# Leveraging Temporal Dynamics of Document Content in Relevance Ranking

Jonathan L. Elsas (CMU)

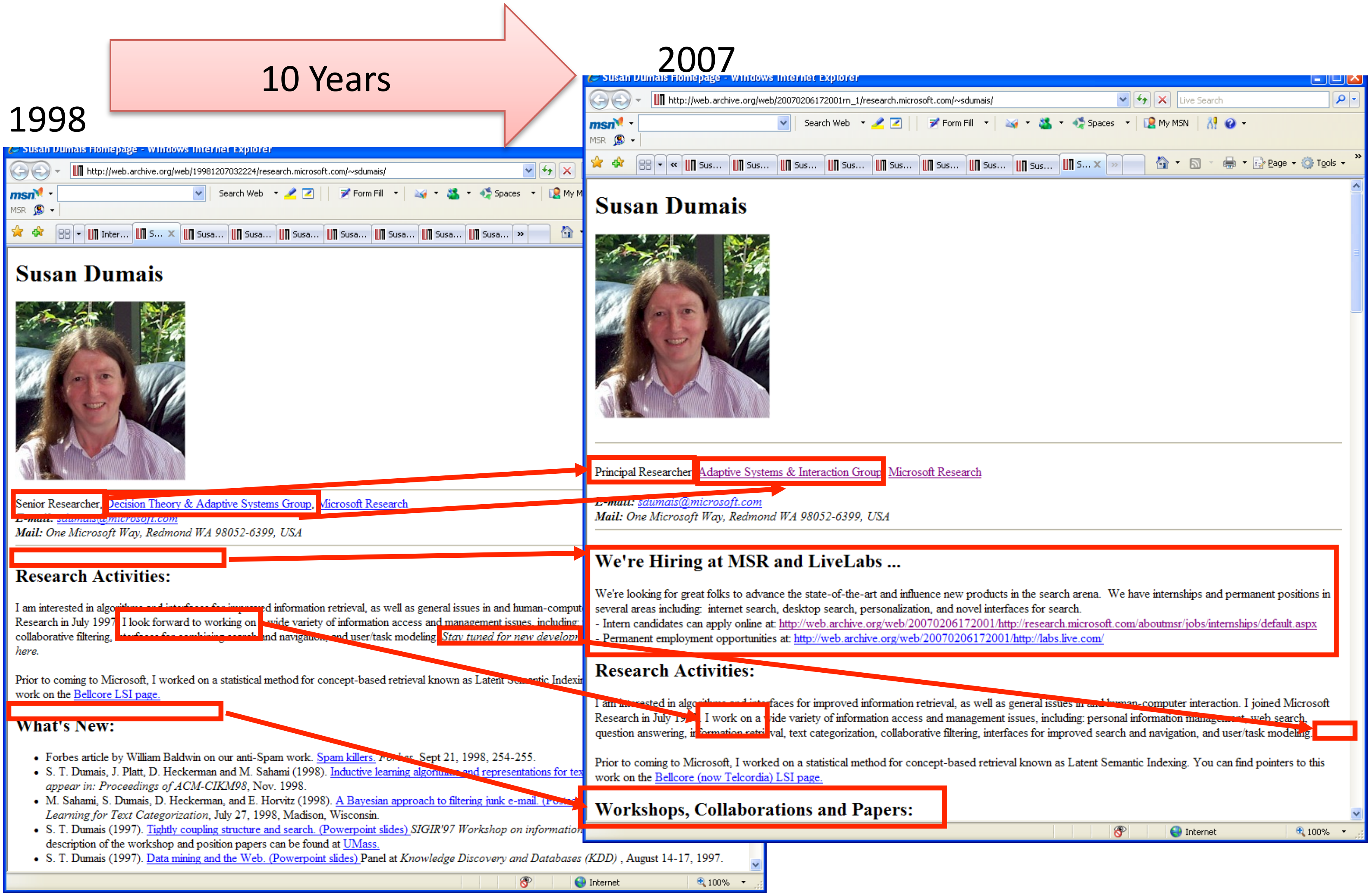
Susan T. Dumais (MSR)

# Outline

- Document Dynamics on the Web
  - Previous Work on Change & What's Missing
- Our Setting: Ranking Dynamic Documents
  - Test Collection & Measuring change
- Two ways to leverage change in ranking
  - Document Prior based on Gross Change Measures
  - Document Representation based on Term-Level Change
- Discussion

# The Web is Dynamic

# The Web is Dynamic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2007
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http://web.archive.org/web/19981207032224/research.microsoft.com/~sdumais/
http://web.archive.org/web/20070206172001rn_1/research.microsoft.com/~sdumais/
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**1998**

## Susan Dumais

Senior Researcher, Decision Theory & Adaptive Systems Group, Microsoft Research
*E-mail:* saumais@microsoft.com
*Mail: One Microsoft Way, Redmond WA 98052-6399, USA*

### Research Activities:

I am interested in algorithms and interfaces for improved information retrieval, as well as general issues in and human-comput
Research in July 1997. I look forward to working on a wide variety of information access and management issues, including:
collaborative filtering, interfaces for combining search and navigation, and user/task modeling. *Stay tuned for new developn*
*here.*

Prior to coming to Microsoft, I worked on a statistical method for concept-based retrieval known as Latent Semantic Indexin
work on the Bellcore LSI page.

### What's New:

- Forbes article by William Baldwin on our anti-Spam work. Spam killers. *Forbes*, Sept 21, 1998, 254-255.
- S. T. Dumais, J. Platt, D. Heckerman and M. Sahami (1998). Inductive learning algorithms and representations for tex
  *appear in: Proceedings of ACM-CIKM98*, Nov. 1998.
- M. Sahami, S. Dumais, D. Heckerman, and E. Horvitz (1998). A Bayesian approach to filtering junk e-mail. (Post
  *Learning for Text Categorization*, July 27, 1998, Madison, Wisconsin.
- S. T. Dumais (1997). Tightly coupling structure and search. (Powerpoint slides) *SIGIR'97 Workshop on information*
  description of the workshop and position papers can be found at UMass.
- S. T. Dumais (1997). Data mining and the Web. (Powerpoint slides) Panel at *Knowledge Discovery and Databases (KDD)* , August 14-17, 1997.

**2007**

## Susan Dumais

Principal Researcher, Adaptive Systems & Interaction Group, Microsoft Research

*E-mail:* saumais@microsoft.com
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### Research Activities:

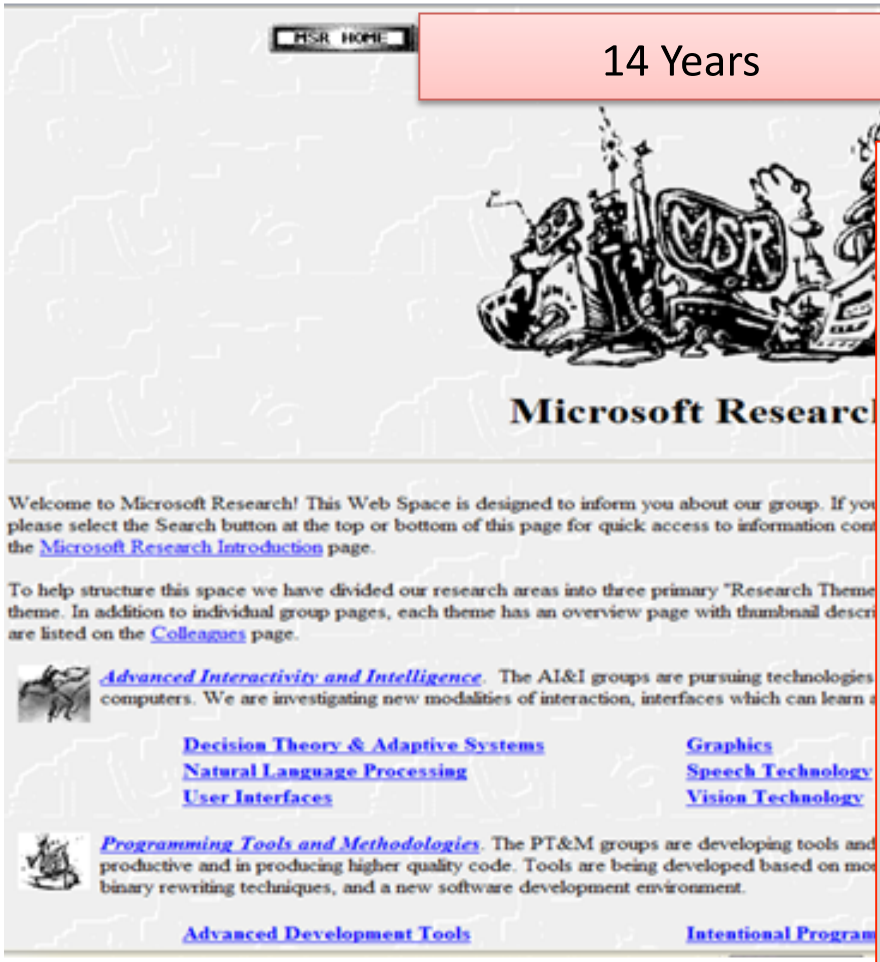
I am interested in algorithms and interfaces for improved information retrieval, as well as general issues in and human-computer interaction. I joined Microsoft Research in July 1997. I work on a wide variety of information access and management issues, including: personal information management, web search, question answering, information retrieval, text categorization, collaborative filtering, interfaces for improved search and navigation, and user/task modeling.

Prior to coming to Microsoft, I worked on a statistical method for concept-based retrieval known as Latent Semantic Indexing. You can find pointers to this work on the Bellcore (now Telcordia) LSI page.

### Workshops, Collaborations and Papers:

# The Web is Dynamic

1996



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*Advanced Interactivity and Intelligence*. The AI&I groups are pursuing technologies computers. We are investigating new modalities of interaction, interfaces which can learn

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**Natural Language Processing** | **Speech Technology**
**User Interfaces** | **Vision Technology**

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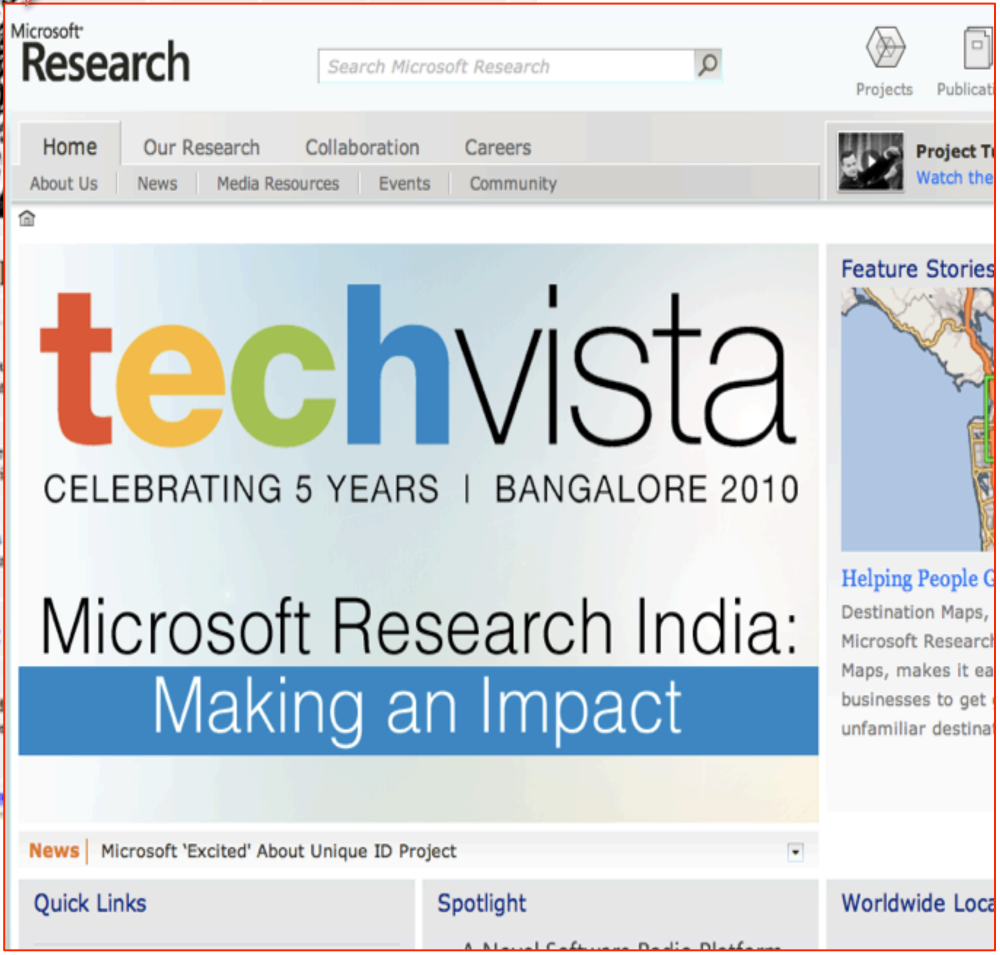
**Advanced Development Tools** | **Intentional Program**

14 Years

2010



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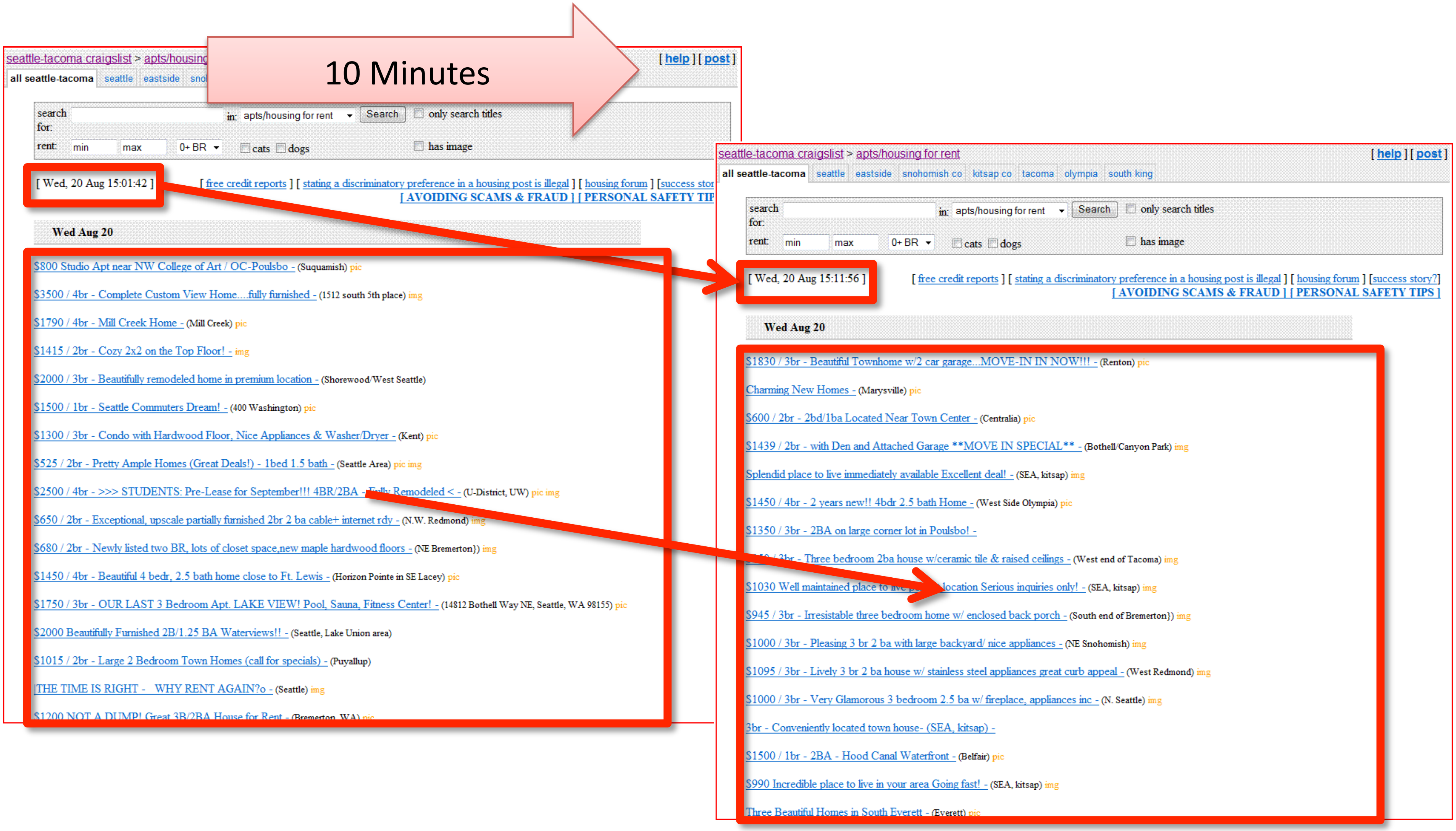

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search for: in: apts/housing for rent Search □ only search titles

rent: min max 0+ BR □ cats □ dogs □ has image

[ Wed, 20 Aug 15:01:42 ]

[ free credit reports ] [ stating a discriminatory preference in a housing post is illegal ] [ housing forum ] [success stor

[ AVOIDING SCAMS & FRAUD ] [ PERSONAL SAFETY TIP

**Wed Aug 20**

$800 Studio Apt near NW College of Art / OC-Poulsbo - (Suquamish) pic

$3500 / 4br - Complete Custom View Home....fully furnished - (1512 south 5th place) img

$1790 / 4br - Mill Creek Home - (Mill Creek) pic

$1415 / 2br - Cozy 2x2 on the Top Floor! - img

$2000 / 3br - Beautifully remodeled home in premium location - (Shorewood/West Seattle)

$1500 / 1br - Seattle Commuters Dream! - (400 Washington) pic

$1300 / 3br - Condo with Hardwood Floor, Nice Appliances & Washer/Dryer - (Kent) pic

$525 / 2br - Pretty Ample Homes (Great Deals!) - 1bed 1.5 bath - (Seattle Area) pic img

$2500 / 4br - >>> STUDENTS: Pre-Lease for September!!! 4BR/2BA - Fully Remodeled < - (U-District, UW) pic img

$650 / 2br - Exceptional, upscale partially furnished 2br 2 ba cable+ internet rdy - (N.W. Redmond) img

$680 / 2br - Newly listed two BR, lots of closet space,new maple hardwood floors - (NE Bremerton}) img

$1450 / 4br - Beautiful 4 bedr, 2.5 bath home close to Ft. Lewis - (Horizon Pointe in SE Lacey) pic

$1750 / 3br - OUR LAST 3 Bedroom Apt. LAKE VIEW! Pool, Sauna, Fitness Center! - (14812 Bothell Way NE, Seattle, WA 98155) pic

$2000 Beautifully Furnished 2B/1.25 BA Waterviews!! - (Seattle, Lake Union area)

$1015 / 2br - Large 2 Bedroom Town Homes (call for specials) - (Puyallup)

|THE TIME IS RIGHT - WHY RENT AGAIN?o - (Seattle) img

$1200 NOT A DUMP! Great 3B/2BA House for Rent - (Bremerton, WA) pic

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[ help ] [ post ]

all seattle-tacoma | seattle | eastside | snohomish co | kitsap co | tacoma | olympia | south king

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rent: min max 0+ BR □ cats □ dogs □ has image

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[ AVOIDING SCAMS & FRAUD ] [ PERSONAL SAFETY TIPS ]

**Wed Aug 20**

$1830 / 3br - Beautiful Townhome w/2 car garage...MOVE-IN IN NOW!!! - (Renton) pic

Charming New Homes - (Marysville) pic

$600 / 2br - 2bd/1ba Located Near Town Center - (Centralia) pic

$1439 / 2br - with Den and Attached Garage **MOVE IN SPECIAL** - (Bothell/Canyon Park) img

Splendid place to live immediately available Excellent deal! - (SEA, kitsap) img

$1450 / 4br - 2 years new!! 4bdr 2.5 bath Home - (West Side Olympia) pic

$1350 / 3br - 2BA on large corner lot in Poulsbo! -

[illegible] / 3br - Three bedroom 2ba house w/ceramic tile & raised ceilings - (West end of Tacoma) img

$1030 Well maintained place to live p [illegible] location Serious inquiries only! - (SEA, kitsap) img

$945 / 3br - Irresistable three bedroom home w/ enclosed back porch - (South end of Bremerton}) img

$1000 / 3br - Pleasing 3 br 2 ba with large backyard/ nice appliances - (NE Snohomish) img

$1095 / 3br - Lively 3 br 2 ba house w/ stainless steel appliances great curb appeal - (West Redmond) img

$1000 / 3br - Very Glamorous 3 bedroom 2.5 ba w/ fireplace, appliances inc - (N. Seattle) img

3br - Conveniently located town house- (SEA, kitsap) -

$1500 / 1br - 2BA - Hood Canal Waterfront - (Belfair) pic

$990 Incredible place to live in your area Going fast! - (SEA, kitsap) img

Three Beautiful Homes in South Everett - (Everett) pic

# Previous Work on Dynamics

Characterizing Change

Implications of Change

# Characterizing Change

Change & Page Type / Source

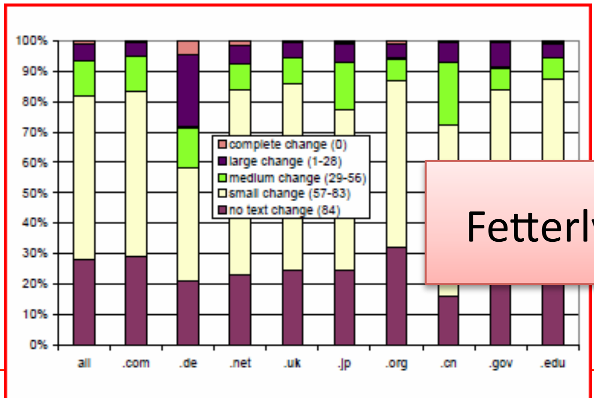
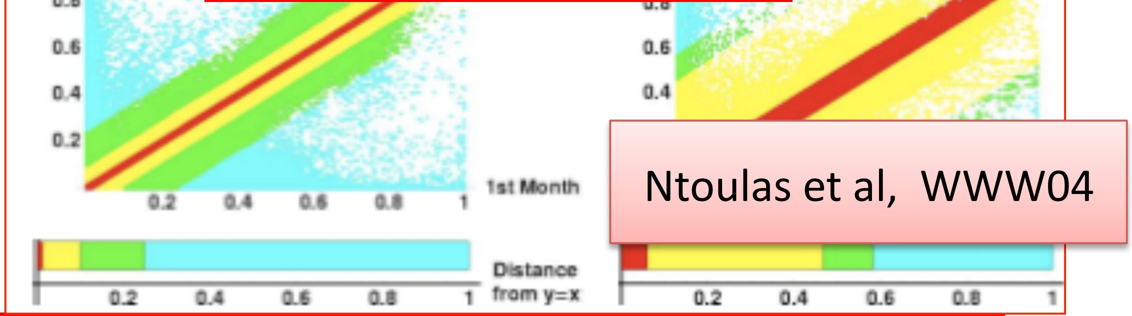


**Figure 12:** Clustered rates of change, broken down by selected top-level domains, and omitting the *no change* cluster.

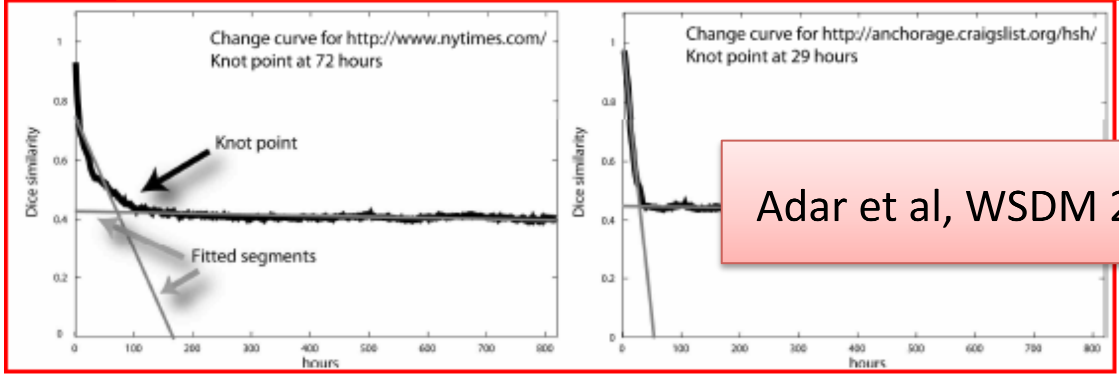
Fetterly et al, WWW03

New Content & Links



Ntoulas et al, WWW04

Within-Doc. Change



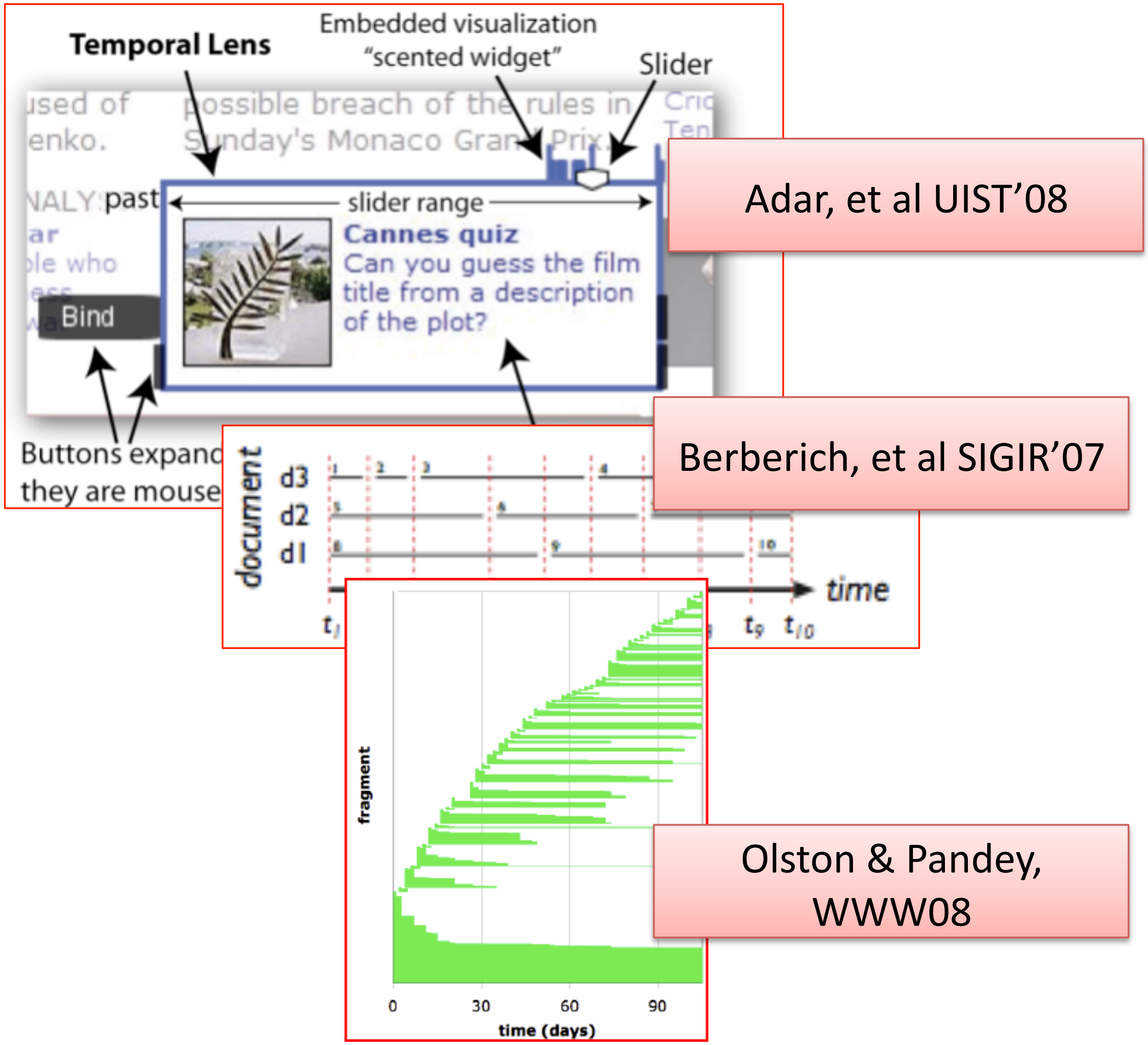
Adar et al, WSDM 2009

# Implications of Change

On Browsing

On Indexing

On Crawling



Adar, et al UIST'08

Berberich, et al SIGIR'07

Olston & Pandey, WWW08

# Implications of Change

On Ranking?

# Implications of Change on Ranking

- Gross Measures of Document Change

  Are there general characteristics of document dynamics indicate high quality pages?

- Representing Term-Level Change Within the Document

  Are there characteristics of a document's dynamic content that indicate some content may be more important?

# Test Setup: Queries & Documents

- 18K Queries, 2.5M Judged Documents
  - 5-level relevance judgment (Bad…Perfect)
- 2.5M Documents crawled weekly for 10 weeks

- Navigational queries
  - 2k queries identified with a “Perfect” judgment
- 60/40 Training/Test split

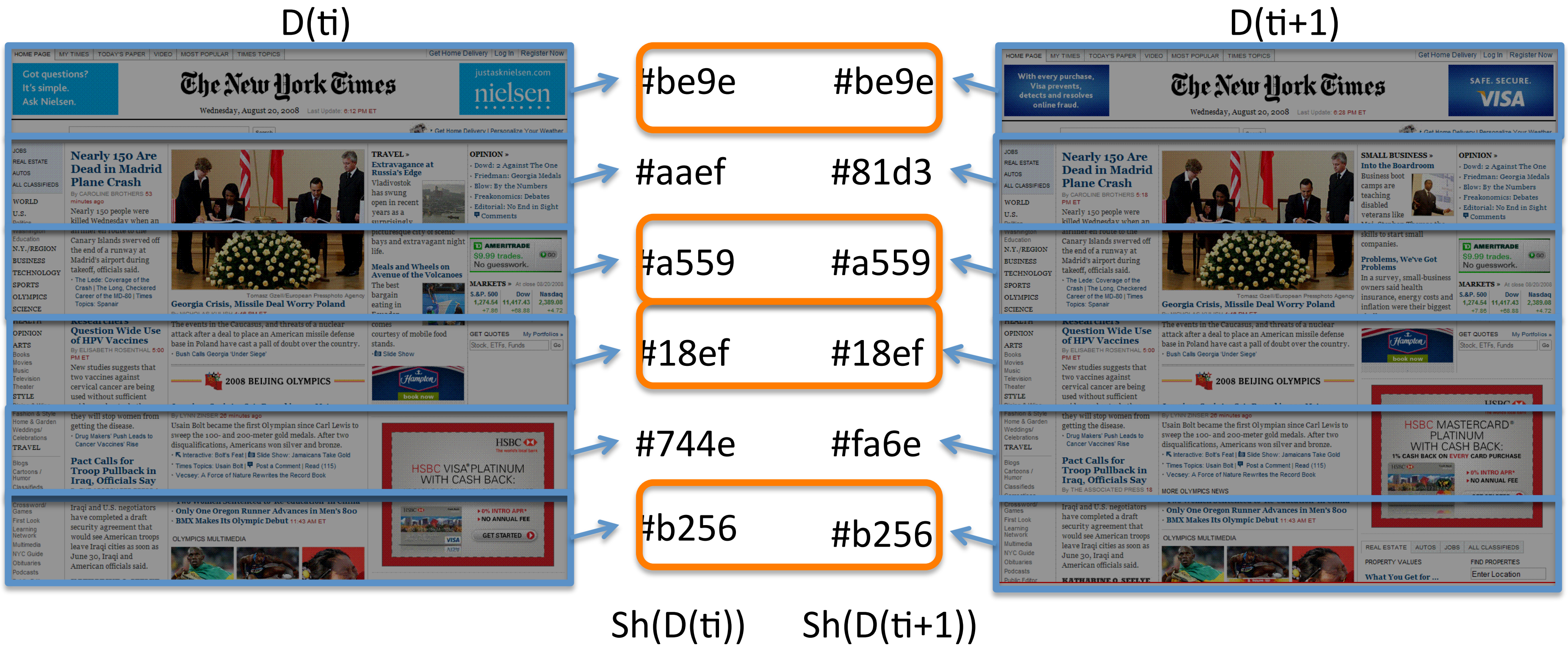
# Test Setup: Queries & Documents

- 18K Queries, 2.5M Judged Documents
  - 5-level relevance
- 2.5M Documents

We focus on Navigational Queries here for ease of evaluation.

- Navigational queries
  - 2k queries identified with a “Perfect” judgment
- 60/40 Training/Test split

# Measuring Change: Shingleprints



D(ti)

D(ti+1)

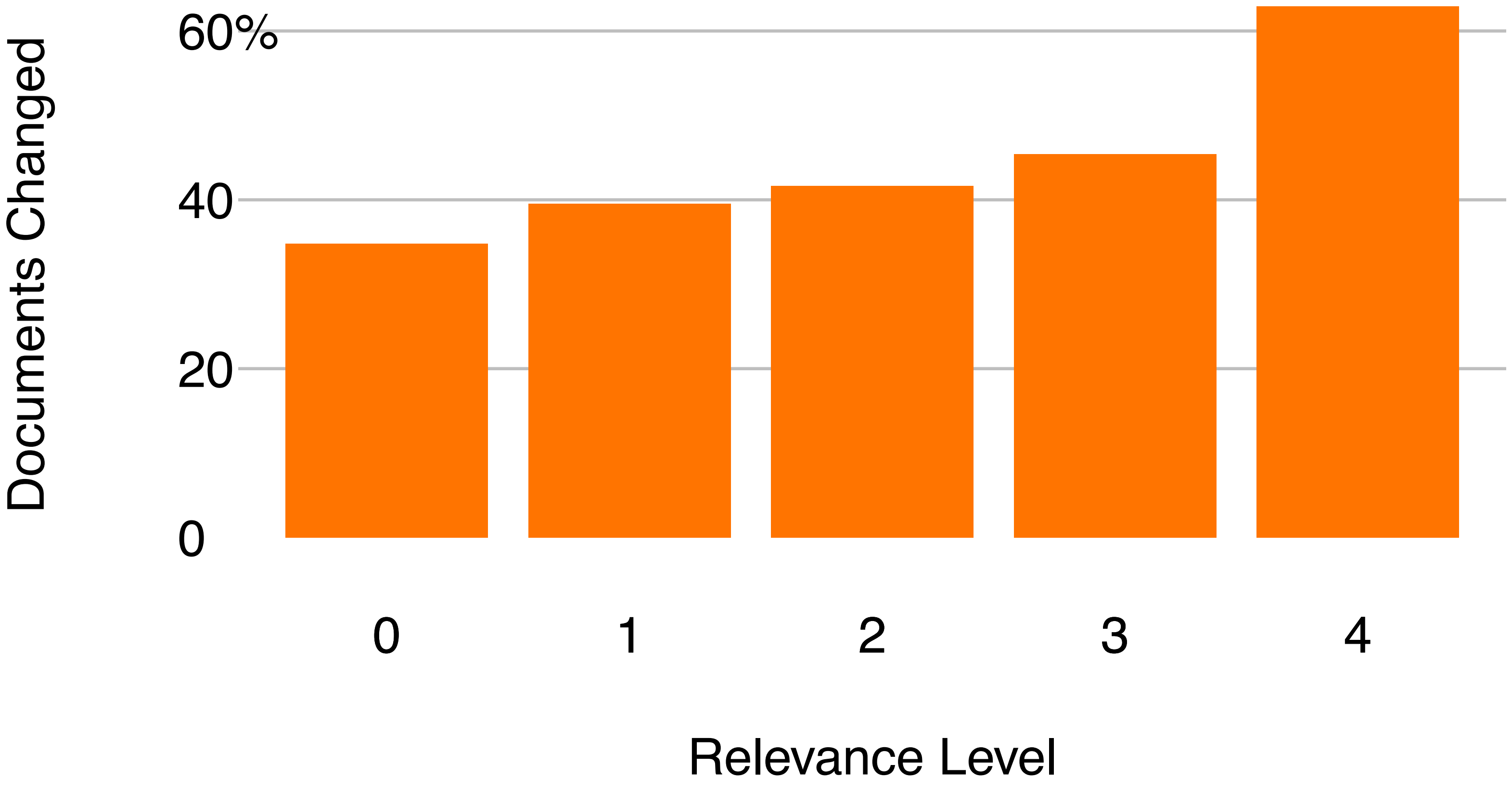
| | |
|---|---|
| #be9e | #be9e |
| #aaef | #81d3 |
| #a559 | #a559 |
| #18ef | #18ef |
| #744e | #fa6e |
| #b256 | #b256 |

Sh(D(ti)) Sh(D(ti+1))

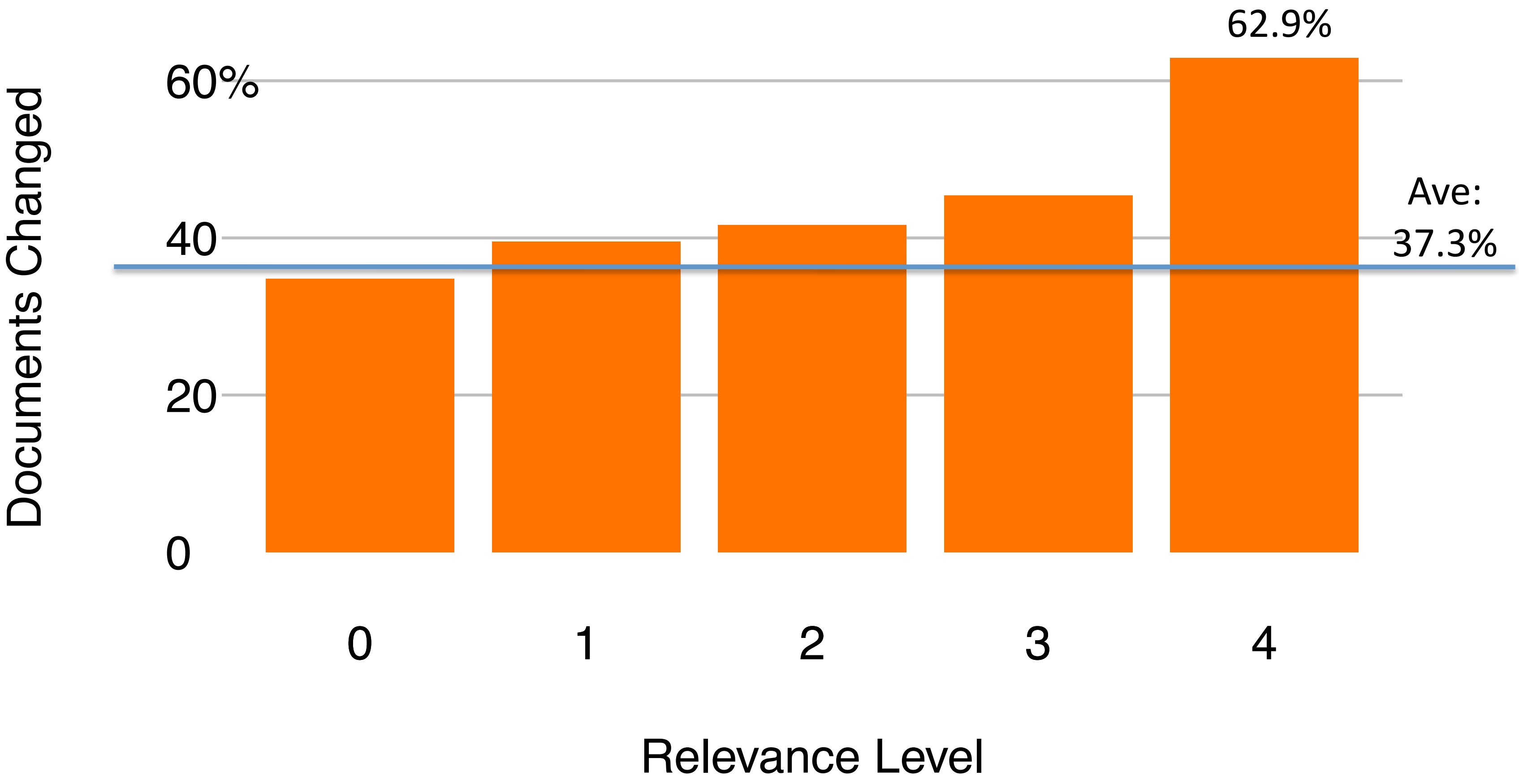
$$ShDiff(D) = 1 - \frac{1}{T-1} \sum_{t=1}^{T-1} \frac{|Sh(D^{(t)}) \cap Sh(D^{(t+1)})|}{N}$$

Broder, et al, “Syntactic Clustering of the Web”
Computer Networks & ISDN Sys., 1997

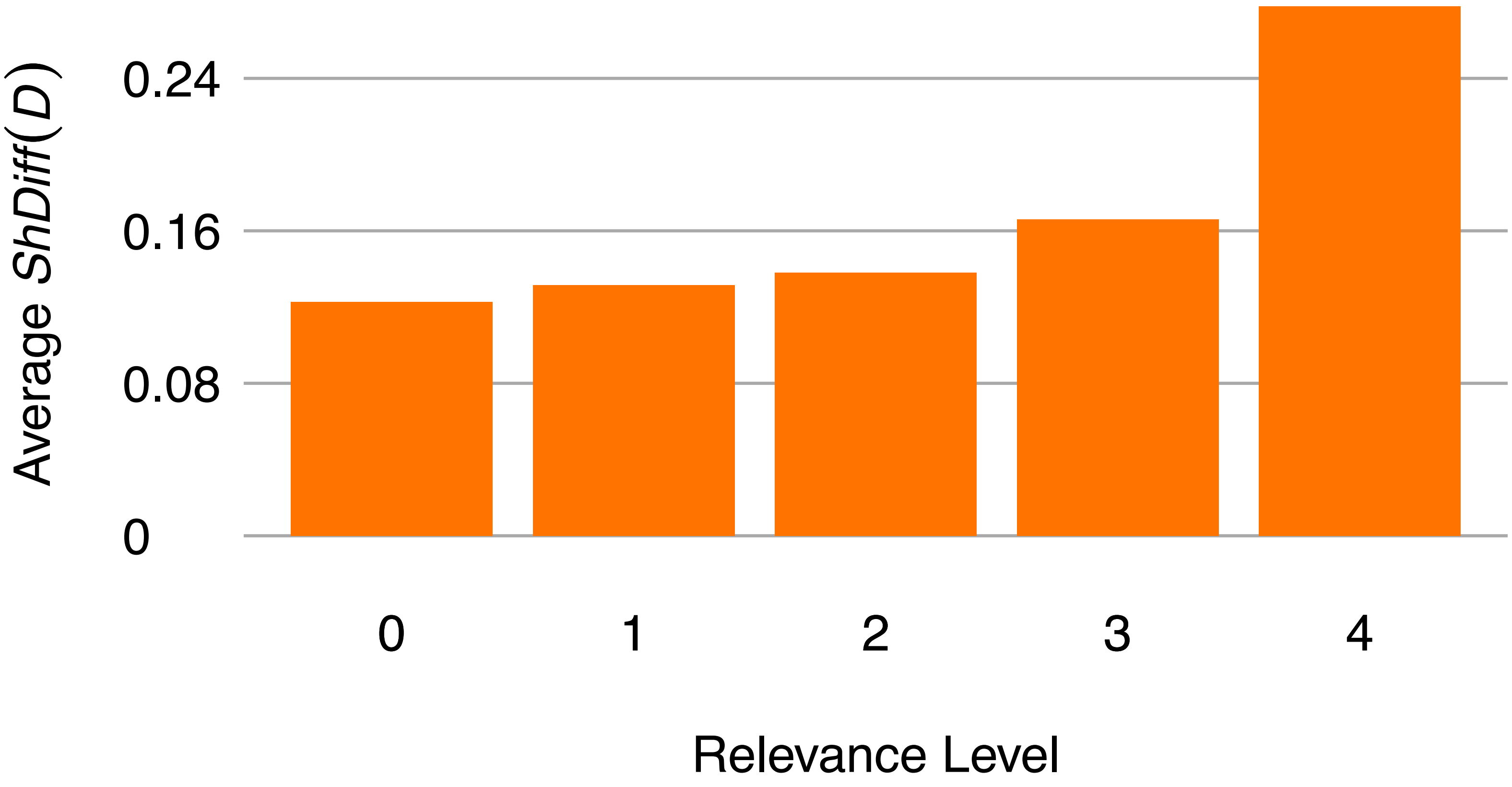
# Change & *Relevance*



# Change & *Relevance*



# Change Amount & *Relevance*



# Change & *Relevance*

- More relevance documents tend to change more often, *and* to a greater degree than non-relevant documents.

- Could favoring dynamic documents in ranking improve performance?

# Favoring Dynamic Documents

Language-Modeling Ranking Function:

$$P(D|Q) \propto P(D)P(Q|D)$$

# Favoring Dynamic Documents

Language-Modeling Ranking Function:

$$P(D|Q) \propto \boxed{P(D)} P(Q|D)$$

Uniform Prior:

$$P(D) \propto 1.0$$

“Static Model”

# Favoring Dynamic Documents

Language-Modeling Ranking Function:

$$P(D|Q) \propto \boxed{P(D)}P(Q|D)$$

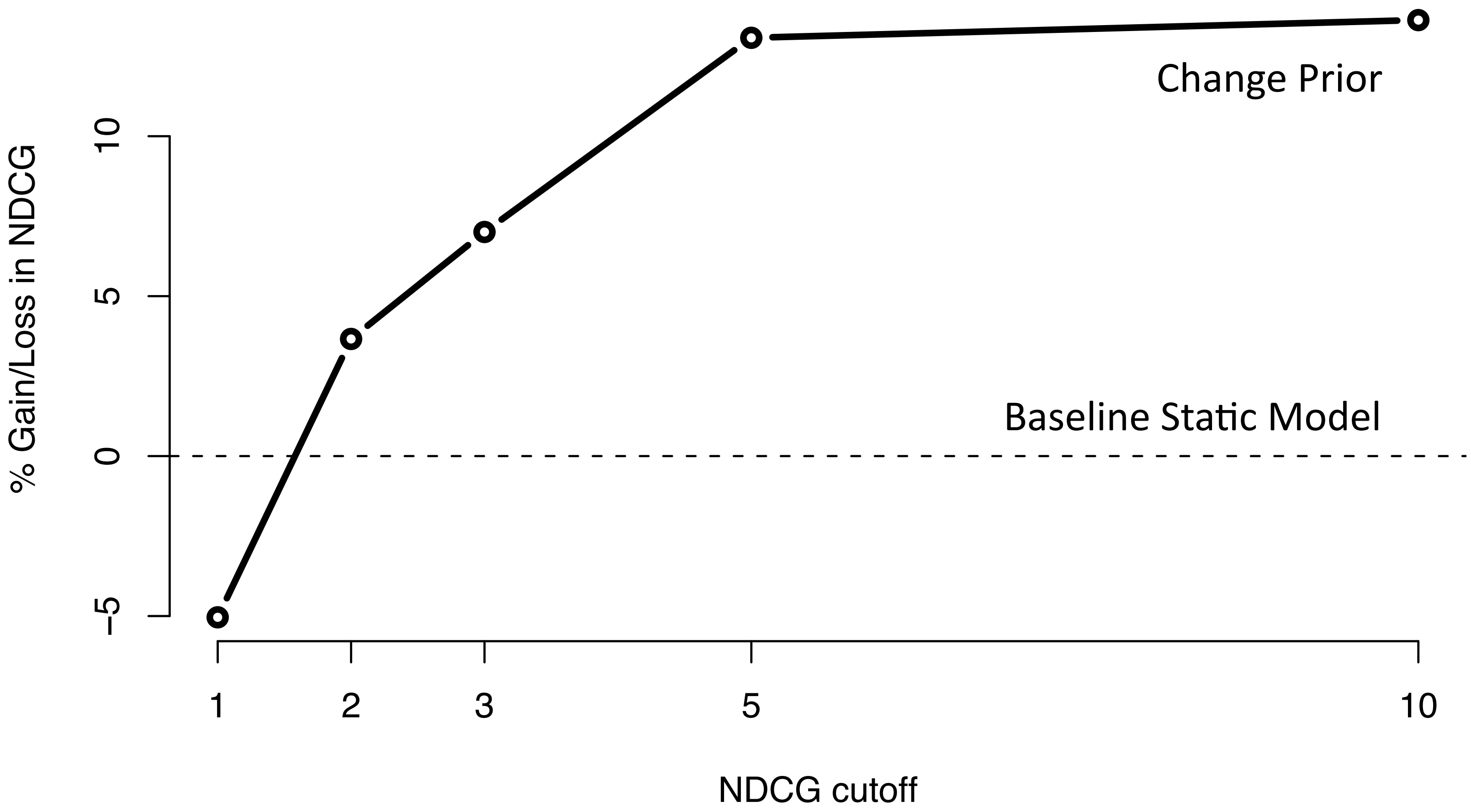
Uniform Prior:

$$P(D) \propto 1.0$$

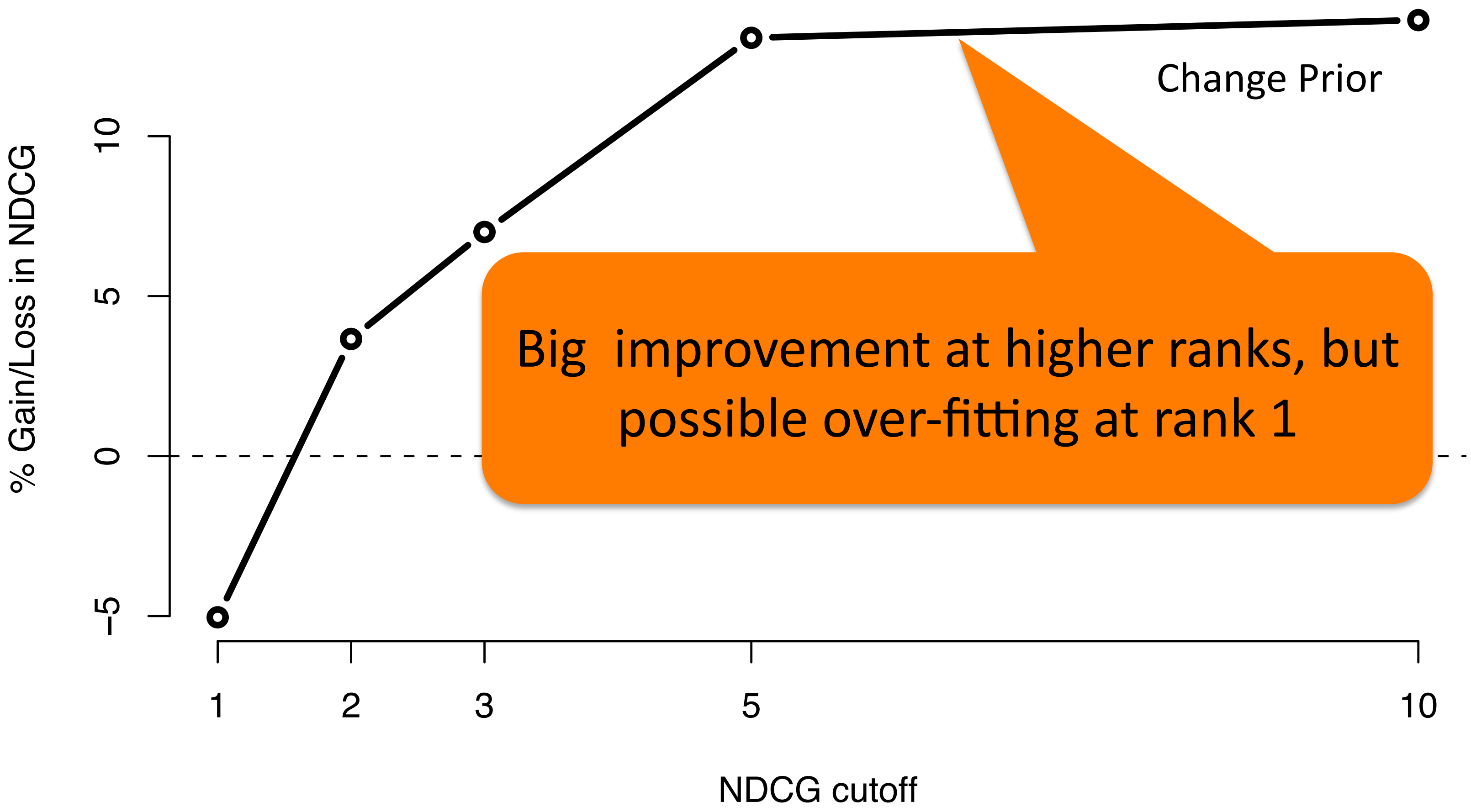
“Change” Prior:

$$P_{ch}(D) \propto (ShDiff(D) + 1)^{\gamma}$$

# Favoring Dynamic Documents



# Favoring Dynamic Documents

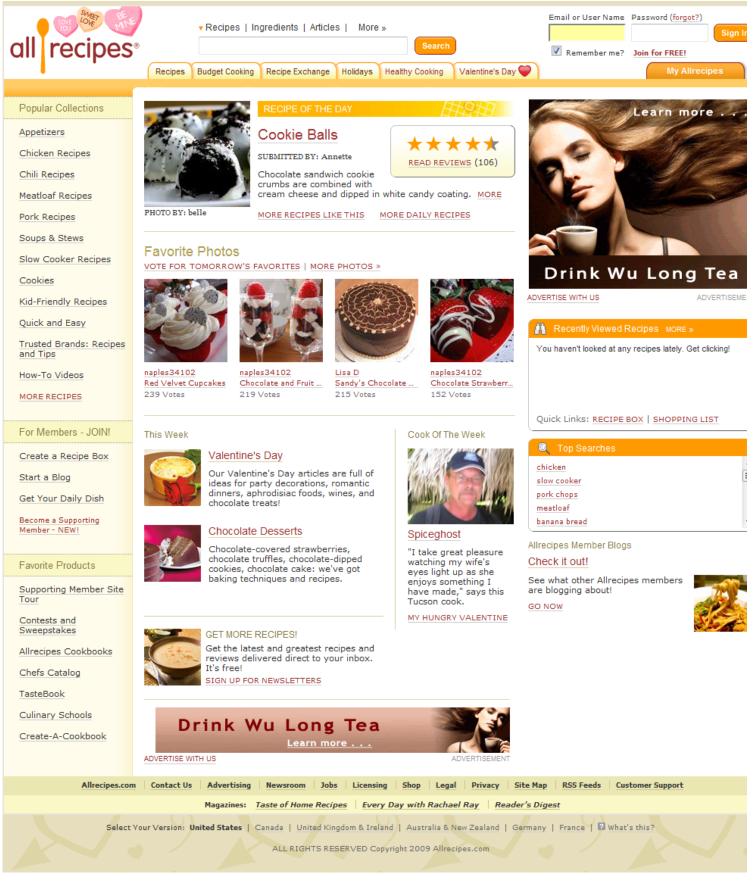


Big improvement at higher ranks, but possible over-fitting at rank 1

# Change Within the Document

Are there characteristics of a document’s dynamic content that indicate some content may be more important?

# Change Within the Document



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RECIPE OF THE DAY

Cookie Balls

SUBMITTED BY: Annette

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Chocolate sandwich cookie crumbs are combined with cream cheese and dipped in white candy coating. MORE

PHOTO BY: belle

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|---|---|---|---|

This Week

Valentine's Day

Our Valentine's Day articles are full of ideas for party decorations, romantic dinners, aphrodisiac foods, wines, and chocolate treats!

Chocolate Desserts

Chocolate-covered strawberries, chocolate truffles, chocolate-dipped cookies, chocolate cake: we've got baking techniques and recipes.

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Spiceghost

"I take great pleasure watching my wife's eyes light up as she enjoys something I have made," says this Tucson cook.

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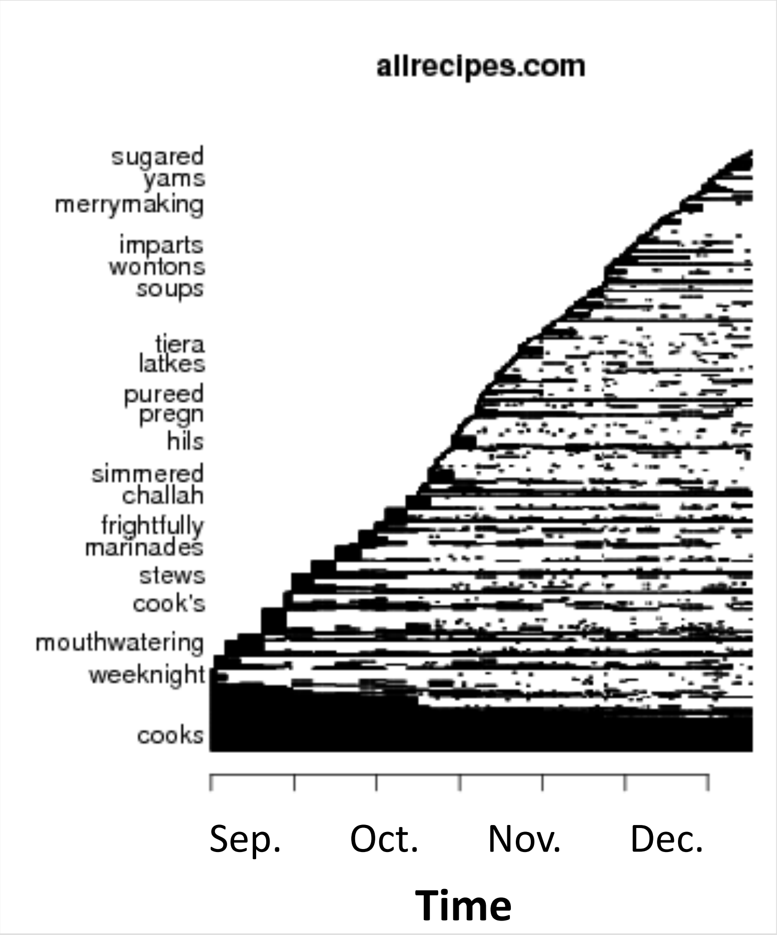

Adar, Teevan, Dumais & Elsas, "The Web Changes Everything: Understanding the Dynamics of Web Content" WSDM 2009

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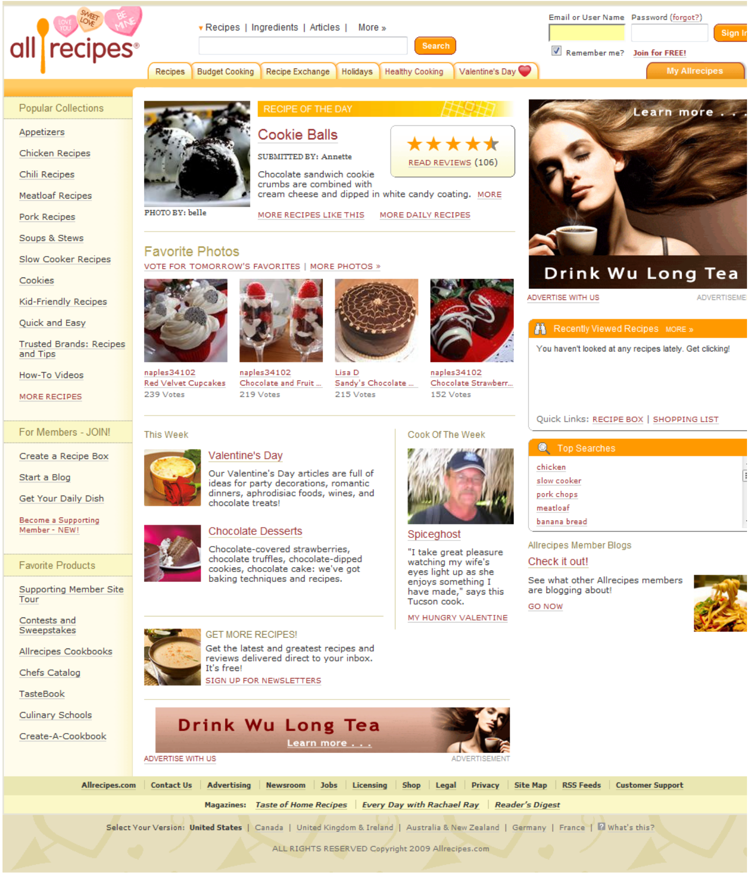

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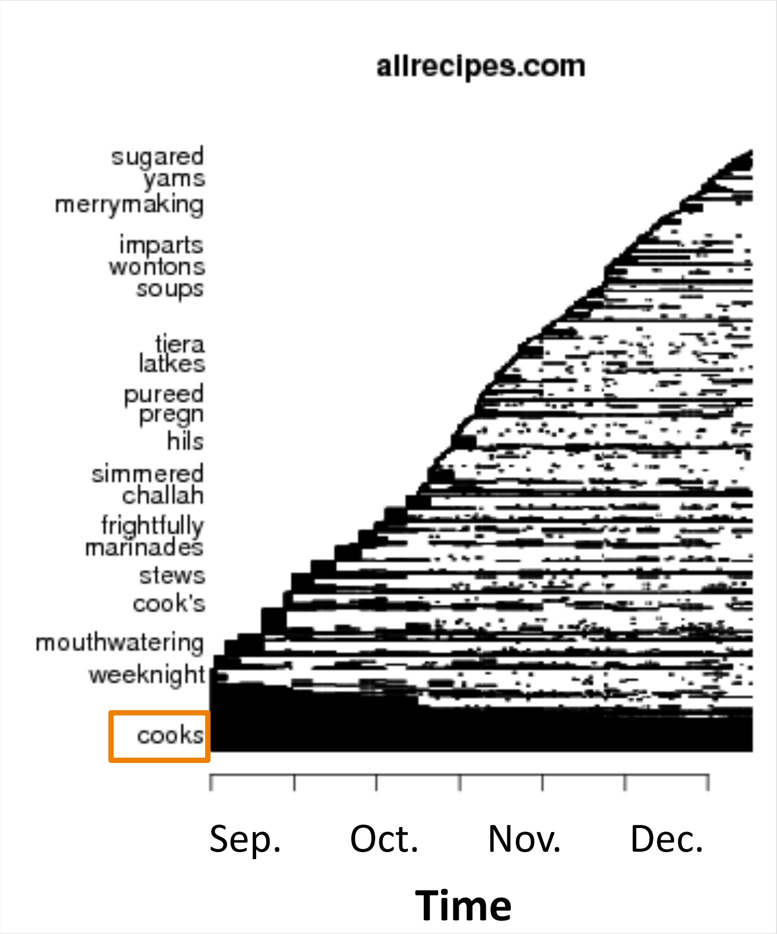

Adar, Teevan, Dumais & Elsas, "The Web Changes Everything: Understanding the Dynamics of Web Content" WSDM 2009

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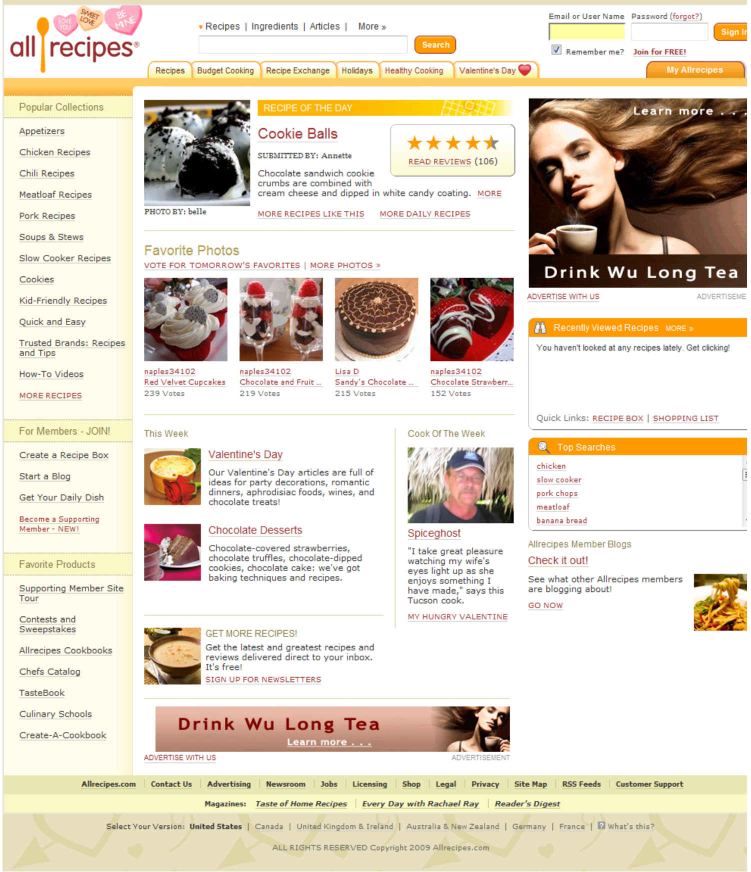

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SUBMITTED BY: Annette

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PHOTO BY: belle

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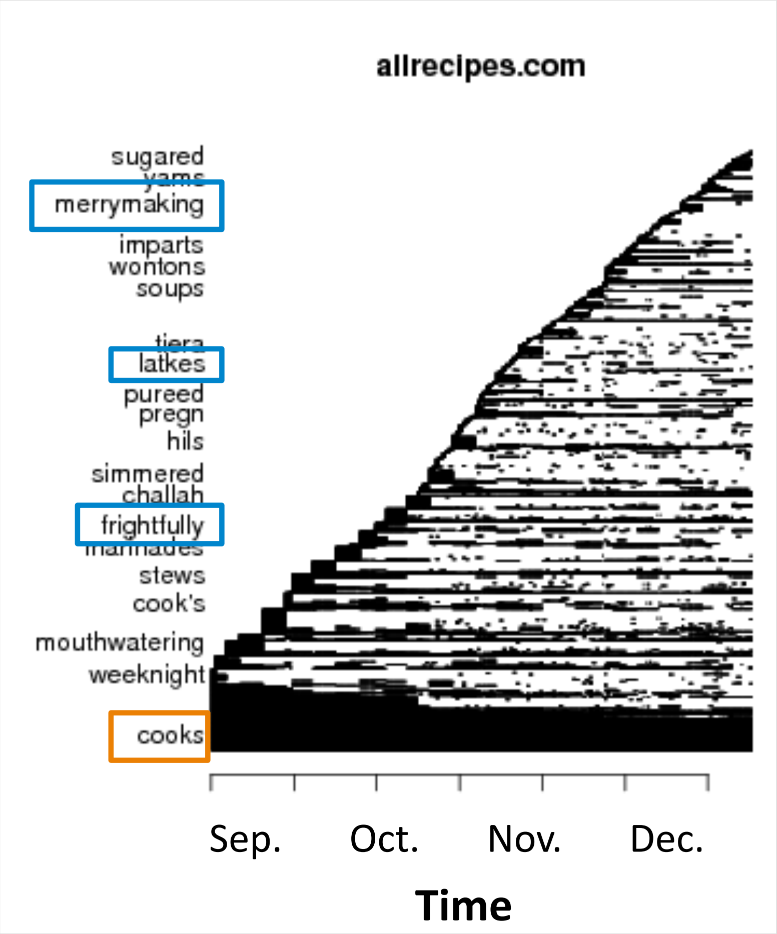

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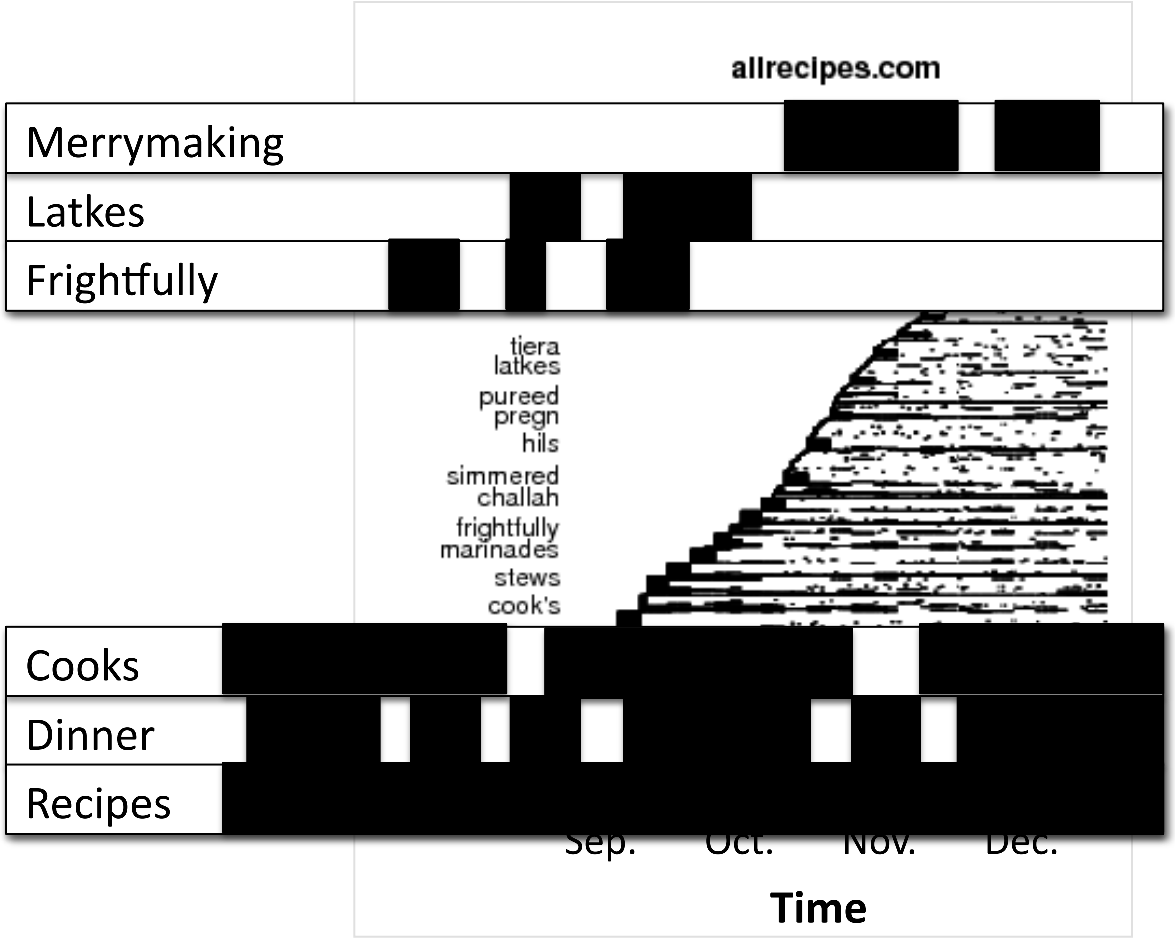
# Change Within the Document

Short-Lived Vocabulary

Long-Lived Vocabulary



# Leveraging Change Within the Document

Identifying transient & permanent vocabulary:

- **Short-lived**: come & go quickly

  in fewer than 50% of the document's slices
- **Medium-lived**:

  in 50-90% of the document's slices
- **Long-lived**: tend to stick for a long time

  in > 90% of the document's slices

# Leveraging Change Within the Document

Model relevance as a *mixture* of LONG- MEDIUM- and SHORT-lived vocabulary:

$$
\begin{aligned}
P(D|Q) \propto P(D)\Big(&\lambda_L P(Q|D_L) \\
&+\lambda_M P(Q|D_M) \\
&+\lambda_S P(Q|D_S)\Big)
\end{aligned}
$$

“Dynamic Model”

# Leveraging Change Within the Document

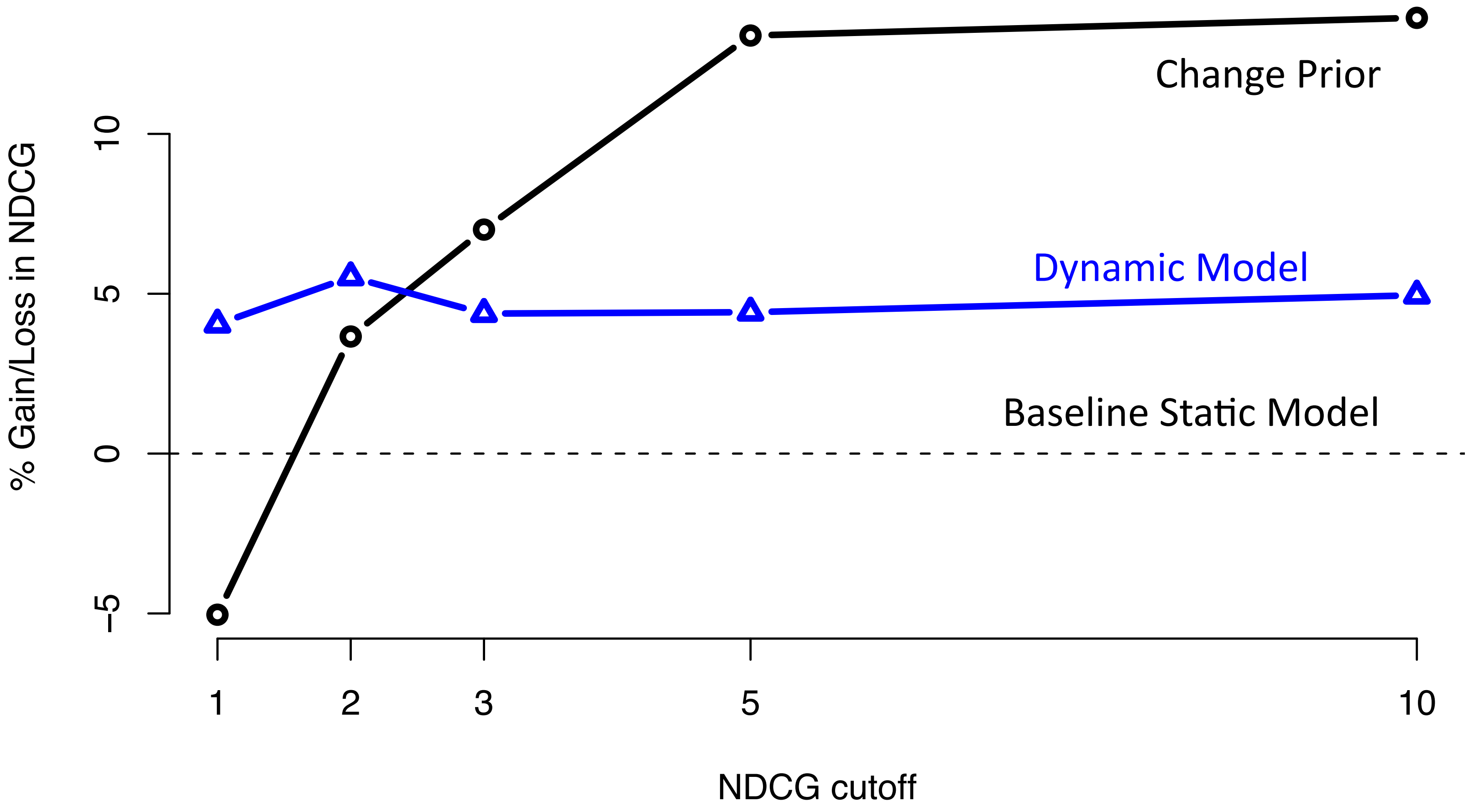
Model relevance as a *mixture* of LONG-MEDIUM- and SHORT-lived vocabulary:

$$
\begin{aligned}
P(D|Q) \propto P(D)\Big(& \boxed{\lambda_L P(Q|D_L)} \\
&+\lambda_M P(Q|D_M) \\
&+\boxed{\lambda_S P(Q|D_S)}\Big)
\end{aligned}
$$

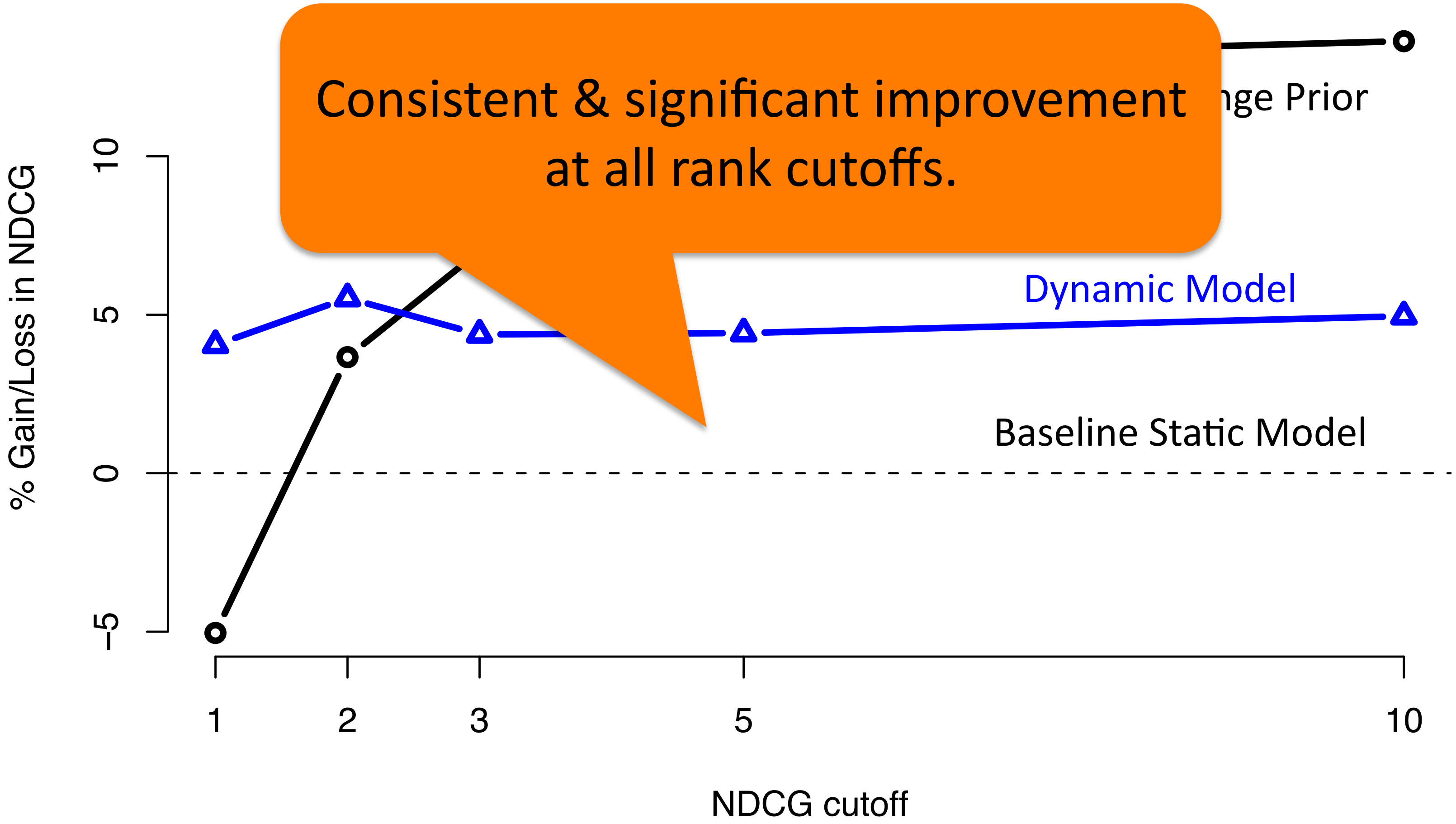
Differentially weight long-lived and short-lived vocabulary.

“Dynamic Model”

# Leveraging Change Within the Document



# Leveraging Change Within the Document

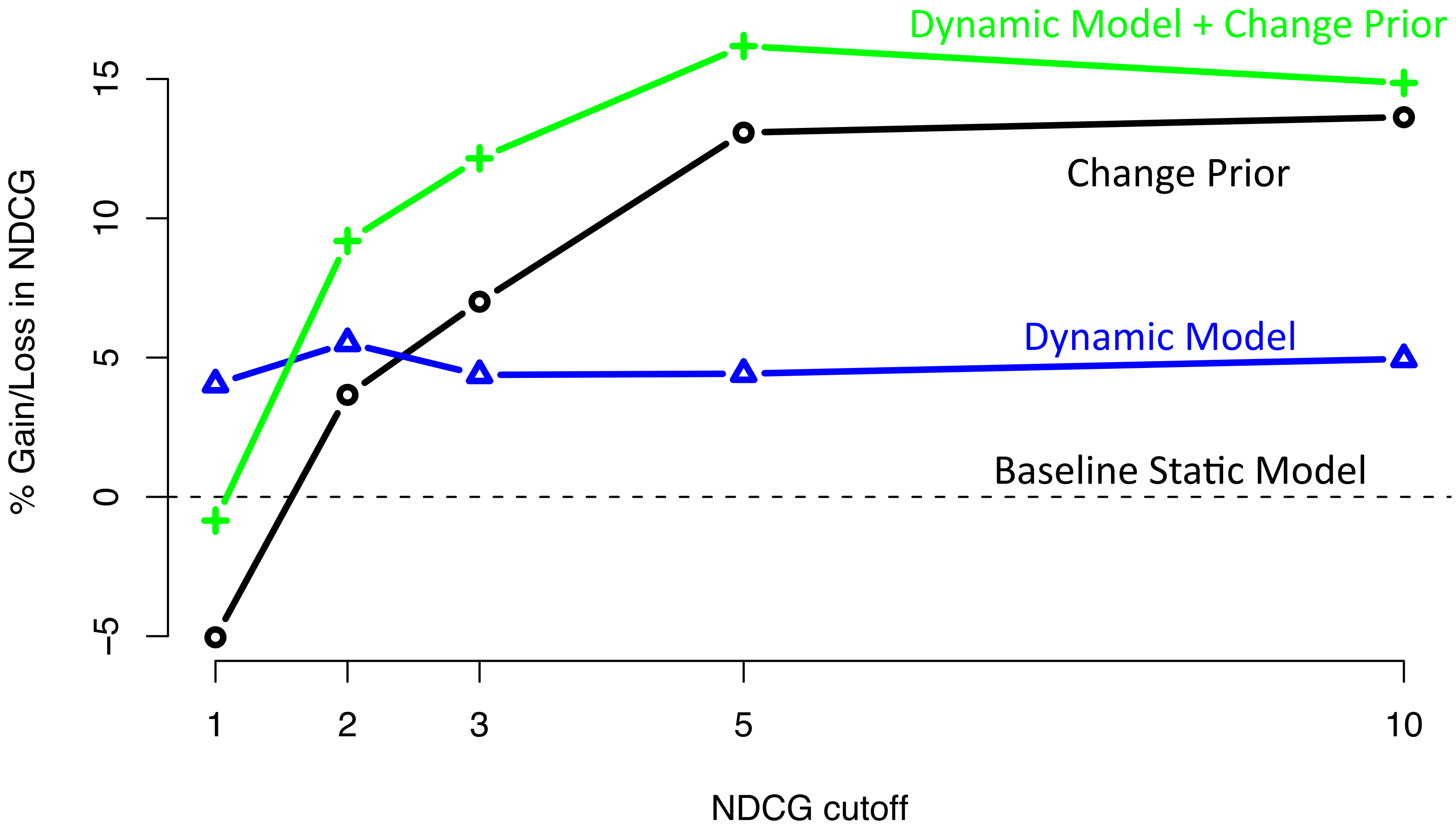


Consistent & significant improvement at all rank cutoffs.

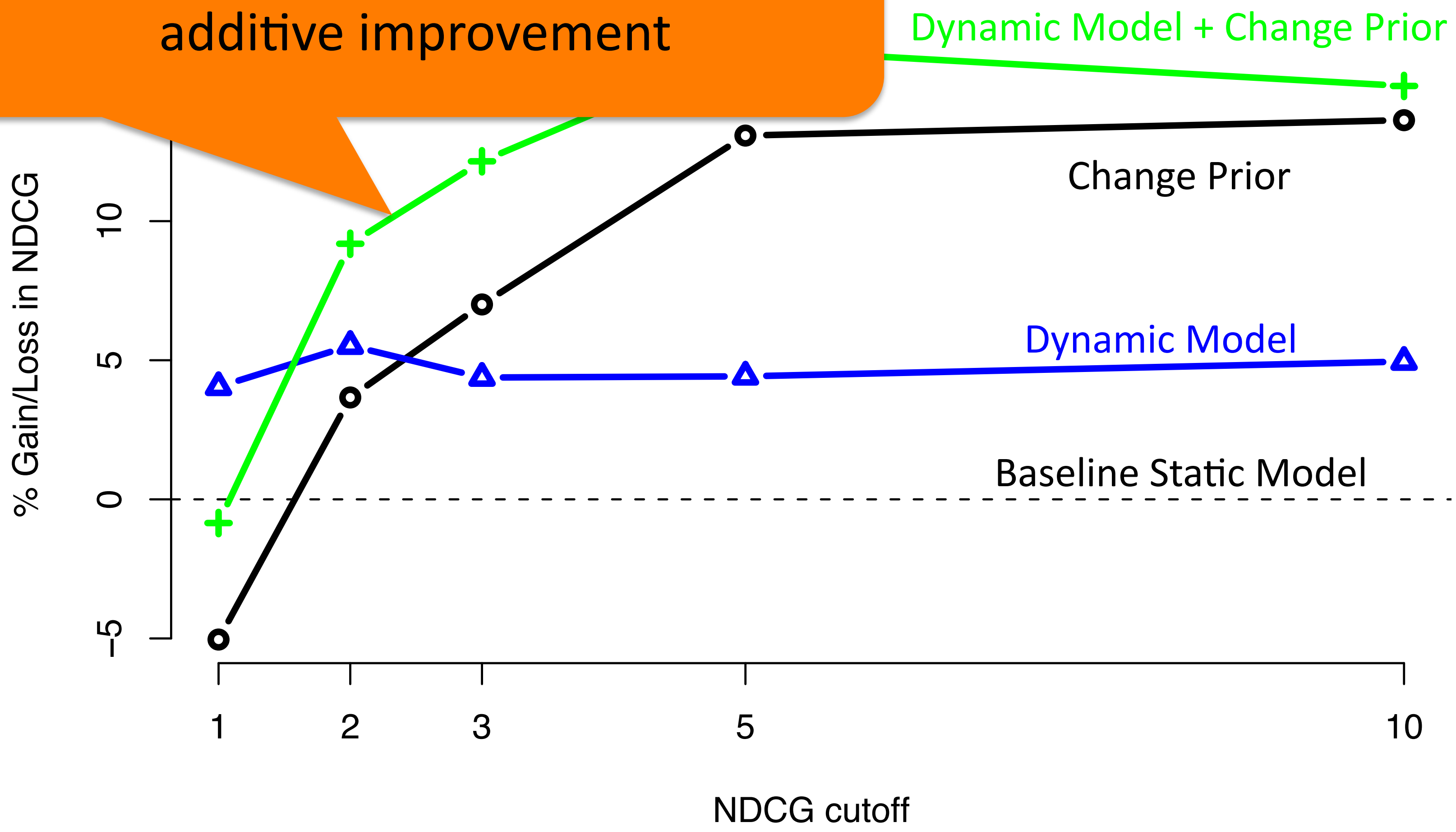
# Change & Relevance Ranking

- Presented two methods for leveraging changing content in relevance ranking:
  - **Query-Independent Change Prior,** favoring dynamic documents irrespective of query
  - **Dynamic Document Representation**, differentially weighting long-term and short-term vocabulary
- Combined Model: Best of both worlds?

# Combined Model



# Combined Model



Combined model shows (roughly) additive improvement

# Conclusion & Next Steps

- Documents change, and we can use characteristics of those dynamics to improve retrieval performance.
- Presented two complementary methods of leveraging change in ranking.
- Focus here on navigational queries; current work is looking at *dynamic* information needs.

Relevance may change over time.

Thank You

Questions?