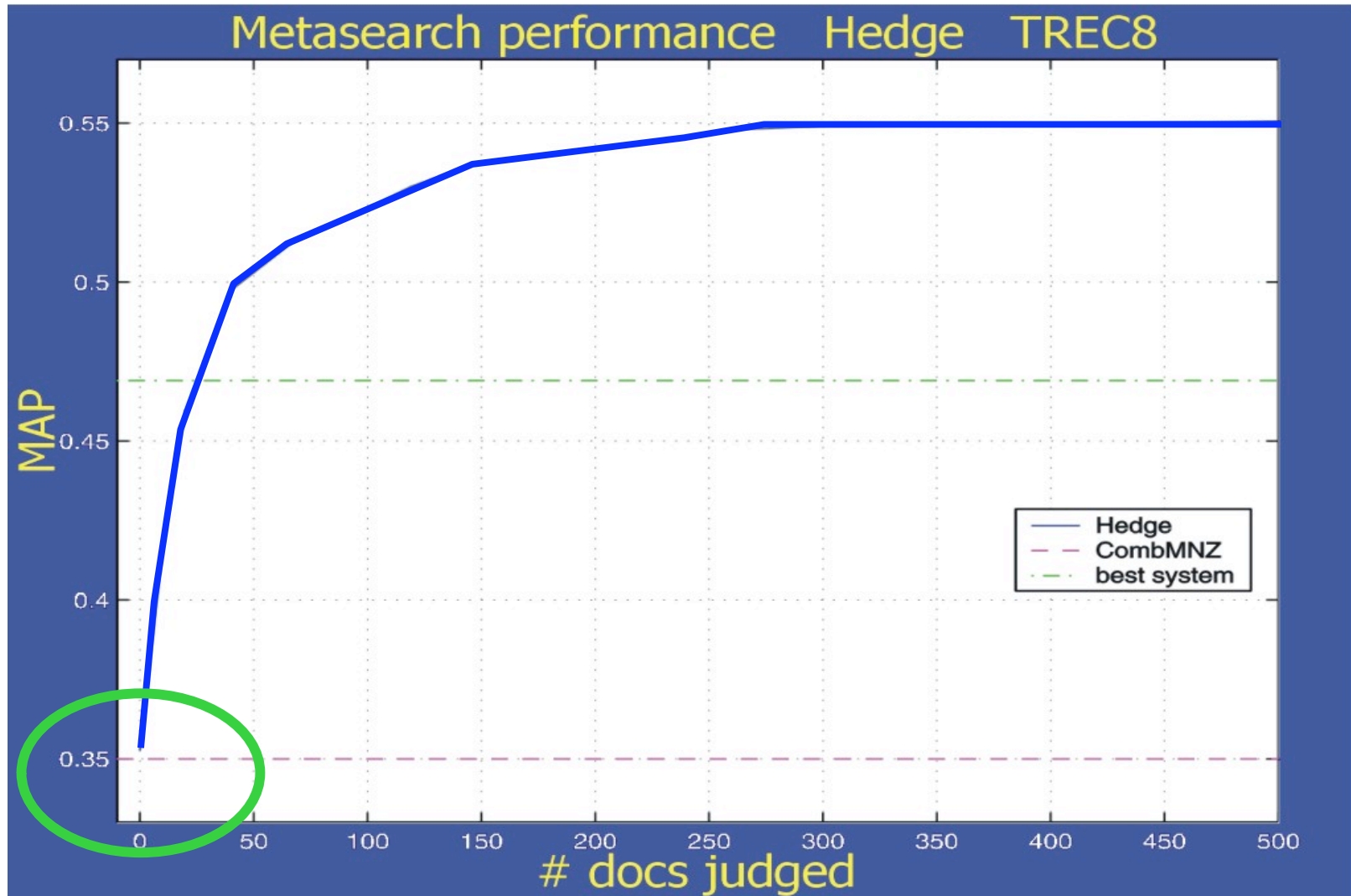
$$LOSS(d, s) = label(d) \cdot value(rank_{d,s}) \approx label(d) \cdot \ln \frac{Z}{r}$$

total loss vs. total precision vs. average precision

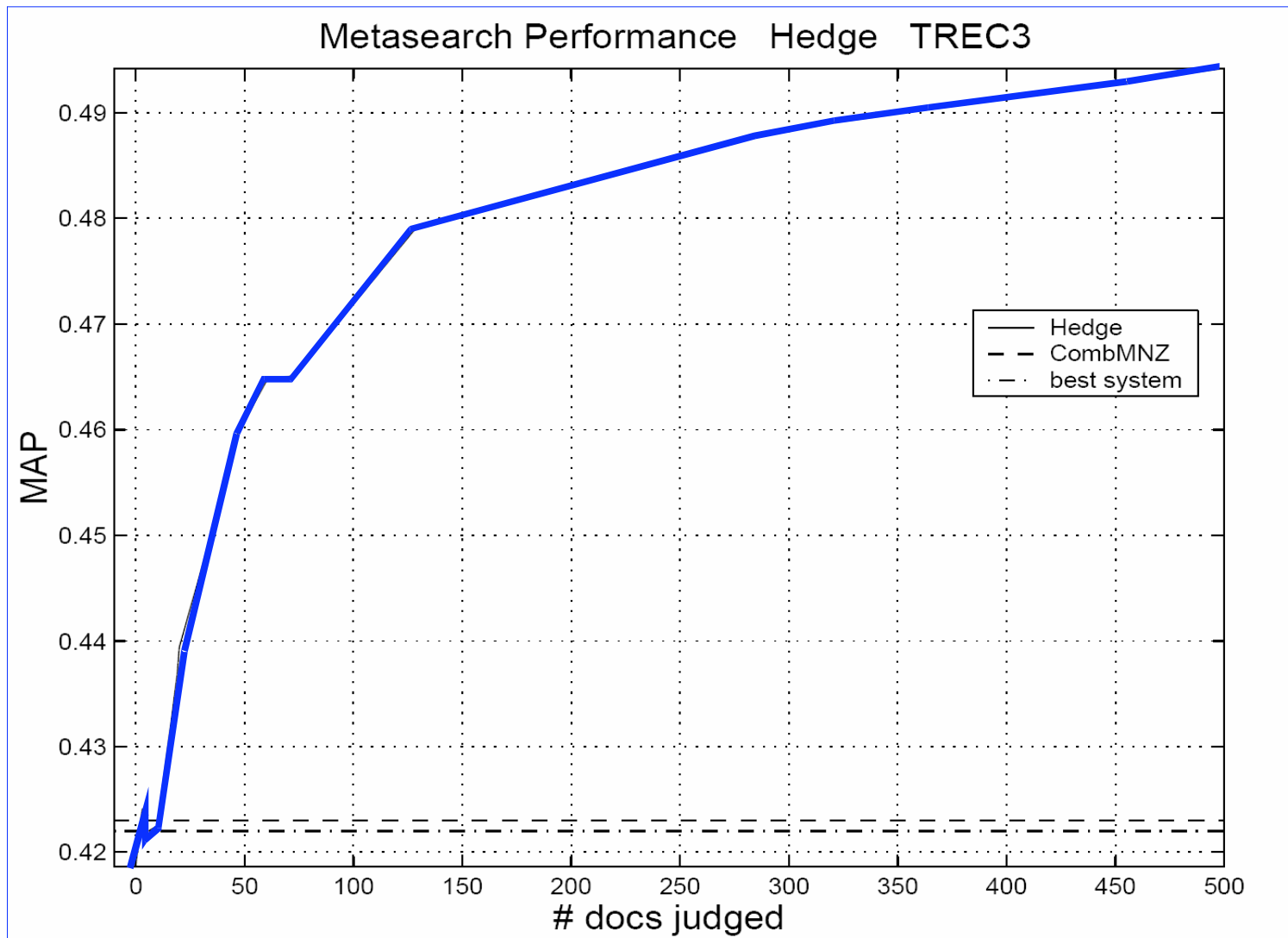
Experiments

- TREC 3,5,6,7,8
 - 41-129 systems
 - 50 queries per TREC
 - Metasearch combines *all* systems
- Use TREC judgments as user feedback

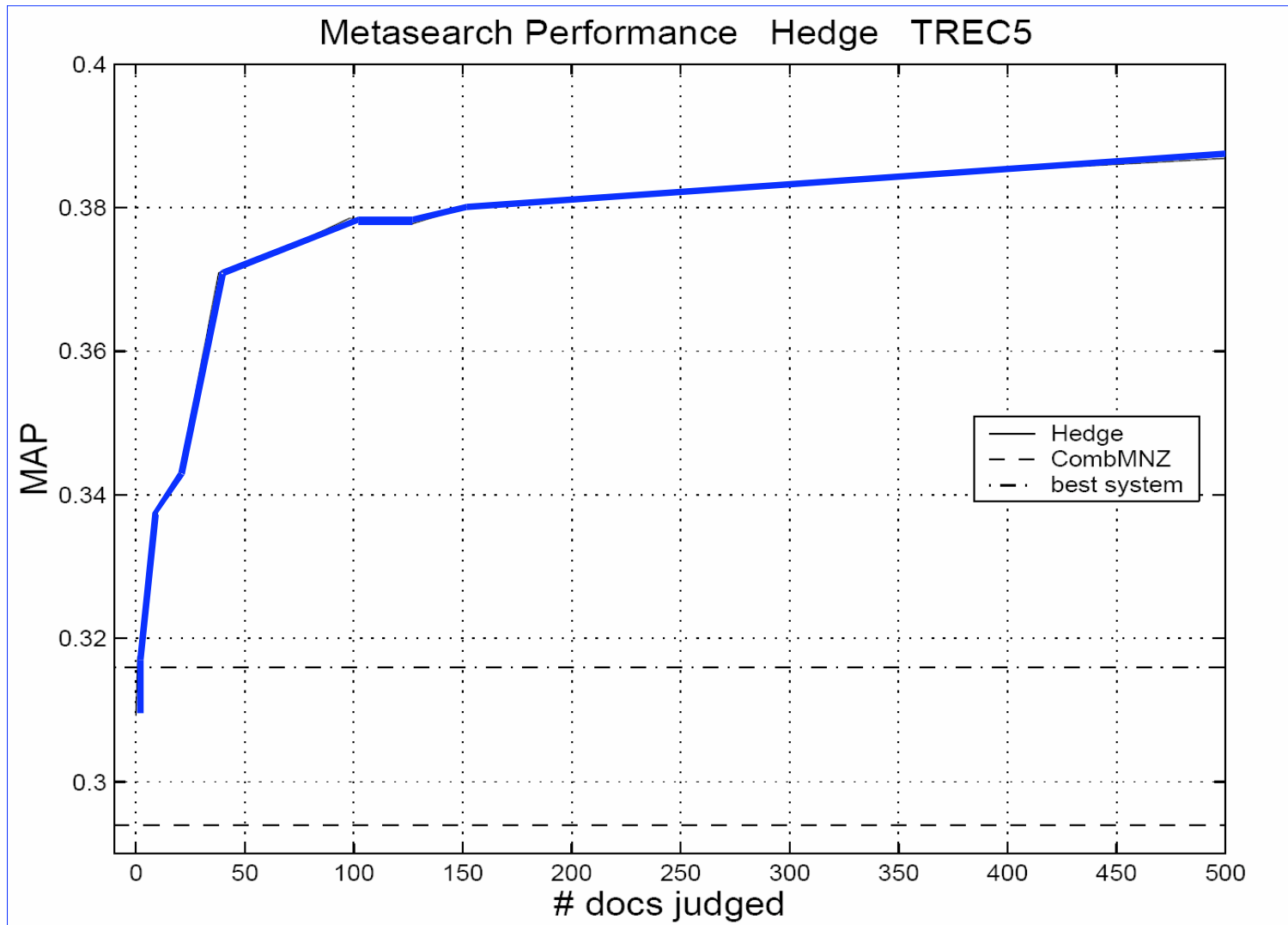
Metasearch – TREC8



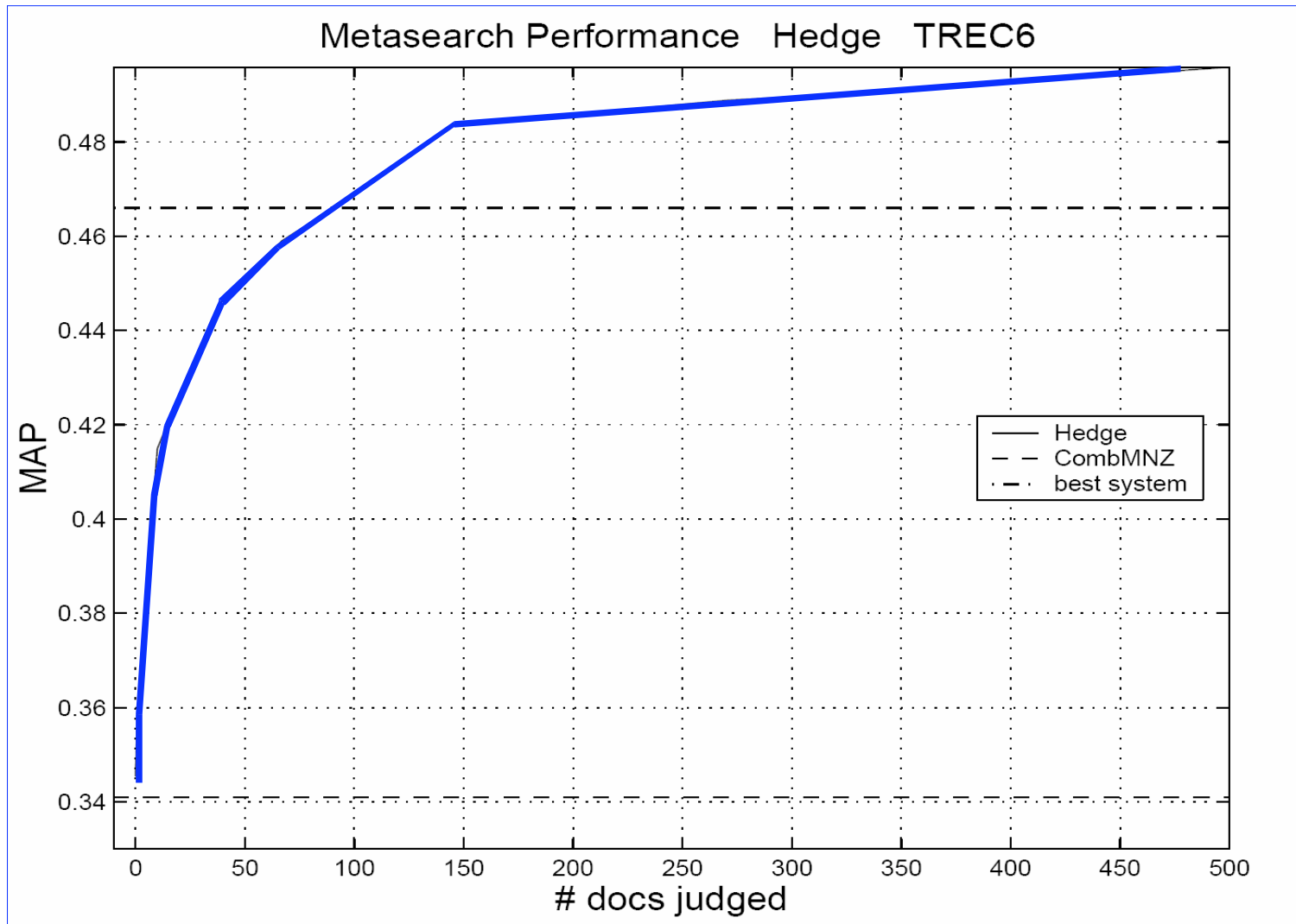
Metasearch – TREC 3



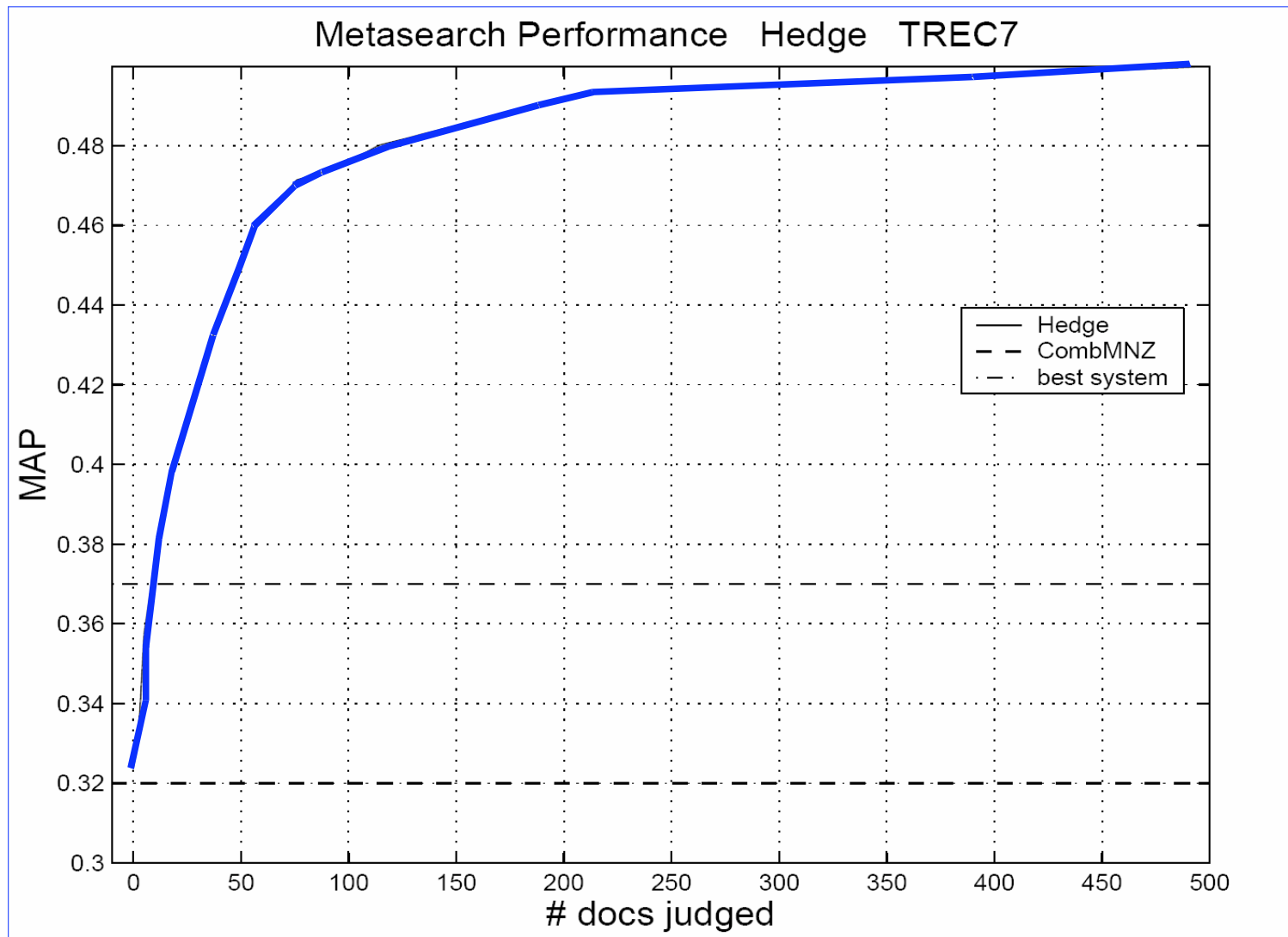
Metasearch – TREC 5



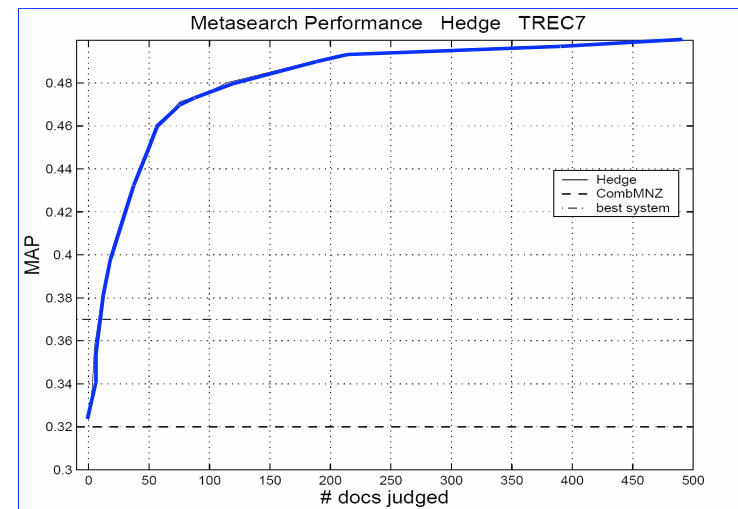
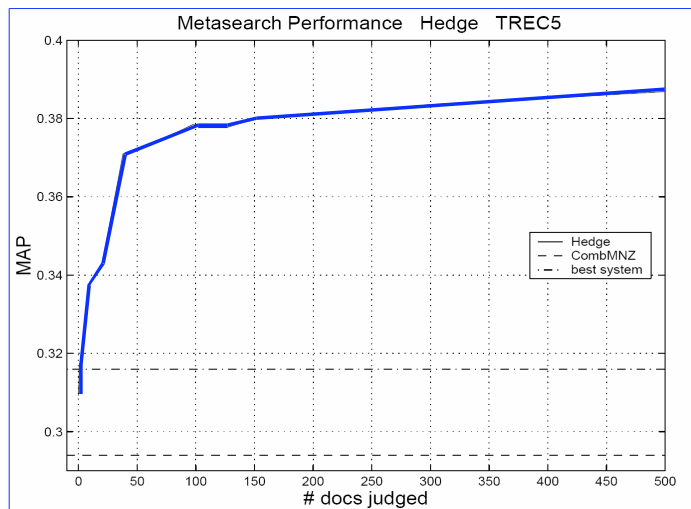
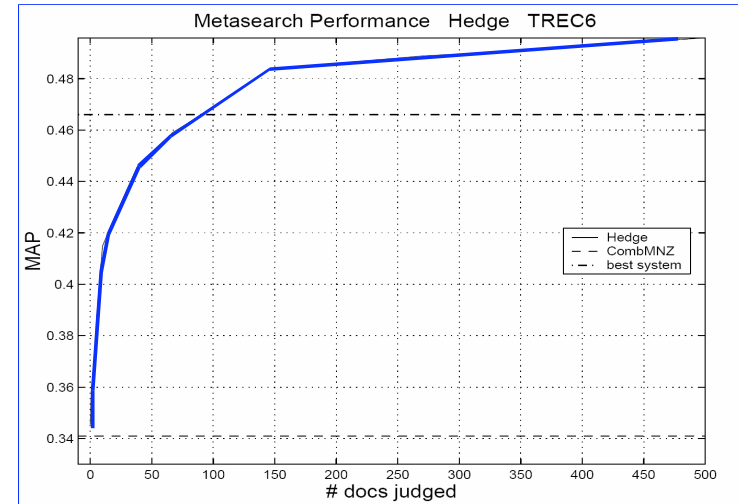
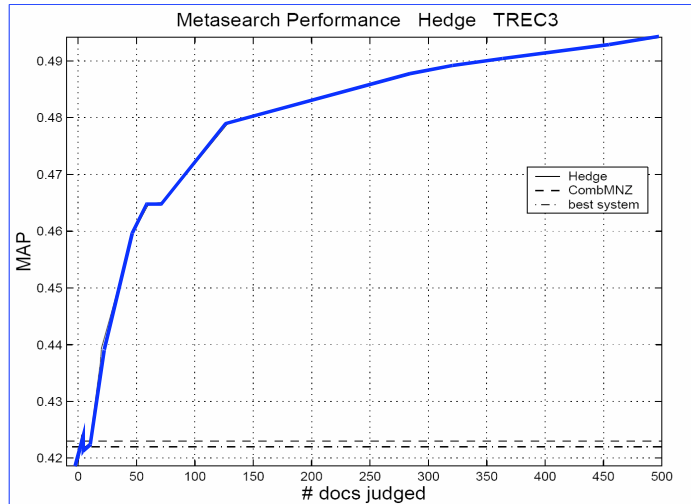
Metasearch – TREC 6

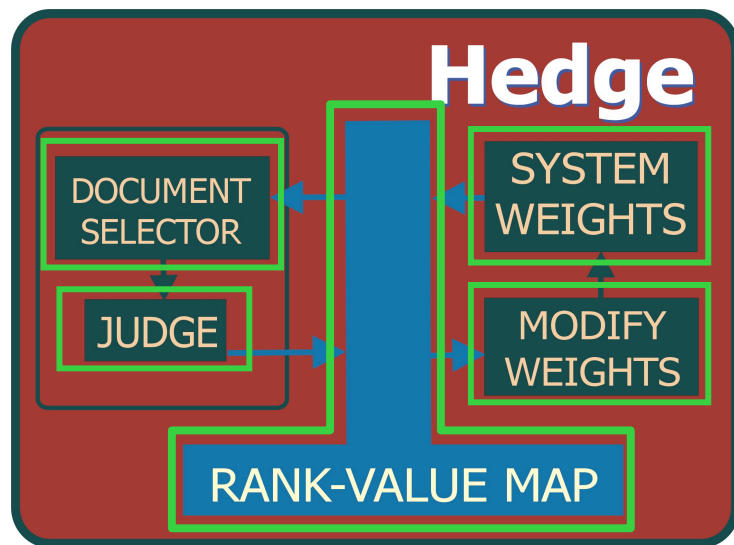


Metasearch – TREC 7



Metasearch – TREC 3,5,6,7





$$average_value_t(d) = \sum_{s=1}^N w_s^{t-1} \cdot value(rank_{d,s})$$

Loop

metasearch

- CIKM 2003 Homepage
- CIKM-2003 Registration
- CIKM 2002 Homepage
- ACM CIKM 2003 Call For Paper
- ACM CIKM 2003 Call For Paper
- CIKM Home Page ACM DL: CIKM
- Conference on Information and Knowledge Management
- ACM CIKM 2003 PRELIMINARY PROGRAM
- CIKM Home Page ACM DL: CIKM
- ACM CIKM 2003 PRELIMINARY PROGRAM
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- Mario A. Nascimento - Personal Page
- Received
- Conferences and Journals on Information Science
- Conferences On Information Science
- Calendrier des manifestations

- average_value at episode t
 - “trust” in systems change with t
- metasearch : include already judged docs
- pooling $d_t = \arg \max_d (average_value(d))$
 - system evaluation
- get feedback $LOSS(d_t, s) = label(d_t) \cdot value(rank_{d_t, s})$
- modify weights $w_s^{t+1} = w_s^t \cdot \beta^{LOSS_t(d_t, s)}$