

Action Modeling: Using Language Models to Predict Query Behavior

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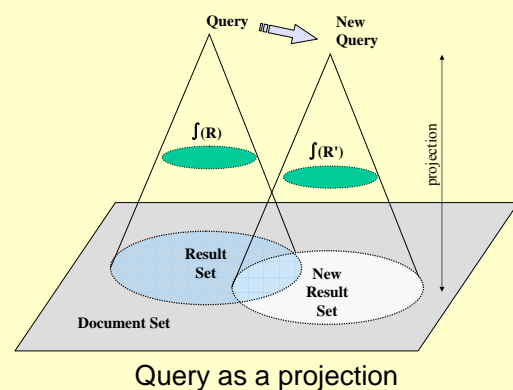
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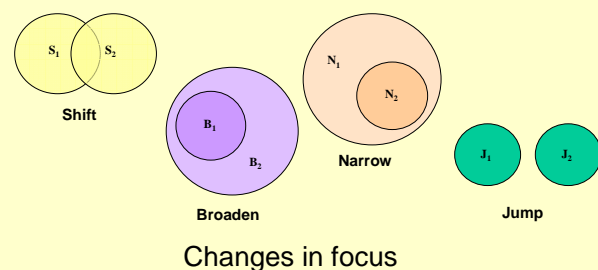
Research Questions

- Can prior users' query history be used to predict new users query behavior?
- What predictions can be made based on types of query changes?
- Do sequences of queries express syntagmatic relationships?

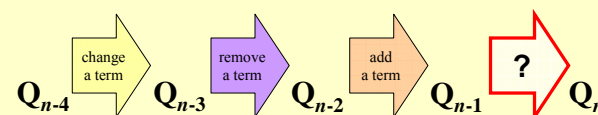
The Framework



Each query is a projection into a document space. Users only focus on a subset $f(R)$ of the retrieved search results. Each new query is a change in projection, resulting in a change of focus.

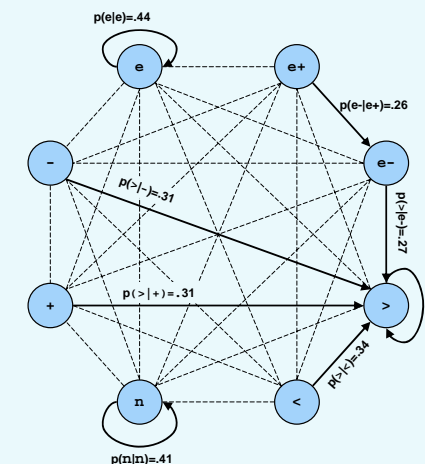


Changes in focus can be modeled as sequences of intentional linguistic actions. Any sequence of n queries can be reduced to a sequence of $n-1$ focus-changing 'moves'.



The Model

Query Move	Description	Prior Prob.
n	new	0.135
>	repeat	0.494
<	return	0.075
+	add to previous	0.035
-	remove from previous	0.014
e+	edit longer	0.100
e	edit same length	0.058
e-	edit shorter	0.088



The Data

- 3 months of search log data
- 8,269,030 queries
- 216,065 unique users
- Users randomly split into 10 groups for cross-validation
- Search sessions reduced to sequences of query 'moves'
- 100,000 query 'moves' randomly selected as prediction targets

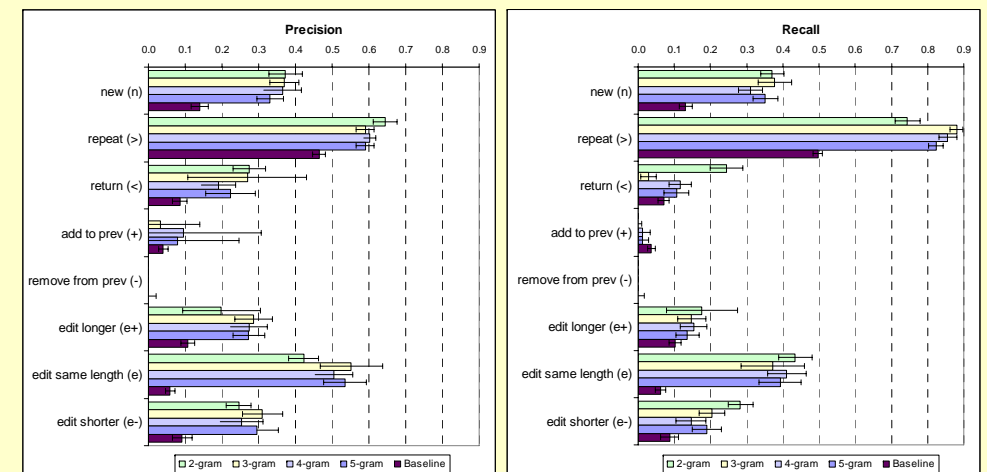
Example Session

Timeline (mm:ss)	Query	Focus Change	Move Type
00:00	carolina health association		n
02:03	carolina health association	Broaden	>
04:18	nursing registry	Jump	n
08:48	certified registry assistant 1	Shift/Narrow	e+
09:48	nursing assistant registry	Shift	e-
10:06	license lookup for nursing assistants	Narrow	e+
11:42	nursing assistant 1 certification	Shift	e-
12:18	nursing assistant 1 license look ups	Narrow	e+
12:30	nursing assistant expiration look up	Narrow	e
13:24	nursing registry in Raleigh	Shift	e-
15:00	nursing aid registry of Raleigh	Narrow	e+
16:06	nursing aid registry of Raleigh website	Narrow	+
19:48	nursing aid registry of Raleigh	Broaden	<
22:24	north carolina board of nursing information	Shift	e+
24:36	north carolina board of nursing	Broaden	-
28:30	license lookup for nursing assistant	Shift	e+
31:43	license information for nursing assistant expiration	Shift	e+
33:12	north carolina license nursing assistant expiration	Narrow	e+

The Experiment

1. Establish baseline
 - Weighted random guess following the unigram distribution of query 'moves'
2. Train language models on observed sequences of query 'moves'
 - Bi-gram, tri-gram, 4-gram and 5-gram models trained using SRILM toolkit
 - Each model trained on 8 of 10 user data sets; one data set is held out, one reserved for test.
3. Predict query moves using language models
 - Given the sequence ' $m_1 m_2 \dots m_{n-1}$ ' and model Θ choose $m_n = \arg\min_m \text{perplexity}(m_n | m_1 m_2 \dots m_{n-1}, \Theta)$
4. Evaluate predictions in 10-way cross-validation
 - Compare prediction results to ground truth observations
 - Calculate precision and recall for each model

Results



Move	2gram	3gram	4gram	5gram	Baseline
n new	0.373**	0.369**	0.365**	0.331**	0.140
> repeat	0.644**	0.590**	0.603**	0.590**	0.464
< return	0.275**	0.269**	0.190**	0.224**	0.086
+ add to previous	0	0.033	0.096	0.079	0.040
- remove from previous	0	0	0	0	0
e+ edit longer	0.198*	0.286**	0.274**	0.273**	0.108
e edit same length	0.423**	0.552**	0.505**	0.535**	0.059
e- edit shorter	0.246**	0.310**	0.253**	0.296**	0.091
Overall	0.490**	0.520**	0.506**	0.497**	0.279

Move	2gram	3gram	4gram	5gram	Baseline
n new	0.371**	0.377**	0.310**	0.351**	0.131
> repeat	0.745**	0.880**	0.856**	0.824**	0.497
< return	0.244**	0.028	0.116**	0.107**	0.070
+ add to previous	0	0.002	0.012	0.011	0.037
- remove from previous	0	0	0	0	0
e+ edit longer	0.176*	0.148*	0.153**	0.136*	0.102
e edit same length	0.434**	0.371**	0.410**	0.393**	0.061
e- edit shorter	0.283**	0.204**	0.146**	0.189**	0.087
Overall	0.490**	0.520**	0.506**	0.497**	0.279

- Query moves *can* be predicted from sequences of previous moves.
- Predictive power of previous moves is limited to short context.
 - Short n -grams are highly predictive, but longer n -grams are not.
 - One or two prior moves can help predict some types of moves, but a longer context is not helpful.
- Some types of moves are easier to predict than others.

Implications

- Factors contributing to query prediction can be separated into component layers, e.g. of syntax, semantics, and activity.
- Action models can be blended with other models to improve user modeling.
- Possible improvements include adding features like semantic similarity between queries, novelty of new query to the user, novelty to the collection, etc.
- Separate models may be required for different move types.