

# Beyond DCG: User Behavior as a Predictor of a Successful Search

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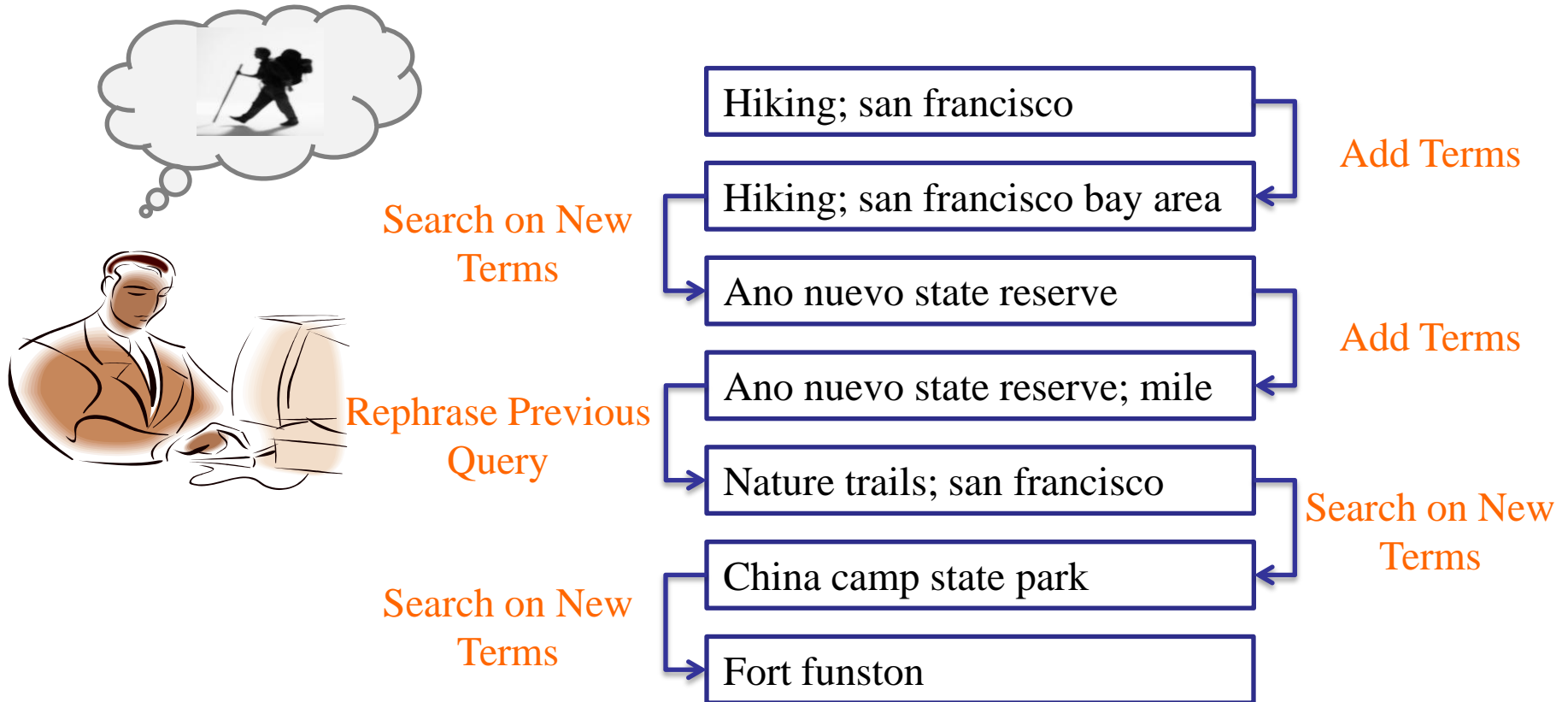
<sup>2</sup>Yahoo! Labs



<sup>3</sup>Carnegie Mellon University



# Web Search is Interactive



# Web Search is Interactive



Hiking; san francisco



Hiking; san francisco bay area



Ano nuevo state reserve



Ano nuevo state reserve; mile



Nature trails; san francisco



China camp state park



Fort funston



# Web Search is Interactive



Hiking; san francisco

Hiking; san francisco bay area

**Ano nuevo** state reserve

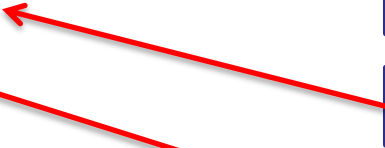
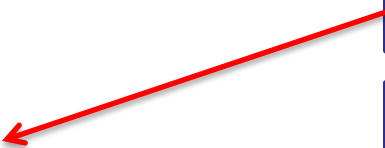
Ano nuevo state reserve; mile

Nature trails; san francisco

**China camp** state park

**Fort funston**

**Learned about  
three hiking areas**



# Web Search is Interactive



Hiking; san francisco

Hiking; san francisco bay area

**TASK AS CONTEXT**

Ano nuevo state reserve

Ano nuevo state reserve; mile

**PREDICT TASK SUCCESS**

Nature trails; san francisco

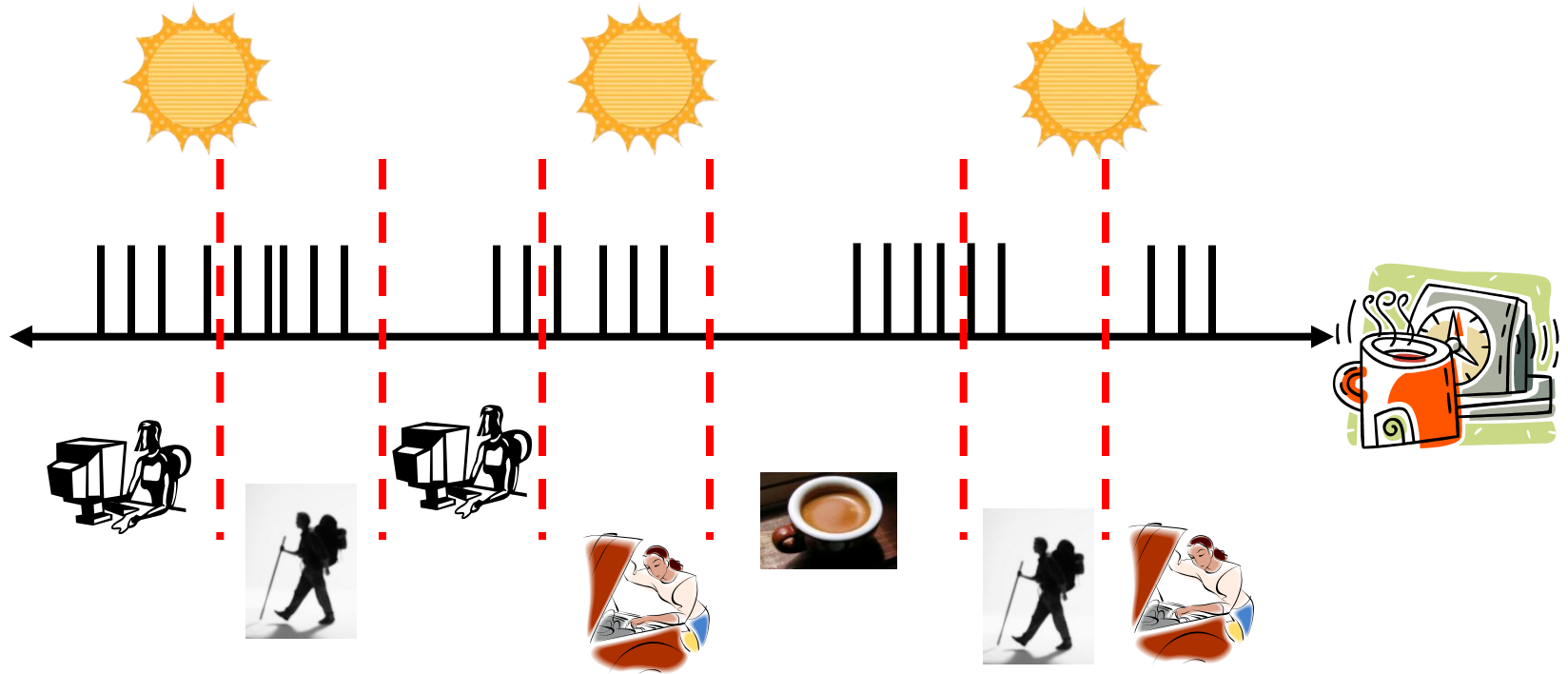
China camp state park

Fort funston

# Current Automated Metrics are Ambiguous

- Click-through rate may not tell the complete picture
- Abandonment rate is ambiguous (Li et al. 2009)
- Task success is what matters to our users

# Data



# Editorial Guidelines

Definition. A search goal is an atomic information need, resulting in one or more queries.

- The editors judged success of goals on a five point scale
- The editors used information about:
  - landing page content
  - sequence of queries in a goal
  - click patterns on search results and suggestions



# Goals as a Sequence of Actions

- A user search goal can be represented by:
  - an ordered sequence of user actions
  - time between those actions.

$$G = \langle START, \langle a_1, t_1 \rangle, \dots, \langle a_n, t_n \rangle, END \rangle$$

where *START*, and *END* are the start and end states respectively.  $a_1, \dots, a_n$  are the possible set of user actions.  $t_1, \dots, t_n$  are the times between actions.

# Types of Actions

**YAHOO!** Web Images Video Local Shopping More ▾

**guess** ← Query Search Options ▾

View Notes (6)  
SearchScan - On

851,000,000 results for **guess**:

- ... who
- ... jeans
- ... outlet
- ... shoes
- ... bags

**Also try:** [guess watches](#), [guess clothing](#), [guess handbags](#), [More...](#)

**Sponsored Results**

**GUESS Official Site** **Related Search Click**  
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**Algorithmic Search Click**

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[shop.guess.com](#) - [Cached](#)

<a href="#">Stores</a>	<a href="#">Gift Cards</a>
<a href="#">Shopping Bag</a>	<a href="#">Customer Services</a>
<a href="#">Guess</a>	<a href="#">My Wish List</a>
<a href="#">Customer Care</a>	<a href="#">Track Order</a>

[more results from »](#)

**GUESS: Women**  
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**Sponsored Search Click**

**Sponsored Results**

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**Guess on Sale**  
Save on **Guess** \$5, \$10, or \$15 Off (Select Stores).  
[RetailBerry.com/guess](#)

**Guess**  
Cute Clothes. Trendy Brands. Find **guess** You Like.  
[Like.com/clothing](#)

# Types of Actions

**YAHOO!** Web Images Video Local Shopping More ▾

weather new york city  Options ▾

View Notes (6) SearchScan - On

243,000,000 results for weather new york cit...:

[Extended weather forecast for New York, NY](#) (Change Location) ← **Shortcut Click** Sponsored Results

[weather.yahoo.com](#)

Currently: 36°F Mostly Cloudy 38°F   26°F	Tomorrow Sunny 37°F   22°F	Friday Mostly Cloudy 39°F   28°F
---	----------------------------------	--

[Yahoo! Shortcut - About](#)

[New York City Weather Forecast](#)  
Detailed **New York City Weather** Report & Extended **Weather** Forecast

**YAHOO!** Web Images Video Local Shopping More ▾

university of michigann  Options ▾

View Notes (6) SearchScan - On

2,480 results for university of michig...:

university of michig...

**Did you mean:** [university of michigan](#) ← **Spelling Suggestion Click**

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[CollegeDegreeNetwork.com](#)

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[DegreeSearchNetwork.com/University](#)

# Clickstream Data

Web | [Images](#) | [Video](#) | [Local](#) | [Shopping](#) | [more](#) ▾

[Options](#) ▾ [Customize](#) ▾

**YAHOO!**

1 - 10 of 832,000,000 for guess ([About](#)) - 0.03 s | SearchScan<sup>BETA</sup> On

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[The Guess at Amazon](#)  
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[Amazon.com/music](#)

Pattern: Q 4s

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[The Guess at Amazon](#)

Low prices on new & used music. Qualified orders over \$25 ship free.  
[Amazon.com/music](#)

Pattern: Q 4s RL 1s

# Clickstream Data


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Pattern: Q 4s RL 1s SR 53s

# Clickstream Data


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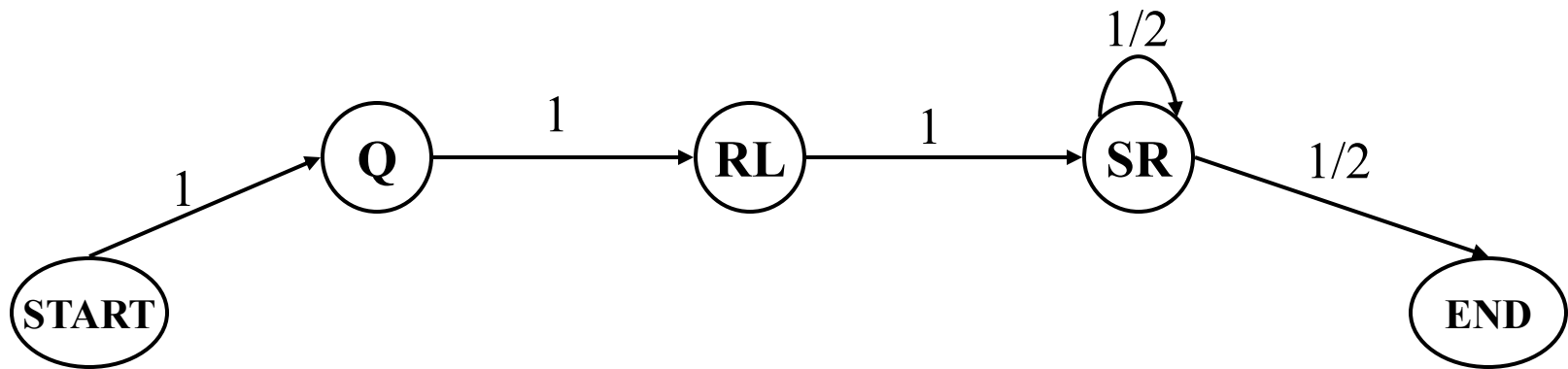
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Pattern: Q 4s RL 1s SR 53s SR 118s END

# Clickstream Data

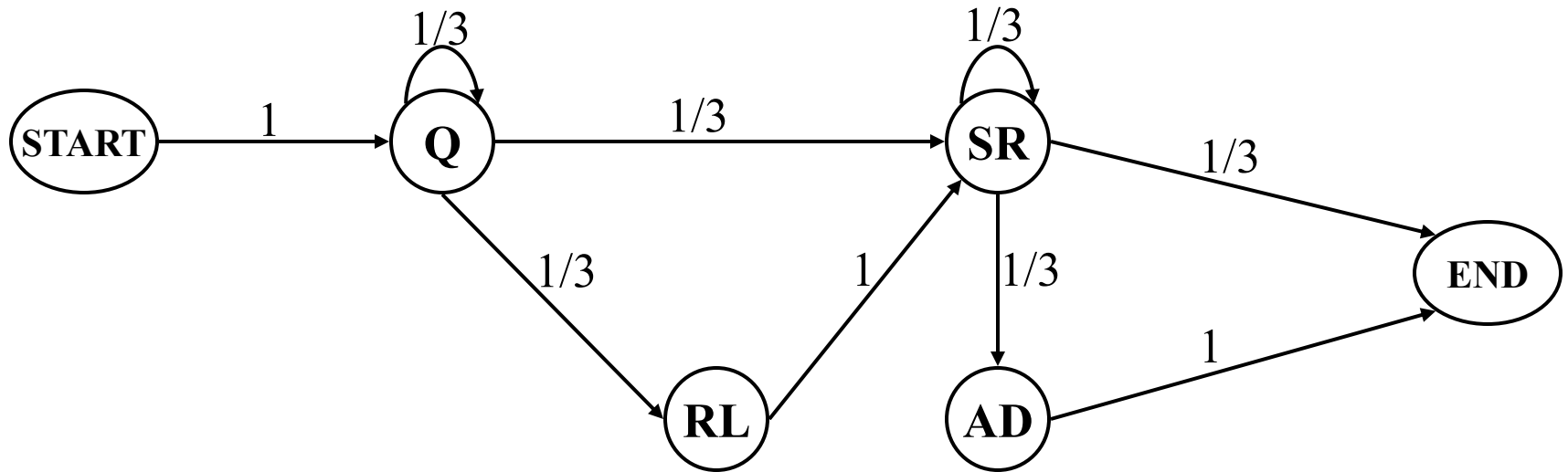
- Action sequence  $\rightarrow$  Path in a graph.



Goal 1: Q 4s RL 1s SR 53s SR 118s END



# Clickstream Data



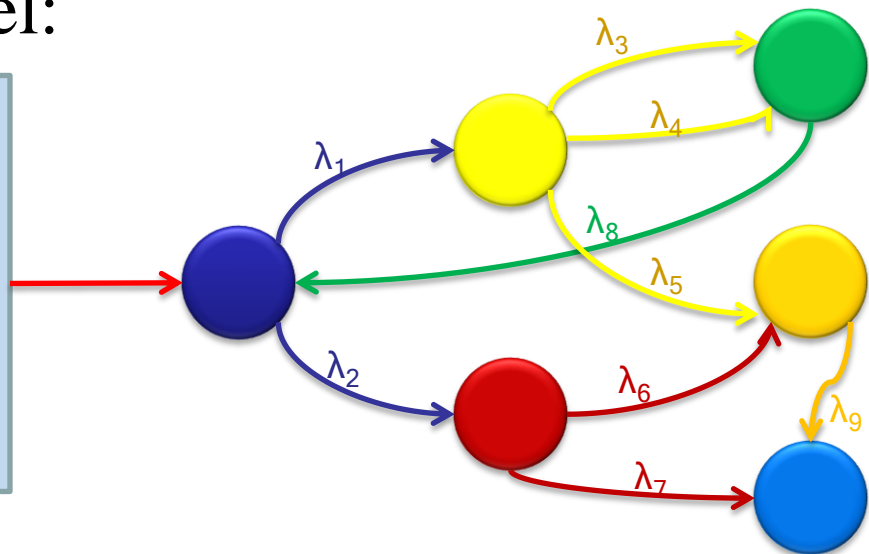
Goal 1: Q 4s RL 1s SR 53s SR 118s END

Goal 2: Q 3s Q 5s SR 10s AD 44s END

# Modeling User Sessions

- Each set of goals may be represented by a first order Markov Model:

Goal<sub>1</sub>: Q 4s RL 1s SR 53s SR 118s END  
 Goal<sub>2</sub>: Q 3s Q 5s SR 10s AD 44s END  
 Goal<sub>3</sub>: Q 4s RL 1s SR 53s SR 118s END  
 Goal<sub>4</sub>: Q 3s Q 5s SR 10s AD 44s END  
 .....  
 Goal<sub>n</sub>: Q 4s RL 1s SR 53s SR 118s END  
 Goal<sub>n-1</sub>: Q 3s Q 5s SR 10s AD 44s END



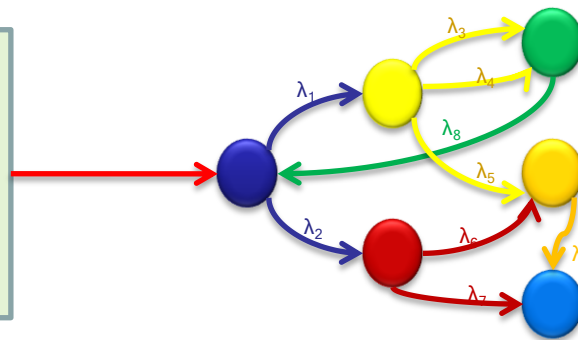
- Small state space:  $\{Q, SR, AD, SC, RL, SP, OTH\}$
- Transition Probabilities:  $\Pr(i, j) = \frac{Q_{i,j}}{Q_i}$

# Markov Model

- Build two models:

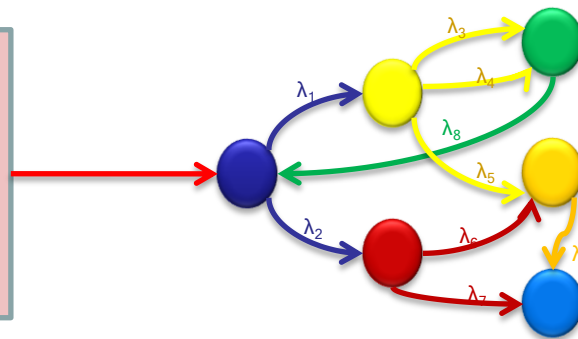
## Successful Goals

Goal 1: Q 4s RL 1s SR 53s SR 118s END  
Goal 2: Q 3s Q 5s SR 10s AD 44s END  
Goal 3: Q 4s RL 1s SR 53s SR 118s END  
Goal 4: Q 3s Q 5s SR 10s AD 44s END  
.....  
Goal n: Q 4s RL 1s SR 53s SR 118s END  
Goal n-1: Q 3s Q 5s SR 10s AD 44s END

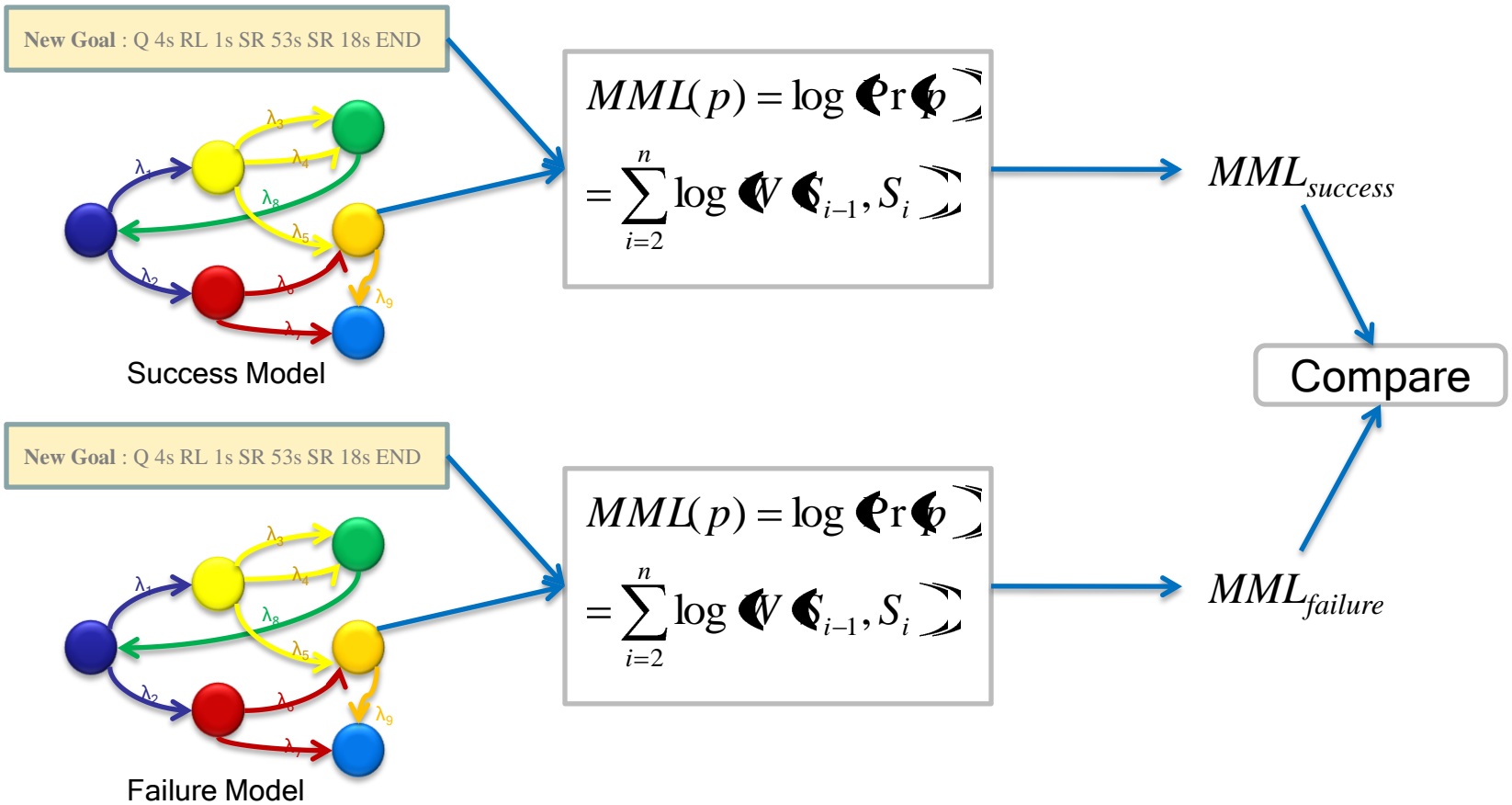


## Unsuccessful Goals

Goal 1: Q 4s RL 1s SR 53s SR 118s END  
Goal 2: Q 3s Q 5s SR 10s AD 44s END  
Goal 3: Q 4s RL 1s SR 53s SR 118s END  
Goal 4: Q 3s Q 5s SR 10s AD 44s END  
.....  
Goal n: Q 4s RL 1s SR 53s SR 118s END  
Goal n-1: Q 3s Q 5s SR 10s AD 44s END

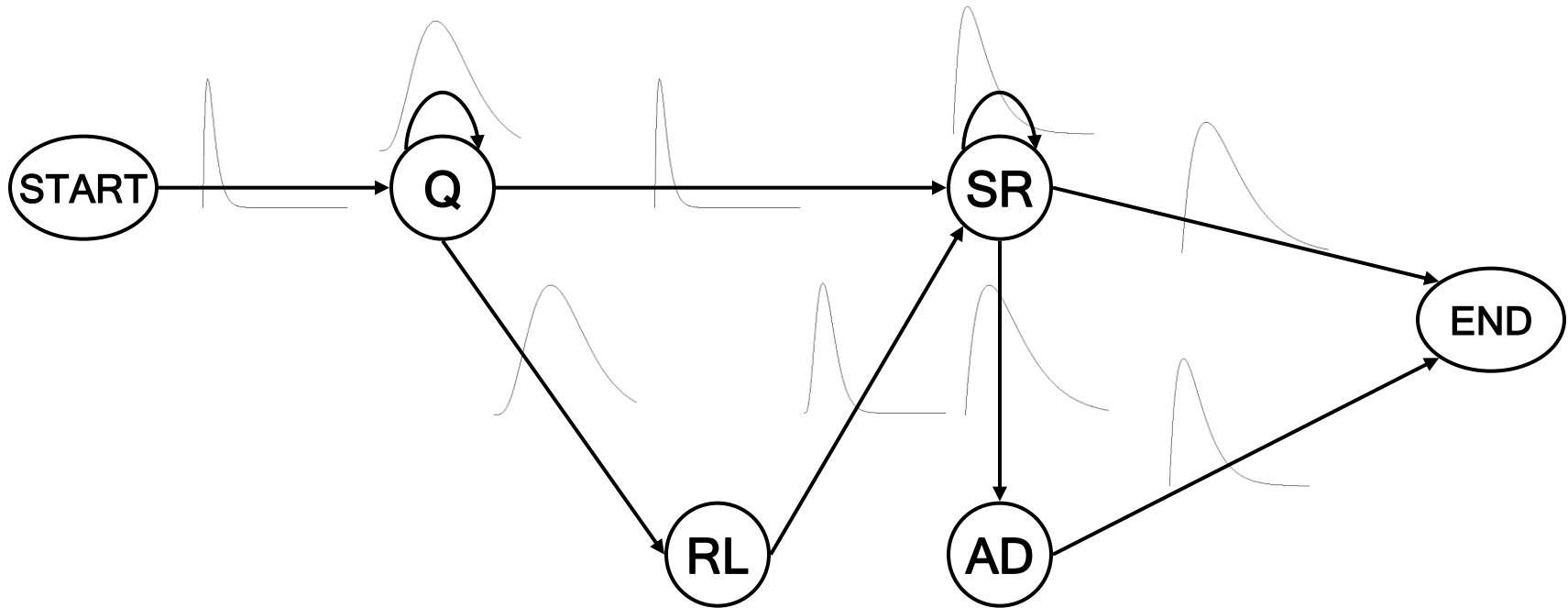


# Classifying New Goals



# Modeling Time

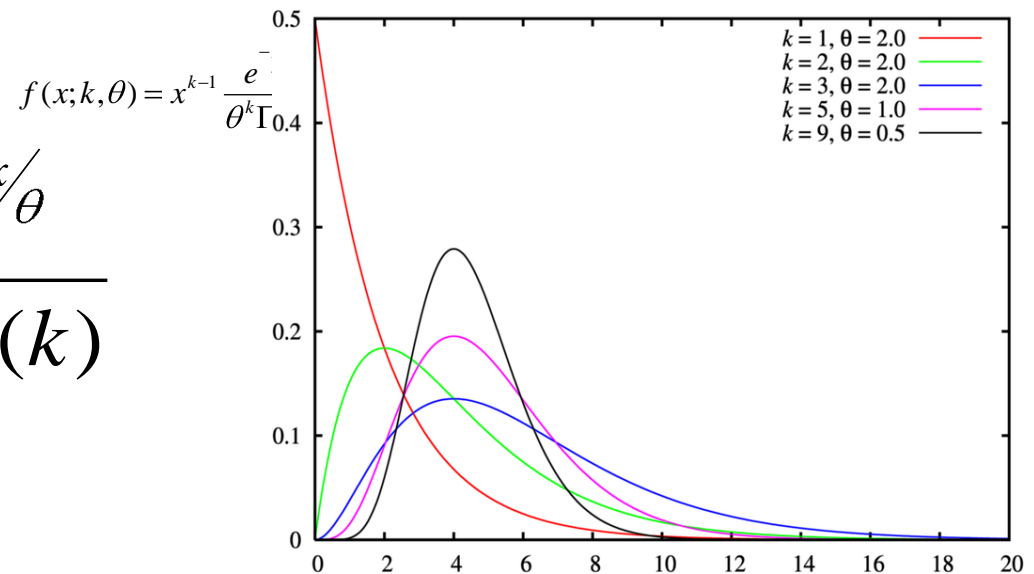
- Attach a time distribution to each transition in the Markov chain.



# Modeling Time

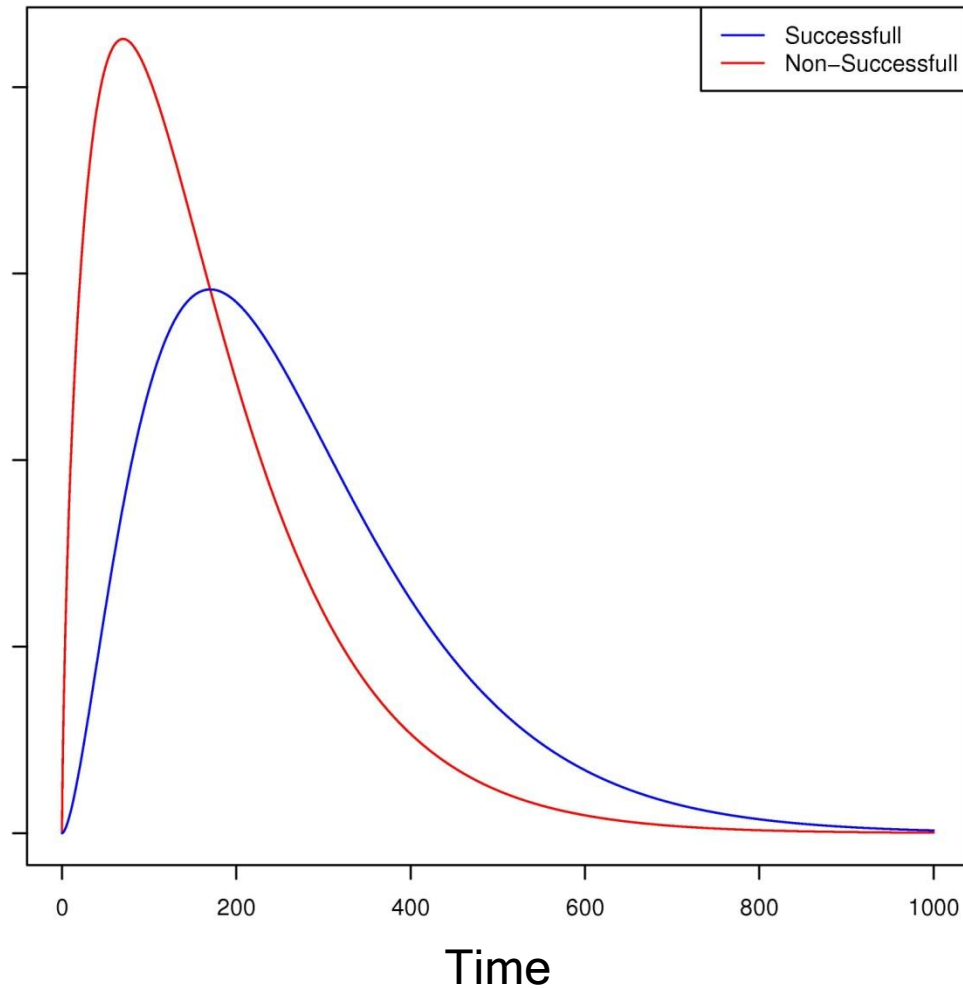
- Choose the parametric form for the distributions:
  - The gamma distribution is a rich two-parameter family of continuous distributions.

$$f(x; k, \theta) = x^{k-1} \frac{e^{-x/\theta}}{\theta^k \Gamma(k)}$$



Source: Wikipedia

# Time distributions of SR $\rightarrow$ Q transitions

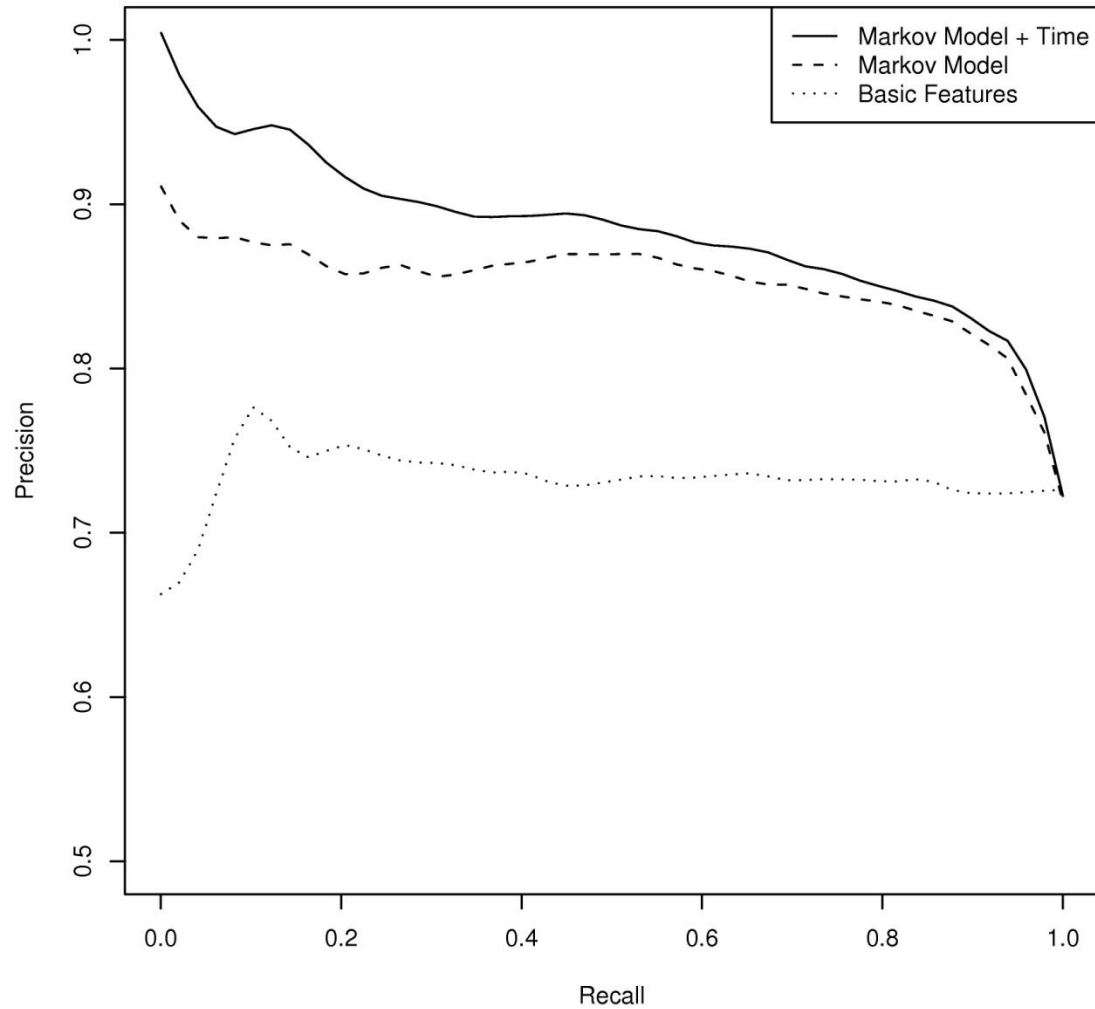


# Baseline - Static Features

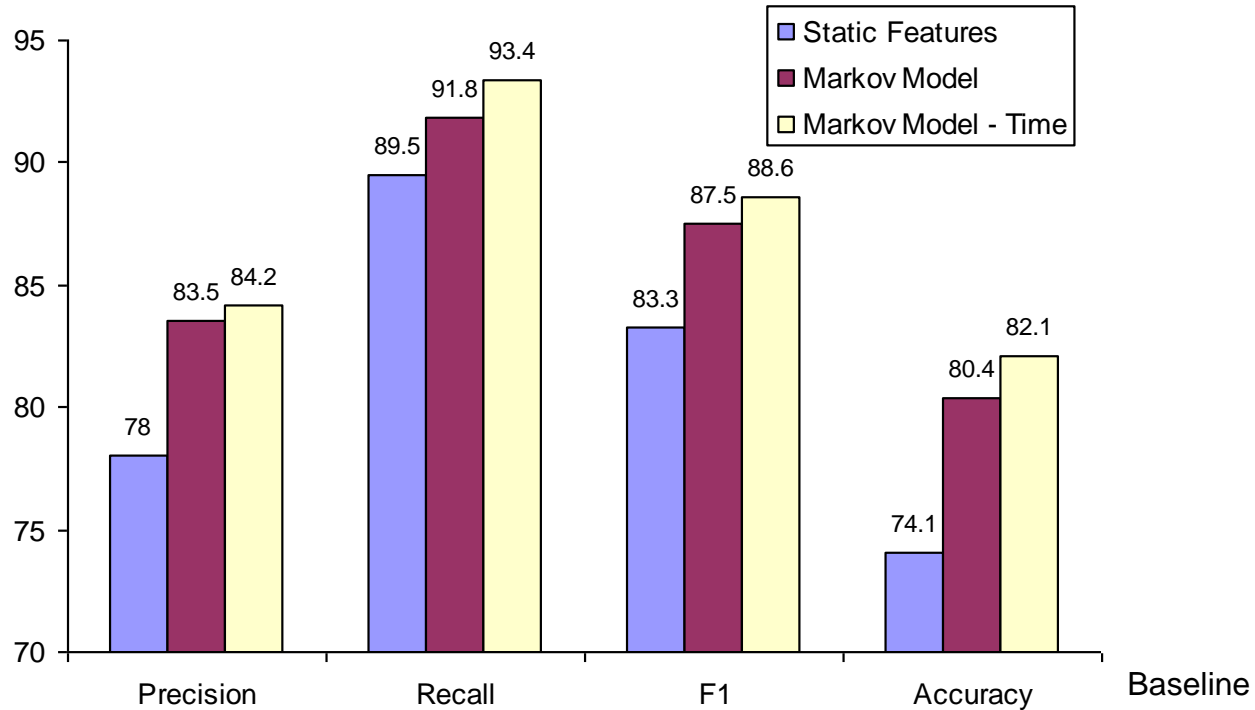
- Pose the problem as a classic machine learning problem
- Train a classifier using a set of static features:
  - Number of clicks
  - Time between clicks
  - Number of queries
  - ... etc



# Markov Models Do Much Better Than Baseline



# Time Models Improve Performance



	Precision	Recall	F1	Accuracy
Static Features	78.0	89.5	83.3	74.1
Markov Model	83.5	91.8	87.5	80.4
Markov Model+Time	<b>84.2</b>	<b>93.4</b>	<b>88.6</b>	<b>82.1</b>

# Relevance (DCG) based Prediction

- Predict the goal success based on the relevance of the first 3 results to the first query (Huffman and Hochster 2007)

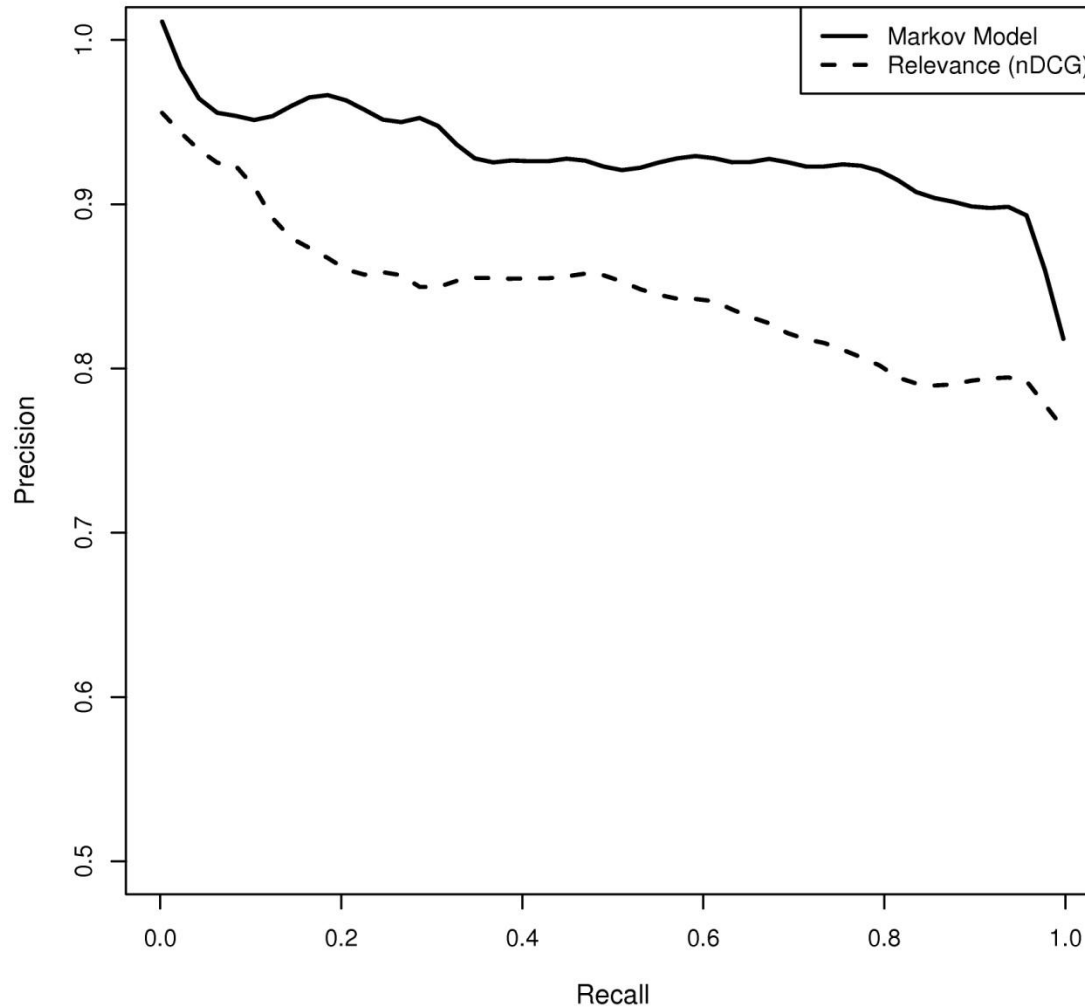
$$\text{Relevance} = \frac{rel_1 + rel_2/2 + rel_3/3}{1 + 1/2 + 1/3}$$

- And using a standard form of DCG

$$DCG_p = rel_1 + \sum_{i=2}^p \frac{rel_i}{\log i}$$

- Data: a random subset of the data for which we have query-url relevance judgments.

# User Behavior Outperforms Relevance based Prediction



# Markov Model vs. DCG – Example 1



## [Furniture Auction](#)

... thousands of **furniture auctions** and sales. ... **Auctions**. Living Room **Furniture Auction** ... Kitchen **Furniture Auction**. Bakers Racks. Bar Stools. Kitchen ...

[www.furniture-auction.com](http://www.furniture-auction.com) - [Cached](#)

Excellent

## [Online Auction items at Furniture Trader.com](#)

... used online **auction** items - antiques, jewelry, **furniture**, etc. - at FurnitureTrader. ... of the **auctions** around the nation including **auctions** for antiques, ...

[www.furnituretrader.com/category/index.php/auctions](http://www.furnituretrader.com/category/index.php/auctions) - [Cached](#)

Good

## [AuctionZip Furniture Auctions](#)

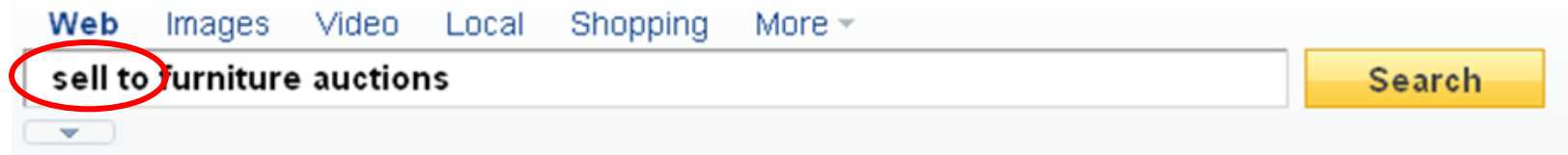
The largest source of live **furniture auctions** provided by AuctionZip.com. ... Coins, **Furniture**, Sports Cards And Collectibles. Bernville **Auction** Service ...

[www.auctionzip.com/furniture.html](http://www.auctionzip.com/furniture.html) - 118k - [Cached](#)

Good

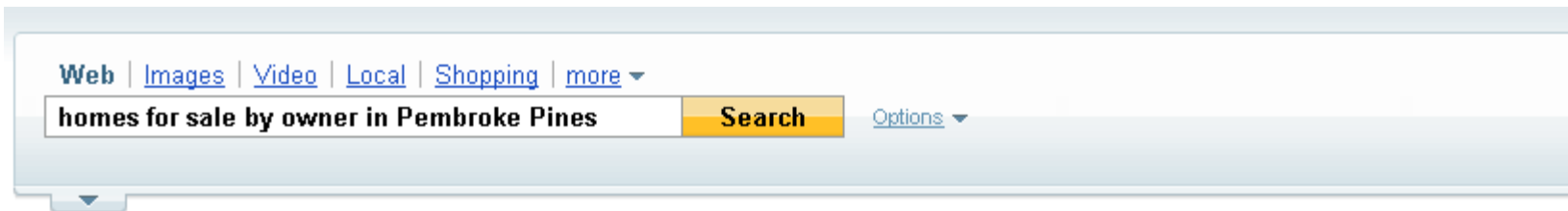
From the relevance point of view, the goal seemed to be successful.

# But User Reformulated without Clicking



- User reformulated query, and
- didn't click
- pattern: Q1 27s Q2 3s END
- Unsuccessful goal despite high DCG

# Markov Model vs. DCG – Example 2



[Pembroke Pines Real Estate & Pembroke Pines Homes for Sale - Zillow](#)

... **Pembroke Pines** real estate listings and **homes for sale, for sale by owner homes, ...** In or Register. **Homes. Pembroke Pines Homes For Sale. Pembroke Pines ...**  
[www.zillow.com/homes/for\\_sale/Pembroke-Pines-FL](#) - 174k - [Cached](#)

Bad

[Pembroke Pines Open Houses - Zillow](#)

Sign In or Register. **Homes. Pembroke Pines Homes For Sale. Pembroke Pines For Sale By Owner ...** estate information on millions of **homes for sale in Pembroke ...**  
[zillow.com/homes/for\\_sale/.../1\\_open?scid=homes-site-topnavhomessub](#) - 110k - [Cached](#)

Bad

[Pembroke Pines, Florida - 3 bed 2 bath Manufactured Home - FTL69440 ...](#)

**Homes For Sale By Owner - 3 bed 2 bath Manufactured Home - Pembroke Pines, Florida - FTL694**  
... platform for Real Estate **for sale in Pembroke Pines, FL** (Broward ...  
[www.buyowner.com/FTL69440](#) - 56k - [Cached](#)

Fair

From the relevance point of view, the goal seemed to be unsuccessful.

# Markov Model vs. DCG – Example 2

- Relevance judgments usually consider the first 3,5, or 10 results
- The user found what he was looking for at position 11
- DCG based models predicted the goal as unsuccessful
- User behavior models predicted the goal as successful



# Successful Goals More Likely to Use Shortcuts

Action following query		Odds-ratio
SC	Shortcut	2.0
SR	Search result	1.8
RL	Also-Try	1.2
SP	Spell-correction	0.9
Q	Query	0.5
END	End of goal	0.1

Odds-ratio of transitions from query to other actions in successful goals, compared to unsuccessful goals.

# Highly Probable Successful Paths

Highly probable successful paths
Q SR END
Q SR SR END
Q SR SR SR END
Q SR SR SR SR END
Q AD END
Q SC END
Q SR Q SR SR END

# Highly Probable Unsuccessful Paths

Highly probable unsuccessful paths
Q END
Q Q END
Q OTH END
Q SR Q END
Q Q Q END
Q RL END
Q Q SR Q SR Q END

# Conclusions and Future Work

- We proposed a Markov model that captures user behavior in search to predict success
- We can predict goal success with 82% accuracy
- The Markov model outperforms relevance based models
- Taking transition time into consideration improves performance
- Build other predictive models for sessions
  - User frustration
  - Good abandonment

Questions?

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