Building a Click Model
From Idea to Implementation

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User Behavior & Search Result Ranking

• A simple solution: user click = relevance voting
  • Works well for most navigational queries (e.g. SIGIR15)

• Problem: position bias
  • Users tend to click more on higher-ranked results

[Graph showing user click versus search ranking]

Result Examination: Click models

• Examination Hypothesis (Richardson et al., 2007)
  \[ C_i = 1 \rightarrow E_i = 1, R_i = 1 \]

• Estimating examination probabilities
  • Cascade model: 
    \[ P(E_{i+1} = 1 | E_i = 1, C_i) = 1 - C_i \]
  • Dependent click model (DCM):
    \begin{align*}
    P(E_{i+1} = 1 | E_i = 1, C_i = 0) &= 1 \\
    P(E_{i+1} = 1 | E_i = 1, C_i = 1) &= \lambda_i
    \end{align*}
  • User browsing model (UBM):
    \[ P(E_i = 1 | C_{1...i-1}) = \lambda_{r_i,d_i} \]
  • Other models: DBN, CCM, TCM...
From Idea to Implementation

• Click model assumptions

  • Ideal case (homogeneous results): Position is the only factor that affects behavior
  • Problem: results have different presentation styles
  • Ideal case (cascade assumption): Results are examined from top to bottom
  • Problem: results are often skipped or revisited
Research Questions

• *Presentation bias problem:*  
  a click model incorporating vertical results

• *Non-sequential examination problem:*  
  a click model incorporating revisiting behaviors
Heterogeneous Search Results

• Vertical results are everywhere (over 80% SERPs)
**Vertical-aware Click Model**

- **Attractiveness Effect** (Wang et al., 2013; Liu et al., 2015)

- Certain verticals draw much attention from users

**Rank 1st**

**Rank 3rd**

**Rank 5th**
**Vertical-aware Click Model**

**Cut-off Effect** *(Liu et al., 2015)*

After users have viewed **on-topic** verticals, they are more likely to **decrease** their visual attention on the **organic results** which are **below** verticals.

<table>
<thead>
<tr>
<th>Relevant Vertical</th>
<th>Textual</th>
<th>Encyclopedia</th>
<th>Image-only</th>
<th>Application-download</th>
<th>News</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position = 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic</td>
<td>30.13%</td>
<td>16.70%</td>
<td>8.44%</td>
<td>13.04%</td>
<td>22.61%</td>
</tr>
<tr>
<td>Vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff</td>
<td>-12.95%</td>
<td>-51.74%**</td>
<td>-75.62%**</td>
<td>-62.32%**</td>
<td>-34.68%</td>
</tr>
<tr>
<td>Position = 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic</td>
<td>26.30%</td>
<td>19.27%</td>
<td>10.33%</td>
<td>6.21%</td>
<td>38.69%</td>
</tr>
<tr>
<td>Vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diff</td>
<td>4.09%</td>
<td>-23.76%</td>
<td>-59.10%*</td>
<td>-75.44%*</td>
<td>53.09%</td>
</tr>
</tbody>
</table>
Vertical-aware Click Model

• **Restart effect (Wang et al., 2013)**

• Most users (70%) will restart from the beginning to continue
Vertical-aware Click Model

• Model Construction (based on UBM)

Original UBM

\[
\begin{align*}
P(C_i = 1|E_i = 0) &= 0 \\
P(C_i = 1|E_i = 1) &= P(A_i = 1|E_i = 1) \\
P(E_i = 1|F = 0, C_{1:i-1}) &= \gamma_{i,i-l_i} \\
P(A_i = 1|E_i = 1, F = 0) &= \alpha_{q,i}
\end{align*}
\]

Users examine vertical results at first

\[P(F = 1) = \phi_{t_v,l_v}\]

Simplified case: difficult to quantify the effect when not all results are affected

Effect on Examination

\[P(E_i = 1|F = 1, C_{1:i-1}) = \gamma_{i,i-l_i} + \theta_{q,i}\]

Effect on Click-through

\[P(A_i = 1|E_i = 1, F = 1) = \alpha_{q,i} + \beta_{q,i}\]

Restart effect

\[
\begin{align*}
P(B = 1|F = 0) &= 0 \\
P(B = 1|F = 1) &= \sigma_{t_v,l_v}
\end{align*}
\]
Vertical-aware Click Model

• Experimental results
  • About 300,000 queries and 11,000,000 sessions collected from a major Chinese search engine

Click/skip perplexity

<table>
<thead>
<tr>
<th>Perplexity</th>
<th>UBM</th>
<th>VCM</th>
<th>VCM Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text vertical</td>
<td>1.2266</td>
<td>1.2139</td>
<td>+5.58%</td>
</tr>
<tr>
<td>Multimedia vertical</td>
<td>1.3735</td>
<td>1.3071</td>
<td>+17.78%</td>
</tr>
<tr>
<td>Application vertical</td>
<td>1.1908</td>
<td>1.1601</td>
<td>+16.09%</td>
</tr>
</tbody>
</table>

Log-likelihood

<table>
<thead>
<tr>
<th>Perplexity</th>
<th>UBM</th>
<th>VCM</th>
<th>VCM Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Text vertical</td>
<td>-2.9093</td>
<td>-2.7968</td>
<td>+11.90%</td>
</tr>
<tr>
<td>Multimedia vertical</td>
<td>-4.1142</td>
<td>-3.8638</td>
<td>+28.44%</td>
</tr>
<tr>
<td>Application vertical</td>
<td>-2.2671</td>
<td>-2.1427</td>
<td>+13.24%</td>
</tr>
</tbody>
</table>
Possible Future Directions

• How to rank items within vertical blocks?
  • An example vertical block composed of an image and several hyperlinks (e.g. news, Q&A portal results, etc.)
  • Position bias: only for the top result
  • Attractiveness effect: not so significant
Research Questions

• *Presentation bias problem:* a click model incorporating vertical results

• *Non-sequential examination problem:* a click model incorporating revisiting behaviors
Sequential order of Examination/Clicking

• Sequential examination happens a lot
  • Cascade assumption: Users tend to examine results from top to bottom
  • Mean time of arrival v.s. result ranking position

Joachims et.al, Eye-tracking analysis of user behavior in www search. SIGIR 2005
Non-sequential Examination Problem

• Revisiting behavior cannot be ignored
  • Chinese search engine (Sogou): 27.9% sessions
  • Non-Chinese search engine (Yandex): 30.4% sessions
Non-sequential Examination Problem

• Depth-first strategy (cascade assumption)
  - Users examine search result lists from top to bottom
  - Accepted by most existing click models

Examine (unobserved)
Click (observed)

Problem#1: not the true last click
Problem#2: sequential information is missing
Non-sequential Examination Problem

• Why is it difficult to retain sequential information

Cascade assumption

Retaining Sequential Information

Long Revisit

Short Revisit

Skip and revisit
Non-sequential Examination Problem

• Any rules in users’ non-sequential examination?

• How often do users change the direction of examination between clicks?
Non-sequential Examination Problem

• Any rules in users’ non-sequential examination?

• How far do users’ eye gazes jump after examining the current clicked result?
Non-sequential Examination Problem

• Locally Unidirectional Examination
  • Users tend to examine search results in a single direction without changes between clicks

![Chart showing examination direction change count](chart.png)
Non-sequential Examination Problem

• Non First-order Examination
  • Users may skip a few results and examine a result at some distance away from the current one after clicks
Non-sequential Examination Problem

• Locally Unidirectional Examination Assumption
  • Between adjacent clicks, user’s examination direction is strictly consistent with click direction (↑ or ↓).
  • Compared with position based models: Allow non-sequential click/examination sequence
  • Compared with click sequence based models: Reduce lots of examination sequences

• Non First-order Examination Assumption
  • Skipped results may not be examined: Cascade model and DCM do not work, should try UBM
Non-sequential Examination Problem

- Partially Sequential Click Model (PSCM)
Non-sequential Examination Problem

• Experimental results: Perplexity
  • Compared with UBM (Sogou: +30.1%, Yandex: +27.4%)
  • Compared with DBN (Sogou: +31.6%, Yandex: +27.9%)
Non-sequential Examination Problem

• Experimental results: relevance estimation
  • Query-URL Relevance Generated from Click Models
  • Annotated by Sogou’s professional assessors
Non-sequential Examination Problem

• Experimental results: user preference test
• 200 queries and 22 human assessors
• Which ranking lists is preferred by real users
Take-Home Messages

• Presentation bias problem: a click model incorporating vertical results
  • Attractiveness effect; Cut-off effect: for organic results; Restart effect: different examination sequence

• Non-sequential examination problem: a click model incorporating revisiting behaviors
  • Non-sequential examination happens a lot: Locally unidirectional and non First-order patterns

User studies ➔ Assumptions ➔ Better Click models
Reference

• *(Presentation bias problem)* Chao Wang, *Yiqun Liu*, Min Zhang, Shaoping Ma, Meihong Zheng, Jing Qian, Kuo Zhang. Incorporating Vertical Results into Search Click Models. The 36th ACM SIGIR conference (SIGIR 2013)


• Codes are available on https://github.com/THUIR/PSCMMModel
Dataset is available for academic use:
Eye fixations, mouse movement features, clicks, relevance annotation, examination feedback, ...

http://www.thuir.cn/group/~YQLiu/