Focused Crawling with Scalable Ordinal Regression Solvers

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Focused Crawling & Large scale OR

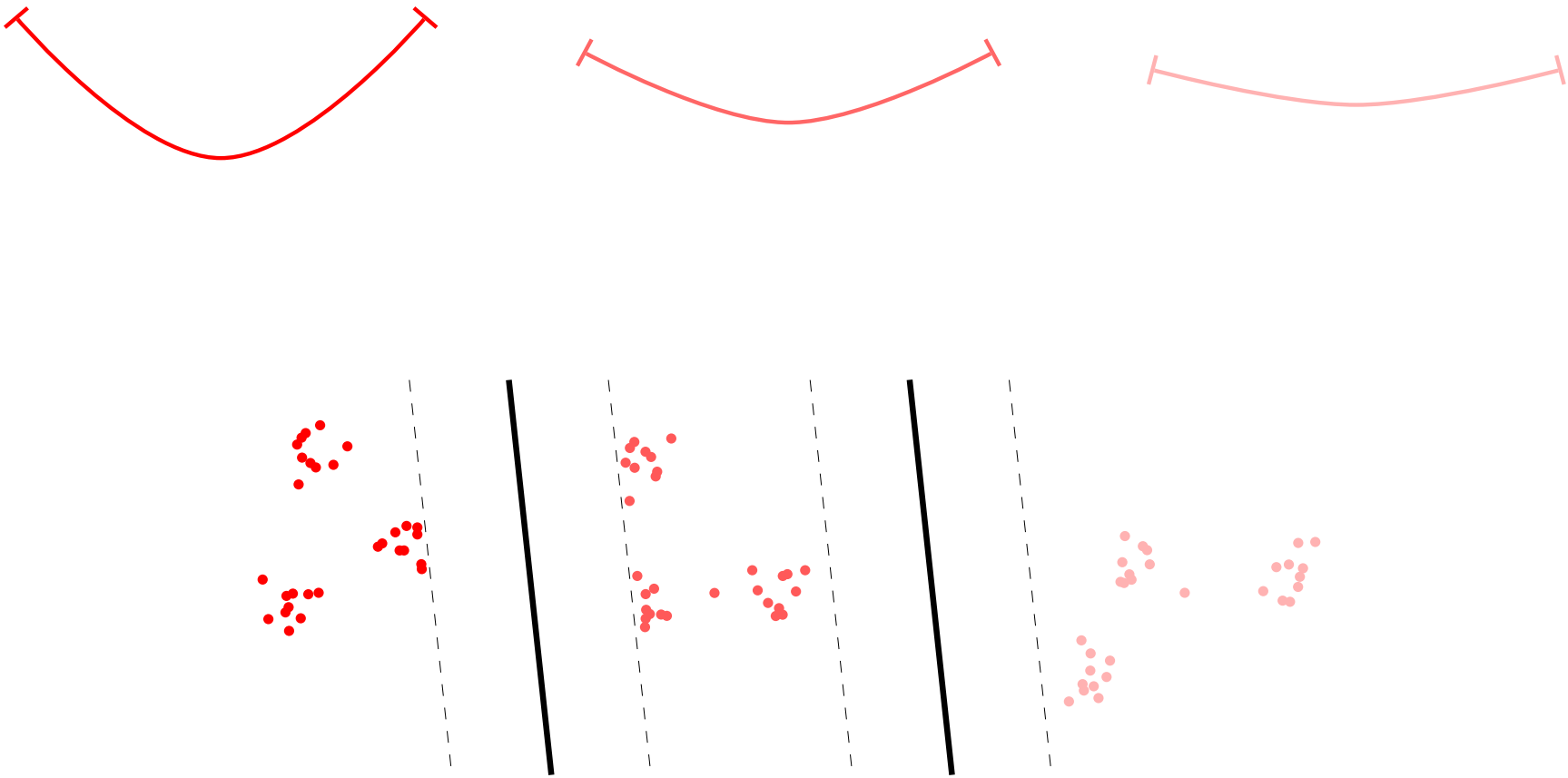
Focused Crawling

- Given a topic (seed pages) find out relevant pages from the web
- Pose Focused Crawling as a large scale OR problem

Ordinal Regression

- Fast OR training algorithm — scales to millions of datapoints
  - Fast algorithm to solve an SOCP with one SOC constraint
- Low prediction time

Baseline OR Formulation [Chu & Keerthi, 2005]



Clustering based scalable OR Formulation

- Describe data using clusters instead of data points

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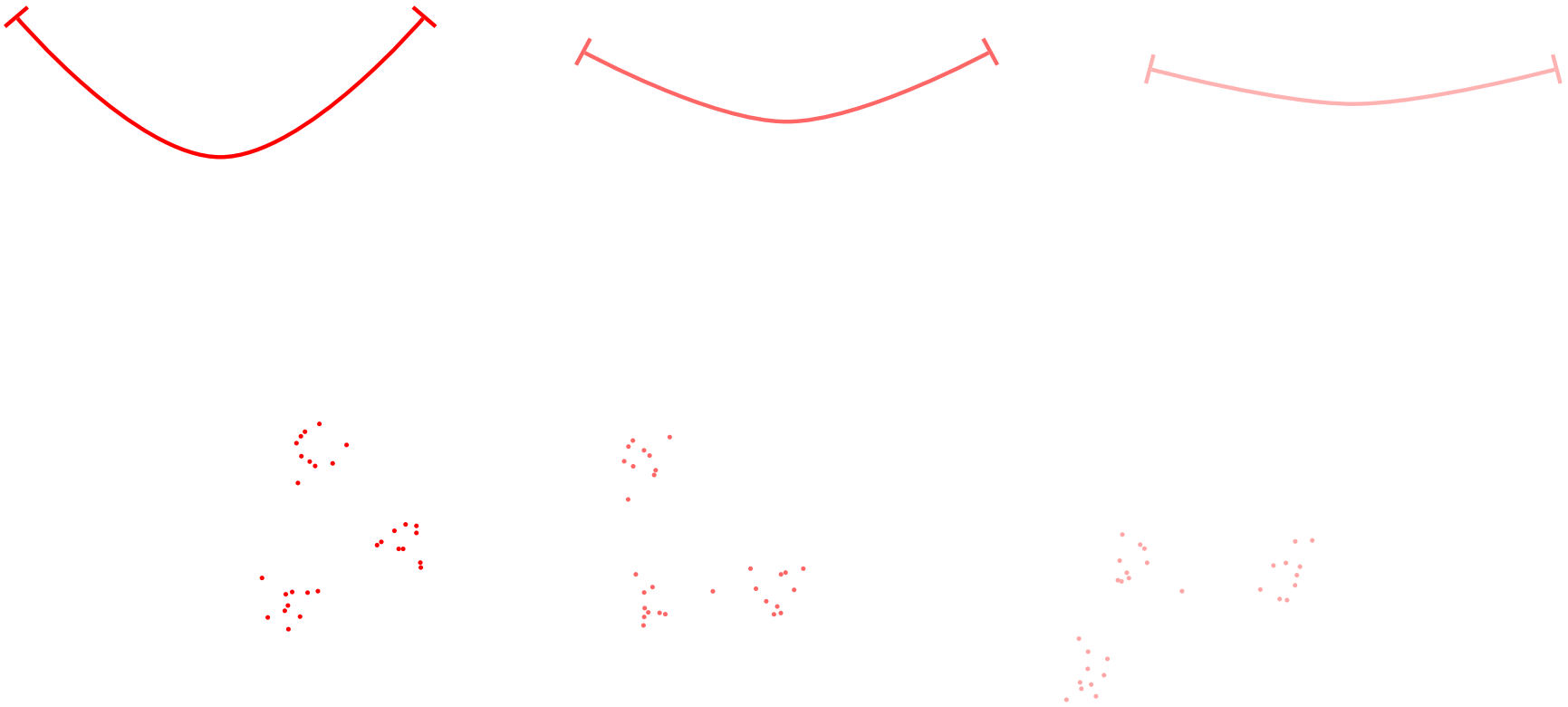
  - Class conditional distributions — mixture models with spherical covariance
- Using second order moments $(\mu, \sigma^2\mathbf{I})$, classify clusters
- Proposed formulation will have constraints per cluster
- Size of optimization problem $O(clusters)$ rather than $O(datapoints)$

Proposed OR formulation's solution



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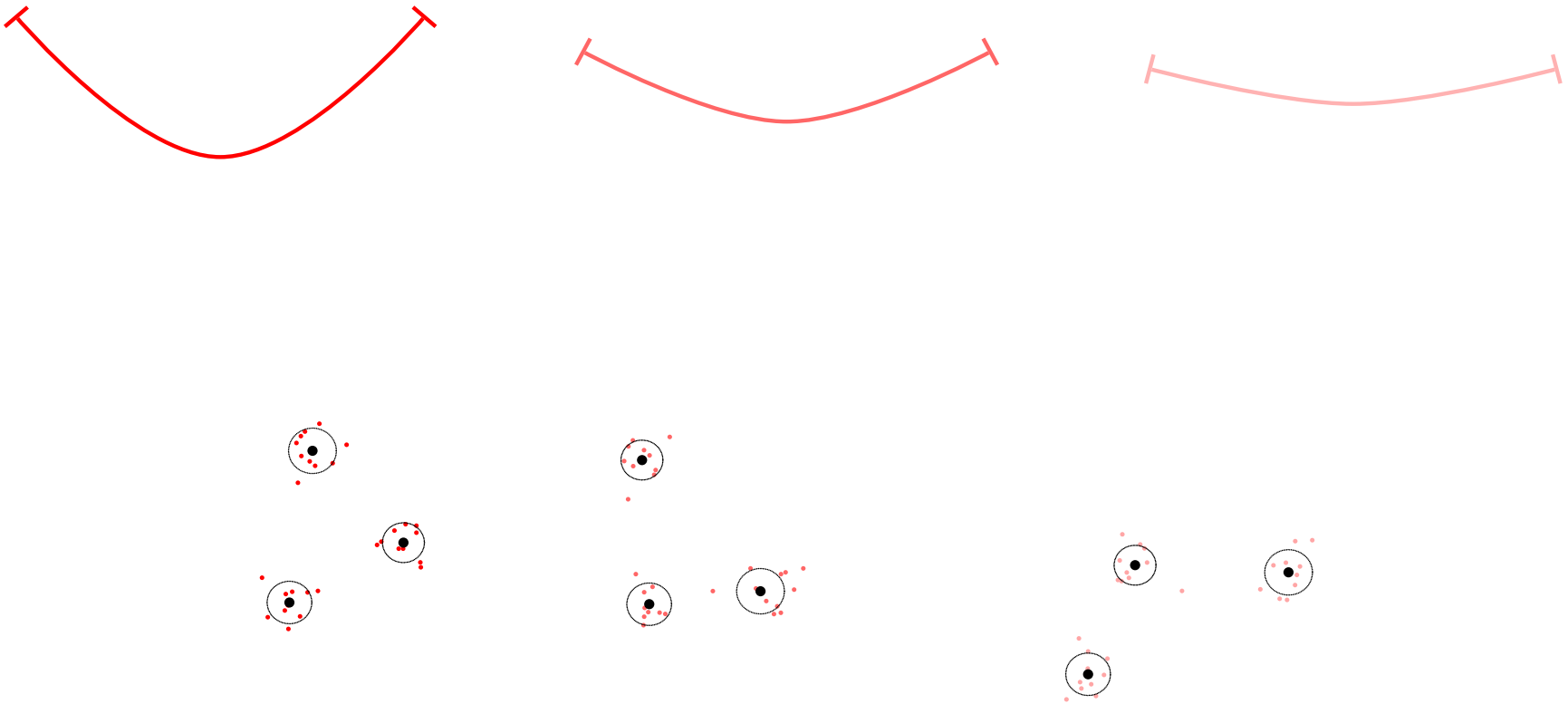

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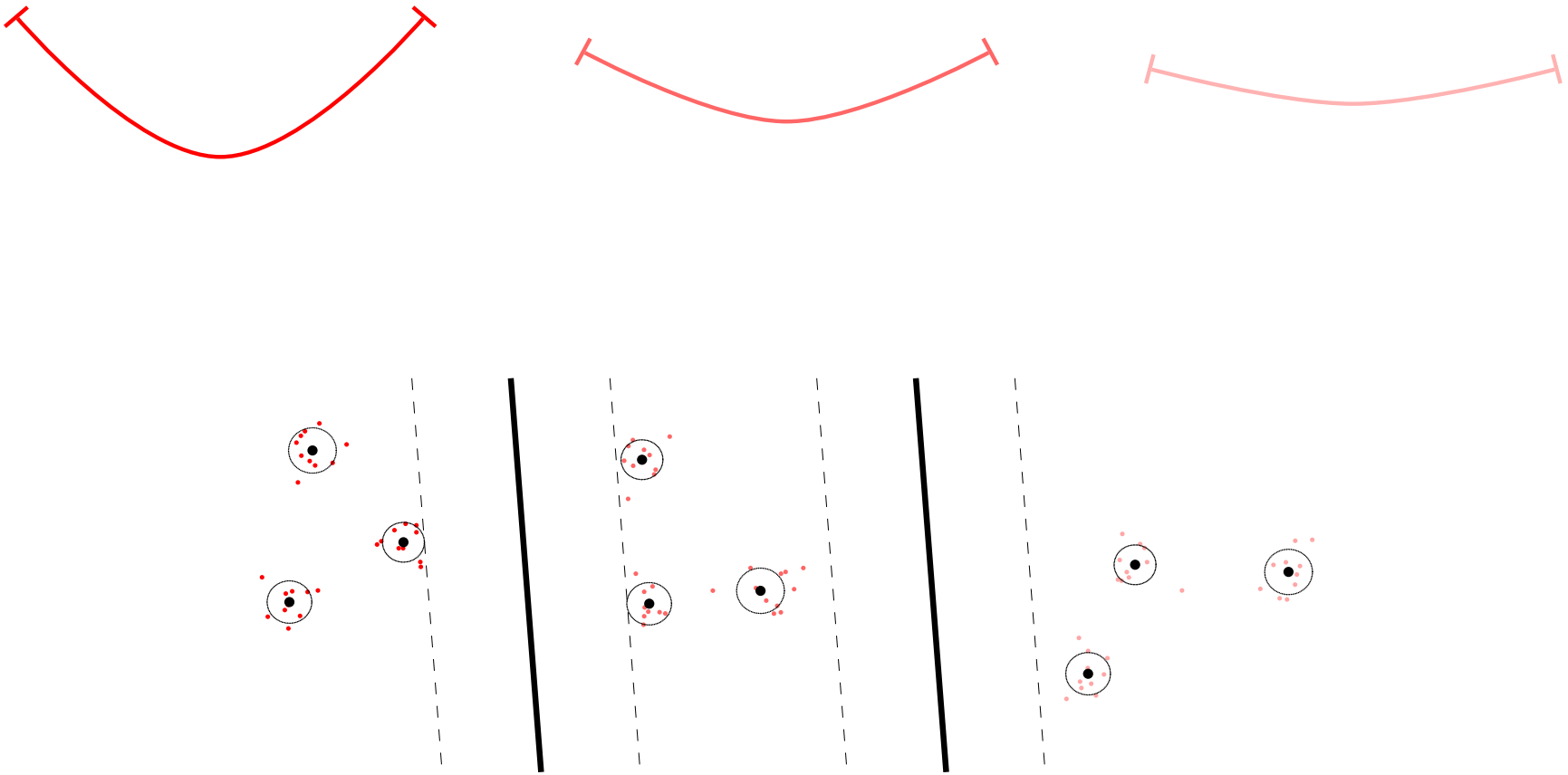


Proposed OR formulation

Features:

- SOCP Problem with one SOC constraint
- $T_{train} = T_{clust} + T_{SOCP} = O(n)$
  - Cluster moments estimated using BIRCH [Zhang et.al., 1996] $T_{clust} = O(n)$
  - SOCP solved using SeDuMi[a]. T_{SOCP} is independent of n
- Can be Kernelized — using input space cluster moments
  - No. of Support Vectors at max. k — low prediction time

[a] http://sedumi.mcmaster.ca/

Clustering + SOCP gives speedup

Table: Training times (sec) with **SeDuMi** and **SMO-OR** [Chu & Keerthi, 2005] on synthetic dataset.

S-Rate	S-Size	SMO-OR	SeDuMi
0.002	10,000	182	1
0.0025	12,500	260	1
0.003	15,000	340	1
0.3	1,500,000	×	9
1	5,000,000	×	**36**

Table: Training times (sec), test error rate with **SeDuMi** and **SMO-OR** [Chu & Keerthi, 2005] on CS-Census dataset.

	S-Size	SMO-OR	SeDuMi
		sec (err)	sec
CS	5,690	893 (.128)	20.4 (.109)
	11,393	5281.6 (.107)	108.8 (.112)
	15,191	9997.5 (.107)	271.1 (.108)
	22,331	×	**435.7** (.119)

Large number of clusters is still challenging

Table: Training times (sec), test error rate with **SeDuMi** and **SMO-OR** [Chu & Keerthi, 2005] on CH-California Housing dataset.

	S-Size	**SMO-OR**	**SeDuMi**
		sec (err)	sec
CH	10,320	551.9 (.619)	112 (.623)
	13,762	1033.2 (.616)	768.8 (.634)
	15,482	1142 (.617)	×
	17,202	1410 (.617)	×
	20,230	1838.5 (.62)	×

CB-OR Solver

Key Idea:

- Exploit special SOCP form — SOCP problem with one SOC constraint
  - Erdougan et.al., 2006 — specialized solvers scale better
- Fast algorithm similar in spirit to Platt's SMO for QP

Features:

- More scalable than generic solvers
- Easy to implement, uses no optimization tools

CB-OR Solver

Rewrite Dual as follows:

$$\begin{aligned} \min_{\alpha,\alpha^*} \quad & W\sqrt{(\alpha^* - \alpha)^\top \mathbf{K}(\alpha^* - \alpha)} - \mathbf{d}^\top(\alpha + \alpha^*) \\ \text{s.t.} \quad & 0 \le \alpha \le 1, 0 \le \alpha^* \le 1 \\ & s_i^* \le s_i, \ \forall\ i = 1, \ldots, r-2, s_{r-1}^* = s_{r-1} \end{aligned}$$

$\mathbf{K}$ is Gram matrix for cluster centers
$s_i = \sum_{k=1}^{i} \sum_{j=1}^{n_k} \alpha_k^j$ and $s_i^* = \sum_{k=2}^{i+1} \sum_{j=1}^{n_k} \alpha_k^{*j}$

CB-OR Solver

Minimization wrt. two multipliers

$$\begin{aligned} \min_{\Delta\alpha} \quad & \sqrt{a(\Delta\alpha)^2 + 2b(\Delta\alpha) + c} - e\Delta\alpha \\ \text{s.t.} \quad & lb \leq \Delta\alpha \leq ub \end{aligned}$$

Has closed form solution:

$$\Delta\alpha = \begin{cases} \left\lceil \frac{e\sqrt{\frac{ac-b^2}{a-e^2}} - b}{a} \right\rceil_{lb}^{ub} & \text{if } ac - b^2 > 0, a - e^2 > 0 \\ \left\lceil \frac{-b}{a} \right\rceil_{lb}^{ub} & \text{if } ac - b^2 = 0, a - e^2 > 0 \\ ub & \text{if } e - \sqrt{a} \geq 0 \\ lb & \text{if } e + \sqrt{a} \leq 0 \end{cases}$$

CB-OR Solver

CB-OR Algorithm

Step 1 Pick two most KKT violators

Step 2 Solve the 1-d minimization problem

Step 3 Update unknowns

Step 4 Check for KKT violators. If none terminate. Else Step 1

CB-OR — Evaluation

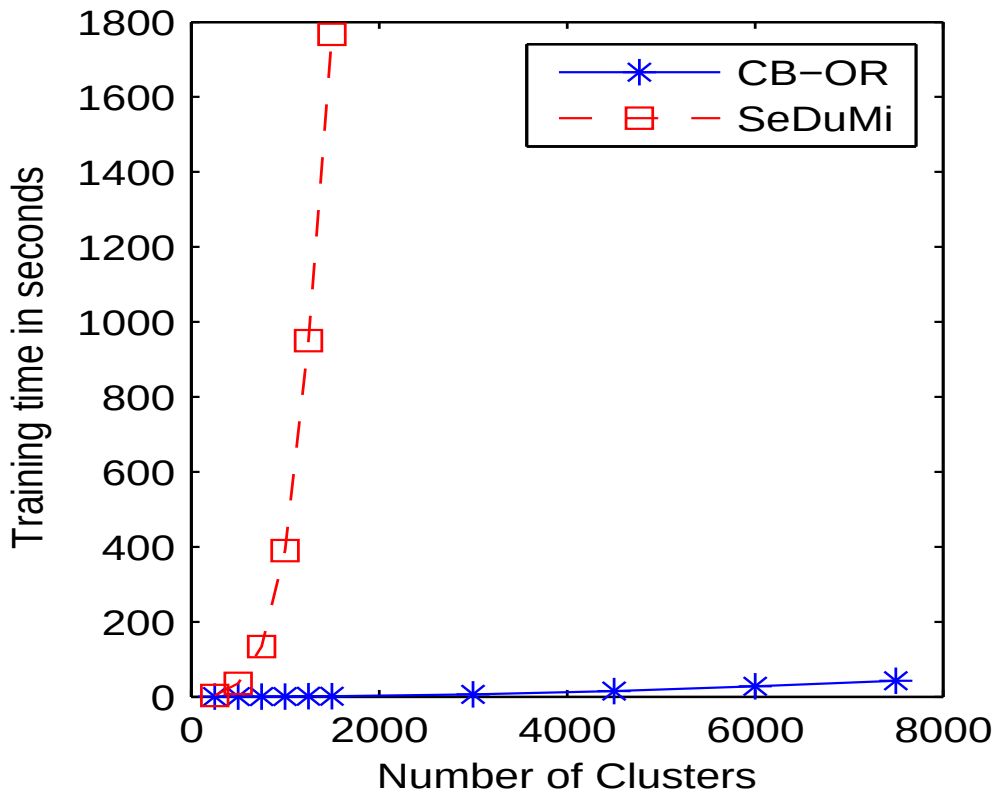


Figure: Dashed line represents training time with **SeDuMi** and continuous line that with **CB-OR** on a synthetic dataset.

CB-OR — Evaluation

Table: Comparison of training times (in sec) with **CB-OR**, **SMO-OR** and **SeDuMi** on benchmark datasets. The test set error rate is given in brackets. (CH-California Housing, CS-Census datasets).

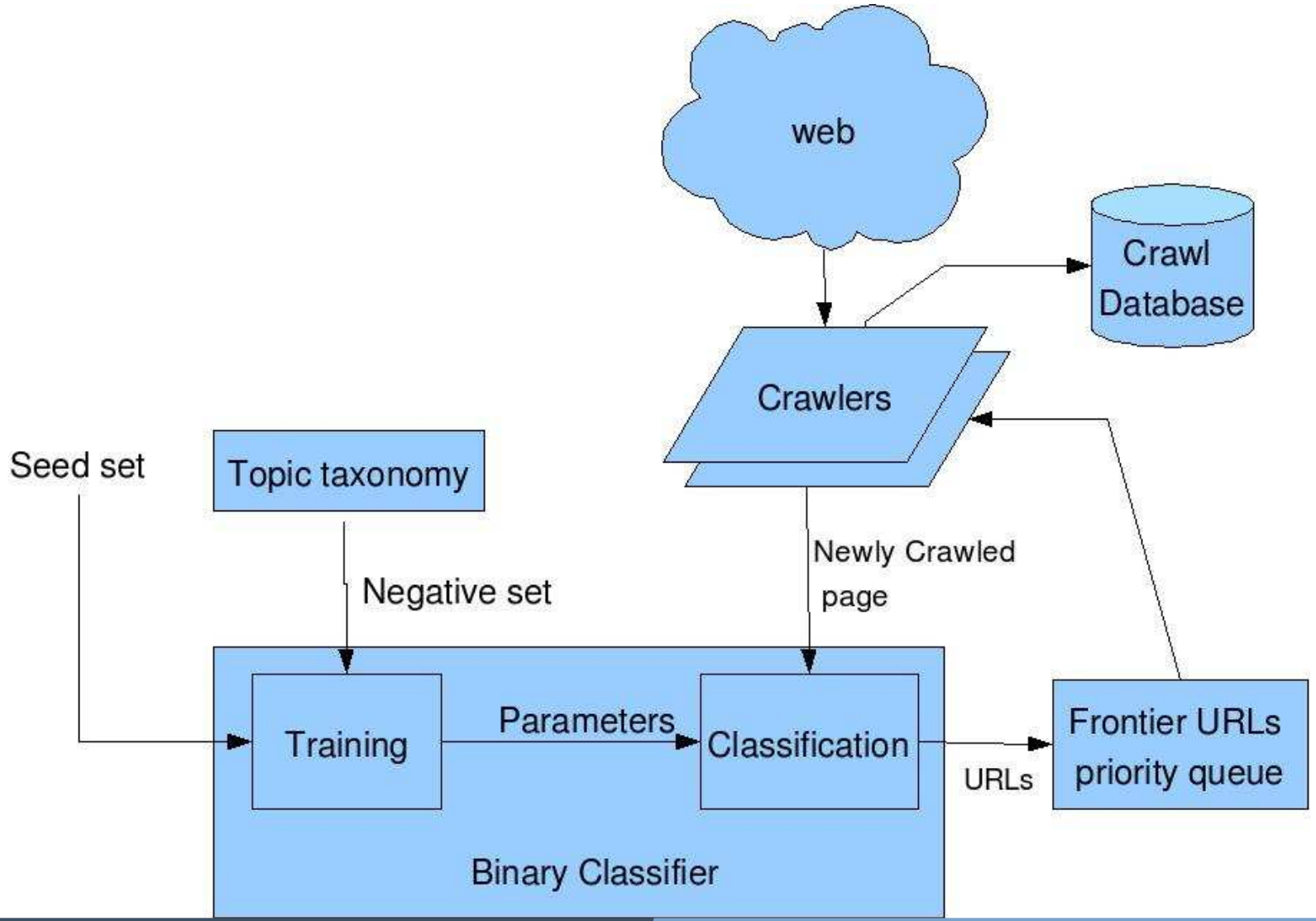
	S-Size	**CB-OR**	**SMO-OR**	**SeDuMi**
		sec (err)	sec (err)	sec
CH	10,320	.5 (.623)	551.9 (.619)	112
	13,762	1.5 (.634)	1033.2 (.616)	768.8
	15,482	8.4 (.618)	1142 (.617)	×
	17,202	14.3 (.621)	1410 (.617)	×
	20,230	**10.4** (.62)	1838.5 (.62)	×
CS	5,690	.3 (.109)	893 (.128)	20.4
	11,393	.7 (.112)	5281.6 (.107)	108.8
	15,191	1 (.108)	9997.5 (.107)	271.1
	22,331	**1.5** (.119)	×	435.7

Focused Crawling

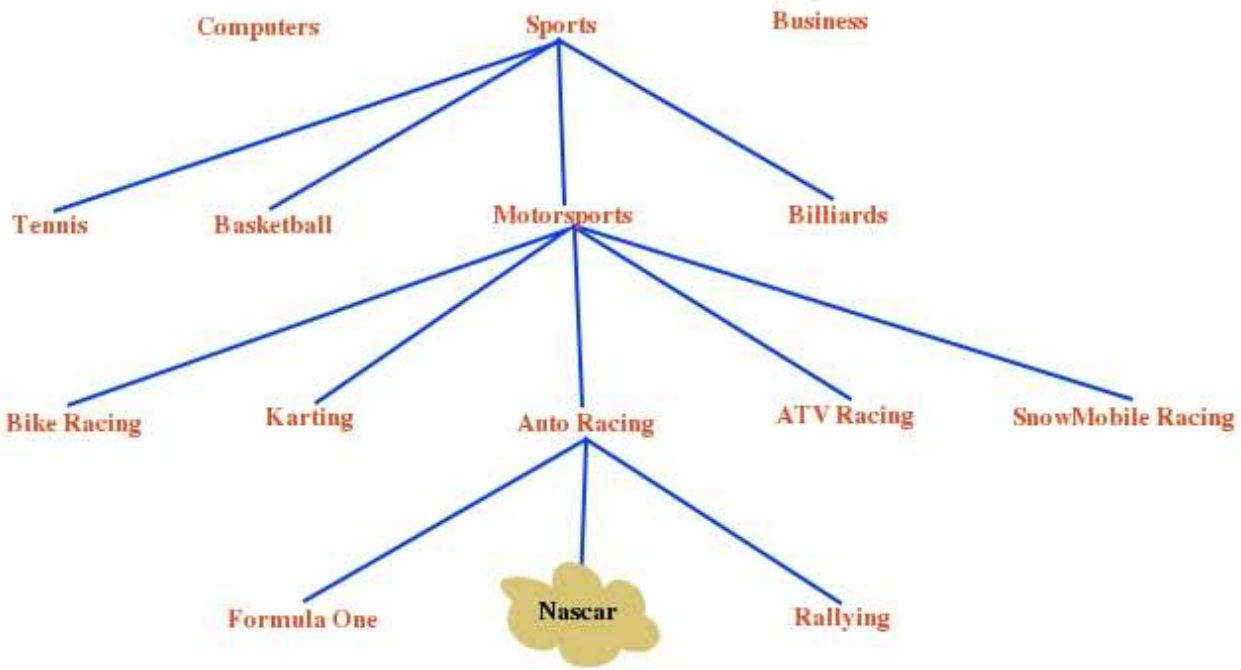
Focused Crawling

- Given a topic (seed pages) find out relevant pages from the web.
- S. Chakrabarti et.al (1999,2002), C. Aggarwal et.al (2001), M. Diligenti et.al (2000)
- Requires low bandwidth and low disk space.
- Small updation cycle.

Baseline Focused Crawler [Chakrabarti et.al., 1999]



Topic Taxonomy



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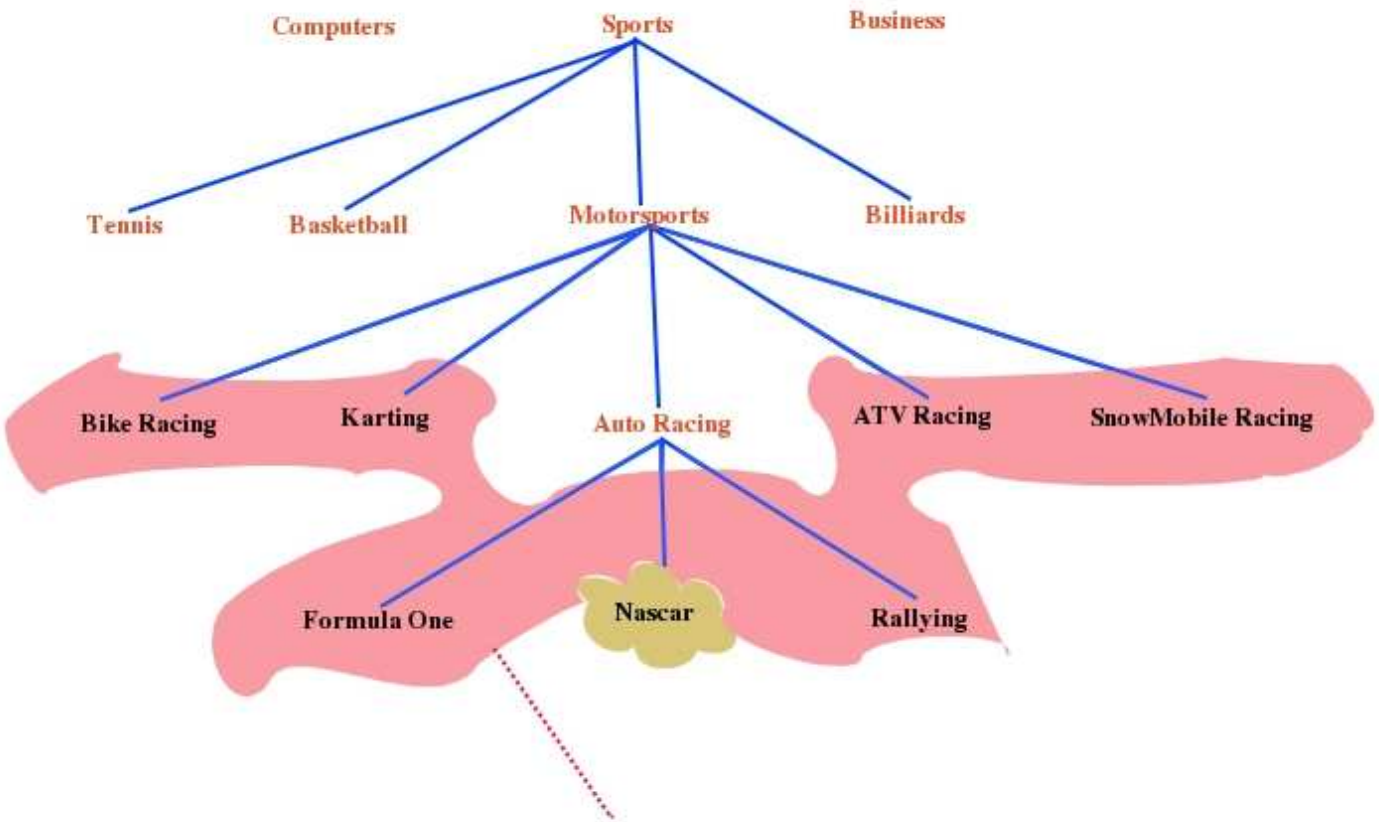
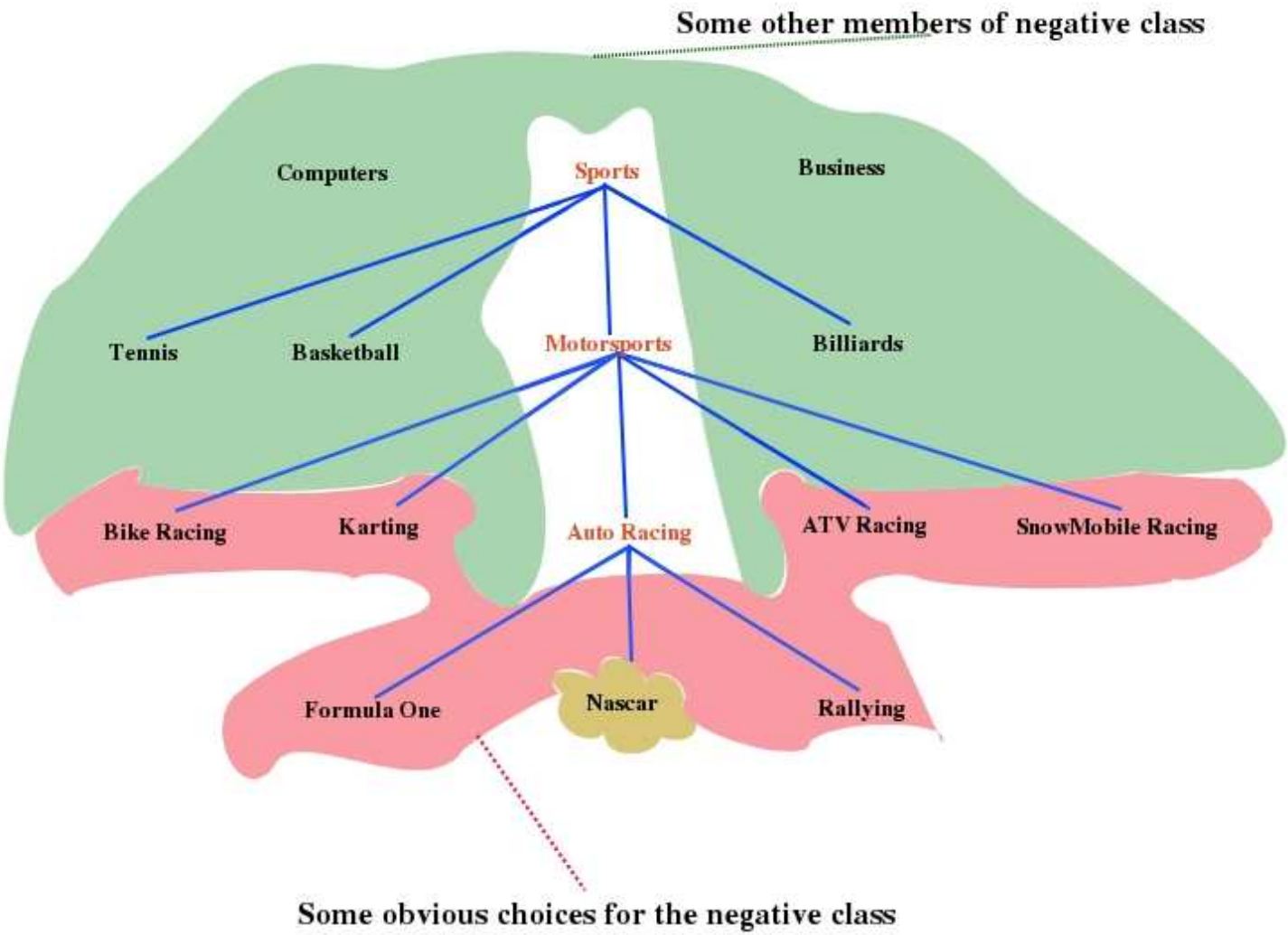


Some obvious choices for the negative class

Topic Taxonomy



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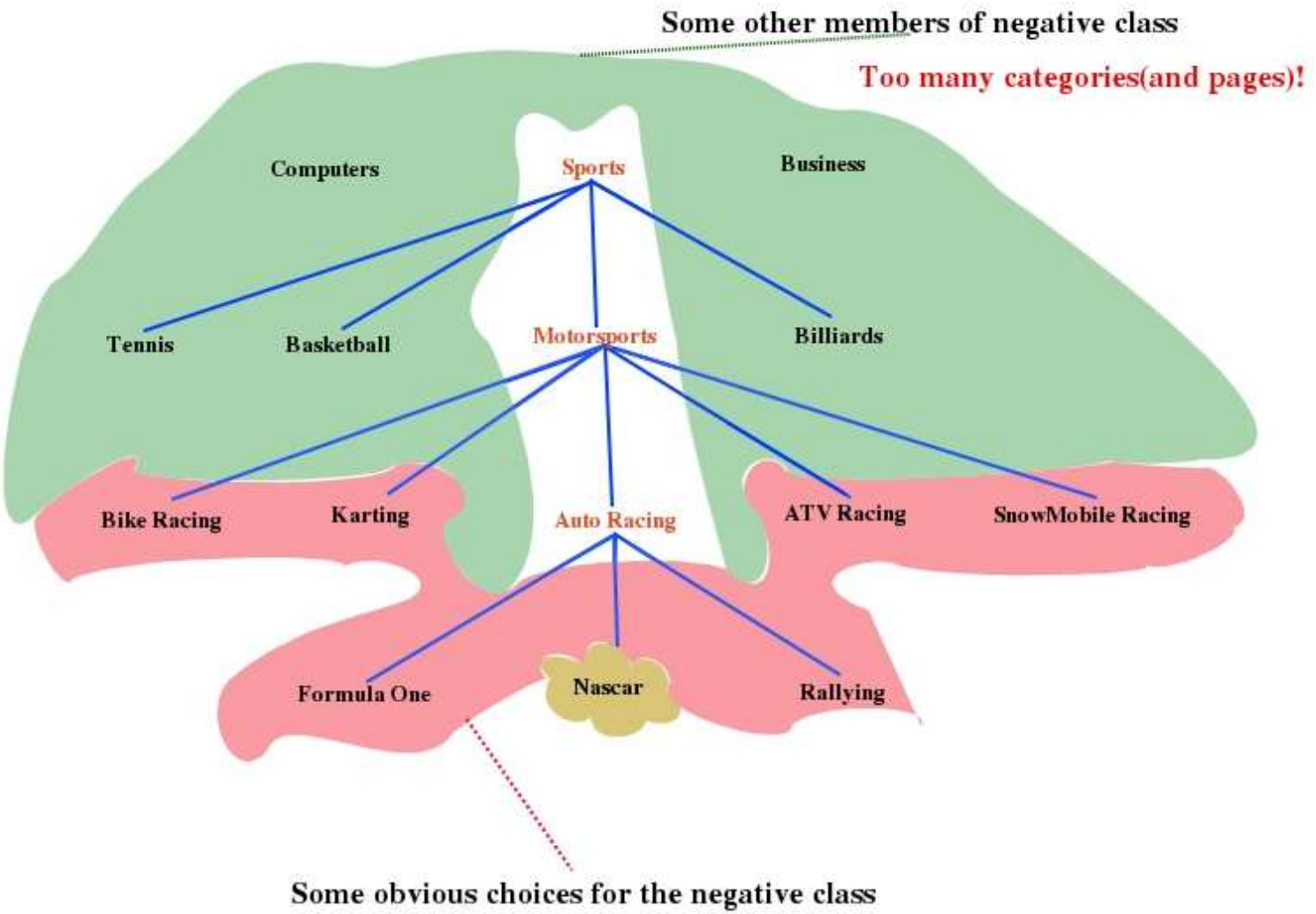

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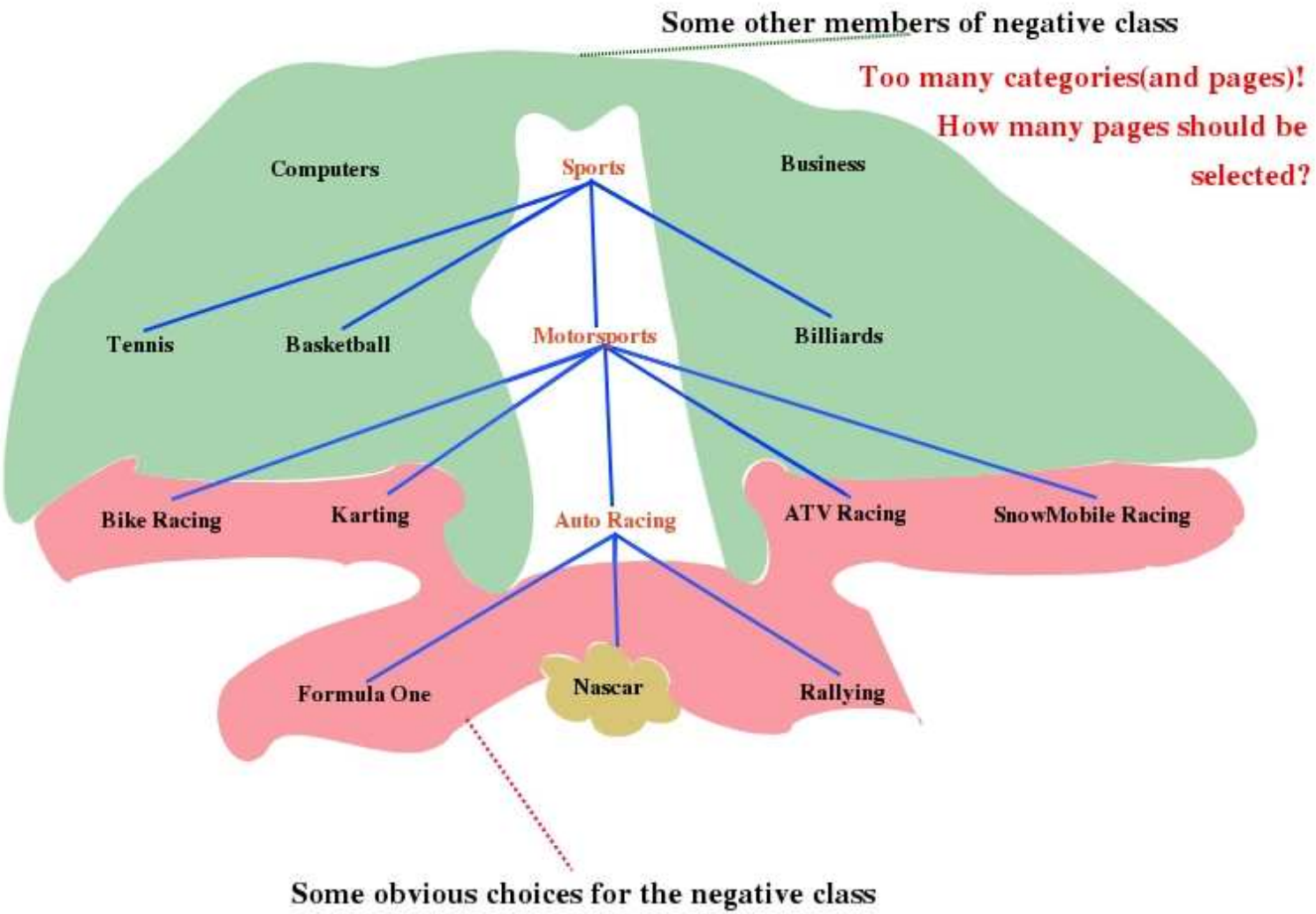

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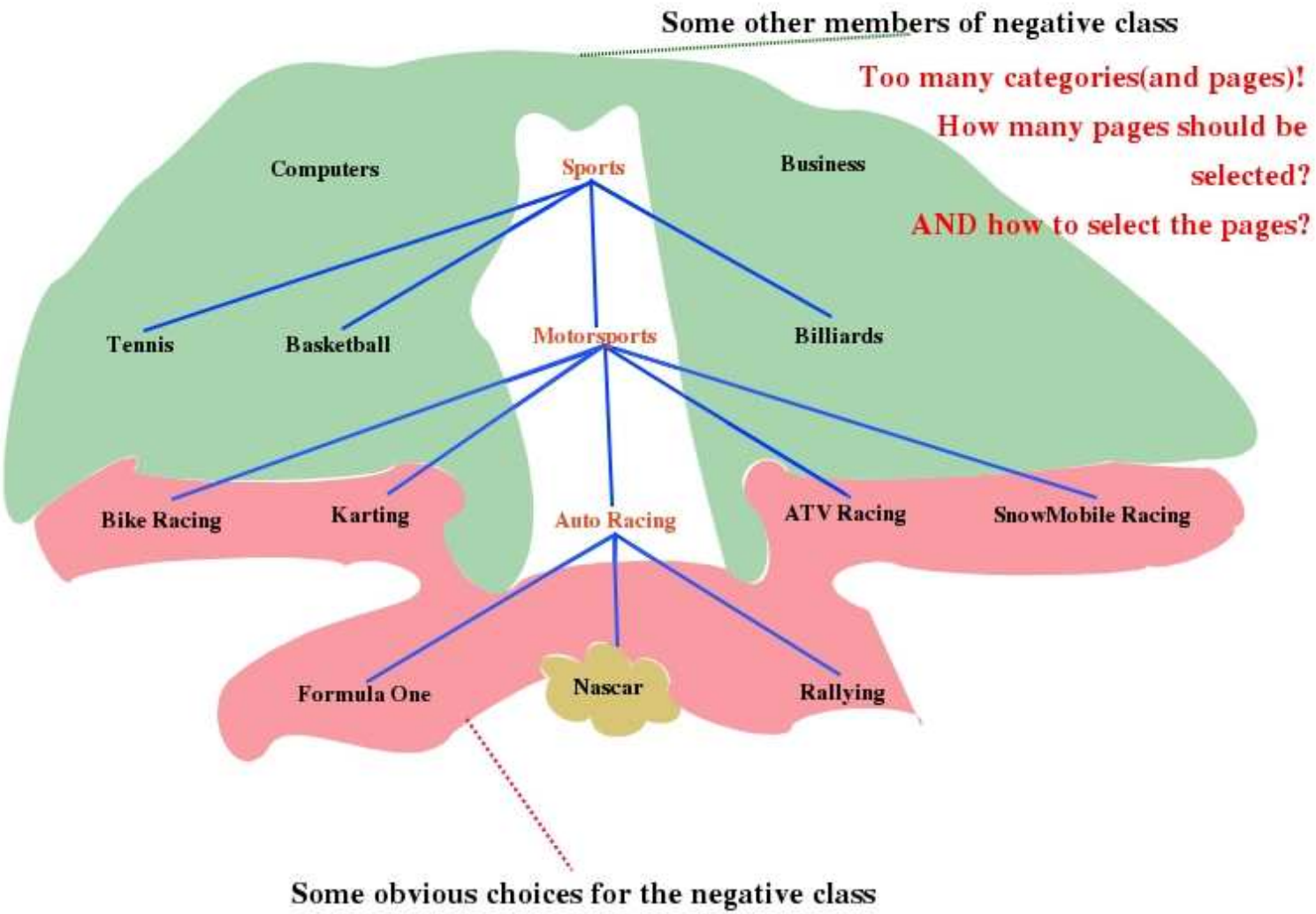

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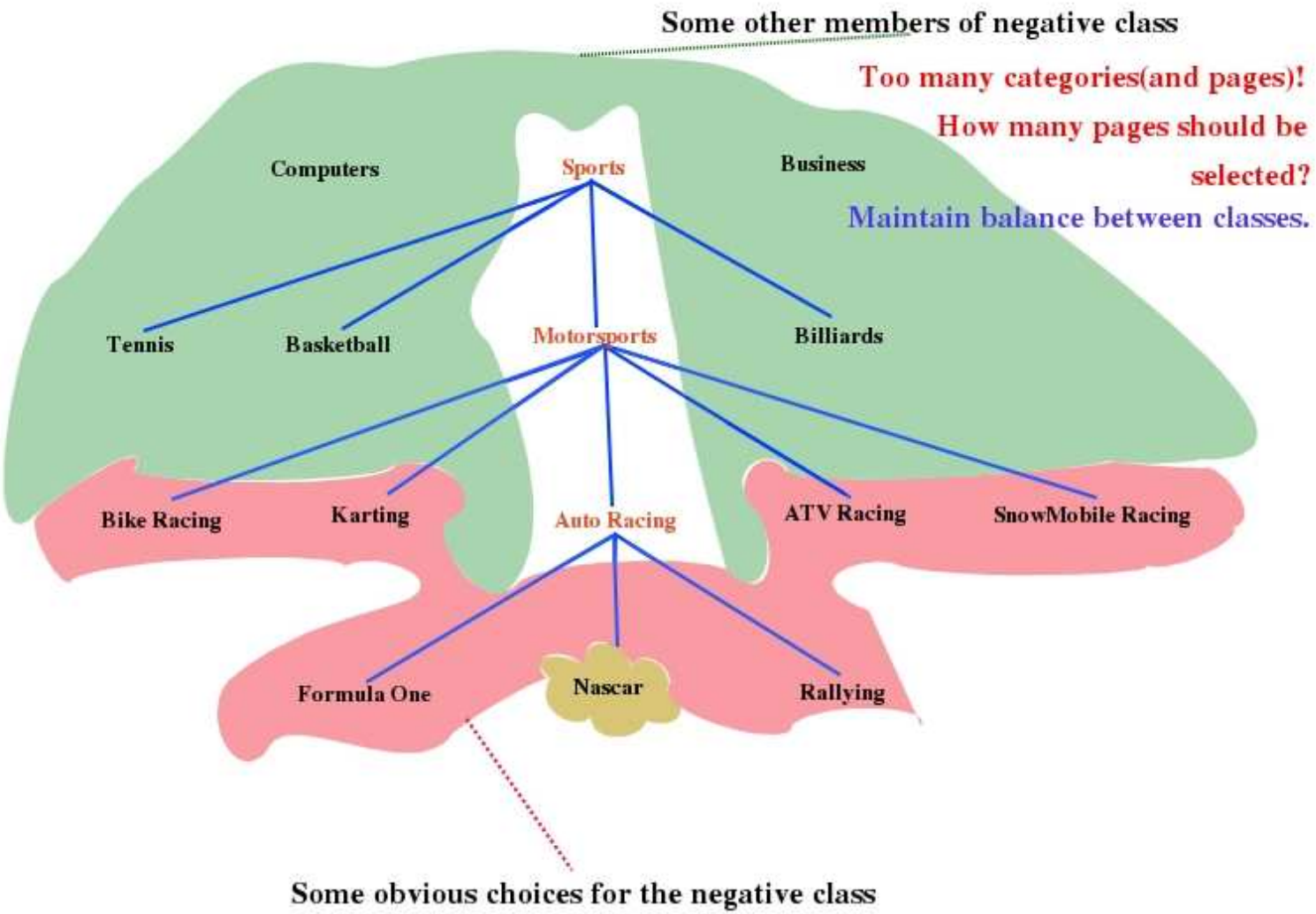

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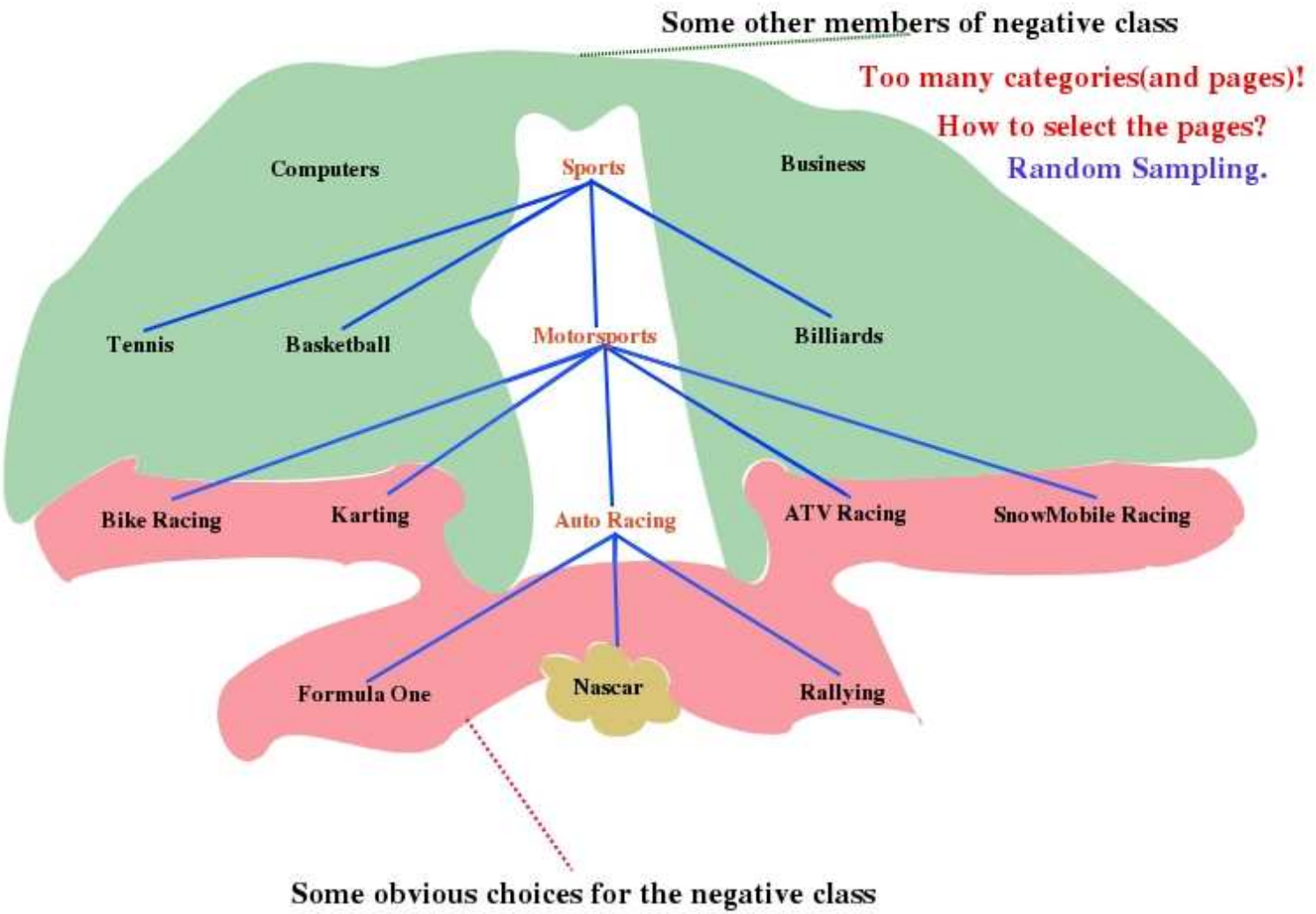

Exploit link structure

- Grangier and Bengio observe that hyperlinked documents are semantically closer.
- One link away pages are more similar to seed pages compare to two link away pages.

Link structure in web

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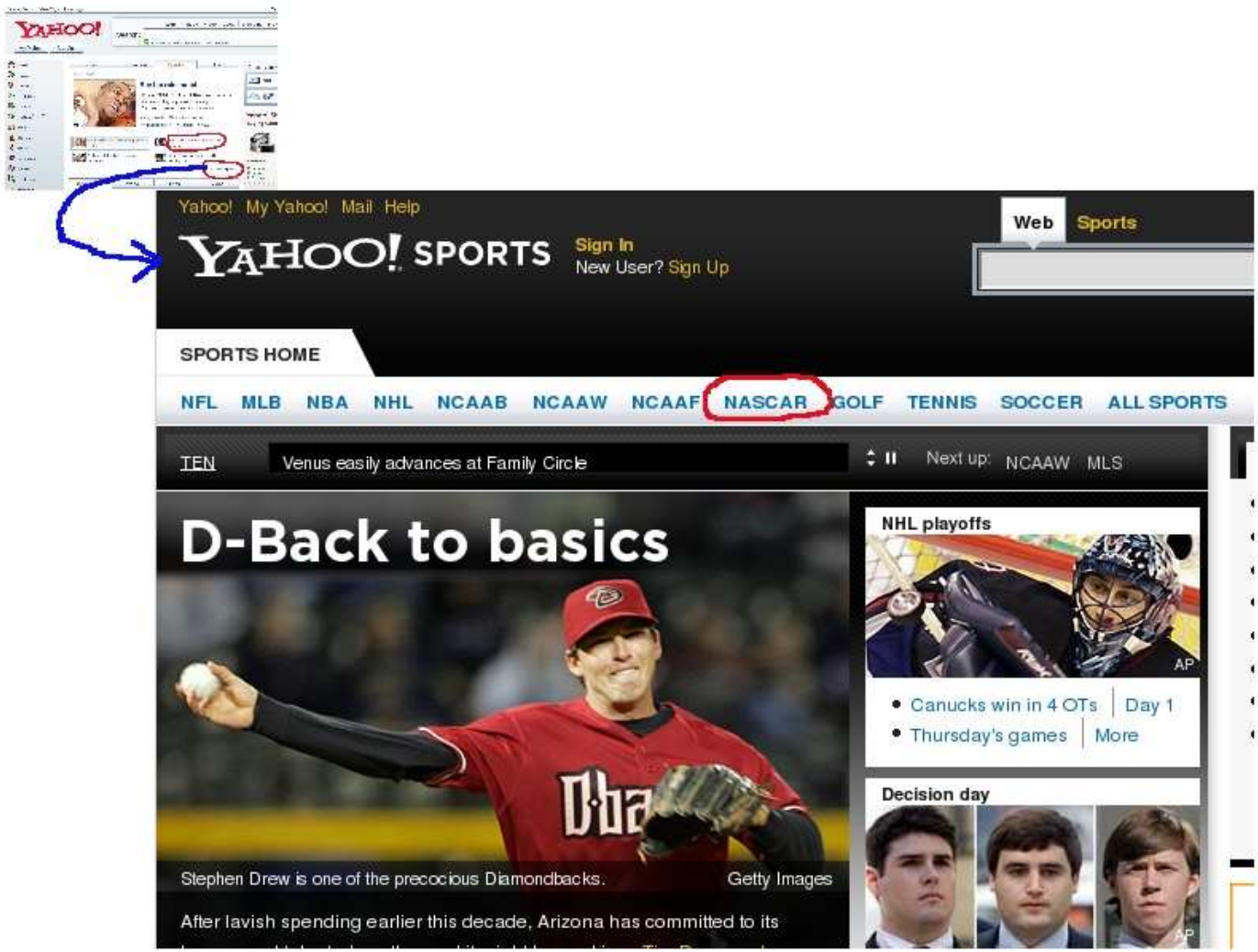
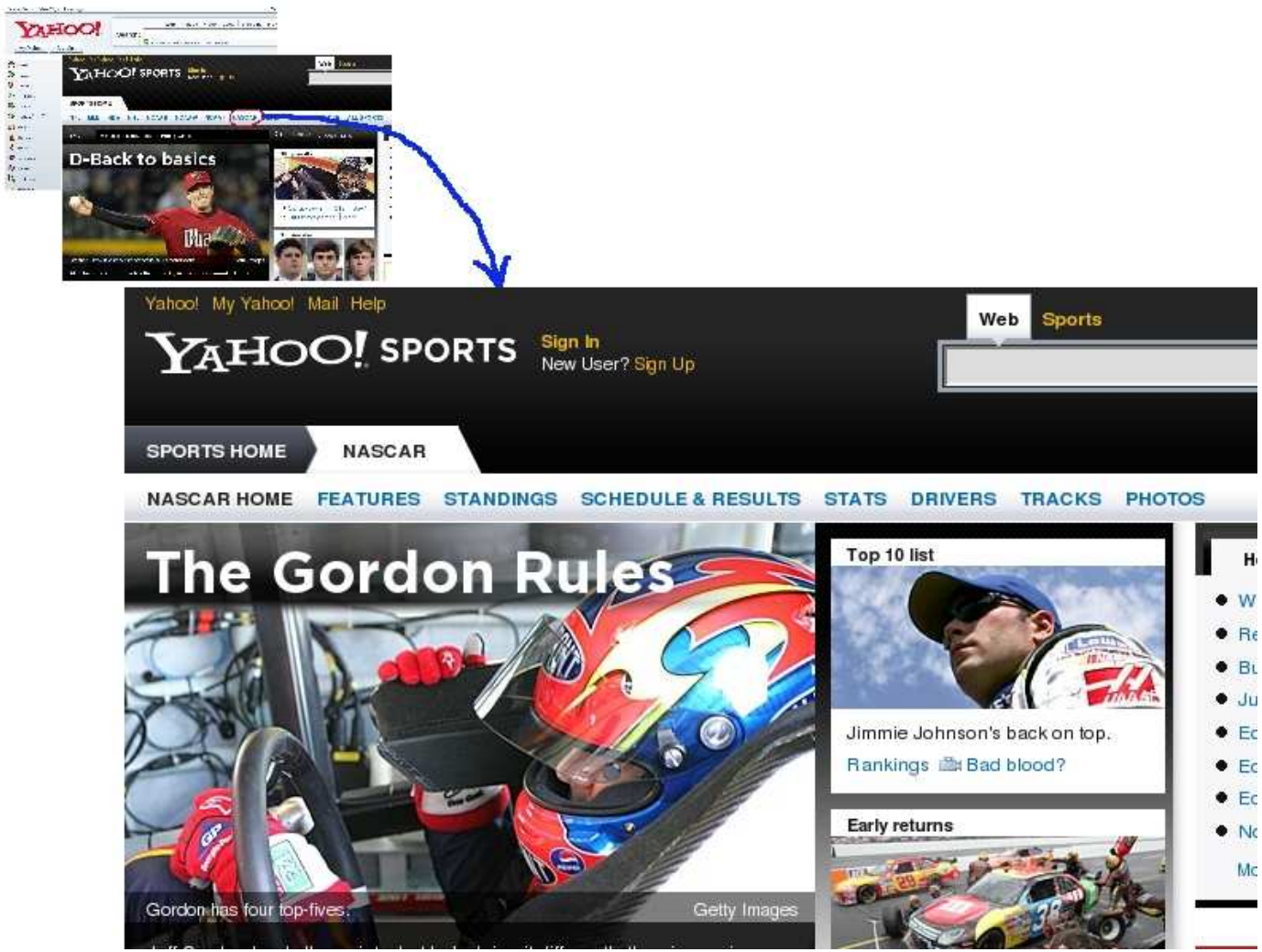
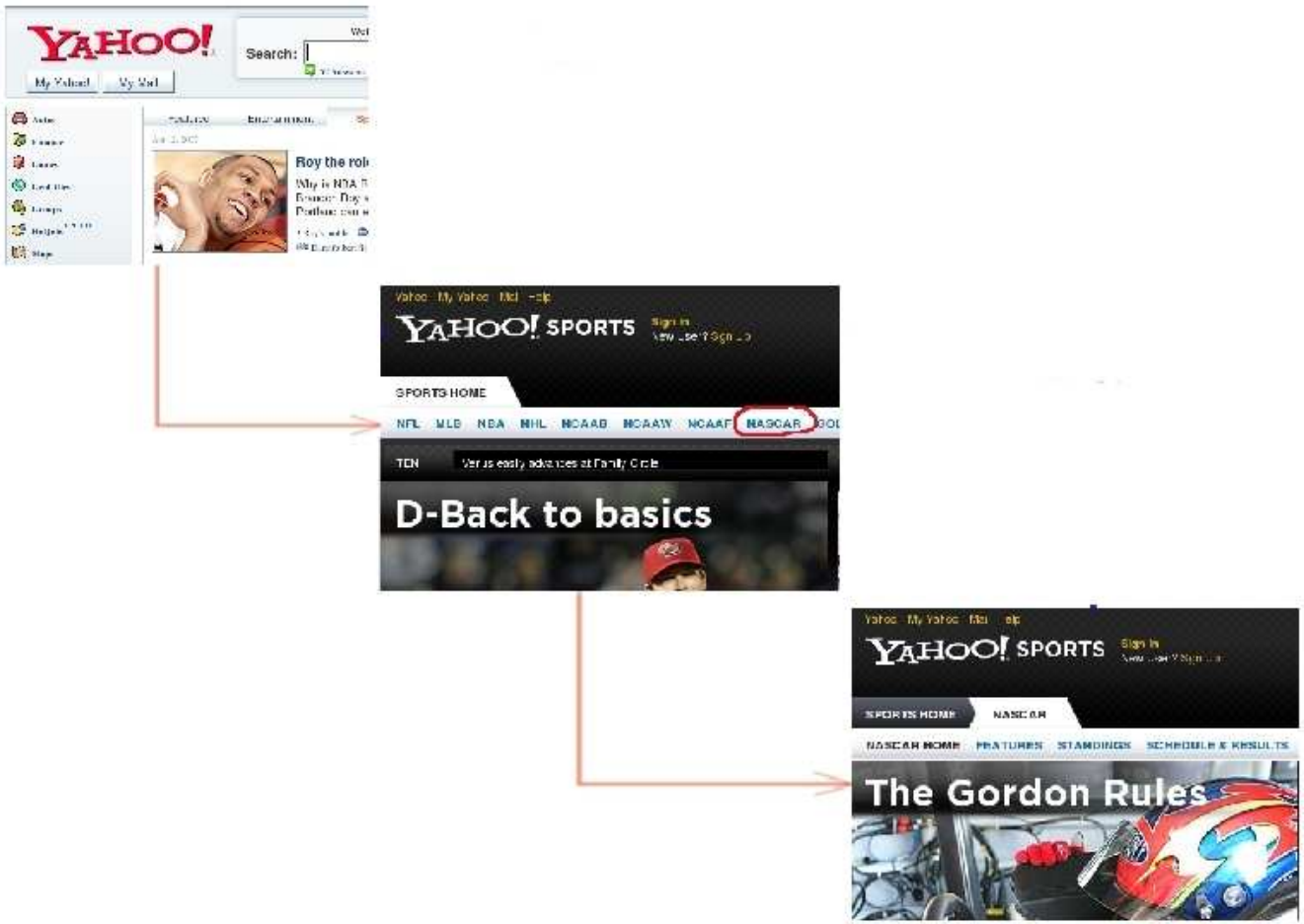


Link structure in web



Focused Crawling as OR problem — exploit link structure



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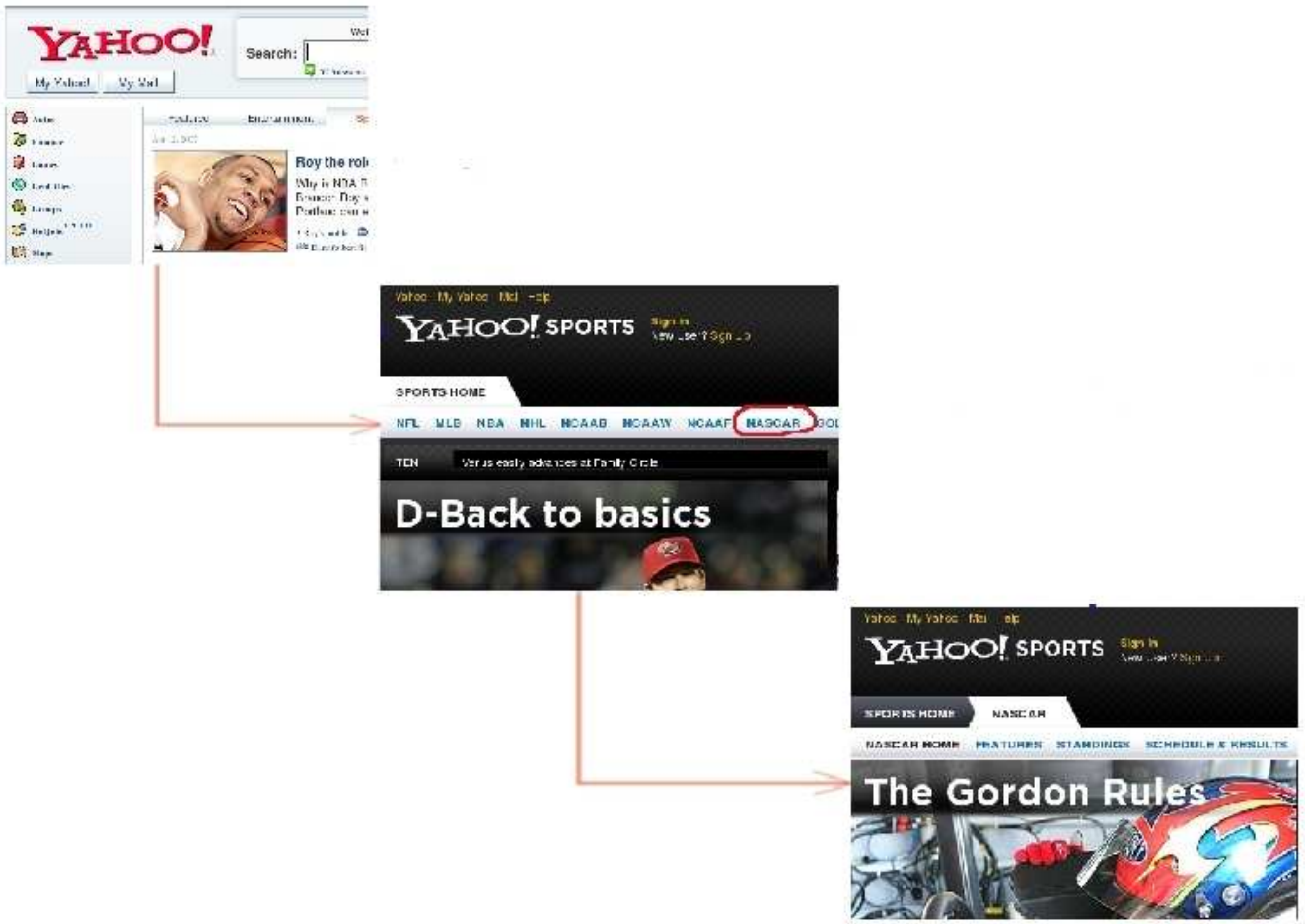
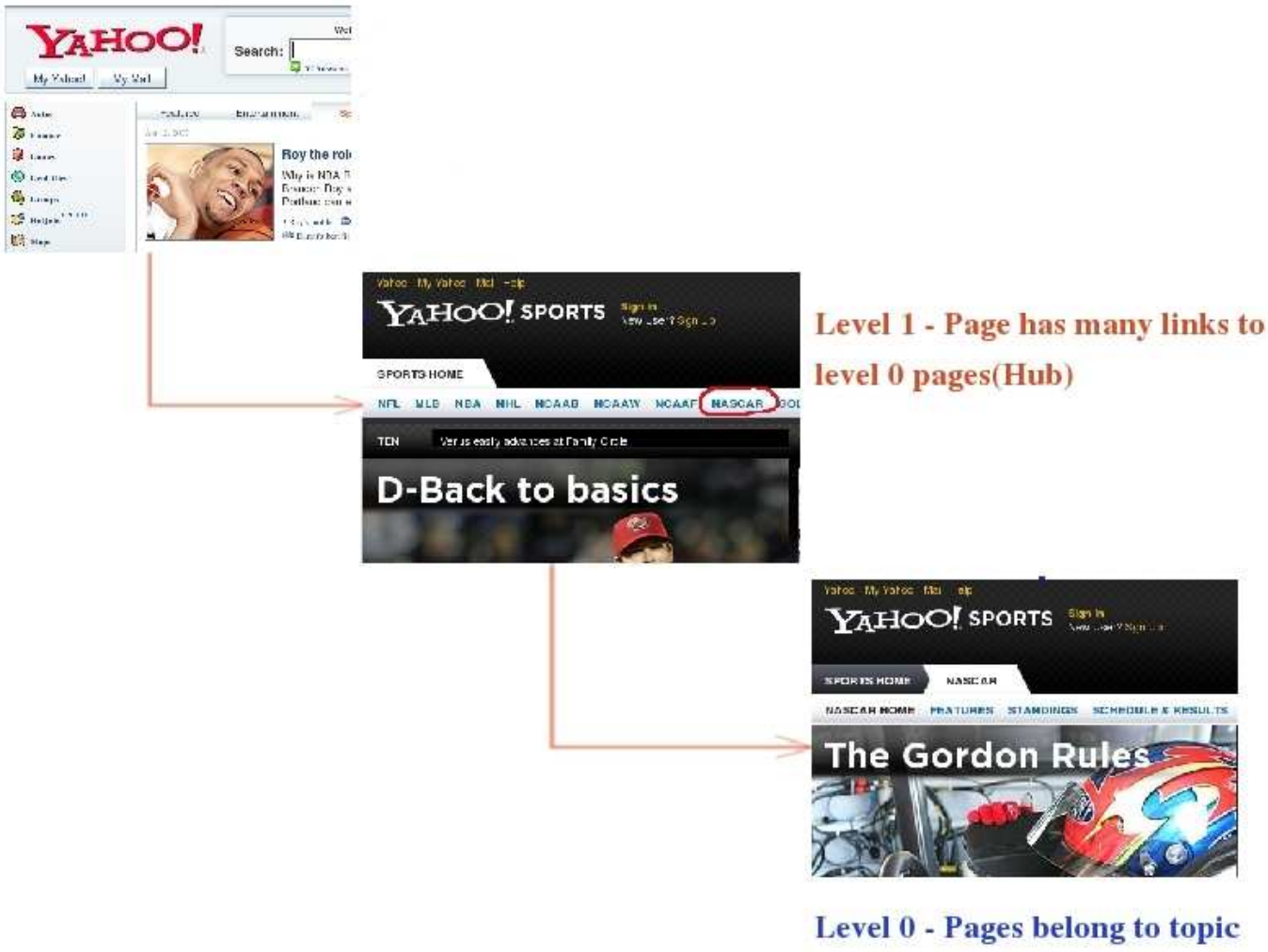


Level 0 - Pages belong to topic

Focused Crawling as OR problem — exploit link structure



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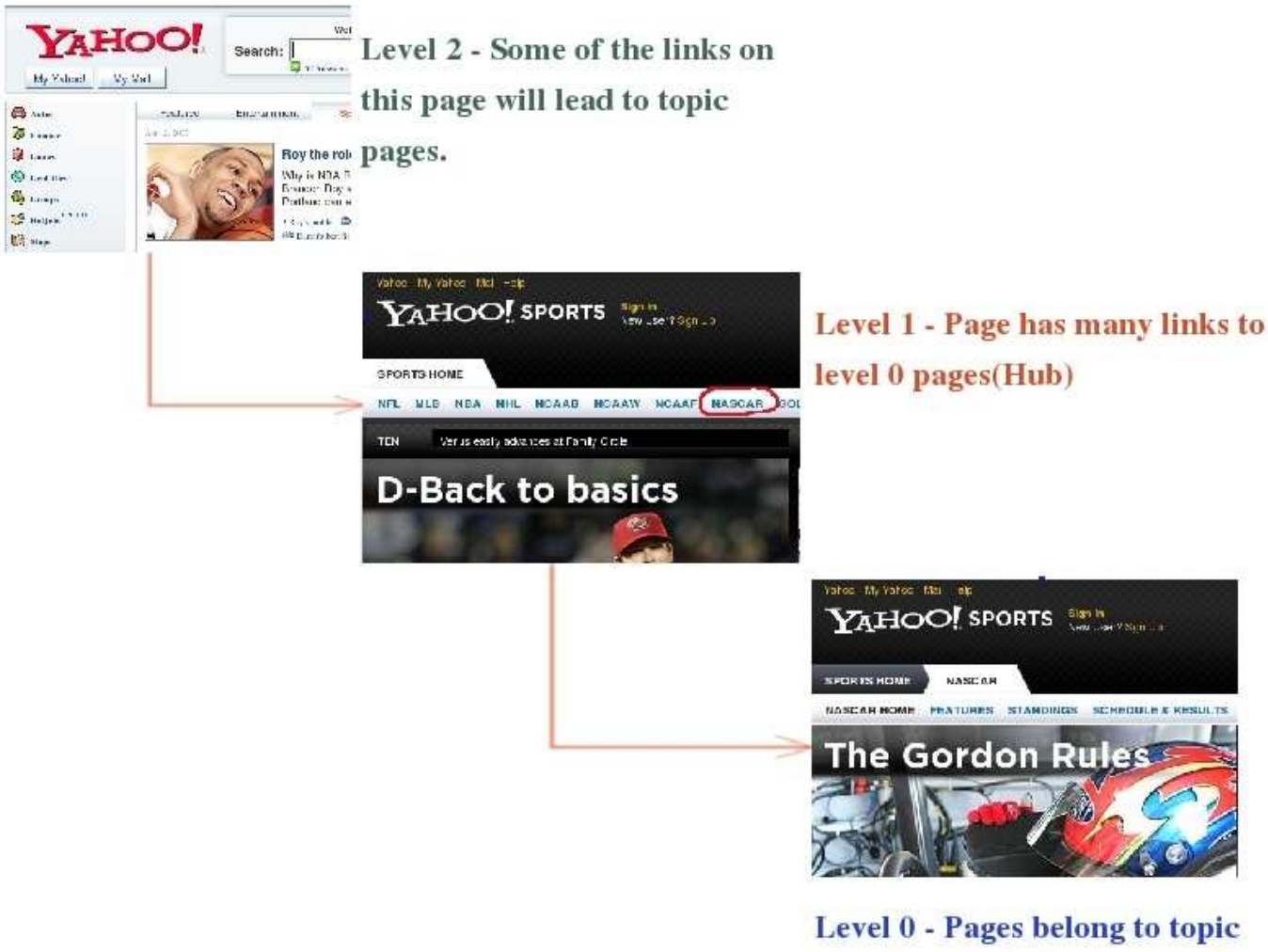
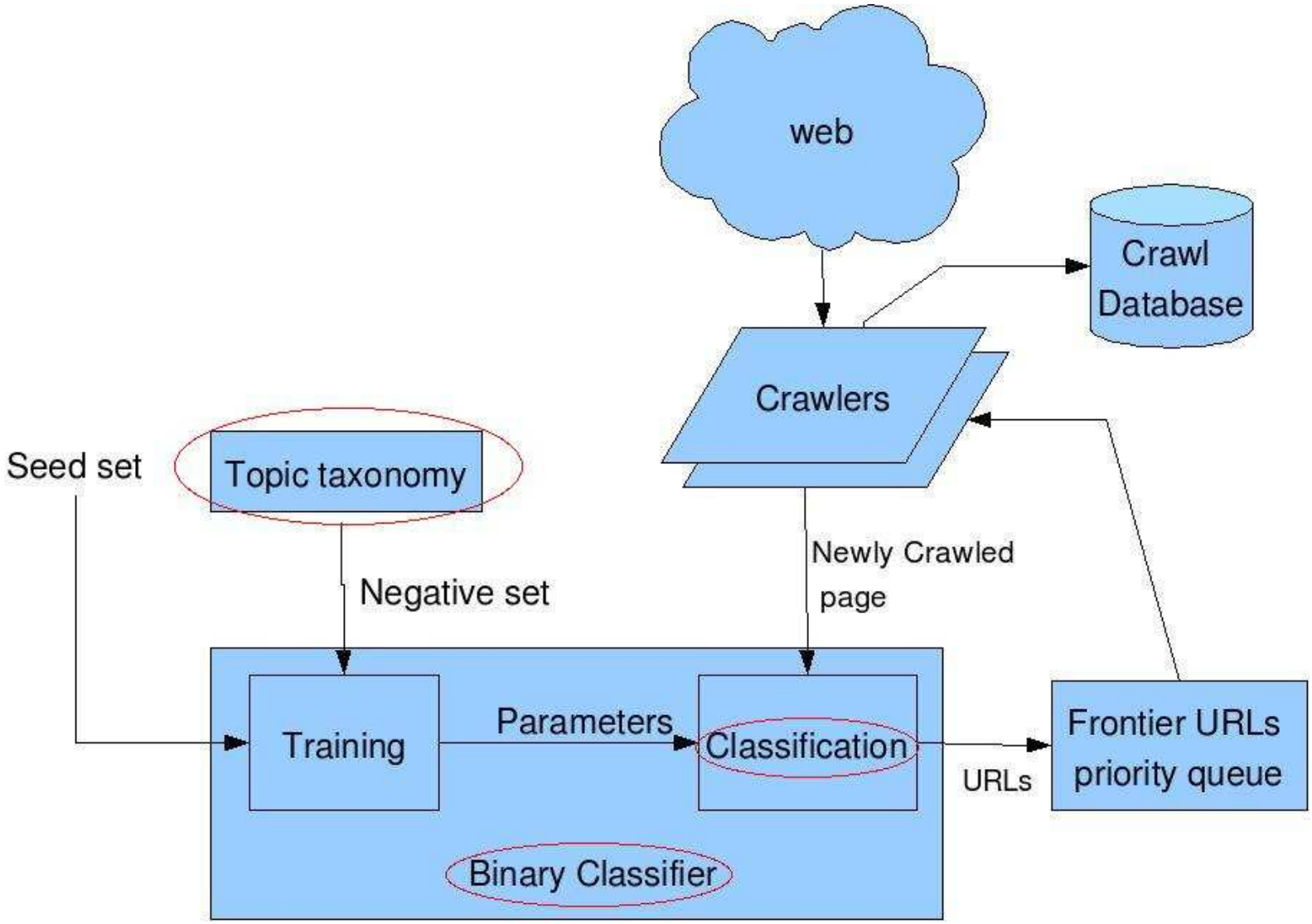
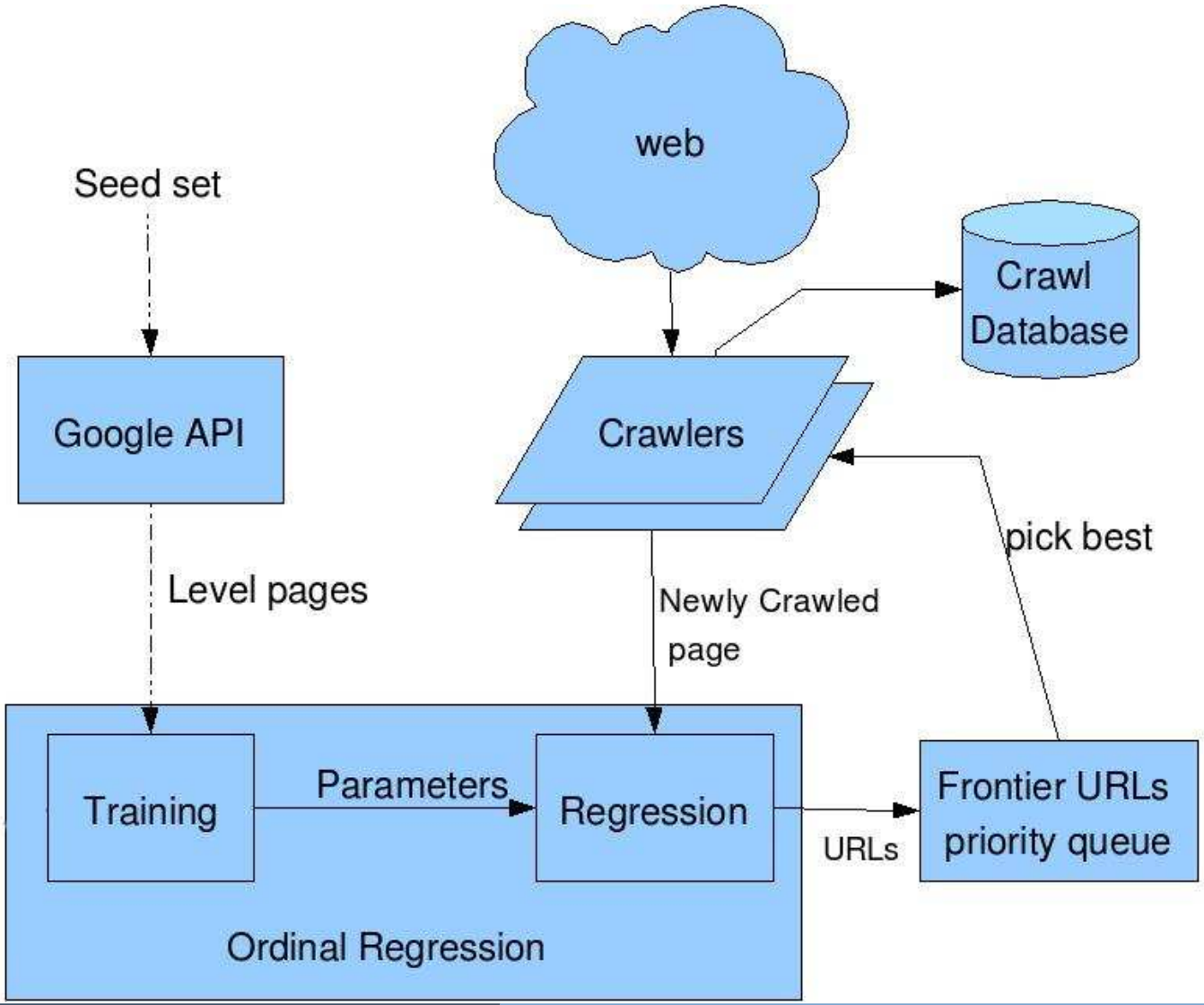


Baseline Focused Crawling architecture



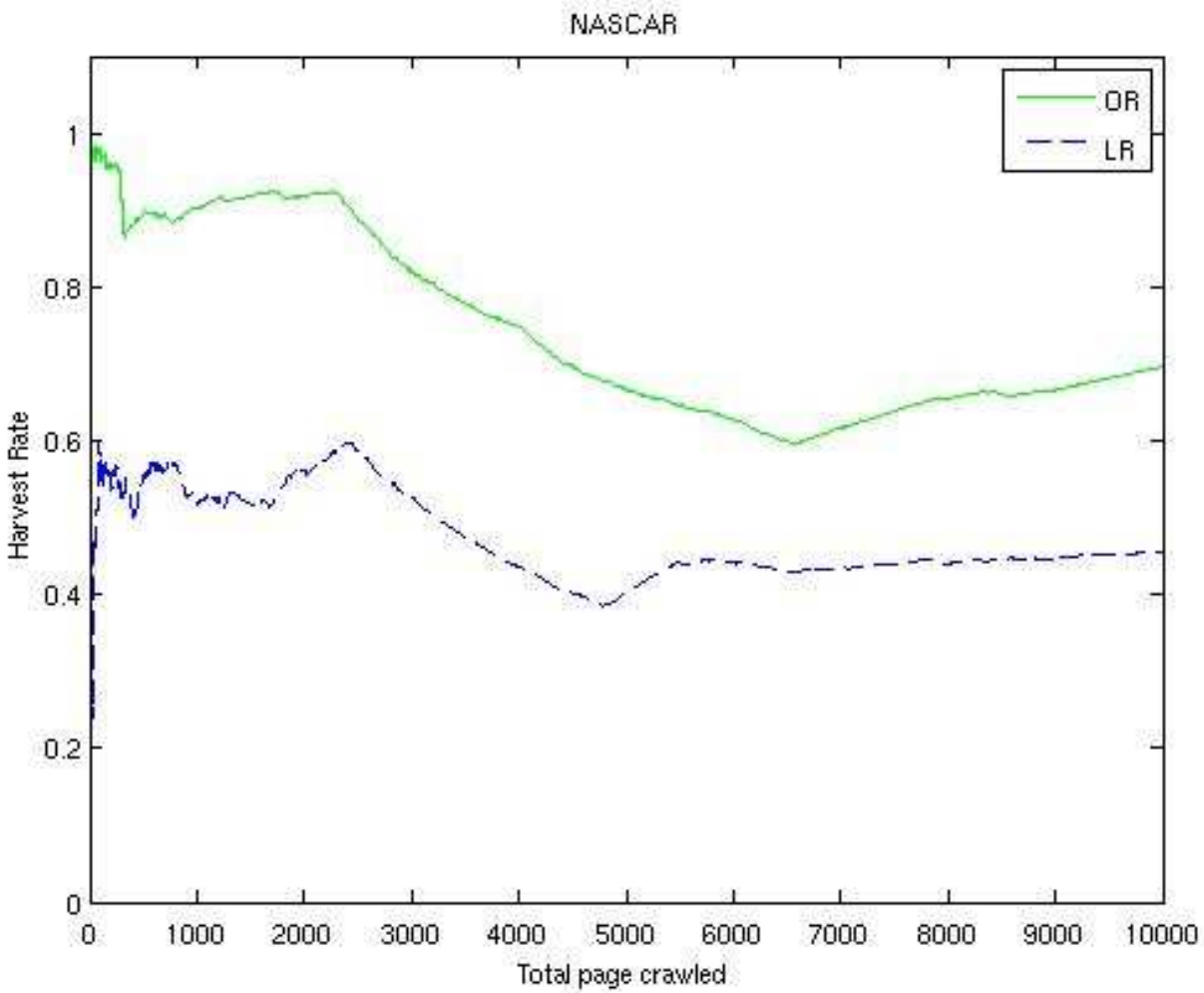
Proposed Focused Crawling architecture



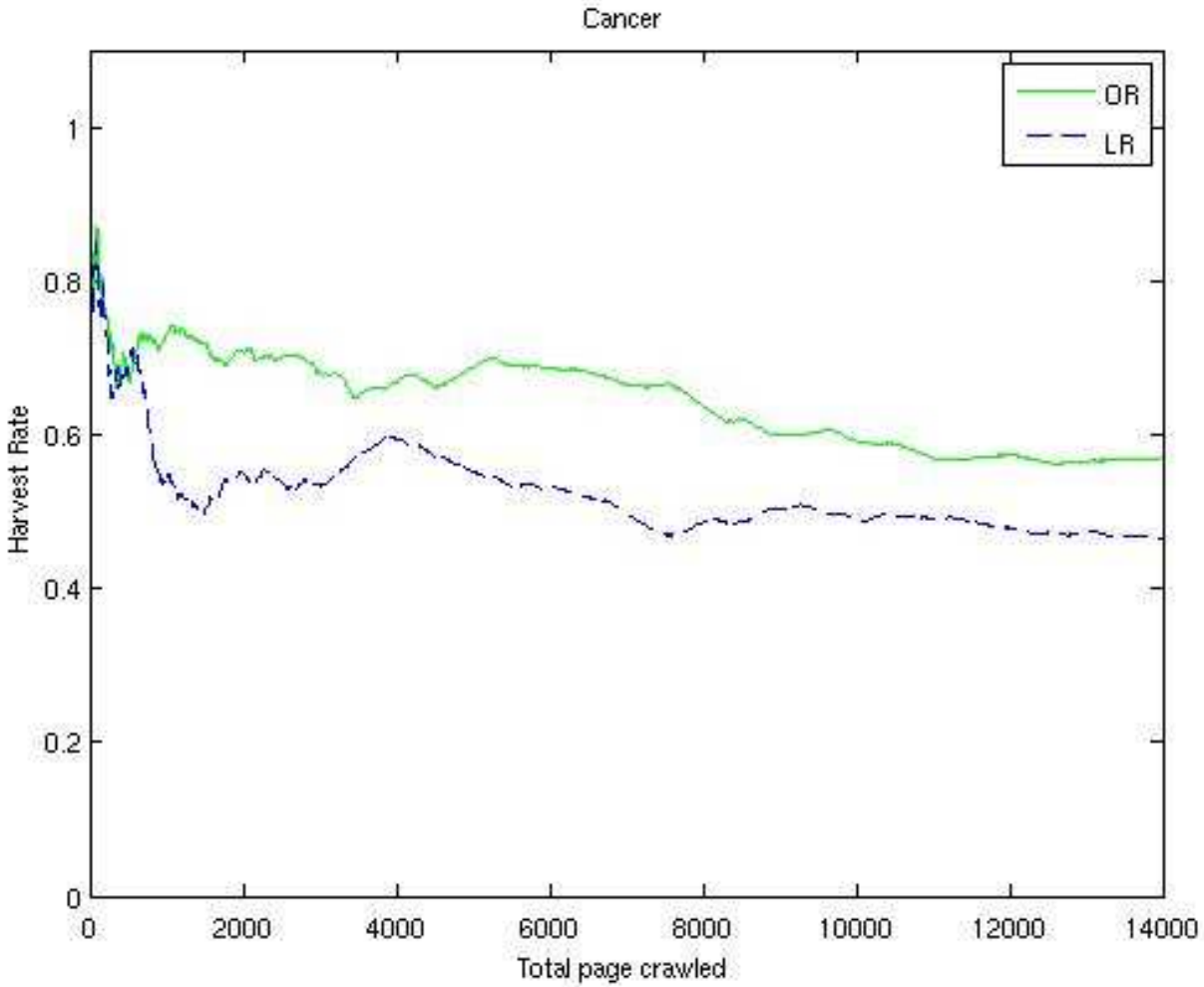
Focused Crawling is a large scale OR problem

Category	Seed	1	2	3	4
NASCAR	1705	1944	1747	1464	1177
Soccer	119	750	1109	1542	3149
Cancer	138	760	895	858	660
Mutual Funds	371	395	540	813	1059

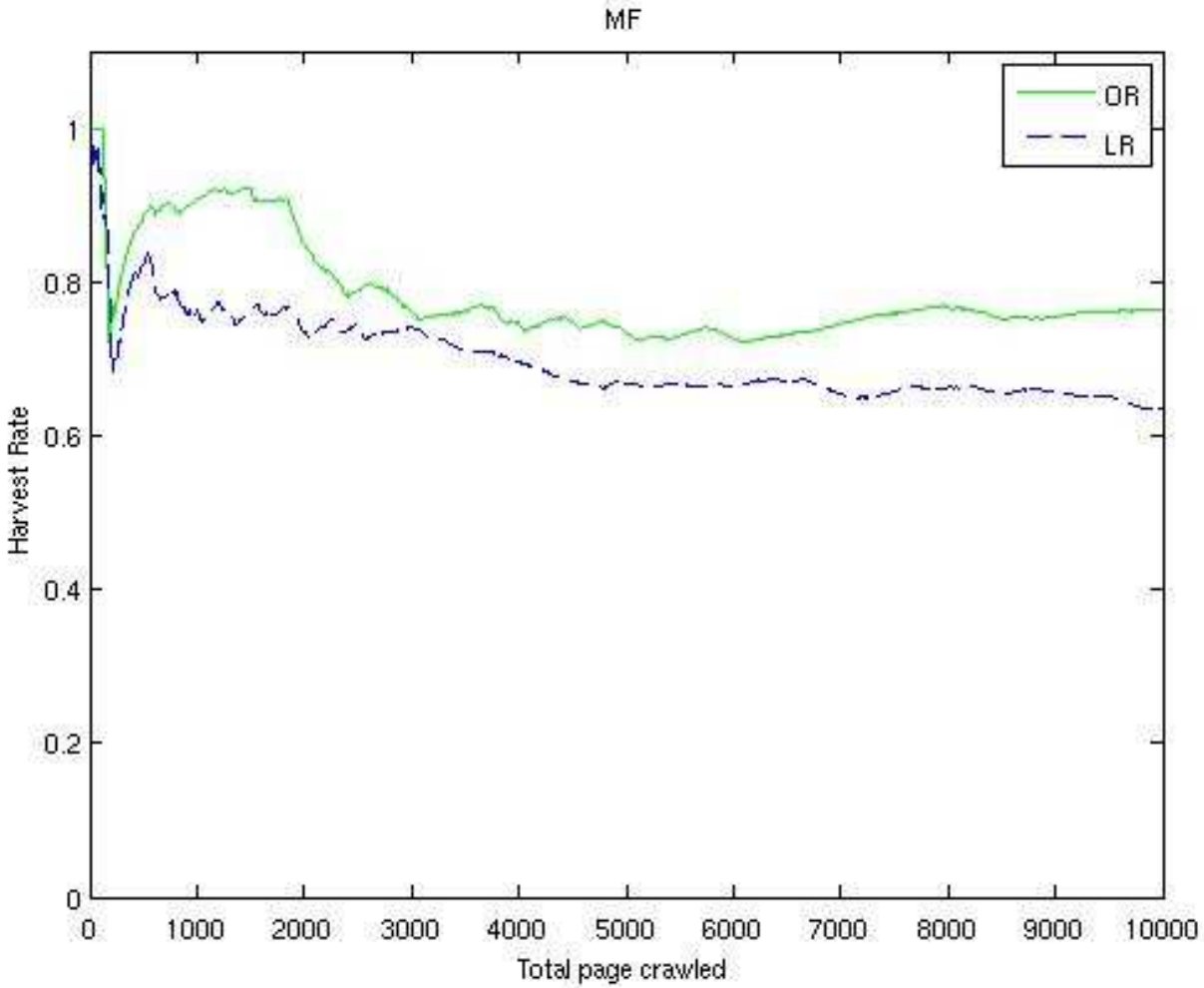
NASCAR harvest rate



Cancer harvest rate



Mutual Funds harvest rate



Harvest rate comparison

Dataset	Baseline	OR
NASCAR	.3698	.6977
Cancer	.4714	.58
Mutual Fund	.526	.5969
Soccer	.34	.4952

Conclusions

- Proposed a scalable clustering based OR formulation
  - Training time $O(datapoints)$
  - Support Vectors $O(clusters)$
- Exploited special structure of the formulation to develop a fast solver, CB-OR
  - Scalable to tens of thousands of clusters
- We formulated focused crawling as large scale ordinal regression
  - No need for negative class definition
  - Independent of topic taxonomy
  - OR captures link structure of web graph.

Focused crawler code available at

http://mllab.csa.iisc.ernet.in/downloads/focusedcrawler.html

Acknowledgments

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Questions?